

Assessing the nature of early farming in Neolithic western Asia: a functional ecological approach to emerging arable weeds

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Abstract

Research on the origins of agriculture in western Asia has placed great emphasis on the location and pace of domestication. However, much less attention has been given to reconstructing the specific nature and social implications of early cultivation practices across the agricultural transition, and to the potentially varied land management strategies involved. By employing a functional ecological approach to the interpretation of arable 'weed' taxa associated with early cultivars, this research addresses this gap in archaeobotancial research by enabling detailed analysis of the growing conditions and farming methods involved in early plant cultivation in western Asia.

The core methodology analyses the functional ecological attributes (e.g. leaf area and thickness; canopy dimensions; stomatal density and distribution) of the relevant arable weed taxa isolated from archaeological contexts to determine the specific growing conditions of early crops and hence the nature of management practices. Functional attributes are morphological or behavioural characteristics that predict species' potential in relation to major environmental variables, such as soil productivity, disturbance and moisture. Statistical analysis incorporating these attributes is used to explore variation amongst early cultivation contexts and compare them with weed survey data from contrasting (semi-)arid modern regimes, including a recent study of traditional cereal farming in Morocco.

Ecological 'signatures' were determined using the isolated weed dataset from four well documented and contextually rich Pre-Pottery and Pottery Neolithic sites, which were strategically selected to explore agricultural strategies from its initial stages through to the established Neolithic, as well as to exploit detailed sample-by-sample data and

extensive *in situ* deposits. The sites investigated are PPNA Jerf el-Ahmar and PPNA/EPPNB Dja'de in northern Syria, PPNB Tell Aswad in southern Syria, and PPN-PN Çatalhöyük in Central Anatolia. Refined identification of selected weed genera at these sites enabled more accurate indications of their arable ecologies. The results generated suggest that early farming practices were highly variable *within* sites, reflecting the specific affordances of local climate and surrounding landscapes, but relatively labour-intensive in comparison with later urban agrosystems. Furthermore, there are indications for greater cultivation intensity over time, as households became more autonomous.

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Dedicated to Auntie Rita

who inspired me from childhood and was always so proud.



Abbreviations

AGRICURB	The 'Agricultural Origins of Urban Civilization' Project
CNRS	Centre national de la recherche scientifique
DGAM	Directorate-General for Antiquities and Museums
EBA	Early Bronze Age
F.	Feature number
FIBS	Functional Interpretation of Botanical Surveys
Fl.	Flotation number
Flot	Flotation sample
LN	Late (pottery) Neolithic
PPN	Pre-pottery Neolithic
u.	Unit

Table of Contents

Abstract
Acknowledgements
Abbreviations
List of Figures
List of Tables

Chapter 1: Introduction 1

1.1 Current perspectives: the nature of early farming in western Asia 2
1.2 Weed ecology 6
1.3 Isolating relevant 'weed' taxa 9
1.4 Research questions and objectives 12

Chapter 2: Origin of arable weeds 15

2.1 What is a 'weed'? 15
2.2 Origin of weeds 18
2.3 Weed characteristics 20
2.4 Evolution of weed species 22
2.5 Identifying arable weeds archaeologically 24

Chapter 3: Case study sites - Archaeological and environmental background ... 27

3.1 Northern Levant – Pre-Pottery Neolithic Jerf el-Ahmar, Dja'de, & Tell Aswad 28
3.2 Central Anatolia – Neolithic Çatalhöyük [East] 48

Chapter 4: Plants in context - Spatial relationships of plant storage 57

4.1. Emergence of food storage in western Asia 57
4.2. Critical review of early storage evidence from western Asia 60
4.3. Built storage facilities at Late Neolithic Çatalhöyük 72
4.4. Discussion 83

Chapter 5: Archaeobotanical methods 87

5.1 Field methods: on-site sampling strategies and sample processing 87
5.2 Previous sample assessment and analysis 91
5.3 Selection of samples for present study 98
5.4 New sample analysis at Çatalhöyük 103
5.5 Amalgamation for statistical analysis 111
5.6 Selection of weed genera for further refinement 113

5.7 Documentation and measurement of weed taxa 117
5.8 Analytical methods 120

Chapter 6: Modern weed ecological studies 131

6.1 Previous studies: collection of modern weed ecological data 131
6.2 Selected model: combined FIBS analysis 138
6.3 Examining ecological variability 143

Chapter 7: Refined identification of weed taxa 147

7.1 Identification keys in archaeobotany 147
7.2 Challenges for weed identification 158

Chapter 8: Building identification keys 167

8.1 Methods for building identification keys: *Bromus* case study 167
8.2 Presentation and application of the *Bromus* key 195

Chapter 9: Results 203

9.1 Overview of assemblage: Çatalhöyük 203
9.2 Overview of assemblage: Jerf el-Ahmar, Dja'de and Tell Aswad 235
9.3 Correspondence analysis: Çatalhöyük 258
9.4 Crop-processing analysis 266
9.5 Assessing the intensity of cultivation 305

Chapter 10: Discussion - Comparative assessment of cultivation intensity and its implications for understanding early farming regimes 331

10.1 Jerf el-Ahmar 331
10.2 Dja'de 340
10.3 Tell Aswad 347
10.4 Çatalhöyük 351
10.5 Comparison of cultivation intensity between sites 360

Chapter 11: Conclusions - Assessing the nature of early Neolithic farming in western Asia 371

11.1 Addressing the research questions 371
11.2 Isolating and identifying relevant weed taxa 375
11.3 Future directions and final remarks 376

Bibliography 379

Appendix 1- Raw data for analyses 399

Appendix 2 - Archaeobotanical identification 431

Identification catalogue 445

Supplementary material 483

List of Figures

Figure 2.1 – Mimicry of *Echinochloa oryzicola* (right) to rice (left) (Yamasue 2001). 23

Figure 3.1 – Map showing location of sites under analysis in western Asia in relation to average annual precipitation (Map: Hütteroth & Höhfeld 2002). 28

Figure 3.2 – Excavation areas at the Jerf el-Ahmar in relation to the mound's topography. Trenches targeted two sections of the mound, Éminence Ouest (green) and Éminence Est (red) (Stordeur 2015: Fig. 77). 32

Figure 3.3 – Circular 'communal' structure at Jerf el-Ahmar surrounded by a range of construction types identified as domestic buildings in level II/W (Stordeur 2014: Fig. 6). 33

Figure 3.4 – Excavation areas across the mound at Dja'de (Coqueugniot 2006). 37

Figure 3.5 – Plan of the communal building from phase DJ I (Coqueugniot 2014: Fig. 7). 38

Figure 3.6 – Preserved geometric painting on the wall of the large communal structure at Dja'de (Coqueugniot 2014: Fig. 8). 39

Figure 3.7 – General view of the excavations at Tell Aswad (Stordeur & Jamous 2009: Fig. 1). 45

Figure 3.8 – Position of the site in relation to the two late Pleistocene lakes, Aateibé and Hijjâné (van Zeist & Bakker-Heeres 1982: fig. 1). 46

Figure 3.9 – Map of excavation areas on the East Mound at Çatalhöyük (Hodder 2014). 49

Figure 3.10 – Excavations in the South Area at Çatalhöyük (Photograph by author). 50

Figure 3.11 – Typical subdivision of buildings at Çatalhöyük, with larger main rooms and smaller side room that were used for food storage and preparation (House 2014: fig. 23.1). 52

Figure 3.12 – Reconstruction of the immediate landscape around Çatalhöyük, based on recent geoachaeological and archaeobotanical analysis (Bogaard 2016) (Illustration by Kathryn Killackey). 54

Figure 4.1 – Plan of 'communal' building EA30 from Jerf el-Ahmar with its several internal 'storage' compartments. The photograph shows the narrow opening into cell 5, which has been interpreted as an access point for its contents (Willcox & Stordeur 2012: Fig. 8). 64

Figure 4.2 – F.2005 from Building 52, which contained 30 litres of *Descurania sophia* (wild mustard) (Çatalhöyük Online database). 77

Figure 4.3 – Plan of triple bin F.3092 (top left corner) in Building 77, which contained limited primary plant remains in its basal fill (16488) (Bogaard *et al.* 2013: 121; House 2014: Fig. 23.1). 79

Figure 4.4 – Grouped storage bins in Space 93 from Building 52 (Demiregri *et al.* 2014: Fig. 7.1). 81

Figure 4.5 – The spatial distribution of botanical remains in B.52, highlighting the association of plant storage in side room spaces (Bogaard *et al.* 2013a: Fig. 7.23). 82

Figure 5.1 – Screenshot of the image acquisition software 'Image Pro Insight' by Media Cybernetics, which enabled high quality photographs to be taken of modern and archaeological material, which were able to be precisely measured. 118

Figure 5.2 – Comparison of archaeological samples from Abu Salabikh (black points) with ethnographic samples from known crop processing stages at Amorgos. The two discriminant analyses show different results when entered as (a.) 'ungrouped' and (b.) 'grouped', indicating significant amounts of taxa from non-arable sources (i.e. dung) (Charles 1998). 124

Figure 5.3 – Triangular scatter plot indicating the different proportions of grain, weed and rachis material in different free-threshing cereal products and by-products. This study of different crop-processing stages is based on modern ethnobotanical data from Amorgos, Greece (Jones 1990). 125

Figure 6.1 – Examples of the procedures used to measure functional attributes: calculating leaf area (left), measuring of canopy dimensions (right). 133

Figure 6.2 – Comparison of the pulse 'fields' (o) and pulse 'gardens' (•) from Evvia, Greece (a & c) with high intensity cereal plots (▲) from Asturias, Spain (b & d), showing both quantitative and semi-quantitative data. Larger circles indicate the positions of the group centroids for the Evvia groups (Charles *et al.* 2002: Fig. 2). While a degree of information is lost within the semi-quantitative analysis, presence/absence data are more comparable between modern survey and archaeobotanical datasets than fully quantitative data. 136

Figure 6.3 – a) Distribution along the discriminant function for the four modern field studies, including Morocco, Greece, Spain and southern France (Bogaard *et al.* 2016b). Each data point represents the combined attribute data for a single field. b. The relative importance of each attribute used to successfully classify the samples. 141

Figure 6.4 – The separate field data from each of the modern studies in the combined intensity model compared with archaeobotanical samples from mid-late third-millennium BC Tell Brak (Charles & Bogaard 2001; Bogaard *et al.* 2016b). The much lower values for Tell Brak indicate that farming methods related to low intensity regimes. 142

Figure 6.5 – The relationship of the different *Adonis* species to the established discriminant function for cultivation intensity. 144

Figure 6.6– The relationship of the different *Bromus* species to the established discriminant function for cultivation intensity. 145

Figure 8.1 – Simplified vegetation map, which was used to characterise the zones where species occurred in the *Flora of Iraq* (Guest & Townsend 1966). These simplified zones, which were largely based on altitude, were extended into Syria to exclude taxa restricted to upland and sub-desert areas. 175

Figure 8.2 – Dimensions recorded for each *Bromus* specimen from its dorsal, lateral and cross-section view. L= length, B= breadth, T= thickness, A= apical end (blunt only), S= scutellum, E= embryo tip (used for seed body conversions). 180

Figure 8.3 – Diagram demonstrating the differences between steps taken in a single-access key (left) and multi-access keys (right) (Hagedorn *et al.* 2010). 187

Figure 8.4 – The construction of multi-access keys with Lucid Builder. 188

Figure 8.5 – 'Score analyser' function in Lucid Builder, which helps to highlight the extent of differences between species, as well as potential groups with similar traits. 188

Figure 8.6 – The final *Bromus* key as presented in Lucid player. A range of features can be selected on the left side of the screen. The top-right box displays the remaining candidates, while the bottom-left box shows species that have been excluded. 189

Figure 8.7 – Use of GIS to analyse distances between each site and a series of different altitude zones. This process was used to inform the final altitudinal filters for the key. 193

Figure 8.8 – Ecological signatures for the different *Bromus* species identified from the four sites (green), compared with the full ecological distribution for *Bromus* (purple). 200

Figure 9.1 – Storage type 1: bin F.7182 from Building 122, an example of *in situ* naked barley grain storage preserved within a built bin feature. 207

Figure 9.2 – Storage type 2: separate clusters of peas (u.11911) within built storage bin F.2004, Building 52 (Çatalhöyük Online database). 207

Figure 9.3 – Storage type 4: clusters of new type glume wheat (u.16480) in Building 7 (Photographs by Jason Quinlan) (House 2014: 499). 211

Figure 9.4– Species composition of selected storage samples at Çatalhöyük, with crop types based on the grain/seed component. Chaff, wild/weed, and fruit/nut are indicated separately. 216

Figure 9.5 – Species composition of selected storage samples at Çatalhöyük, with crop types based on both grain/seed and chaff. Proportions of of wild/weed and fruit/nut are also indicated. 217

Figure 9.6 – Glume wheat spikelets embedded in collapsed bin wall fragments (u.16480) (Bogaard *et al.* 2013a: Fig. 9.27). 218

Figure 9.7 – Distribution and composition of storage samples from the North Area (Farid 2014). 225

Figure 9.8 – Distribution and composition of storage samples from the South Area (Farid 2014). 226

Figure 9.9 – Distribution and composition of storage samples from the IST Area (Özbaşaran *et al.* 2014). 227

Figure 9.10 – Distribution and composition of storage samples from the TPC Area. N.B. Full plan to follow. 227

Figure 9.11 – Communal building EA30 (Willcox & Stordeur 2012: Fig. 8). 238

Figure 9.12 – Burnt building EA47 at Jerf el-Ahmar from the middle phase of the occupation (Stordeur 2015). 238

Figure 9.13 – Percentages of crop types in selected samples from Jerf el-Ahmar. 241

Figure 9.14 – Percentages of crop types in selected samples from Dja'de. 247

Figure 9.15 – Percentages of crop types in selected samples from Tell Aswad. 255

Figure 9.16 – Correspondence analysis plot of 33 samples on the basis of 34 wild taxa that occur in at least two of the samples. a. Wild taxon distribution with labelled data points indicating genus. b. Sample distribution with labelled data points representing abundances of *Helianthemum* sp. 259

Figure 9.17 – Correspondence analysis plot of 33 samples on the basis of 30 taxa that occur in at least two of the samples. a. Wild taxa distribution with labelled data points indicating genus. b. Wild taxa distribution coded by deposition type. c. Sample distribution with labelled data points representing abundances of *Juncus* sp. 260

Figure 9.18 – Correspondence analysis plot of 33 samples on the basis of 30 taxa that occur in at least two of the samples. Sample distribution coded by identified storage type. 261

Figure 9.19 – Correspondence analysis plot of 32 samples on the basis of 22 potential weed taxa with dung and collected removed. a. Wild taxa distribution with labelled data points indicating genus. b. Sample distribution with labelled data points indicating sample number. 262

Figure 9.20 – Correspondence analysis plot of 32 samples on the basis of 22 potential weed taxa with dung and collected removed. a. Sample distribution coded by crop type. b. Sample distribution coded by building number. 263

Figure 9.21– Correspondence analysis plot of 32 samples on the basis of 22 taxa with dung and collected removed. Sample distribution coded by identified storage type. 264

Figure 9.22 – Discriminant analysis of Jerf el-Ahmar and Jones' (1984) ethnographical crop processing samples, (a.) classified with regard to the ethnographic data (ungrouped), and (b.) with the Jerf el-Ahmar samples entered as a separate fifth group following Charles (1998). 270

Figure 9.23 – Ungrouped versions of the discriminant analysis comparing samples from Jerf el-Ahmar and Jones' (1984) ethnographical crop processing samples. The four analyses relate to the different levels of species removals: a. All wild taxa, b. Collected removed (large concentrations only), c. Collected removed (all) & d. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.22. 271

Figure 9.24 – Discriminant analysis of Dja'de and Jones (1984) ethnographical crop processing samples, (a.) classified with regard to the ethnographic data (ungrouped), and (b.) with the Dja'de samples entered as a separate fifth group following Charles (1998). 276

Figure 9.25 – Ungrouped versions of the discriminant analysis comparing samples from Dja'de and Jones' (1984) ethnographical crop processing samples. The four analyses relate to the different levels of species removals: a. All wild taxa, b. Collected removed (large concentrations only), c. Collected removed (all) & d. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.23. 277

Figure 9.26 – Discriminant analysis of Tell Aswad and Jones (1984) ethnographical crop processing samples, (a.) classified with regard to the ethnographic data (ungrouped), and (b.) with the Tell Aswad samples entered as a separate fifth group following Charles (1998). 282

Figure 9.27 – Fifth group versions of the discriminant analysis, following Charles (1998) comparing samples from Tell Aswad and Jones' (1984) ethnographical crop processing samples. The six analyses relate to the different levels of species removals: a. All wild taxa, b. Collected removed (large concentrations only), c. Collected removed (all), d. Collected (all) and dung (large concentrations) removed, e. Collected (all) and dung (all) removed & f. Collected (all), dung (all), and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.24 283

Figure 9.28 – Discriminant analysis of Çatalhöyük and Jones (1984) ethnographical crop processing samples, (a.) classified with regard to the ethnographic data (ungrouped), and (b.) with the Çatalhöyük samples entered as a separate fifth group following Charles (1998). 287

Figure 9.29 – Fifth group versions of the discriminant analysis, following Charles (1998) comparing samples from Çatalhöyük and Jones (1984) ethnographical crop processing samples. The four analyses relate to the different levels of species removals: a. All wild taxa, b. Collected removed, c. Collected and dung (excl. ambiguous taxa) removed & d. Collected and dung (incl. ambiguous taxa) removed. A full list of the taxa excluded can be consulted in Table 9.25. 288

Figure 9.30 – Final fifth group version of the discriminant analysis (analysis 4) coded by storage type. 289

Figure 9.31 – Triplot displaying proportions of grain, rachis and weeds for Jones' (1990) ethnobotanical dataset, which examined different crop-processing stages for free-threshing cereals. 290

Figure 9.32 – Triplot displaying the proportions of grain, rachis and weed for each sample from Jerf el-Ahmar, based on the increasing wild exclusions of the four crop-processing discriminant analyses: 1. All wild taxa, 2. Collected removed (large concentrations only), 3. Collected removed (all) & 4. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.22. 291

Figure 9.33 – Triplot displaying the proportions of grain, rachis and weed for each sample from Jerf el-Ahmar (based on weed content from the second version of the discriminant analysis), coded by crop type. 292

Figure 9.34 – Triplot displaying the proportions of grain, rachis and weed for the three clean barley samples at Dja'de, based on the increasing wild exclusions of the four crop processing discriminant analyses: 1. All wild taxa, 2. Collected removed (large concentrations only), 3. Collected removed (all) & 4. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.23. 294

Figure 9.35 – Triplot displaying the proportions of grain, rachis and weed for the mixed samples at Dja'de, based on the increasing wild exclusions of the four crop-processing discriminant analyses: 1. All wild taxa, 2. Collected removed (large concentrations only), 3. Collected removed (all) & 4. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.23. This plot is not directly comparable with ethnobotanical data. 294

Figure 9.36 – Triplot showing mixed samples only from Dja'de (based on weed content from the second version of the discriminant analysis), coded according to main crop type (i.e. cereal or pulse). This plot is not directly comparable with ethnobotanical data. 295

Figure 9.37 – Triplot displaying the proportions of grain, rachis and weed for each sample at Tell Aswad, based on the increasing wild exclusions of the three final discriminant analyses: 4. Collected (all) and dung (large concentrations) removed, 5. Collected (all) and dung (all) removed & 6. Collected (all), dung (all), and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.24. 296

Figure 9.38 – Triplot displaying the proportions of grain, rachis and weed for each sample from Tell Aswad (based on weed content from the fifth version of the discriminant analysis), coded by crop type. 297

Figure 9.39 – Triplot showing the proportions of weeds, grain and glume bases of glume wheat samples at Tell Aswad. The dashed lines indicate the lower and upper cut offs for the spikelet like ratios following Bogaard (2011) (above, 5.8.2.2). 297

Figure 9.40 – Triplot comparing the relative sample compositions across the three Syrian sites, Jerf el-Ahmar, Dja'de and Tell Aswad. 299

Figure 9.41 – Triplot exploring levels of grain cleaning by crop type (colours) in the stores at Çatalhöyük. The different symbols relate to their crop-processing class (Table 9.5). The class for two samples contradicted with their dominant grain (*). This plot is not directly comparable with ethnobotanical data. 300

Figure 9.42 - Triplot showing the proportions of weeds, grain and glume bases for the three new type wheat stores from Çatalhöyük. The dashed lines indicate the lower and upper cut offs for the spikelet like ratios following Bogaard (2011) (above, 5.8.2.2). 302

Figure 9.43 - Triplot exploring levels of grain cleaning by storage type (colours) in the samples at Çatalhöyük. The different symbols relate to their crop-processing class (Table 9.5). The class for two samples contradicted with their dominant grain (*). This plot is not directly comparable with ethnobotanical data. 302

Figure 9.44 – Proportion of grain, weed, rachis in the 16 stores from Çatalhöyük dominated (≥70%) by a single cereal type. 304

Figure 9.45 – The relationship of the Jerf el-Ahmar samples (bottom - green) to the established discriminant function and modern regimes (top). This discriminant analysis is based on 19 samples and 18 taxa. The two lines represent the group centroids for low-input (white) and high-input (black) regimes. 309

Figure 9.46 – The relationship of the Jerf el-Ahmar samples to the established discriminant function, coded by site phase. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. All samples from the late phase relate to the large communal building EA30. 310

Figure 9.47 – The relationship of the Jerf el-Ahmar samples to the established discriminant function, coded by crop type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 310

Figure 9.48 – The relationship of the Dja'de samples (bottom - purple) to the established discriminant function and modern regimes (top). This discriminant analysis is based on 21 samples and 18 taxa. The two lines represent the group centroids for low-input (white) and high-input (black) regimes. 314

Figure 9.49 – The relationship of the Dja'de samples to the established discriminant function, coded by site phase. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 315

Figure 9.50 – The relationship of the Dja'de samples to the established discriminant function, coded by crop type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 315

Figure 9.51 – The relationship of the Tell Aswad samples (bottom - blue) to the established discriminant function and modern regimes (top). This discriminant analysis is based on 11 samples and 15 taxa. The two lines represent the group centroids for low-input (white) and high-input (black) regimes. 319

Figure 9.52 – The relationship of the Tell Aswad samples to the established discriminant function, coded by site phase. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 320

Figure 9.53 – The relationship of the Tell Aswad samples to the established discriminant function, coded by crop type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 320

Figure 9.54 – The impact of removing non-weed contaminants upon the intensity signatures. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. When potential dung-derived species are included, the group of samples is significantly more shifted towards the input end of the spectrum. 321

Figure 9.55 – The relationship of the Çatalhöyük storage samples (bottom - orange) to the established discriminant function and modern regimes (top). This discriminant analysis is based on 28 samples and 19 taxa. The two lines represent the group centroids for low-input (white) and high-input (black) regimes. 327

Figure 9.56 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by site phase. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 328

Figure 9.57 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by building number. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 328

Figure 9.58 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by building number and crop type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 329

Figure 9.59 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by dominant stored crop type (see Table 9.5). The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 329

Figure 9.60 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by dominant stored crop type with samples of mixed crop type (<70%) classification distinguished in grey. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 330

Figure 9.61 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by storage type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 330

Figure 10.1 – Plan of large 'communal' building EA30 at Jerf el-Ahmar, indicating spatial alignment in relation to the structures roof supports (Stordeur 2015: Fig. 30). 334

Figure 10.2 – Δ13C values for barley and wheat/rye at Jerf el-Ahmar from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of watering threshold for poorly watered (red) and well-watered (blue) values (after Wallace *et al.* 2013). 336

Figure 10.3 – Plot of modern barley and bread wheat δ15N values analysed from different known farming regimes against a natural log scale of rainfall. The manuring bands have been adjusted for the regression between unmanaged plant δ15N values and rainfall (Styring *et al.* 2016). 337

Figure 10.4 – δ15N values for barley and wheat/rye at Jerf el-Ahmar from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of thresholds adjusted for rainfall to indicate possible levels of manuring (after Styring *et al.* 2016). 337

Figure 10.5 – Δ13C values for wheat/rye at Dja'de by phase from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of watering threshold for poorly watered (red) and well-watered (blue) values (after Wallace *et al.* 2013). 344

Figure 10.6 – Δ13C values for barley at Dja'de by phase from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of watering threshold for poorly watered (red) and well-watered (blue) values (after Wallace *et al.* 2013). 345

Figure 10.7 – δ15N values for barley and wheat/rye at Dja'de from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of thresholds adjusted for rainfall to indicate possible levels of manuring (after Styring *et al.* 2016). 345

Figure 10.8 – Subset of Δ13C values for different crop types at Çatalhöyük, suggesting barley was grown in drier conditions than other crop types (Wallace *et al.* 2015). 358

Figure 10.9 – The relationship of the four study sites to the established discriminant function and modern regimes. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 361

Figure 10.10 – The selected samples from the four study sites plotted by approximate date (based on site phases – see Appendix 1g). The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. 365

Figure 10.11 – The relationship of the four early farming study sites to samples from the Early Bronze Age occupation at Tell Brak, Syria along the same cultivation intensity scale. The two lines represent the group centroids for the modern low input (white) and high-input (black) regimes. The unshaded area indicates the area of overlap between the two regime types. 367

List of Tables

Table 1.1 – The relationship of four major crop husbandry models to the three variables of permanence, intensity and seasonality (Bogaard 2004: Table 3.1). 9

Table 1.2 – Willcox's (2012b: 165) list of potential arable weeds from pre–domestication sites. The specific criteria used by Willcox to distinguish weeds are also summarised. 11

Table 3.1 – Simplified chronology for western Asia (after Aurenche *et al.* 2001; Goring morris *et al.* 2009; Stordeur 2015). The exact dating for each phase may differ slightly in each region (i.e. Syria, Turkey). 29

Table 3.2 – Simplified architectural styles throughout the sequence at Jerf el–Ahmar (Stordeur 2015: 25). 31

Table 3.3 – Summary of architectural styles throughout the PPN levels at Dja'de (Coqueugniot 2014). 39

Table 3.4 – Summary of architectural styles throughout the PPN levels at Tell Aswad (Stordeur *et al.* 2010). 44

Table 3.5 – Temporal groupings of levels for Çatalhöyük [East] (Çatalhöyük Research Project phasing, autumn 2017). 51

Table 4.1 – Critical review of identified storage evidence with associated plant remains. 61

Table 4.2 – Summary of storage characteristics. 67

Table 4.3 – Identified storage evidence with associated plant remains at Çatalhöyük. 74

Table 4.4 – Bin features with additional associated deposits. 79

Table 5.1 – Initial priority list, which was used to inform refined identification attempts at the beginning of the project. The list is based on the collective number of samples (between the four sites) that a genus occurs, as well as the number of associated species in the *Flora of Turkey* (FOT) and *Flora of Iraq* (FOI). 116

Table 6.1 – The functional attributes measured and their possible ecological significance within an arable context (Bogaard *et al.* 2016b). 132

Table 8.1 – Approximate number of taxa in countries of the Middle East and the status of their Floras (Adapted from Ghazanfar & McDaniel 2016). 172

Table 8.2 – Comparison of Bromus species listed in relevant Floras for the selected sites in western Asia (Frodin 2004). 173

Table 8.3 – Shape characteristics systematically recorded for each specimen during the construction of the *Bromus* identification key. 182

Table 8.4 – Average adjusted seed length (body measurements – without embryo tip) by *Bromus* species. Averages are based on eight specimens for each species that were analysed for the presented key. See Appendix 2d for full range of measurements. 184

Table 8.5 – Final altitude buffer used to filter Bromus species for each site, including an arbitrary buffer of 200m to account for shifts in vegetation since the Neolithic. 194

Table 8.6 – The species listed below were indicted as difficult to separate by the 'Score analyser' function, with at most 8 differences between them. Using the combined FIBS model (above, 6.3), ecological signatures were calculated for each species to explore variability between the groups. *There was no functional data available for two species, so average values were calculated by averaging data for the species from the same botanical section. 196

Table 8.7 – Ecological signatures (discriminant function) for each of the identified *Bromus* species/types in relation to the combined FIBS cultivation intensity model (Chapter 6). *The estimated discriminant function for this species was calculated by averaging the attribute data for all species from the Section *Bromus*. 199

Table 9.1 – Number of selected storage samples according to site area, building number and phase. 205

Table 9.2 – Current understanding of the relationship between levels in the South, North and TPC Areas (Hodder 2014; Bogaard *et al.* 2017; Çatalhöyük Research Project phasing, autumn 2017) 205

Table 9.3 – Selected storage samples from Çatalhöyük by their identified storage type, including further information regarding their total number of crop items (100% of sample), densities per litre, and crop/grain/wild taxa percentages. All totals and percentages exclude *Descurania sophia* (see footnote 1) and fruit/nut taxa. 208

Table 9.4 – Number of selected storage samples per main grain type. 213

Table 9.5 – Dominant crop composition of the selected storage samples at Çatalhöyük (excluding *Descurania sophia* (see footnote 1) and fruit/nut). The two dominant classes are determined by an arbitrary threshold of ≥70%, while the main grain type reflects the most abundant grain within the sample. Indeterminate grain identifications (i.e. cereal indet., wheat indet.) have been proportionally reassigned based on confirmed identifications to determine the main grain type. 214

Table 9.6 – Dominant crop types of selected storage samples by building. 228

Table 9.7– Fruit and nut items within the selected storage samples from Çatalhöyük. 229

Table 9.8 – Ubiquity and abundance of the wild/weed assemblage (to genus level) within the selected samples from Çatalhöyük. Max no. refers to the maximum number of items within a single sample. 231

Table 9.9 – Context and basic sample composition for the selected samples at Jerf el–Ahmar. 236

Table 9.10 – Samples associated with building structures within the selection from Jerf el–Ahmar and their associated cereal densities (Willcox & Stordeur 2012). 239

Table 9.11 – Number of selected samples per dominant crop class. 240

Table 9.12 – Dominant crop composition of the selected samples at Jerf el-Ahmar (excluding fruit/nut). The two dominant classes are determined by an arbitrary threshold of ≥70%, while the main crop type reflects the most abundant crop within the sample. 240

Table 9.13 – Ubiquity and abundance of the wild/weed assemblage (to genus level) within the selected samples from Jerf el-Ahmar. Max no. refers to the maximum number of items within a single sample. 243

Table 9.14 – Context and basic sample composition for the selected samples at Dja'de 245

Table 9.15 – Number of selected samples per dominant crop class. 245

Table 9.16 – Dominant crop composition of the selected samples at Dja'de (excluding fruit/nut). The two dominant classes are determined by an arbitrary threshold of ≥70%, while the main crop type reflects the most abundant crop within the sample. 246

Table 9.17 – Ubiquity and abundance of the wild/weed assemblage (to genus level) within the selected samples from Dja'de. Max no. refers to the max number of items within a single sample. 249

Table 9.18 – Context and basic sample composition for the selected samples at Tell Aswad. 252

Table 9.19 – Number of selected samples per dominant crop class. 253

Table 9.20 – Dominant crop composition of the selected samples at Tell Aswad (excluding fruit/nut). The two dominant classes are determined by an arbitrary threshold of ≥70%, while the main crop type reflects the most abundant crop within the sample. 254

Table 9.21 – Ubiquity and abundance of the wild/weed assemblage (to genus level) within the selected samples from Tell Aswad. Max no. refers to the maximum number of items within a single sample. 257

Table 9.22 – Different taxon combinations examined in the Jerf el–Ahmar discriminant analyses 269

Table 9.23 – Different taxon combinations examined in the Dja'de discriminant analyses. 275

Table 9.24 – Different taxon combinations examined in the Tell Aswad discriminant analyses. *Each analysis includes the exclusions from the previous stage. 281

Table 9.25 – Different taxon combinations examined in the Çatalhöyük discriminant analyses. *Each analysis includes the exclusions from the previous stage. 286

Table 9.26 – The 18 taxa used to investigate the intensity of cultivation at Jerf el–Ahmar. When taxa were not identified to species, average functional attribute values were calculated based on other identified specimens. 307

Table 9.27 – The classification of archaeobotanical samples (n=19) by high and low input regimes, showing samples in relation to site phase, classified with high probability (≥0.90) and low probability (<0.90). 307

Table 9.28 – The classification of archaeobotanical samples (n=19) by high and low input regimes, showing samples in relation to crop type, classified with high probability (≥0.90) and low probability (<0.90). 308

Table 9.29 – The 18 taxa used to investigate the intensity of cultivation at Dja'de. When taxa were not identified to species, average functional attribute values were calculated based on other identified specimens. 312

Table 9.30 – The classification of archaeobotanical samples (n=21) by high and low input regimes, showing samples in relation to site phase, classified with high probability (≥0.90) and low probability (<0.90). 312

Table 9.31 – The classification of archaeobotanical samples (n=21) by high and low input regimes, showing samples in relation to crop type, classified with high probability (≥0.90) and low probability (<0.90) 313

Table 9.32 – The 15 taxa used to investigate the intensity of cultivation at Tell Aswad. 318

Table 9.33 – The classification of archaeobotanical samples (n=11) by high and low input regimes, showing samples in relation to site phase, classified with high probability (≥0.90) and low probability (<0.90). 318

Table 9.34 – The 19 taxa used to investigate the intensity of cultivation at Çatalhöyük. When taxa were not identified to species, average functional attribute values were calculated based on other identified specimens. 325

Table 9.35 – The classification of archaeobotanical samples (n=28) by high and low input regimes, showing samples in relation to site phase, classified with high probability (≥0.90) and low probability (<0.90). 325

Table 9.36 – The classification of archaeobotanical samples (n=28) by high and low input regimes, showing samples in relation to building number, classified with high probability (≥0.90) and low probability (<0.90) 326

Table 9.37 – The classification of archaeobotanical samples (n=19) by high and low input regimes, showing samples in relation to crop type, classified with high probability (≥0.90) and low probability (<0.90) 326

Table 10.1 – Average discriminant functions with ±SD for each of the study sites in relation to the established cultivation intensity scale (Bogaard *et al.* 2016b). 360

Chapter 1
Introduction

Research on the origins of agriculture in western Asia has placed great emphasis on the location and pace of domestication processes. Much less attention has been given to the specific nature and social implications of early cultivation practices across the agricultural transition, and to the potentially varied land management strategies involved. By contrast, discussion of agricultural practices adopted by early Neolithic communities in Europe has generated a diverse range of models, which have often focused on explaining the factors involved in its widespread adoption (Childe 1929; 1957; Sherratt 1981; Rowley-Conwy 1981; Barker 1985; Halstead 1989; Whittle 1996; Bogaard 2004). European based models commonly debate the permanence, fertility, intensity and seasonality of cultivated land in early farming societies, which may offer reflections upon general mobility levels, the development of social inequality through surplus production, and the organisation of agricultural labour (Whittle 1996; Halstead 1995; Bogaard 2004). Such explicit models have rarely been explored in relation to early cultivation practices in western Asia, though these approaches have equal relevance for establishing a wider understanding of these transitional societies.

A functional ecological approach to ecological interpretation of arable 'weed' taxa associated with early archaeologically identified cultivars enables nuanced comparison between modern flora developed under known conditions and ancient assemblages (Jones 2002; Charles *et al.* 2002). The usefulness of this approach has been demonstrated in the context of early farming in central Europe, by offering a systematic method to assess levels of permanence, intensity and seasonality as a way of excluding implausible models

(Bogaard 2004). Interpretation of the Near Eastern data has so far been limited by the general nature of the ecological data used, but inferences to date suggest that cultivation practices changed considerably through the Pre-Pottery Neolithic (Colledge 1998).

This project was designed to address a major gap in archaeobotancial research on the Neolithic Near East, by applying a functional ecological approach to the now substantial 'weed' dataset available from the Pre-Pottery (PPN) and Late (Pottery) Neolithic (LN) in western Asia, with particular reference to the Northern Levant and Central Anatolia. It aims to contribute to wider discussions regarding the emergence of agricultural societies by establishing clearer inferences on the growing conditions and farming methods involved in early plant cultivation in western Asia. Furthermore, it considers the social implications of these practices, as well as their lasting social and ecological consequences.

1.1 Current perspectives: the nature of early farming in western Asia

Sherratt's (1980) theory of floodplain cultivation remains the most clearly defined model to directly address the nature of early farming in western Asia. His approach draws attention to the associations of many early Neolithic settlements with riverine and spring-side locations, and proposes that rich alluvial silts with extensive ground and surface-water were essential for the initial stages of cultivation. This theory further acted as a rejection of earlier models suggesting an initial swidden phase (i.e. shifting cultivation) (e.g. Childe 1929; Clark 1952: 93; Boserup 1965). Sherratt's main argument regarding specific cultivation techniques suggests that initial farming methods only required simple technology, with minimal soil preparation and maintenance, making the process 'practically self-cultivating' (Sherratt 1980: 318). While describing the system as 'fixed plot horticulture', Sherratt adds that labour efforts would have been 'trivial' compared with later regimes, effectively describing agricultural practices more akin to extensive forms of cultivation (e.g. broadcast sowing) (Sherratt 1980; Bogaard 2005). To account for such

opportunistic forms of exploitation, Sherratt additionally argues that early farmers cultivated cereals during the short spring season (March-May), making use of optimum water availability, while avoiding damage to crops from the winter floods (Sherratt 1980: 317). Sherratt's model presents interpretations of early crop *intensity, fertility* and *seasonality*, though its arguments are largely based on settlement data, with only minimal reference to the archaeobotanical evidence. A fleeting reference is made to the potential weed ecology in some early Neolithic sites, by commenting on the frequent presence of *Scirpus* seeds (a genus of aquatic reeds) with early cereal deposits, which may suggest damp growth conditions (Flannery 1969: 81; Sherratt 1980); however these may alternatively represent taxa derived from animal dung (cf. Charles 2011).

In another 'least effort' based model, which assumes that early cultivators merely exploited areas of natural fertility (cf. Bogaard 2005: 178), Harris (2002) applies long-standing debates of 'shifting-field' cultivation to the earliest cultivating societies in western Asia. In this work, Harris emphasises the lack of discussion concerning the nature of early cultivation systems, the types of terrain where initial crops were first grown, and its subsequent integration with forms of animal herding (Harris 2002). While accepting elements of Sherratt's (1980) floodplain theory in the exploitation of lowland alluvial soils, based on indications of 'wet-loving' weed taxa in the Pre-Pottery Neolithic A (PPNA) period (cf. Colledge 2001; see summary below), he further proposes a system of shifting cultivation that would have made use of upland woodland environments (Harris 2002). Harris draws upon the ground stone evidence that indicates an increase in axe production in the PPNB compared with the preceding PPNA period, which Wright (1993) interprets as a reflection of increasing emphasis on tree felling. Harris also suggests the possible use of fire as a method of clearance for early cultivators, which would have promoted crop growth through added nitrogen and phosphorus to the soil (Harris 2002: 72). While Harris offers negligible archaeobotanical evidence in support of this model for early PPN sites, the forms of cultivation indicated present extremes in the levels of field *permanence* and *fertility* levels, which enable such hypotheses to be tested through closer examination of the associated arable weed evidence, and with additional methods such as isotope analysis.

When turning to models based on bioarchaeological evidence, a limited number of approaches have been devised, and many are still in their preliminary stages. The examination of arable weed ecology is one of the most instructive approaches for assessing crop-growing conditions. Sue Colledge (1998; 2001) analysed archaeobotanical assemblages from a range of early cultivation sites across western Asia, and was able to identify samples with distinct taxonomic composition from different sites and periods, which she interpreted as representing a 'vegetational fingerprint' of plant-related activities (Colledge 2001: 190-1). Among the wild taxa, she identified the unintentional collection of contaminants alongside harvested crops at these sites, i.e. 'weeds', and offered preliminary indications of their associated ecology (Colledge 2001: 191). 'Wet-loving' taxa were found in abundance at the earlier phases from several of the sites analysed, including those from PPNA Mureybit and PPNB Ghoraifé, which she links to initial cultivation practices occurring in areas of high groundwater (Colledge 2001: 191); these indications are also consistent with some of Sherratt's (1980) arguments for early cultivation. Notably, this trend appears to shift by the later phases at such sites, with an increasing dominance of 'field' taxa adapted to frequent disturbance; Colledge relates this pattern to an increasing *intensity* of cultivation methods over time, with the introduction of tillage practices (Colledge 2001: 191). These initial indications suggest the potential for considerable changes in cultivation practices through the Pre-Pottery Neolithic.

Signatures for 'weed' taxa adapted to high levels of soil disturbance were further indicated in Amy Bogaard's (2005) preliminary assessment of the evidence for farming strategies in western Asia. Potential 'weed' taxa identified from the later levels at PPNB Çayönü indicate a dominance of annual species, which are able to thrive in disturbed areas due to their short life-cycles, again suggesting increases in farming *intensity* (Bogaard 2005: 188). She further relates such developments in farming practice to the emergence of a broad set of crops across western Asia in the PPNB period, which would have been possible with increasingly artificial growing conditions; this contrasts with the more local exploitations of locally adapted species observable in the earlier PPNA period (Bogaard 2005: 188). Such indications are also integrated with the faunal evidence, such as the increasing focus on

caprines in late PPNB sites, to suggest an 'intensive mixed farming' model for early cultivation in western Asia (Bogaard 2005). Cross-examination of the available bioarchaeological datasets for each region also served to highlight the need for further investigations into *how* early farming was practiced and the social implications of such methods for early farming communities (Bogaard 2005).

In an additional model based on bioarchaeological evidence, Araus *et al.* (2014) proposed temporal shifts in farming *intensity* in western Asia, suggesting initial cultivation methods gradually developed into more extensive, low-yielding agricultural practices from the Neolithic to the Bronze Age. This study was based on indications from stable isotope analysis applied to archaeobotanical material, and examined the $\delta^{15}N$ and $\delta^{13}C$ ratios of wild and domesticated cereals from 11 sites from the Middle and Upper Euphrates, dating from the Epipalaeolithic to Bronze Age periods. This included five key early farming sites: Jerf el-Ahmar (PPNA), Tell 'Abr 3 (PPNA), Dja'de (PPNA/early PPNB), Akarçay Tepe (middle PPNB/Pre-Halaf) and Tell Halula (middle PPNB/Halaf). Such applications can be used to evaluate crop water status ($\delta^{13}C$) and other aspects of farming practice, such as soil fertility or potential manuring practices ($\delta^{15}N$) (Fiorentino *et al.* 2014). Samples of associated wood charcoal (*Quercus* sp. and *Pistacia* sp.) were also analysed to establish a comparable basis for expected local values. One of the main temporal trends to emerge from the study was a gradual decrease in $\delta^{15}N$ composition from the earliest sites to the later periods, which Araus *et al*. relate to cultivation practices occurring under gradually less-fertile soil conditions (Araus *et al.* 2014). The highest values were observed from pre-domestication cultivation contexts, and are thought to indicate that initial cultivation practices were conducted on naturally fertile soils and/or midden areas (Araus *et al.* 2014). When considering water status, consistent correlations between the $\delta^{13}C$ ratios in barley and corresponding wood charcoal indicated the absence of artificial water management strategies, though universally elevated $\delta^{13}C$ levels suggest a wetter climate than the present day (Araus *et al.* 2014). The authors explain these trends as indicating that initial cultivation strategies that targeted fertile soils were unsustainable, and resulted in more *extensive* forms of rain-fed agriculture in the subsequent periods (Araus *et al.* 2014).

1.2 Weed ecology

Trends in ecological requirements are much easier to determine for suites of 'weed' species than associated crops, and provide useful indicators for the specific conditions in which they were grown. Cereal and pulse crop species, on the other hand, are generally able to tolerate a range of different growing conditions, so cannot be analysed based on their ecological traits. While the ecological implications of weed taxa for inferring the potential conditions of cultivation practices have been acknowledged for decades (cf. Flannery 1969: 81), the application of such approaches to investigate early farming regimes is greatly underdeveloped for western Asia. Sue Colledge's (1998; 2001) pioneering ecological interpretations of early weed flora have provided a useful framework for further investigations, with her preliminary observations providing a number of testable hypotheses for more detailed ecological analyses. Nevertheless, the interpretation of ancient weed ecology has been approached in a number of different ways, with each method enabling different levels of conclusions to be made.

1.2.1 Ellenberg numbers

Ellenberg numbers, or 'indicator values' represent a series of scales for major environmental variables (light, soil moisture, soil nitrogen content etc.) that have each been scored for a number of key plant species (Ellenberg 1950; Ellenberg *et al.* 1992). This method was developed on the basis of modern field observations to use plant species as indicators of environmental conditions, and has since been applied to archaeobotanical assemblages as a way of inferring specific growing conditions, such as levels of fertility, soil moisture and shadiness etc. (e.g. van der Veen 1992: 108-9). Species may be further assigned to ecological groups sharing a suite of similar preferences, to be compared with ancient weed assemblages for the identification of a particular set of environmental

conditions (Ellenberg 1950; Jones 1992: 136). However, past species compositions may differ greatly from those observable in modern weed flora (Hillman 1991). Additionally, with this approach based primarily on field observations, it only addresses the issue of *where* a species is found and not *why* it is there, so it is difficult to distinguish the individual ecological factors that determine the particular location of a species (Charles *et al.* 1997).

1.2.2 Phytosociology

Phytosociology characterises certain ecological settings by classifying stands of vegetation into communities, and identifying key 'character species' (Westhoff & van der Maarel 1973; Jones 1992). However, this grouping method is of limited use for the reconstruction of ancient vegetation as compositions of plant communities are not static, and may have changed considerably through time (Jones 1992). The generally incomplete nature of the archaeobotanical record, as well as mixed sources of deposition, also makes this a problematic form of comparison (Jones 1992: 136). On the other hand, the identification of 'character species' from archaeobotanical assemblages has been frequently used as a way of signifying certain habitats. However, like Ellenberg numbers, phytosociological associations are based on observations of species co-occurrence, therefore do not isolate why species occur under certain conditions and not others (Bogaard 2004: 6; Jones 1992: 137).

1.2.3 Functional ecology

The '*Functional Interpretation of Botanical Surveys*' (FIBS) approach has proven to be the most effective method for comparing modern weed flora developed under known conditions with ancient assemblages, and forms the basis of this research (Charles *et al.* 1997; Jones *et al.* 2000; Bogaard 2004; Jones *et al.* 2010). Functional ecology relates the

behaviour of individual plant species to specific ecological variables, by measuring their functional traits or attributes. Functional attributes are morphological or behavioural characteristics that predict species' potential in relation to major environmental variables, such as soil productivity, disturbance and moisture; these include a variety of measurements, such as canopy dimensions, leaf area, root type and tap root thickness, stomatal size and density etc. (Charles *et al.* 1997). As this method crucially links species characteristics with ecological conditions rather than merely observing the general habitat preferences of specific species, it provides a means of comparing modern weed floras under known husbandry with ancient weed assemblages, while allowing ecological factors to be isolated (Bogaard 2004). The method also provides the potential to reconstruct ancient farming regimes for which no modern parallel exists (Bogaard 2004).

This approach has been successfully applied in the context of early farming in central Europe, in Bogaard's study of Neolithic sites in the loess belt and Alpine Foreland regions (Bogaard 2004). Four major plant husbandry models for the European data were related to three key variables, which could be tested using this functional approach: *permanence*, *intensity* and *seasonality* (Table 1.1) (Bogaard 2004). The ecological implications of the archaeological weed assemblages indicated high levels of disturbance and weedy annuals, and contrary to models of shifting cultivation, was able to determine the presence of long established cultivation plots that were artificially maintained (Bogaard 2004). The seasonality of the crops grown was also determined, with indications for autumn sown crops that reject models for floodplain cultivation (Bogaard 2004). As discussed above, there are a number of similar hypotheses for the western Asian data that may also be tested using this functional ecological approach; however, a lack of species-level identification for early weedy taxa, in addition to an absence of modern weed ecological data from (semi-)arid regions, has prevented such analyses from being applied. The isolation of arable weeds from alternative sources of wild taxa (e.g. animal dung, ruderal) presents further difficulties for this approach, particularly for early cultivation sites (below, 1.3).

Table 1.1 – The relationship of four major crop husbandry models to the three variables of permanence, intensity and seasonality (Bogaard 2004: Table 3.1).

Models	*Permanence*		
Shifting cultivation	Transient plots	*Intensity*	
Extensive ard cultivation	Fixed plots	Extensive	*Seasonality*
Floodplain cultivation		Intensive	Spring sowing
Intensive garden cultivation			Autumn or spring sowing

Recent field studies in Morocco (Bogaard *et al.* 2016b) have enabled the development of a weed ecological model directly applicable to (semi-)arid regions such as western Asia. The model combines the Moroccan functional ecological data with previous modern field studies in Europe (below, Chapter 6) to infer relative levels of cultivation *intensity* (i.e. labour inputs per unit area). Ecological models related to the *permanence* and *seasonality* of cultivation plots are not yet available for (semi-)arid regions, with existing datasets collected from temperate Europe; further fieldwork is required to establish the effects of increased aridity on these two variables.

1.3 Isolating relevant 'weed' taxa

Before such ecological comparisons can be determined from early farming contexts in western Asia, the relevant 'weed' data must first be isolated from the archaeological material. The difficulties of this process have presented one of the main barriers for ecological applications on the western Asian dataset. Identification of arable weeds is particularly contentious for early Neolithic sites, as their emergence has been used as an indicator for the initial stages of crop cultivation in pre-domestication contexts (Willcox *et al.* 2008; Willcox 2012a; Willcox 2012b). These must be distinguished from other wild plants, which in some cases continued to be intentionally collected alongside early cultivars throughout the Neolithic; this can be clearly demonstrated from the *in situ* processing

contexts of wild mustard preserved from a burnt building at PPNA Jerf el-Ahmar, as well as in later established farming communities, such as the extensive collected stores of wild mustard from Late Neolithic levels at Çatalhöyük (Willcox 2002; Bogaard *et al.* 2013a); while morphologically wild, wild mustard may have been deliberately cultivated or further collected as a weed in arable contexts, presenting further ambiguity.

Willcox (2012a; 2012b) established a series of 19 potential weed taxa from pre-domestication sites (PPNA/B) in western Asia (Table 1.2), defining them as 'plants which thrive when the soil is disturbed by cultivation', as well as representing taxa with no known uses (Willcox 2012a: 171). In this investigation, which considered 97 wild plant taxa, edible plants that may have been intentionally gathered for food were eliminated, for example small-seeded grasses, vetches (*Vicia*), knotweed (*Polygonum*) and goosefoots (*Chenopodium*) (Willcox 2012b), though it is notable that these are all common field taxa in modern cultivation regimes. Ruderal taxa, such as greater rock jasmine (*Androsace maxima*) and henbanes (*Hyoscyamus*), were also disregarded due to the possibility that these grew within settlements rather than being collected from fields (Willcox 2012b). The final 19 selected weed taxa could be recognised as weeds of cultivation in later agricultural sites, though were mainly identified to genus level only, limiting ecological interpretations.

Willcox's (2012b) study, however, does not account for possible incorporations of dung-derived taxa into the archaeobotanical record, despite its potential relevance even as early as the PPNA period (cf. Miller 2001; Arranz-Otaegui *et al.* 2016). A number of wild seed types have been demonstrated to survive digestion through livestock in an identifiable form, due to their small size and/or hard protective seed coats; this presents an additional depositional factor to consider when identifying arable weeds (Wallace & Charles 2013).

The burning of animal dung for fuel, which is clearly attested at Neolithic Çatalhöyük, for example, may char surviving dung-derived taxa directly within primary archaeobotanical assemblages, and may be subsequently mixed with other sources of disposal, such as the

Table 1.2 – Willcox's (2012b: 165) list of potential arable weeds from pre-domestication sites. The specific criteria used by Willcox to distinguish weeds are also summarised.

Table 2 The criteria for the selected taxa were (1) they had no known use for their seeds, (2) they were interpreted as arable weeds on later agricultural sites

Potential weed taxa	JA 1	JA 2	DJ	Extant weed species
Adonis	17	38	48	*A. microcapa*[a], *A. dentata*
Bellevalia	107	72	27	*B. warburgii*[a], *B. egii*, *B. macrobotrys*[a], *B. longipes*[a], *B. trifoliata*, *B. kurdistanica*
Centaurea	2	17	338	*C. procurrens*, *C. verutum*[a], *C. verutum*
Coronilla	2	1	4	*C. scorpioides*, *C. repanda*
Crucianella	1	1		*C. herbacea*
Erodium	20	13	66	*E. moschatum*, *E. cicutarium*
Fumaria	6	2	24	*F. densifolia*, *F. micrantha*, *F. tenuiflora*, *F. parviflorum*[a]
Galium	68	118	67	*G. uropetalum*[a], *G. tricorne*[a], *G. tricornutum*
Glaucium	1	12	288	*G. corniculatum*[a], *G. leiocarpum*
Heliotropium	14	4	19	*H. europaeum*[a], *H. villosum*, *H. rotundifolium*, *H. bovei*
Onobrychis	5	1	107	*O. squarrosa*
Ornithogalum	13	1	2	*O. narbonense*[a], *O. brachystachys*, *O. neurostegium*
Papaver	1	1		*P. rhoeas*[a]
Silene/Gypsophila	126	372	148	*S. muscipula*[a], *S. colorata*, *S. damascena*[a], *S. longipetala*
Teucrium			4	*T. spinosum*[a], *T. parviflorum*
Thymelaea	9	9	5	*T. hirsuta*
Trigonella astroites	15	15	10	*Trigonella*
Vaccaria			1	*V. segetetalis*[a]
Valerianella			2	*V. coronata*[a], *V. vesicaria*[a]
Totals	407	677	1,160	

Absolute totals from the lower levels at Jerf el Ahmar (JA1), from the upper levels at Jerf el Ahmar (JA2) and from Dja'de (DJ). Note the increase in totals between early and late levels at Jerf el Ahmar. Extant weed species corresponding to the genera, after Zohary (1950)

[a] Indicates obligatory weed, that is arable weeds not known outside cultivation

burning of crop processing waste (Filipović 2012; 2014). These may greatly skew the general ecological signature if not isolated from the arable weed taxa. Correspondence analyses have been developed as a way of separating such depositional sources (cf. Filipović 2012; 2014; Bogaard *et al.* 2013a); however, the relative influence of such taxa must be re-examined separately for each site under investigation.

For the purpose of this study, 'weeds' can be defined as wild taxa with limited economic use, that are directly associated with crop storage or processing contexts (below, Chapter 2). Such a classification, however, must be assessed separately in relation to each site analysed, and will require careful examination of contextual information on a sample-by-sample basis. Potential dung-derived taxa must be highlighted from each weed assemblage, so that ecological signatures can be compared with or without their inclusion.

1.4 Research questions and objectives

The primary aim of this research is to develop a new understanding of the growing conditions and farming methods involved in early plant cultivation in western Asia. This is conducted using a functional ecological approach to test the various hypotheses presented by current models for farming practices in western Asia. The core method involves the application of a recent weed ecological model (cf. Bogaard *et al.* 2016b) to infer the relative *intensity* of arable land management practices, offering insights into soil *disturbance* and *fertility* (below, Chapter 6). The project analyses ecological trends on both broader and local scales to address the following research questions:

1. *What growing conditions and farming methods were involved in early plant cultivation in western Asia?*

2. *What social implications do these practices have for understanding the emergence of early farming societies?*

3. *What were the lasting social and ecological consequences of such methods?*

These research aims were achieved through close contextual and statistical analysis of the samples and deposits from which early crop and weed assemblages derive (below, Chapter 4 & 9). A core approach was to isolate the 'potential weed flora' from the samples of relevant contexts and analyse their functional ecological attributes (e.g. leaf area and thickness; canopy dimensions; stomatal density and distribution). For more accurate indications of their ecological implications, a major aspect of this study was to re-identify weed taxa as close to species-level as possible. This involved in-depth observation with light microscopy and the use of traditional morphometric analysis to construct detailed identification keys (below, Chapter 8). Statistical analysis of these established attributes determined the specific growing conditions of early crops, and hence the nature of management practices. Comparisons will be made with weed survey data from relevant modern regimes, including a recent study of traditional cereal farming in Morocco (below, Chapter 6), to assist the identifications of certain farming strategies.

Sample-by-sample data from a sequence of recently excavated and analysed Pre-Pottery and Late Neolithic sites from western Asia will be crucial to this project. These include a number of archaeobotanically rich datasets with previously identified weed flora (cf. Willcox 2012b), including those from PPNA Jerf el-Ahmar and early PPNB Dja'de in northern Syria, PPNB Tell Aswad in southern Syria, and the later established farming centre of Late Neolithic Çatalhöyük in central Anatolia. The results of the ecological analyses will be closely explored in relation to other contextual data at the selected sites and will aim to determine the cultural context of specific farming practices and processing regimes. Statistical analyses between regions and through time will also establish the extent of variation in cultivation methods, with implications for the social factors and consequences involved in the emergence of agricultural societies.

Ecological signatures determined from the weed data will further be compared in relation to complementary stable isotope studies. These have recently been conducted on samples from Jerf el-Ahmar and Dja'de (cf. Araus *et al.* 2014), with similar investigations undertaken from Neolithic Çatalhöyük as part of the NERC-funded project, '*Crop stable isotope ratios: new approaches to palaeodietary and agricultural reconstruction'* at the University of Oxford (Wallace *et al.* 2015).

Chapter 2

Origin of arable weeds

Weed species have received substantial attention in the plant sciences, with recent decades of research heavily focused upon developing greater controls and more effective methods for their eradication. However, weeds with their intimate associations with human activities are also of significant interest to archaeologists. Weeds have accompanied human societies for as long as they have actively disturbed the land through cultivation practices. Their emergence and evolution are closely linked with some of the earliest plant cultivars, with some 'weed-like' species acting as progenitors for later domesticated cereals and pulses. Owing to these subtler and overlapping relationships in early cultivation contexts, which forms a major focus of this thesis, it is important to further define 'weeds' within this framework.

2.1 What is a 'weed'?

The botanical literature provides endless definitions for 'weeds', but they most commonly highlight human perspectives on them as 'unwanted' species, as well as ecologically distinguishing groups of plant species that thrive in habitats disturbed by humans (Harlan & DeWet 1965; DeWet & Harlan 1975; Hill 1977; Ladizinsky 1998). As a criterion for categorising relevant 'weed' species, perceived levels of undesirability can be difficult to determine since they are subjective; there are numerous ethnographic accounts that demonstrate how one societies' 'weed' is another societies' highly desired crop (Harlan & DeWet 1965; Ladizinsky 1998). Studies from modern day northern and southern Greece

detail alternative approaches to 'weeding' activities; communities in the north abandoned weeded plants along the edge of the field to wither, whereas communities further south regarded weeding activities as an opportunity to collect comparable species for use as edible greens or fodder (Halstead 2014: 237-8).

This subjective aspect is even more problematic when considering prehistoric specimens. We are generally unable to assess a former society's attitude towards specific plant taxa, which therefore blends distinctions between accidentally collected 'weed' taxa and intentionally collected wild species. Willcox's (2012) recent study of early cultivation contexts assigned ethnographically known uses (i.e. edible, medicinal) to recovered wild plant taxa as a method of isolating unintentionally collected 'weed' species. However, this approach is largely dependent on modern perspectives and documented analogies and may not necessarily reflect the local knowledge of distant past societies. Nevertheless, a degree of 'un-wantedness' regarding certain wild taxa may be inferred from archaeological deposits by the discovery of highly cleaned crop stores, or the abundance of wild seeds in processing waste from disposal contexts (i.e. hearths, middens). Nevertheless, it must also be noted that recognition of a species as an unwanted 'weed' in one context does not limit it from having other uses in another.

Despite these various issues with 'undesirability' as a defining characteristic of 'weeds', it remains a vital component of any appropriate definition for use in an archaeological context. Archaeobotanists are primarily interested in 'weed' species for their status as 'unintentional' by-products of human activities, to inform independent narratives (Charles & Halstead 2001). However, consideration of their ecological characteristics is equally important for understanding their emergence and complex relationships with early plant cultivars. When defined in purely ecological terms, 'weeds' may refer to a group of competitive species that are well adapted to disturbed or unstable habitats (Harlan & DeWet 1965), although this broad definition also encompasses pioneer species adapted to natural disturbances, such as land slips and areas affected by wind/water erosion (Harlan & DeWet 1965). A suitable definition for 'weeds' therefore must also indicate their

exclusive associations with human made disturbances. Ruderal species, which thrive on waste land and dump heaps, may also be included under this definition (Ladizinsky 1998).

As this research centres upon agricultural practices and is primarily concerned with 'weeds' derived from these contexts (i.e. agrestals), the term 'weed' will be used to refer to the arable form, distinct from ruderal species. 'Weeds' will therefore be defined as the 'unwanted' wild competitors of crop plants, which prosper within human disturbed cultivation habitats and are inadvertently brought back to settlements along with collected crop material. Some species may also be referred to as 'weed-like' or 'weedy'; such terminology may be used to indicate species with similar ecological characteristics/ preferences to arable weeds (i.e. well adapted to disturbed ground), yet are either actively cultivated themselves or come from non-arable sources (e.g. dung-derived taxa). However, these subtle distinctions may be less clear when considering species from early cultivation sites.

Arable weeds under this definition play a vital role in archaeobotany and have been used by scholars as way of identifying the earliest indications of pre-domestic cultivation (Colledge 1998; Hillman *et al.* 2001; Willcox *et al.* 2008; Riehl *et al.* 2013; Snir *et al.* 2015), as well as inferring specific practices undertaken in past agricultural societies (Charles *et al.* 1997; Jones *et al.* 1999; Bogaard 2004; Bogaard *et al.* 2016a). The relationship of weed seeds with other crop material can inform specific processing stages of archaeobotanical deposits, through statistical analysis of their individual seed characteristics (i.e. big/small, heavy/light) (Jones 1984; 1987) (below, 5.10.2.1). The ecology of ancient weed flora also provides a valuable resource for analysing the nature and seasonality of past farming conditions, with several different methodologies developed to interpret this data (Ellenberg 1950; Westhoff & van der Maarel 1973; Charles *et al.* 1997; Jones *et al.* 2000; Bogaard 2004; Jones *et al.* 2010; Bogaard *et al.* 2016a; 2016b) (above, Chapter 1).

Yet despite these clarified definitions, various issues remain regarding the isolation of relevant weed flora from archaeobotanical datasets. As discussed briefly above, wild taxa

with similar 'weed-like' characteristics may also become incorporated within archaeological assemblages as a result of their intentional collection (i.e. for use as food, building material, fodder etc.). To add a further layer of complication, 'weed-like' species can additionally enter archaeological contexts through unintentional sources, such as the burning of fuel resources (i.e. animal dung, turf, peat) or accidental burning of ruderal taxa. These different sources can easily become mixed with crop material, such as processing waste, and therefore can be difficult to separate from weeds. In some instances, it also may be the case that a single species overlaps across a number of these different categories within a single site. Accurate identification of weed taxa in archaeobotanical assemblages requires careful consideration of their relative compositions and individual contexts, and such processes form an important part of this project (below, Chapter 4).

2.2 Origin of weeds

To further understand the significance of weed taxa within early cultivation contexts, as well as their relevance within current archaeobotanical analyses more generally, it is important to consider further the nature of their emergence. In contrast to the origins of domesticated plant species, there have only been limited discussions regarding the origins of arable weed taxa in the archaeological literature (Zohary 1973; Groenman-Van Waateringe 1980; Rösch 1998; Willcox 2012; Hartmann-shenkman *et al.* 2014; Snir *et al.* 2015), despite their intimate relationship with cultivar species and notable impacts upon human societies, such as the reduction of crop yields and increased demands upon labour. The subject is treated more extensively within the botanical literature (cf. Harlan & DeWet 1965; DeWet 1968; DeWet & Harlan 1975; Baker 1965; Baker 1974; Young & Evans 1976; Mohler 2001; Vigueira *et al.* 2013), but this focuses upon the uniqueness of their ecological characteristics rather than exploring the more direct relationships with human activities.

While the emergence of true arable weeds is closely bound with the beginnings of cultivation practices in western Asia, owing to the very nature of their definition (i.e.

relationships with cultivated plant species), the various species that became weeds were already well-established within existing Epipalaeolithic environments across Eurasia (Harlan & DeWet 1965). *Polygonum aviculare* and *Rumex acetosella*, which are two species that are well established as weeds in later farming contexts, can be traced back from peat deposits in Europe as early as the Middle Pleistocene (c. 600,000 years ago), well before the development of modern humans (Hill 1977: 4). Many of the genera that developed as weeds are characteristic of 'open' habitats and would have been previously adapted to sites of natural disturbance, including river banks, cliffs, coastal strands, sand dunes and salt marshes (Baker 1974). The Pleistocene glaciation that affected much of northern Europe has been linked to such developments, through the creation of an extensive array of disturbed environments that provided plentiful habitats for the secondary succession of pioneer and disturbance tolerant species (Harlan & DeWet 1965: 22; Young & Evans 1976). In western Asia, similarly disturbed environments were created by a series of erosion periods throughout the Pleistocene, including the formation of several important river valleys (i.e. Euphrates, Orontes) where many early cultivation sites are situated (Bar-Yosef 1994; Demir *et al.* 2007). Furthermore, several genetic studies link major developments in key weed species from later agricultural periods back to the highly disturbed habitats that emerged in the Pleistocene (Stebbins 1981; Nakamura *et al.* 2012; Inda *et al.* 2014).

With the emergence of archaeologically visible and therefore increasingly permanent human settlements, which can first be detected from the Upper Palaeolithic period in the southern Levant (c. 23,000 BP), humans began to increasingly alter their local surroundings and created further habitats for weed-like species (Goring-Morris & Belfer-Cohen 2008). Human-made disturbances such as cleared open settlement areas, burning and rubbish heaps would have replicated the 'vacant niches' (cf. Van Kleunen *et al.* 2015) previously created by major erosion events and provided ideal conditions for the colonisation of 'weedy' species, including important crop progenitors (Harlan & DeWet 1965; Hill 1977). In previous discussions, this invasion has also been identified as a key factor behind routes to plant domestication (Anderson 1952; Sauer 1952; Harris 1969;

Hawkes 1970). With the beginning of cultivation practices, the increased frequency, intensity and duration of disturbances gradually raised the importance of these well-adapted disturbance tolerant species until they became permanent competitors of such niches (Young & Evans 1976).

2.3 Weed characteristics

While variation among successfully developed arable weed species is diverse, most tend to share a common set of characteristics that have enabled their successful competition with local wild species and established cultivars alike. One of the most fundamental of these characteristics relates to the timing of their individual life cycles, which enable their persistence alongside crops (Baker 1974; Cappers & Neef 2012). The majority of weeds from established arable contexts are annuals, so as to have either fully dispersed their seeds or possess fully matured fruits by the time of harvest (Cappers & Neef 2012). Perennial weeds, on the other hand, respond to conditions of high disturbance through vigorous vegetative reproduction or the ability to regenerate from root fragments (Baker 1965). Regardless of their life history, weed species tend to have very rapid growth patterns (both above and below ground) in order to be able to effectively compete for water, light and nutrients (Ladizinsky 1998: 161; Cappers & Neef 2012: 115). Weed species frequently have more extensive root systems than many cultivars enabling better access to nutrients and water, which may substantially affect crop growth and therefore yields (Ladizinsky 1998: 161). Rapid growth above the ground also encourages weed seeds to be present above the level of reaping, so as to be collected together with crop material and incorporated within seed stores (Cappers & Neef 2012: 116-7).

Furthermore, weeds have tended to proliferate due to them developing advanced dispersal methods. Many successful weed species have a high output of seeds making them difficult to eliminate; an individual poppy (*Papaver rhoeas*) for example, can produce up to 20,000 seeds (Hodson & Bryant 2012: 262). Prolific seed numbers are regularly

combined with staggered germination times; a proportion of seeds remain dormant (some for 100 years or more) to build extensive seed banks in the soil, which may persist for many generations (Ladizinsky 1998: 161; Hodson & Bryant 2012: 262) Other common characteristics include climbing/binding behaviours, with species possessing either tendrils or hooked hairs that attach themselves to the culms of upright crops; these features further increase the likelihood of their collection during harvests, with the potential to be resown with the crop in subsequent seasons (Cappers & Neef 2012; Barrett 1983).

Despite these common features, weeds cannot be defined within a single phytosociological class and are represented by a diverse range of different plant families, which also reflect an array of ecological preferences (Holzner 1978). It is, however, notable that certain families have contributed unusually large numbers of species (i.e. Cruciferae, Polygonaceae, Umbelliferae, Compositae, Gramineae) (Baker 1974). These variations in associated ecology can be related to specific adaptive strategies, such as vigorous growth rate, stress tolerance, or rapid seed production, which enable successful competition with other weed (and crop) species (Grime 1977; 1979). Furthermore, there is a tendency for weed species of similar ecological preferences to share a suite of physical traits, or "attributes" (i.e. are of the same "functional type"), which may be systematically measured to characterise specific growing conditions (below, Chapter 6). The wide variety of species to emerge as weeds are likely to reflect the range of different environmental conditions created by early farming strategies, which is an aspect that is of great interest within this research project. Increasingly intensive agricultural practices, such as tillage, irrigation, and manuring practices, would have further broadened the range of environmental niches, leading to the specialisation of weed flora with more extreme tolerances (Young & Evans 1976). Alternatively, some weed species are characterised by enormous phenotypic plasticity and are able to occupy a range of environments, but are generally less productive in unfavourable conditions and produce only limited numbers of seeds in these circumstances (Harlan & DeWet 1965: 22). This is particularly significant for

archaeobotanical applications, as stunted weed species grown in unproductive environments are less likely to survive archaeologically.

2.4 Evolution of weed species

When considering weed origins, the relative importance of weed preadaptation to environments of human disturbance, versus their subsequent adaptive evolution to exploit these new habitats is a matter of debate within weed science (Vigueira *et al.* 2013). Nevertheless, it can be determined that like domesticated plants, accompanying weed species have also undergone significant evolutionary changes in response to their management by humans. Weeding and crop-processing activities, which developed as methods to separate weeds from crop harvests, have resulted in several evolutionary adaptations to escape eradication and proliferate. Crop mimicry presents one of the most significant changes detected in the characteristics of some weed species, observable across both the seeds and vegetative parts (Barrett 1983; Ladizinsky 1998: 164-5).

Seed mimicry resulted directly from crop-processing activities including threshing, winnowing, sieving and hand cleaning (Ladizinsky 1998). Seeds that were similar to the crop in size, weight and colour would be indistinguishable from the crop and evade the various processes of removal. Contamination within seed stores would have resulted in the resowing of the weed seeds in following seasons, ensuring their continued survival and further selection (Barrett 1983). In addition to comparable seed morphology, this adaptive strategy requires the fine tuning of plant life cycles so that seeds are fully retained until harvest of the crop (Ladizinsky 1998). A well-known example of seed mimicry is *Camelina sativa*, which is a common annual weed of flax (*Linum*); this species comes into flower at the same time as flax, producing nondehiscent fruits that possess similar winnowing properties to flax (Barrett 1983).

Vegetative mimicry in weeds, on the other hand, offers increased protection from activities such as hand-weeding (Ladizinsky 1998). One of the clearest examples of this can be seen in *Echinochloa oryzicola,* which is exclusively found in lowland rice fields (Tominaga & Yamasue 2004). This species closely mimics the rice plant from seedling to the heading of fruits (Figure 2.1) and is so similar in its vegetative growth that it frequently evades detection until panicles have formed, by which time farmers are often reluctant to hand-weed as it may disturb crop growth and pollination (Harlan 1982; 1992; Tominaga & Yamasue 2004).



Figure 2.1 – Mimicry of *Echinochloa oryzicola* (right) to rice (left) (Yamasue 2001).

Mimetic weeds are often exclusively associated with, and therefore dependent upon, a single crop type, owing to the selective processes involved in their development, with many of these specialist weed species becoming extinct or significantly reduced in population with the onset of modern mechanical farming techniques (e.g. seed purification) (Holzner 1982). In some cases, whole suites of characteristic weed species have been known to accompany specific crops since ancient times, for instance flax, whose

weed flora typically consists of *Camelina alyssum*, *Lolium remotum*, *Silene linicola/cretica, Spergula arvensis* and *Cuscata epilinum* (Holzner 1982; Cappers & Neef 2012). While not all of human selection processes resulted in full crop mimicry, the different species in this flax example represent specialists that were able to successfully exploit the different niches created by flax cultivation. Furthermore, even without full specialisation, thousands of years of human intervention likely influenced weed traits to varying degrees, influencing characteristics such as plant height, seed size and flowering period.

A second, and more widespread path of evolution to be detected within arable weed species, is the further development of colonising traits, i.e. weeds that 'specialized in non-specialization' (Holzner 1982). While many weed ancestors would have been predisposed to act as pioneers in human-made disturbances, the main characteristics associated with successful weeds (i.e. able to compete with crops) 2.3) must to some extent be a result of further evolution alongside cultivated crops. Clear instances of adaptive evolution can be detected in modern weed populations, where the introduction of chemical herbicides has led to the evolution of herbicide resistance in some species (Jasieniuk *et al.* 1996). The degree that weed species have evolved since the advent of agriculture is difficult to determine (cf. Vigueira *et al.* 2013), but it is clear that such processes of adaptive evolution were crucial to their continued survival alongside agricultural innovation (Clements *et al.* 2004). This demonstrates the importance of examining suites of weeds in the characterisation of modern husbandry regimes to interpret ancient datasets, as this limits the impact of changes to the behaviour of individual species over time (Jones 1992; Jones 2002; Bogaard 2004) (see Chapter 1 and 6).

2.5 Identifying arable weeds archaeologically

As introduced above (2.1), the wide range of potential wild plant sources within archaeobotanical assemblages presents challenges for the isolation and examination of ancient weed flora, particularly when considering early cultivation contexts. Wild plant

resources continued to be important sources of food, and likely had other uses (e.g. oil, medicinal uses, pigments, building material[1]), throughout the Neolithic in western Asia (cf. Fairbairn *et al.* 2007; Arranz-Otaegui *et al.* 2016); such utilisation of wild plant species can still be observed in modern communities in the region (Ertuğ 2000). In addition to intentional collections, there are various other routes for wild species to have entered the archaeological record besides weed flora. The seeds from ruderal vegetation may have been wind-blown into settlements, while the raising of livestock introduced different taxa from within their dung (Charles 1998; van der Veen 2007; Wallace & Charles 2013). These non-arable sources of wild taxa may be preserved within archaeological assemblages through rubbish disposal (i.e. in hearths or ovens), their deliberate use as fuel, or through accidental burning, which may then become mixed with other sources through later disposal in midden areas and pit fills (van der Veen 2007).

Despite these various wild plant sources that require disentangling, there are a number of approaches that may be used to isolate relevant arable weed data from both unmixed and mixed archaeological deposits. The clearest indications of arable weeds can be identified from primary *in situ* crop stores preserved by large-scale burning events. A large number of *in situ* grain stores were excavated from the Neolithic site of Çatalhöyük, central Anatolia, which will be examined as part of this study (Bogaard *et al.* 2013a; Filipović 2014; Özbaşaran *et al.* 2014) (Chapter 4 and 9). These grain-rich deposits, many of which were charred *in situ* within built storage features, provide unambiguous instances of arable weeds and are directly associated with the crop species that they were grown with. However, these forms of primary storage contexts are rare (Chapter 4), with archaeobotanical assemblages more frequently characterised by secondary contexts that are highly mixed.

A number of statistical analyses have been used to isolate arable weed taxa from more mixed archaeobotanical deposits. Correspondence analysis has been frequently used to

[1] However, these forms of wild plant use are likely to be underrepresented within the archaeobotanical record unless they were accidentally (or deliberately) burnt in larger stores (van der Veen 2007). This is particularly the case for wild species where the leafy parts are principally collected.

identify associations of different taxa deriving from different sources (e.g. dung-derived, collected taxa) (Jones 1991; Bogaard *et al.* 2013a; Filipović 2014) (below, 5.8.1). At the site of Çatalhöyük, a complete suite of dung-derived taxa was recognised from the assemblage through associations with other species found to accompany preserved dung pellets (Bogaard *et al.* 2013a). This statistical method can also emphasise samples that contain unusually large numbers of a single taxon, which may indicate other deposition routes (i.e. intentional collection). An alternative statistical analysis to identify contributions of non-arable wild sources within an assemblage is the use of discriminant analysis (below, 5.8.2.1). Following Jones' (1984) method of assessing crop-processing stages, which relates the size, dispersal method, and aerodynamic properties of weed seeds to specific crop-processing stages, which were observed ethnobotanically (below, 5.8.2.1), Charles (1998) was able to identify the presence of dung-derived taxa through inconsistencies in their collective physical traits when compared with arable contexts. Such methods will be explored in greater detail within this project (below, 5.8 & 9) to isolate the relevant weed data from the selected samples for ecological analysis.

Chapter 3

Case study sites

Archaeological and environmental background

Weed evidence from four early farming sites forms the focus of this project: two Pre-Pottery Neolithic farming sites in the Middle Euphrates region, PPNA Jerf el-Ahmar and early PPNB Dja'de, the PPNB site Tell Aswad in the Damascus Basin, and the later PPN-LN site of Çatalhöyük [East], central Anatolia (Figure 3.1). These sites have been strategically selected to target specific questions regarding the nature of early cultivation methods in western Asia, and the subsequent development of agricultural techniques in established farming societies. Çatalhöyük provides one of the best opportunities to investigate variations in agricultural practice between the households of a single settlement, with its abundant *in situ* contexts, detailed phasing, and extensive horizontal exposure of buildings, while the earlier PPNA/early PPNB sites Jerf el-Ahmar and Dja'de offer some of the earliest recognised indications of pre-domestication cultivation. PPNB Tell Aswad presents a later PPN case study that is chronologically intermediate between the initial adoption of plant cultivation techniques in the PPNA and the fully established Pottery Neolithic.

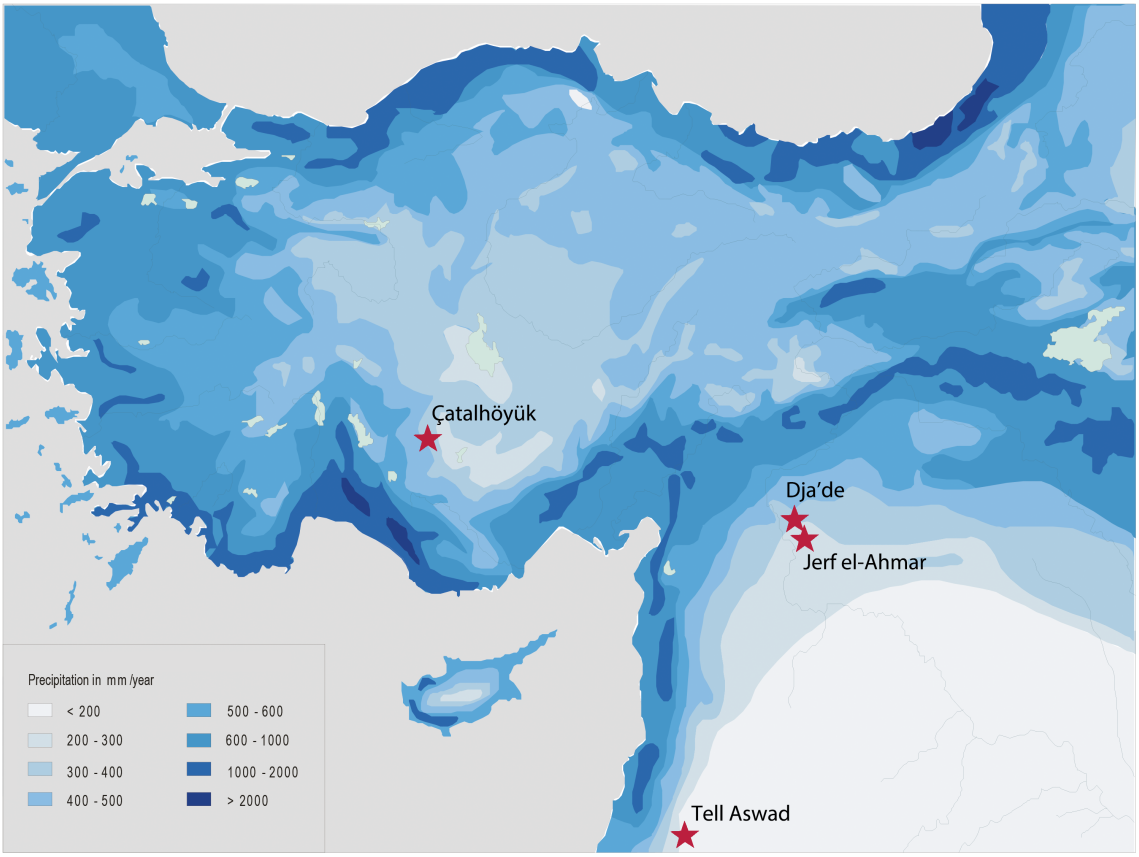


Figure 3.1 – Map showing location of sites under analysis in western Asia in relation to average annual precipitation (Map: Hütteroth & Höhfeld 2002).

3.1 Northern Levant – Pre-Pottery Neolithic Jerf el-Ahmar, Dja'de, & Tell Aswad

The three PPN sites range in date from 9500 cal. BC in the earliest phases at PPNA Jerf el-Ahmar, to 7500 cal. BC in the final phases at PPNB Tell Aswad (Table 3.1) (Willcox & Stordeur 2012; Orange et al. 2013). Jerf el-Ahmar and Dja'de are both located on the left bank of the Middle Euphrates in northern Syria, at a distance of around 30 km from one another. Today this area receives between 250-300mm of rain per year on average (Figure 3.1) (Coqueugniot 1998; Willcox *et al.* 2008). Tell Aswad is situated further south, in the Damascus basin of Syria, and has a slightly drier climate, receiving an average annual rainfall of less than 200mm (van Zeist & Bakker-Heeres 1982).

Table 3.1 – Simplified chronology for western Asia (after Aurenche *et al*. 2001; Goring-morris *et al*. 2009; Stordeur 2015). The exact dating for each phase may differ slightly in each region (i.e. Syria, Turkey).

Pre-Pottery Neolithic A (PPNA) (c. 9500 - 8700 cal. BC)
Pre-Pottery Neolithic B (PPNB) (8700 - 7500 cal. BC)
Pre-Pottery Neolithic C (PPNC) (7500 - 6400 cal. BC)
Late (Pottery) Neolithic (LN) (6400 - 4500 cal. BC)

3.1.1 Jerf el-Ahmar, PPNA

Jerf el-Ahmar, occupied for more than half a millennium between 9500 and 8700 cal. BC, is the earliest site to be analysed in this study, and presents important evidence for the pre-domestication cultivation of wild cereals (below, 3.1.1.3), including some of the earliest potential weed flora (Willcox & Stordeur 2012; Stordeur 2015). This small village-scale site (<1 hectare) was established across two chalk hillocks, rising out of the Euphrates flood plain, which are separated by a small wadi, though it is difficult to determine the original distance between the site and the flood plain during antiquity (Willcox 1996; Stordeur 2014).

The site was discovered by T. McClellan and M. Mottram (Oriental Institute, University of Chicago) in the 1980s who conducted preliminary investigations (McClellan & Mottram 1994). With the construction of Tishrin Dam in the 1990s, full-scale rescue excavations were undertaken by a Franco-Syrian team from 1995 to 1999 under the direction of D. Stordeur (CNRS) and B. Jamous (DGAM) (Stordeur 2015). Significant cultural developments can be detected throughout the occupation phases at Jerf el-Ahmar, represented within architectural form, daily activities, and spatial organisation (Stordeur

2014). While the stratigraphic sequence primarily represents the PPNA horizon, which displays cultural affinities with the Mureybetian Culture (Stordeur *et al.* 1996; Cauvin 2000), later levels indicate a transitional phase signalling the beginning of the PPNB (Stordeur 2014). Symbolic art is prominent throughout the sequence, which primarily depict fierce wild animals, such as raptors, snakes and scorpions; such imagery further displays ties across the northern Fertile Crescent (Stordeur 2014).

3.1.1.1 Site stratigraphy and architecture

An area of over 1,000m2 was exposed during six excavation seasons, with 11 distinct levels identified across the two discrete mounds (Éminence Est and Éminence Ouest) (Table 3.2; Figure 3.2) (Willcox & Stordeur 2012). These five metres of PPN deposits were located less than half a metre from the surface, with later occupation likely damaged from modern ploughing and construction activities (Gourichon 2004). Severe erosion towards the downstream side of the tell has hindered efforts to stratigraphically link the two discrete mounds, which appear to have originally formed as a single entity (Stordeur 2015). Nevertheless, four separate phases of occupation were determined, based on major changes in construction techniques, flint and stone tool technology and figurine form, which enabled broader comparisons between the two areas of the site (Table 3.2) (Stordeur 2015).

Excavations revealed a range of architectural constructions that indicate complex social organisation at the site, including a number of domestic building styles, which were organised around large 'communal' subterranean structures; these large structures were interpreted as having varied functions, for storage, ritual functions, and as meeting places (Figure 3.3) (Stordeur 2014: 39). At the beginning of the occupation, domestic units are largely characterised by rounded, single-roomed buildings, with rectangular mutlicellular style buildings appearing in the later phases (Table 3.2) (Stordeur 2014; 2015). This,

Table 3.2 – Simplified architectural styles throughout the sequence at Jerf el-Ahmar (Stordeur 2015: 25).

Level	Site area	Level	Site area	Architectural styles	New architectural forms
			Phase ancienne (early)		
VII/E VI/E V/E IV/E	Éminence Est (East)			Circular single-roomed buildings	N/A
			Phase moyenne (middle)		
III/E II/E I/E	Éminence Est (East)			Sub-circular single-roomed buildings	Multicellular tripartite structures Large subdivided 'communal' buildings
			Phase récente (late)		
0/E	Éminence Est (East)	III/W II/W	Éminence Ouest (West)	Multicellular tripartite structures Large subdivided 'communal' buildings	Rectangular single-roomed buildings Rectangular quadripartite structures
			Phase de transition		
- I/E - II/E	Éminence Est (East)	I/W 0/W	Éminence Ouest (West)	Rectangular single-roomed buildings Multicellular tripartite structures Rectangular quadripartite structures	Large 'communal' buildings without subdivision

however, does not represent a simplistic progression, as a great diversity in building styles co-exist in the later levels (Stordeur 2014: 35).

Several buildings were destroyed in large-scale burning events, including the destruction of an entire village episode (Level III/E) (Stordeur 2015). A number of *in situ* activity areas were recovered, most notably a burnt 'kitchen' area, which contained substantial primary plant concentrations directly associated with several saddle querns and limestone 'basins' (Willcox 2002). Although even in unburnt areas buildings were frequently adorned with similar forms of equipment, or offered glimpses of previous activities through their recycling as building materials. Over three hundred millstones were recovered from the site, which were found in relation to the majority of buildings excavated (Stordeur 2015). Cooking facilities, such as fire-pits and stone-lined hearths, were also common across the site, but these were usually identified within the external spaces between buildings (Stordeur 2014; 2015).

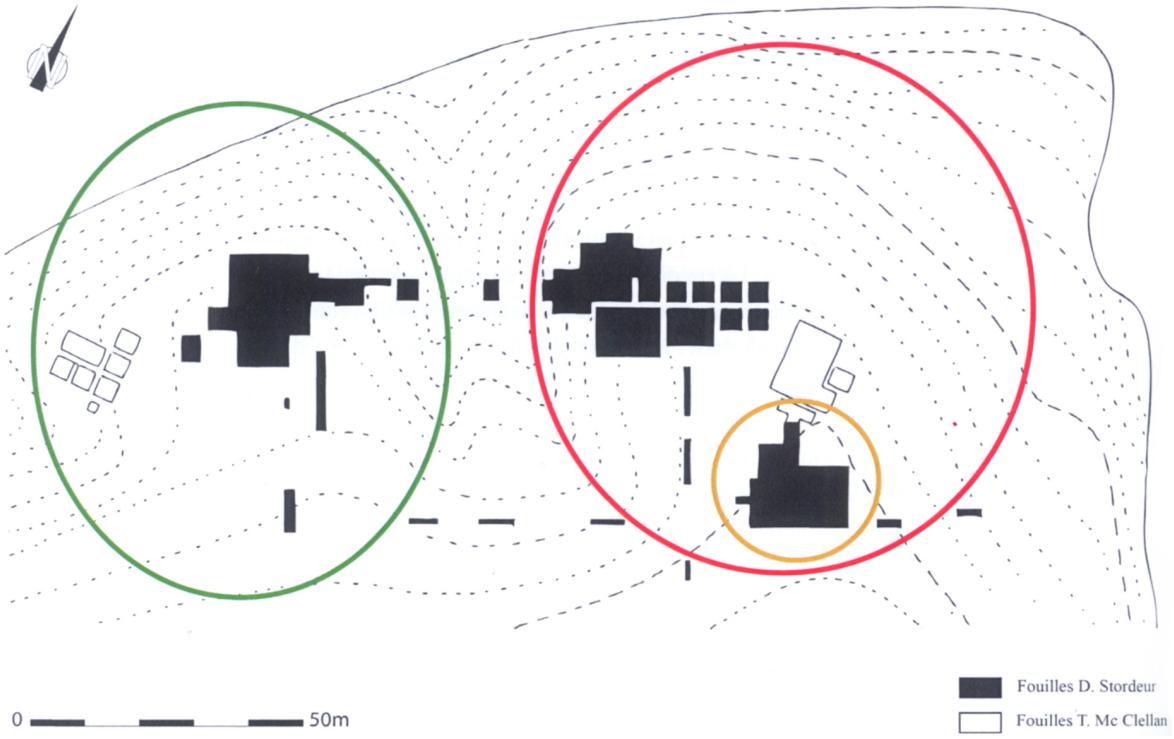
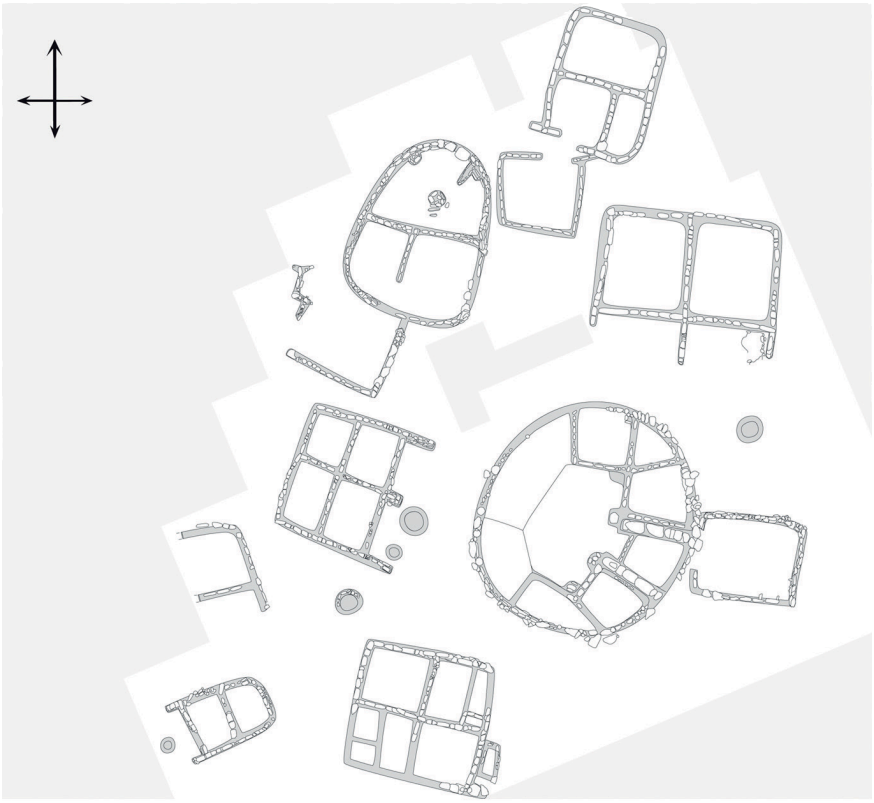


Figure 3.2 – Excavation areas at the Jerf el-Ahmar in relation to the mound's topography. Trenches targeted two sections of the mound, Éminence Ouest (green) and Éminence Est (red) (Stordeur 2015: Fig. 77).



Figure 3.3 – Circular 'communal' structure at Jerf el-Ahmar surrounded by a range of construction types identified as domestic buildings in level II/W (Stordeur 2014: Fig. 6).



3.1.1.2 Environmental background

At an altitude of 320m above sea level, the present-day vegetation surrounding Jerf el-Ahmar is an area of degraded steppe, where rich stands of wild barley continue to grow within its poor chalk soils (Willcox 1996; 2007). However, during the PPNA occupation, the site would have been positioned at the edge of several different ecological zones, including riverine forest, swamps, steppes and hills (Gourichon 2002; Stordeur 2015). Environmental data, including wood charcoal and faunal remains, indicate that this zone was slightly cooler with higher rainfall levels during the Neolithic (Helmer *et al.* 1998; Stordeur 2015). The region was much richer in woodland species, with the most ubiquitous taxa being almond (*Amygdalus*), *Pistacia* cf. *atlantica*, *Prunus microcarpa*, hawthorn (*Crataegus*) and buckthorns (*Rhamnus*); these species are now restricted to higher altitudes, which receive higher annual rainfall (Stordeur *et al.* 1996; Willcox *et al.* 2008). The faunal record shows the frequent exploitation of wild gazelle at Jerf el-Ahmar, as well as the presence of species of voles, dormice and hedgehogs (*Microtus socialis*, *Eliomys melanurus* and *Erinaceus concolor*), which are adapted to cooler, wetter climates (Helmer *et al.* 1998; Stordeur 2015). While it is difficult to ascertain the exact path of the river Euphrates in antiquity, it is likely that the site was established at the edge of the water to access a range of benefits, including diverse resources and the facilitation of trade networks (Stordeur 2015). This riverside location would have attracted a diverse range of wild species; though fish was rarely consumed at the site, an extensive range of aquatic bird species were hunted, as well as various mammals drawn to the water's edge (Gourichon 2002; 2004).

3.1.1.3 Pre-domestication cultivation

While there are no traces of morphologically domesticated plants at Jerf el-Ahmar, there are various lines of evidence to suggest that wild cereals were cultivated and gathered at large scales, presenting some of the earliest evidence for pre-domestication cultivation (Willcox & Stordeur 2012). When compared with neighbouring sites from the preceding Epipalaeolithic, there is a noticeable reduction in the proportion and variety of small-seeded taxa at Jerf el-

Ahmar, whereas cereals such as wild barley (*Hordeum spontaneum*) became dominant, complemented by smaller quantities of an einkorn/rye type (*Triticum/Secale*) (Willcox *et al.* 2008); similar temporal patterns can be detected between the early and late levels at the site (Willcox & Stordeur 2012). Furthermore, increases in grain size (thickness and breadth) can be detected for these two cereal types between the start and end of the occupation, which may be a consequence of their cultivation under optimum growing conditions (Willcox 2007). Accompanying this abundance of cereal grain is an increase in wild taxa that display weedy characteristics (above, Chapter 2), presenting some of the earliest indications for weeds of cultivation (Willcox *et al.* 2008; Willcox 2012).

Various features across the settlement are consistent with the large-scale exploitation of cereals. More than three hundred stone querns were recovered from the site, of which over 30 were preserved *in situ* inside building structures; their oval shape were ideal for grinding cereal grain and they often displayed signs of wear at the base (Willcox & Stordeur 2012; Stordeur 2015). The *in situ* querns were often arranged in groups of two, three and four, which in some cases provided very little space for other activities, suggesting dedicated rooms for food preparation (Willcox & Stordeur 2012). Other equipment related to cereal processing include large limestone basins, which may have been used to soak grain; concentrations of barley grain were found in association with such equipment within the burnt 'kitchen' from building EA10 (Willcox 2002). The large structure EA30 (Figure 3.3) has been interpreted as a communal building for the large-scale storage of cereals, based on its small internal cells and higher than average cereal frequencies (below, 4.2) (Willcox & Stordeur 2012). The large-scale storage of cereals is further supported by the presence of rodent activity across the site, identified by charred droppings, bones, teeth and gnaw marks; these were also found in higher frequencies within building EA30 (Willcox & Stordeur 2012).

3.1.2 Dja'de, PPNA/EPPNB

Dja'de, also known as Dja'de el Mughara, is a small village-scale site (1.5 hectares) located on the left bank of the Euphrates river (c. 30km north of Jerf el-Ahmar), consisting of a low mound that stands 5-6m above the surrounding plain (Coqueugniot 1998; Christidou *et al.* 2009). The site has a date range between c. 9310–8290 cal. BC, with the main occupation relating to the Early PPNB period, around the second half of the ninth millennium BC (Coqueugniot 1998). Recent excavations exposed earlier levels contemporary with the latest PPNA levels from nearby Jerf el-Ahmar, therefore the site documents an important transitional phase from foraging to farming (Coqueugniot 2014).

Excavations began as part of a rescue mission prior to the building of the Tishrin Dam in 1991, with the site now situated only a few metres from the water's edge, narrowly escaping inundation (Christidou *et al.* 2009). However, the settlement would have originally been located several tens of metres from the river during the time of its occupation (Bollongino & Vigne 2008: 874). Multiple excavation seasons were carried out by a French team led by E. Coqueugniot (CNRS), with most of the excavation completed by 2006; the exceptional discovery of geometric paintings from the Final PPNA phase (Figure 3.6) led to the extension of field operations, but these were suspended in the spring of 2011 due to the Syrian war (Coqueugniot 2006; Pichon 2017). The site was particularly rich in archaeological material, featuring large communal architecture, extensive art, varied funerary practices, as well as evidence for collective feasting events (Coqueugniot 2014).

3.1.2.1 Site stratigraphy and architecture

The PPN occupation at Dja'de was extremely rich, forming between 6-9m of archaeological deposits (Coqueugniot 2006; Christidou *et al.* 2009). Several areas of the mound have been explored (Figure 3.4) with investigations concentrated around the mound's summit (Coqueugniot 2006). Three separate phases of occupation have been determined from the PPN

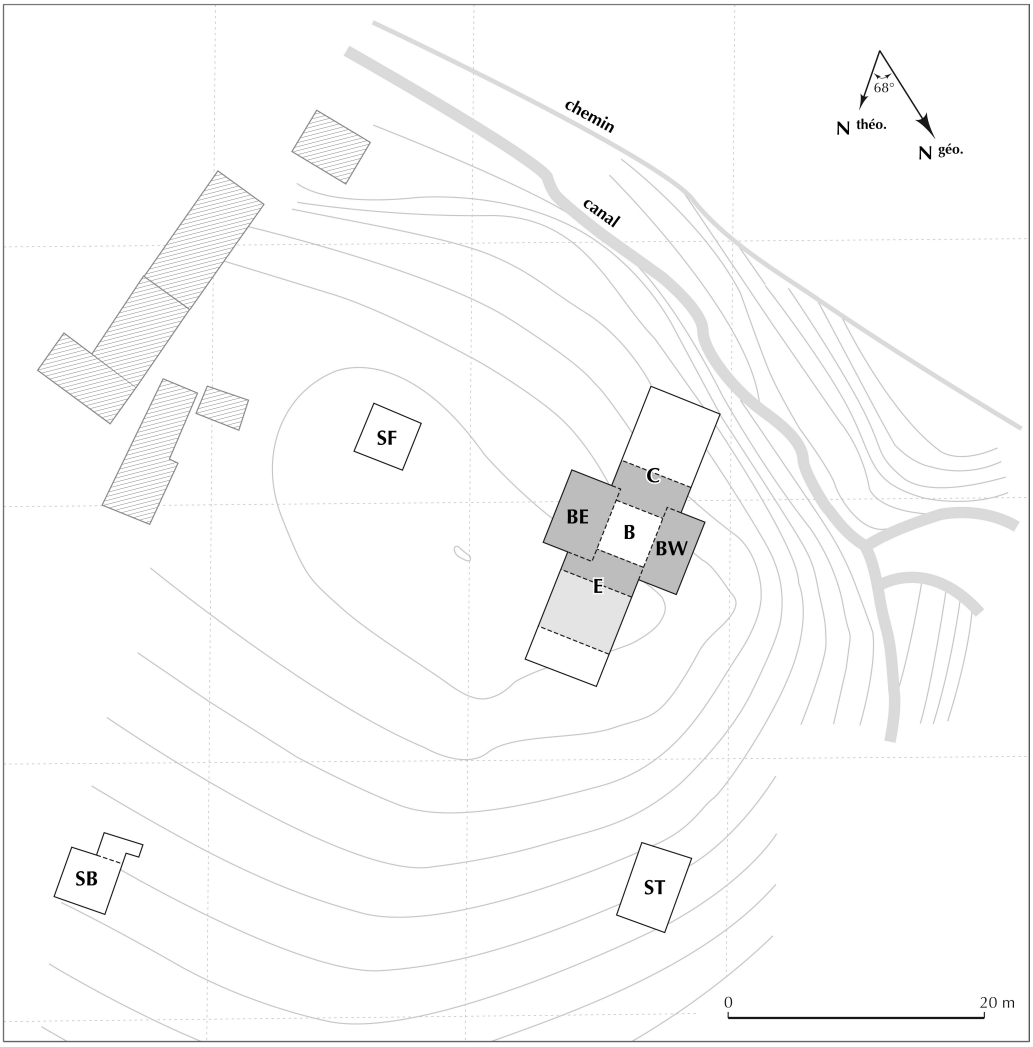


Figure 3.4 – Excavation areas across the mound at Dja'de (Coqueugniot 2006).

levels, primarily based on patterns in architectural style and lithic industry (Table 3.3) (Coqueugniot 2014). The earliest phase, "DJ I", captures the transition period between the end of the PPNA and the beginning of the PPNB (Coqueugniot 2014). The architecture of this early phase is highly variable; it features a large (7.5m diameter) circular semi-subterranean structure with geometric wall paintings, which has been interpreted as a communal building (Figure 3.5 & 3.6), but also smaller ephemeral structures ("tents"), as well as more substantial stone walled rectangular constructions (Coqueugniot 2014). By "DJ II", equivalent to the beginning of the Early PPNB, the architecture is characterised by rectangular buildings, which were more commonly multi-cellular with clay floors (Coqueugniot 2014). This phase is also notable for large-scale dumping episodes of animal butchery waste, interpreted as leftovers

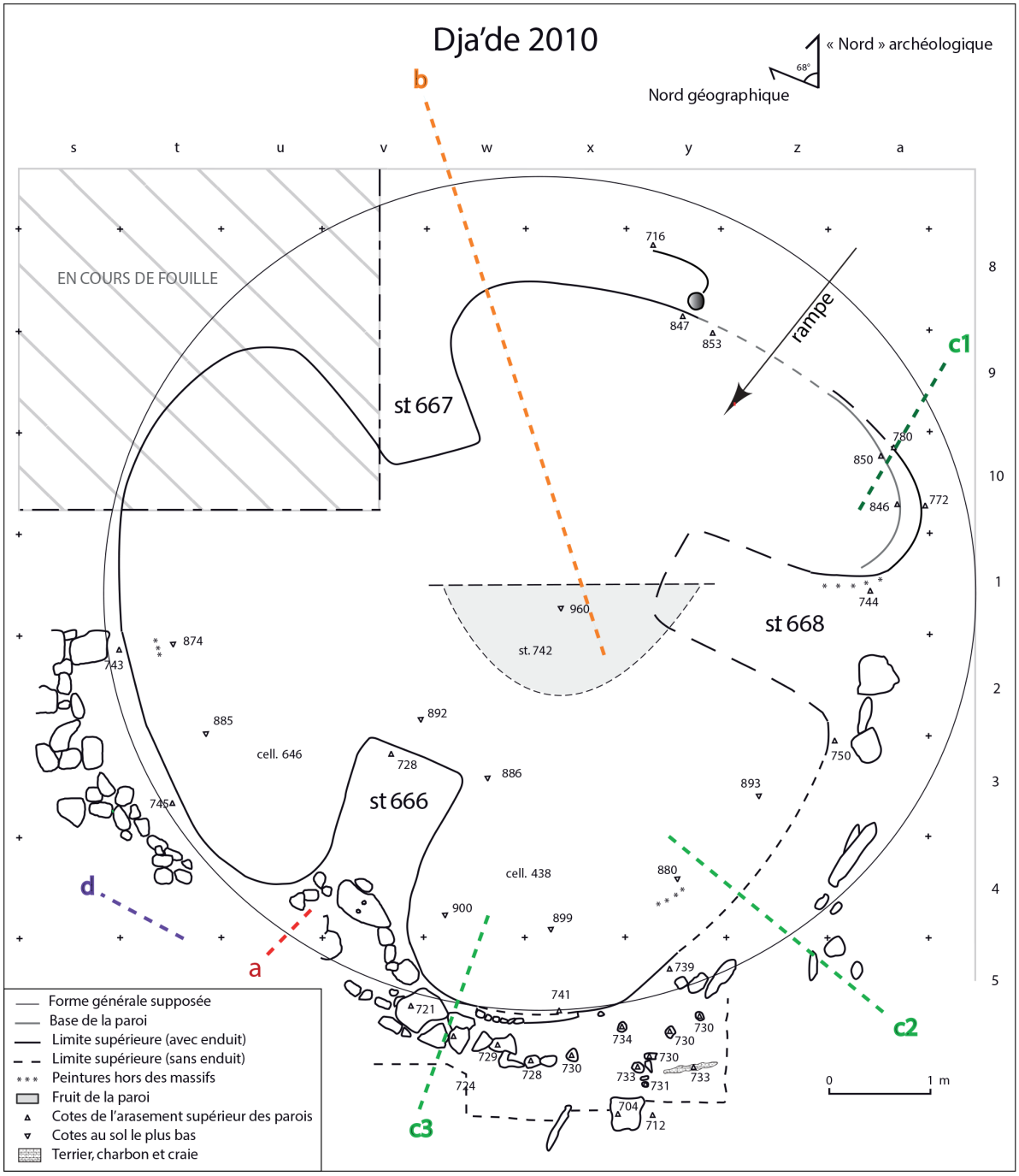


Figure 3.5 – Plan of the communal building from phase DJ I (Coqueugniot 2014: Fig. 7).



Figure 3.6 – Preserved geometric painting on the wall of the large communal structure at Dja'de (Coqueugniot 2014: Fig. 8).

Table 3.3 – Summary of architectural styles throughout the PPN levels at Dja'de (Coqueugniot 2014).

Site Phase	Date (cal. BC)	Architectural styles
PPNA/PPNB		
Dja'de I (Dj I)	c. 9310-8830	– Large circular semi-subterranean "Community House" with geometric polychrome paintings. – Rounded cell buildings and light structures ("tents"). – Rectangular cell buildings (walls of large stones) with paved soil.
EPPNB		
Dja'de II (Dj II)	c. 8800-8500	– Rectangular houses often multi-cellular with large cells. – Emergence of 'grill-plan' buildings in later levels (Dj IIc).
EPPNB		
Dja'de III (Dj III)	c. 8540-8290	– Small rectangular houses, often unicellular and separated from each other by large open spaces. – External 'grill-plan' walls are characteristic of this phase.

from communal feasting events (Gourichon 2004; Coqueugniot 2014). The final PPN phase, "DJ III", represents the main part of the Early PPNB and is the best known phase from the site (Coqueugniot 2006). The architecture from this phase displays notable shifts in spatial organisation, consisting of smaller rectangular buildings (mostly single-celled) separated by open spaces; these open areas, which sometimes contained supports for platforms ("grill-plan" buildings), formed the primary activity areas, including the cooking of food and flint work (Coqueugniot 2006; 2014). Following the PPNB levels, the site was abandoned until the Pre-Halaf period at the beginning of the 6th Millennium BC and was later reoccupied during the Early Bronze Age (3rd millennium BC) (Coqueugniot 2006; 2014).

3.1.2.2 Environmental background

The site is situated on a rocky Pleistocene terrace (composed of gravel and metamorphic rock) at an altitude of 330m above sea level, which overlooks the river Euphrates in a current area of degraded steppe (Coqueugniot 1998; Besancon & Geyer 2006). The path of the river is constrained in this section of the valley due to the formation of conglomerate, which is highly resistant to lateral erosion (Coqueugniot 1998). This slightly elevated position in relation to the river would have protected the site from instances of flooding, as demonstrated following the recent construction of the Tishrin Dam (Christidou *et al.* 2009). Only 30km north of Jerf el-Ahmar, the inhabitants of Dja'de would have had access to a comparable range of habitats, with their diverse set of natural resources (above, 3.1.1.2). Anthracological studies demonstrated by the exploitation of a wide range of environments, with a particular emphasis on riparian forest, as well as marsh areas, the alluvial plain, and surrounding hills (Roitel 1997; Coqueugniot 1998). The steppic hinterland was easily accessible owing to two large valleys formed from drained wadis (Coqueugniot 1998). Beyond this lowland area to the north-east, modern stands of wild cereals (including *Triticum urartu*) have been found to continue growing in the volcanic massif (Willcox 1996; Coqueugniot 1998).

The archaeobotanical assemblage from this later stage of the PPN similarly suggests a moister climate during its occupation, with the presence of pistachio (*Pistacia atlantica*), almond (*Amygdalus*) and wild pear (cf. *Pyrus*), which are all adapted to higher rainfall and cooler temperatures (Willcox 1996). This is equally reflected within the faunal record with the presence of the eastern hedgehog (*Erinaceus concolor*), an indicator of moist steppe environments (Helmer *et al.* 1998). Therefore, it is possible that current distributions of wild cereals would have extended further towards the site's location (Willcox 1996).

3.1.2.3 Pre-domestication cultivation

High densities of charred plant remains were recovered from across the site, including a range of cereals, pulses, fruits and nuts, though all were still morphologically wild (Willcox *et al.* 2008). Fully domesticated plants and animals have been discovered from the nearby Middle PPNB site of Tell Halula, which demonstrates the importance of Dja'de for investigating the processes involved in early plant cultivation (Coqueugniot 1998: 109). As at Jerf el-Ahmar, there are various lines of evidence to suggest the cultivation of plants at Dja'de. The archaeological assemblage is dominated by several founder crops, including barley (*Hordeum spontaneum*), an einkorn/rye type (*Triticum*/*Secale*), lentil (*Lens*), and a large pulse type (*Pisum*/*Vicia*/*Lathyrus*) (Willcox *et al.* 2008). Furthermore, these cultivars are accompanied by a suite of weedy taxa, which were likely inadvertently bought back to site with harvests (Willcox 2012).

Further evidence for pre-domestication cultivation includes the widespread presence of rodent activity at the site, demonstrated by their charred droppings and skeletal remains (Willcox & Stordeur 2012). The Indian gerbil (*Tatera indica*) and house mouse (*Mus musculus*) were particularly numerous, showing a notable increase in identified specimens from the preceding period at Jerf el-Ahmar; these species feed on stored grain and likely represent infestations of stored cereals (Haidar 2004; Willcox & Stordeur 2012). Closer examination of the stone tools from the site also reveal insights into cereal harvesting activities (Pichon 2017). There is a substantial increase in glossy sickle blades during the PPN period, attributed to wear patterns

from the extensive harvesting of cereals; this can also be indicated within the Dja'de assemblage (Pichon 2017). In addition to the cultivation of plants, Dja'de also presents important evidence for animal domestication. The faunal assemblage indicates a reduction in the average size of wild aurochs (*Bos*) when compared with earlier PPNA sites, offering some of the earliest signs for their domestication (Helmer *et al.* 2005).

3.1.3 Tell Aswad, PPNB

The Pre-Pottery Neolithic levels from the tell site of Tell Aswad date between c. 8700–7500 cal. BC, spanning from the later part of the Early PPNB through to the Late PPNB phases (Stordeur *et al.* 2010; Helmer & Gourichon 2017). The tell is situated around 30km east/southeast of Damascus in the area between two late Pleistocene lakes, Aateibé and Hijjâné, which originally covered almost half of the Damascus basin (van Zeist and Bakker-Heeres 1984). The mound itself covers a large area of around 6 hectares, though reaches only 4.5m in height above the surrounding plain (van Zeist and Bakker-Heeres 1982). With the presence of fully domesticated plants and animals, this larger PPNB village offers a valuable opportunity to assess early farming practices alongside the gradual consolidation of agricultural economies (cf. Asouti 2007).

Initial investigations were carried out at the tell between 1971 and 72, where two small-scale soundings (each 4x4m) were undertaken by H. de Contenson (1973; 1995; Contenson *et al.* 1979). The archaeobotanical remains recovered from these preliminary investigations were studied by W. van Zeist and J. A. H. Bakker-Heeres (1982). Full-scale systematic excavations were conducted at the site between 2001 and 2007 by a Franco/Syrian team, under the direction of D. Stordeur and B. Jammous (Stordeur *et al.* 2010). Over 1,000m^2 was exposed over the seven seasons generating a rich archaeological dataset, though detailed analyses are still in progress; several earthen buildings were excavated, as well as an abundance of archaeobotanical and faunal remains, and an extensive funerary record, including plastered skulls (Stordeur *et al.* 2010). The archaeological material displays cultural affinities with both the northern and southern Levant, reflected within lithic technologies and animal husbandry (Helmer & Gourichon 2017).

3.1.3.1 Site stratigraphy and architecture

The stratigraphic sequence at Tell Aswad was highly complex, owing to the intercutting nature of many building structures that were often laid partially buried, or from the construction of terraces (Stordeur *et al.* 2010). A later occupation from the pottery Neolithic, which was characterised by large pits with large quantities of grinding stones (comparable to the ceramic Neolithic of Byblos), also damaged some of the earlier PPN deposits (Stordeur *et al.* 2006; Stordeur & Jamous 2009). Eighteen levels of continuous occupation were determined from the recent phase of investigations, which represent the three main phases of the PPNB; early, middle and late PPNB) (Stordeur *et al.* 2010). A range of structural styles could be observed throughout the sequence, with no indications for standardisation within any of the levels (Table 3.4; Figure 3.7) (Stordeur *et al.* 2010). The main form of architecture is characterised by large (up to 13m in diameter) rounded or polygonal buildings from the MPPNB, which display few parallels with other sites in the region (Stordeur and Jamous 2009). These structures

Table 3.4 – Summary of architectural styles throughout the PPN levels at Tell Aswad (Stordeur *et al.* 2010).

Site Phase	Levels	Examples of architectural styles
Early	B8-12	– Rectilinear buildings. – Large (7m diameter) curvilinear building. – Emergence of mudbrick construction - large (7.6x4m) irregular shaped building (transition level, B8).
Middle	B1-B8	– Very large (13x10m) oval mudbrick building. – Oval, polygonal, sub-circular buildings of various sizes. – Possible small storage structures externally adjoined to houses.
Late	B-5-B0	– Emergence of rectangular buildings



Figure 3.7 – General view of the excavations at Tell Aswad (Stordeur & Jamous 2009: Fig. 1).

present some of the earliest evidence for the use of mudbricks as building material (Stordeur *et al.* 2010). Rectangular dwelling structures more commonly associated with the PPNB period only appear within the final phases of occupation (Stordeur and Jamous 2009). Identified domestic buildings are consistently oriented with their entrances facing east, and are regularly equipped with a number of household amenities, such as hearth areas, clustered 'storage' facilities and fitted internal benches (Stordeur and Jamous 2009).

3.1.3.2 Environmental background

The low mound of Tell Aswad is positioned within the flat plain of the Damascus basin at an altitude of 600m above sea level (van Zeist & Bakker-Heeres 1982; Stordeur *et al.* 2010). To the west, the site is surrounded by hilly landscape, while an area of dry *Artemisa* steppe lies to the east (van Zeist & Bakker-Heeres 1982; Helmer & Gourichon 2017). The area's lacustrine sediments were created by a late Pleistocene lake, which originally extended across most of the Damascus basin (van Zeist & Bakker-Heeres 1982). Remnants of this former lake are

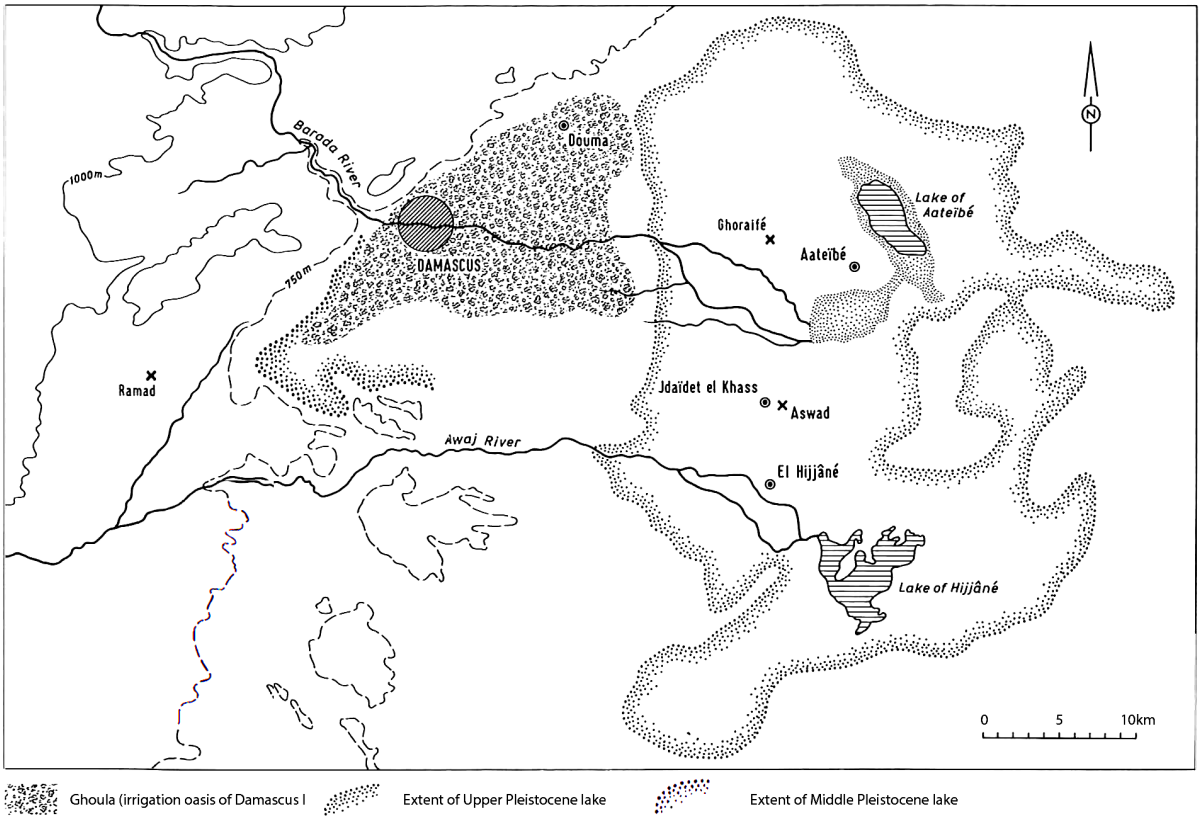


Figure 3.8 – Position of the site in relation to the two late Pleistocene lakes, Aateibé and Hijjâné (van Zeist & Bakker-Heeres 1982: fig. 1).

represented by the two smaller lakes, Aateibé and Hijjâné, located 10-15km northeast and southeast from the tell (Figure 3.8) (van Zeist & Bakker-Heeres 1982); in recent decades, overexploitation of the rivers that replenish these lakes has led to their drying out, with only Lake Aateibé still seasonally active in wetter years (Stordeur *et al.* 2010). In prehistoric times, these two nearby lakes would have been much greater in extent, with the site originally established at the lake's edge or within its marshy margins (van Zeist & Bakker-Heeres 1982). Such inferences are further supported by the abundance of wetland taxa within the archaeobotanical assemblage, such as *Bolboschoenus glaucus*, *Scirpus cf. lacustris* and *Carex* (Douché pers. comm.; Stordeur *et al.* 2010).

While now an area of dry steppe, palaeoenvironmental data indicate an area rich in natural resources during the early Holocene, with a flora of tamarisk, ash and poplar trees, as well as diverse local fauna, including cats, badgers, fish, ducks, cranes, geese and gastropods (Stordeur and Jamous 2009). The presence of species native to desert and upland steppe regions at the

site, such as pistachio (*Pistacia atlantica*), gazelles and wild horse, also indicate the further exploitation of neighbouring vegetation zones around 50km from the site (Stordeur & Jamous 2009; Stordeur *et al.* 2010).

3.1.3.3 Early farming at Tell Aswad

Archaeobotanical material from the site confirms the existence of a range of fully domesticated crops from the earliest levels, including emmer wheat, barley, peas, lentils, and flax (van Zeist & Bakker-Heeres 1982; Douché pers. comm.). With many of these crops beyond their natural distribution zones, it is argued that dry farming methods would have been problematic in this arid region, requiring greater interventions from early farmers (Stordeur *et al.* 2010). The wild cereals that co-existed alongside fully domesticated forms at Tell Aswad are also proposed as indicators of more intensive management strategies; these wild cereals possessed well-formed grains, showing no signs of stress from poor growing conditions (Stordeur *et al.* 2010). Initial identifications of associated arable weeds, such as the frequent presence of the wet-loving rushes/grasses *Scirpus* and *Phalaris*, have been suggested to indicate that crops were grown in moist soil conditions (i.e. irrigated) (Stordeur *et al.* 2010). This hypothesis, which will be tested in detail in this study, forms a useful parallel with Pottery Neolithic Çatalhöyük, where local marshy conditions and high *Scirpus* frequencies are also evident.

In addition to domestic crops, a range of animals were fully domesticated at the site, including cattle, goat, sheep and pig (Helmer & Gourichon 2017). Goat was dominant within the faunal assemblage, exploited for both its meat and milk (Stordeur *et al.* 2010). These domesticates offered a range of opportunities for plant husbandry management, such as a source of manure and labour; deformities present on cattle bones from Tell Aswad indicate that they were already regularly used for traction (Helmer *et al.* 2005; Stordeur *et al.* 2010). Hunting continued to play a prominent role within subsistence strategies at Tell Aswad (see above, 3.1.3.2), but this decreased throughout the occupation, with domesticates becoming more dominant in the later levels (Stordeur *et al.* 2010).

3.2 Central Anatolia – Neolithic Çatalhöyük [East]

Çatalhöyük East, one of two neighbouring prehistoric mounds collectively named Çatalhöyük, signifies the Neolithic occupation under investigation in this study. The site is situated centrally on the Konya Plain, 50km southeast of Konya, central Turkey, and was continuously occupied for 1150 years from 7100 to 5950 cal. BC, overlapping with the LPPNB sequence in its earliest phases (Hodder & Farid 2014; Bayliss *et al.* 2015), although the majority of excavated contexts relate to the mid to later levels, dating after c. 6700 BC in the Pottery Neolithic (Hodder & Farid 2014). This large early farming settlement ('megasite') is formed of a substantial mound of around 13.5 hectares, which reaches 21m above the surrounding plain, a result of extensive superimposed rebuilding of mudbrick structures (Hodder 2006). When examined in a regional context, this established farming community forms part of a local sequence characterised by dense agglomeration of settlement, also indicated at Aşıklı Höyük and Can Hasan III (Hodder & Farid 2014). However, Çatalhöyük's unique emphasis upon symbolic elaboration appears to represent a distinct local tradition on the Konya Plain (Hodder & Farid 2014).

Initial excavations were conducted at the mound by James Mellaart in the 1960s, with the site quickly receiving worldwide attention due to the large extent and dense population (est. 3,500 to 8,000 people) of this early settlement, as well as its extensive and dramatic representations within mural paintings, reliefs and sculpture (Mellaart 1967; Hodder 2006; Hodder & Farid 2014). In recent years, the site has been the focus of a large-scale international project, with systematic excavations undertaken by multiple research teams since 1993 under the lead direction of Ian Hodder (Hodder & Farid 2014). The final excavation season took place in 2017, with final analyses now underway. Though only a small proportion of the mound has been investigated (<10%), a substantial amount of high-resolution archaeological data has been recovered from several areas of the site, presenting unique opportunities to assess and compare agricultural management at the household level (Hodder & Farid 2014; Der & Issavi 2017).

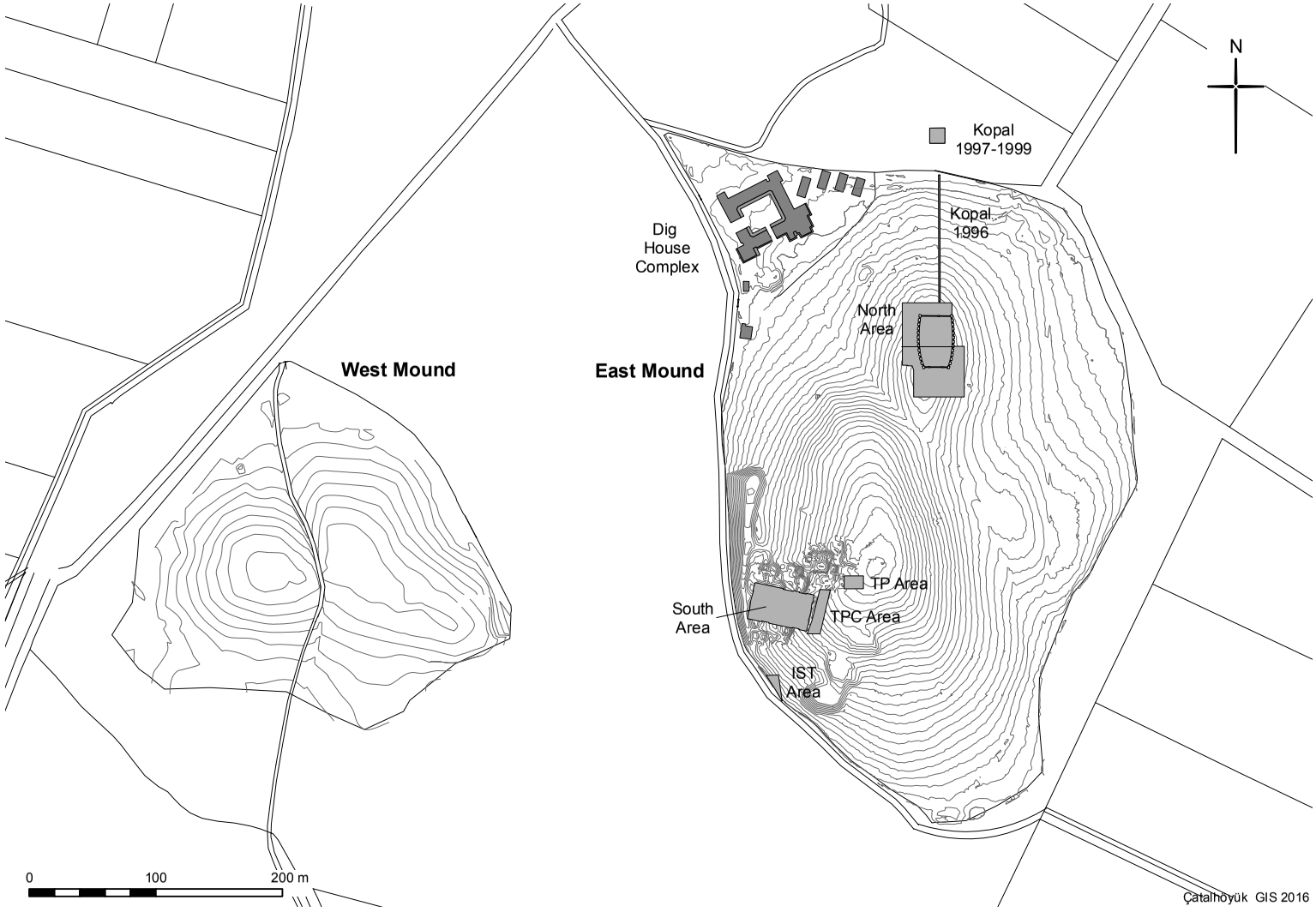


Figure 3.9 – Map of excavation areas on the East Mound at Çatalhöyük (Hodder 2014).

3.2.1 Site stratigraphy and architecture

Excavations of the East Mound have concentrated on two separate zones—the North Area and South Area—with separate excavation areas managed by smaller research teams (e.g. IST Area, TPC Area) (Figure 3.9) (Hodder 2014; Özbaşaran *et al.* 2014; Marciniak 2015). Over 100 rectangular mudbrick built buildings have been excavated in detail (Figure 3.10), identified within 16 distinct levels of occupation (Hodder & Farid 2014). For analytical purposes, these levels can be split into four main phases (Table 3.5): early (7100-6700 cal. BC), middle (6700-6500 cal. BC), late (6500-6300 cal. BC) and final (6300-5950 cal. BC) (Çatalhöyük Research Project phasing, autumn 2017). The early phase represents the Aceramic Neolithic, reached in limited sections of the South Area. At this stage the occupation was localised, divided into clustered neighbourhood communities of around 30–40 structures, which were often separated by open areas, alleys or middens (Marciniak & Czerniak 2007). Excavations have largely focused

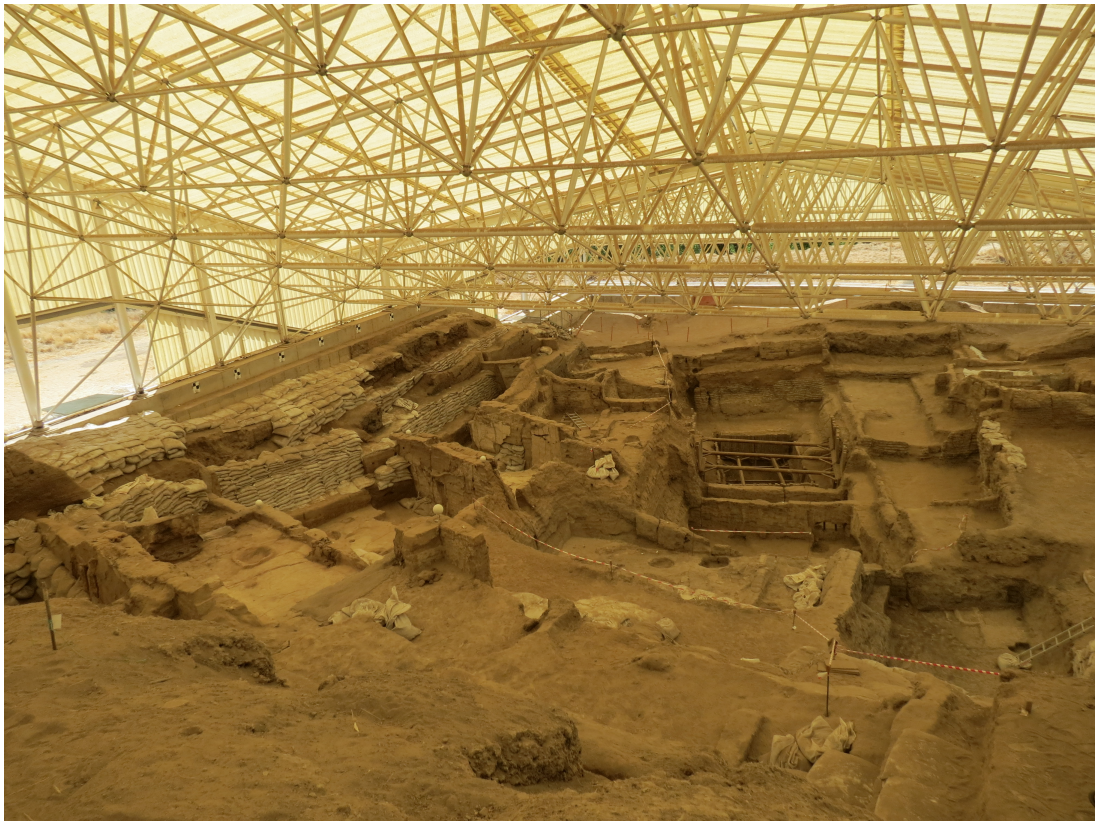


Figure 3.10 – Excavations in the South Area at Çatalhöyük (Photograph by author).

on the middle sequence, where the population size reached its greatest extent (cf. Hillson *et al.* 2013), presenting extensive and densely-packed contemporaneous settlement (Hodder 2013). The late phase sees a return to more open spaces between buildings, with habitation at the site becoming more fragmented and dispersed (Hodder 2013). These changes in settlement layout culminate in the final phase: buildings formed empty spaces following abandonment, with new structures shifting across the settlement, rejecting long-standing traditions of superimposition (Marciniak *et al.* 2015).

Table 3.5 – Temporal groupings of levels for Çatalhöyük [East] (Çatalhöyük Research Project phasing, autumn 2017).

Phase	South	North	Date (cal. BC)
Final	TP.O-R and TPC Trenches 1 and 2 (B109 and 115)		6300-5950 BC
Late	GDN	North.H,I,J and IST	6500-6300 BC
	South.T. TP.N. TPC B110 and B150		
	South.S. TP.M. TPC B150 and B122		
	South.R		
	South.Q		
	South.P		
Middle	South.O	North.F, G	6700-6500 BC
	South.N		
	South.M		
Early	South.L		7100-6700 BC
	South.K		
	South.J		
	South.I		
	South.H		
	South.G		

The style of architecture was remarkably consistent throughout the first three phases in this long-lived settlement, with rectilinear mud-brick structures typically subdivided into main room spaces, with smaller side rooms (Figure 3.11) (Hodder 2013). While the scale of individual buildings varied greatly, ranging from 12 to 62m^2 within a single horizon (i.e. Level North G), all appear to have had a domestic function with each building containing a consistent range of internal features (Demirergi *et al.* 2014). These included hearth areas, built clay ovens, storage 'bins', benches and ladder emplacements, which enabled access to the building from the roof (Hodder & Farid 2014: 21-2). Despite domestic functions, buildings were often elaborately decorated with symbolic art, including wall paintings and installations of cattle heads/horns (bucrania) (Hodder & Pels 2010). Furthermore, some buildings displayed continuity throughout several (up to six) levels, with structures rebuilt over previous layouts, identified as 'history houses' (cf. Hodder 2016). At the end of the site's occupation (final phase), building styles radically changed signalling the start of a new social order: these were composed of smaller, cell-like spaces organised around larger central living areas, without symbolic elaboration (Marciniak *et al.* 2015).

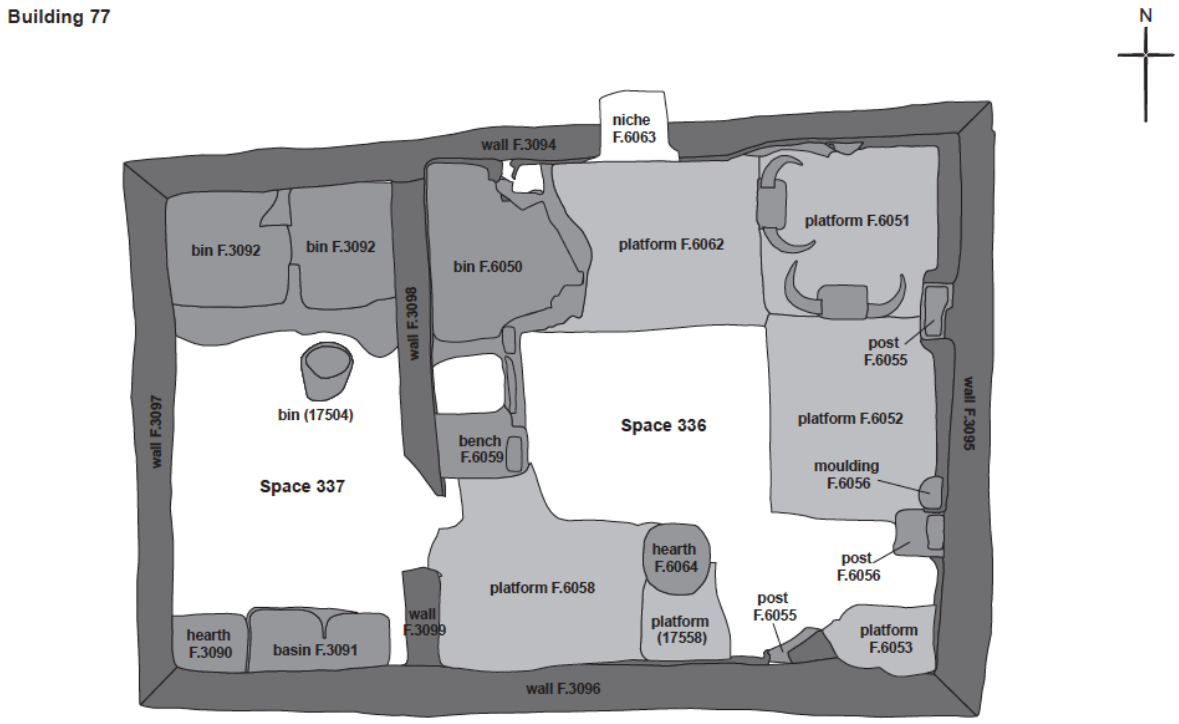


Figure 3.11 – Typical subdivision of buildings at Çatalhöyük, with larger main rooms and smaller side room that were used for food storage and preparation (House 2014: fig. 23.1).

In addition to the extensive horizontal exposure, the site is extremely rich in burnt *in situ* deposits, preserved within the large number of buildings destroyed by fire (Bogaard *et al.* 2009; 2013a). High densities of archaeobotanical remains have been recovered from a range of context types across the site; these contain a suite of domesticated crops, as well as considerable collections of wild plant resources (below, 4.3) (Bogaard *et al.* 2013a). A number of storage contexts are included within these primary burning episodes, which in some cases contain sealed plant concentrations, indicating their original contents (Fairbairn *et al.* 2006; Bogaard *et al.* 2009; 2010; 2013).

3.2.2 Environmental background

Located at c. 1,000m above sea level, the Konya Plain forms part of the Central Anatolian Plateau with a present-day climate defined as cold semi-arid/steppe, characterised by hot, dry summers and cold, wet winters (Hodder 2013; Ayala *et al.* 2017). Today the region receives an average rainfall of 350mm where irrigation agriculture is prevalent, though in recent history there was a predominance of *Artemisia* steppe and Chenopodiaceae vegetation (Ayala *et al.* 2017). Beyond the plain, the vegetation shifts from moist-steppe to steppic-woodland in the foothills, to dense woodland further into the mountains (Charles *et al.* 2014). The climate would have been more humid during the early Holocene, with an annual rainfall of between 350-550mm estimated from pollen records (Charles *et al.* 2014). However, there was a gradual move towards drier conditions throughout the site's occupation (Roberts *et al.* 2008). The mound was founded on rich alluvium soils deposited by the former Pleistocene Konya lake (Hodder 2007: 25). High-resolution sediment coring indicates that this Neolithic landscape would have been highly variable, with a mosaic of wet and dry environments (Figure 3.12) (Ayala *et al.* 2017). The location of the site beside the ancient Çarsamba river, as well as the frequent recovery of wetland species from archaeological deposits, suggest that localised areas were affected by seasonal floodwaters from anabranching channels (Charles *et al.* 2014; Ayala

et al. 2017). Nevertheless, the area east of the tell was characterised by drier conditions presenting suitable areas for farming close to the site (Ayala *et al.* 2017).

In addition to the variable local landscape, palaeoenvironmental data suggests that a wide range of habitats was exploited by these Neolithic inhabitants, at close vicinities to the site and further afield (Charles *et al.* 2014). Anthracological studies indicate that both wet/riparian and dry woodland habitats were exploited for timber supplies, with increasingly distant sources (i.e. uplands) recognisable throughout the site's sequence (Asouti 2013). The faunal assemblage includes wild species adapted to a variety of habitats, including open plains (equids), woodlands (cervids) and wetlands (suids, water-fowl, water voles) (Russell *et al.* 2013; Charles *et al.* 2014). Furthermore, a variety of herding locations (wetland pasture, dry grasslands, limestone terraces) were indicated by dental microwear and stable isotope analysis from sheep, as well as dung-derived plant species (Bogaard *et al.* 2013a; Charles *et al.* 2014).

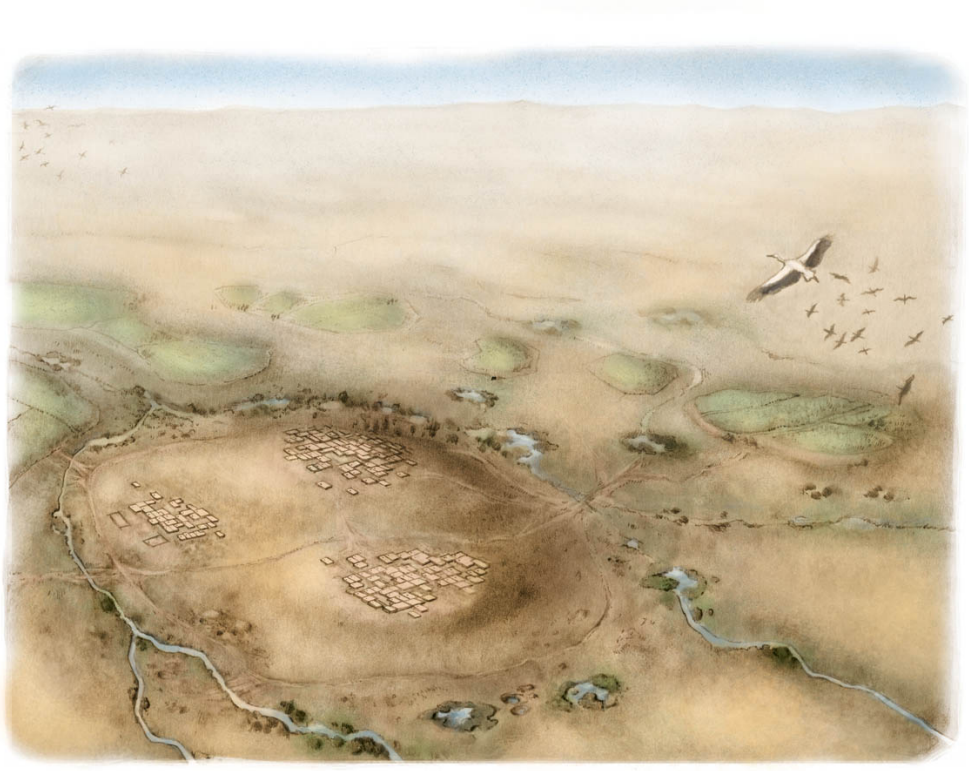


Figure 3.12 – Reconstruction of the immediate landscape around Çatalhöyük, based on recent geoachaeological and archaeobotanical analysis (Bogaard 2016) (Illustration by Kathryn Killackey).

3.2.3 Early farming at Çatalhöyük

While at the periphery of the earliest agricultural developments in in the Fertile Crescent, Çatalhöyük presents a unique opportunity to investigate early agricultural methods between individual households in an established farming community (Bogaard *et al.* 2013a). The combination of sheep/goat-oriented husbandry and a suite of domesticated crops in the site's earliest levels indicates the adoption of a distinct central Anatolian farming 'package' that was well-adapted to the rich ecotonal environment (Bogaard *et al.* 2017). Agricultural innovation and flexible cropping strategies are apparent throughout the mound's sequence, reflecting a wide range of domesticated cereals and pulses that enabled the site to adapt *inter alia* to increasing aridity (Bogaard *et al.* 2017). These included various varieties of wheat (free-threshing wheat, emmer, einkorn, 'new type' glume wheat) and barley (naked, hulled), as well as a wide range of pulses, including pea, lentil and chickpea (Bogaard *et al.* 2013a; 2017). Despite the variety of crops, wild plants sources were extensively gathered throughout the sequence, including almonds and wild mustard, though these resources were likely extensively managed (Bogaard *et al.* 2013a; 2017).

An initial hypothesis proposed that cultivatable land was restricted to distant areas (>13km) from the site (Roberts & Rosen 2009); this was based on previous landscape reconstructions suggesting the site was situated in an extensive alluvial wetland (Roberts *et al.* 2007; Roberts & Rosen 2009). However, recent studies support the notion that instances of flooding were more isolated (see above) (Charles *et al.* 2014; Ayala *et al.* 2017). This opens up the potential for more intensive local cultivation regimes, which due to the availability of labour are typically identified closer to the settlement (cf. Jones 2005). Extensive herding at the site offered significant sources of animal dung, which may have been used to enrich and maintain the fertility of the soil (Charles *et al.* 2014). However, the frequent detection of dung within hearth and 'firespot' contexts indicate its regular use as a fuel at the site (Bogaard *et al.* 2013a; Filipović 2014), thus resulting in the division of this resource. The large assemblage of primary crop stores excavated from Çatalhöyük offer instances of arable weed flora linked to individual farming regimes. These archaeobotanical samples provide some of the best opportunities to investigate the nature and intensity of agricultural activities at the site.

Chapter 4

Plants in context

Spatial relationships of plant storage

The Neolithic 'megasite' at Çatalhöyük, Central Anatolia, provides some of the most extensive direct evidence for early storage practices in western Asia, featuring several burnt built storage facilities with concentrated *in situ* plant remains. Physical characteristics from these exceptionally well-preserved cases have enabled the formal identification of over 100 built storage 'bins' across the site, presenting one of the best opportunities to assess local systems of cooperation regarding food production activities in early farming societies. By critically examining the archaeological evidence for early storage practices in western Asia, this chapter demonstrates the uniqueness of the *in situ* plant storage assemblage at Çatalhöyük for the Neolithic period, which enable separate harvesting events to be isolated and studied.

4.1. Emergence of food storage in western Asia

Food storage practices in western Asia have been linked to a number of key innovations from the Late Epipalaeolithic and initial Pre-Pottery Neolithic phases: emerging sedentism, increasing formalisation of settlements, population growth, and the cultivation of staple plant resources (cf. Testart 1982; Byrd 2005b; Kuijt & Finlayson 2009). Small storage 'silos', in the form of plaster-lined pits, have been proposed from as early as the

Natufian at 'Ain Mallaha, Israel (Valla 1991). However, direct evidence for storage functions, such as concentrations of *in situ* plant remains, cannot be identified until the Pre-Pottery Neolithic A period (PPNA), alongside emerging evidence for plant cultivation techniques (Willcox *et al.* 2008; Bogaard *et al.* 2010). These *in situ* indications further coincide with evidence for rodent activity in the form of charred rodent droppings, which may have infested stored seed supplies, as well as the arrival of potential purpose-built storage buildings (Kenyon 1981; Kuijt & Finlayson 2009; Willcox & Stordeur 2012). From these lines of evidence, direct relationships have been established between storage potential, initial cultivation methods, and the subsequent domestication of plants (cf. Kuijt 2008; Kuijt & Finlayson 2009; Willcox & Stordeur 2012).

The ability to store foods, for consumption beyond their seasonal availability, would have had significant implications within these early Neolithic societies. Increased availability of key plant resources through storage would act as a buffer in less productive periods, which would enable increases in community carrying capacities (Ingold 1983). Additional inputs of labour, through the collection of food surpluses with minimised spoilage, would have had beneficial returns that may have in turn encouraged greater intensification (Flannery 1972; 2002). Furthermore, the distribution of such collected resources would require new strategies for the negotiation of social tensions within expanding societies (Testart 1982; Woodburn 1982; Hayden 1990; Wright 2014).

Storage evidence from the Neolithic period presents opportunities to address these emerging social dynamics, through the assessment of facilities in relation to social space, including the examination of levels of accessibility, as well as investigation of the developing husbandry methods associated with their contents. The current evidence proposed for early storage practices, as a whole, offers a number of general temporal trends. Recognised storage appears to emerge as a centrally accessible innovation in settlements, potentially starting as small-scale pits located in open spaces in the Natufian, such as those observable at ‘Ain Mallaha (Valla 1991). This trend can be seen in the PPNA period, when more convincing evidence for storage practices begin to be identified. Large-

scale structures that are distinct from other buildings begin to appear in settlements, such as those from Dhra' and Jerf el-Ahmar, and often exhibit specialised features, such as suspended floors or internal compartmentalisation (Valla 1991; Kuijt & Finlayson 2009; Finlayson *et al.* 2011; Willcox & Stordeur 2012). Their structural uniqueness when compared to other 'typical' dwelling structures, and in some cases a greater degree of elaboration, suggest possible communal functions.

The Pre-Pottery Neolithic B (PPNB) period brings more frequent but fragmented storage that appear to have been controlled at the household level (Kuijt & Goring-Morris 2002). Storage becomes increasingly 'private' by the Late PPNB, with built features shifting from porch or courtyard spaces to the interior of domestic structures (Wright 2000; Bogaard *et al.* 2009: 650). By the Late Neolithic, patterns in storage facilities diverge, with some settlements exhibiting communal storerooms in the heart of conglomerated settlements, such as at Sabi Abyad, while others show continuity with the preceding PPNB, for example at Çatalhöyük (Duistermaat & Akkermans 1996; Demirergi *et al.* 2014).

While these general trends have been noted, limited studies have been conducted on the variation of storage features *within* individual settlements. It is clear that storage had an important role within early farming communities, and its implications would have greatly influenced developments in settlement layout and the balance of social interactions. By examining intra-site relationships, greater clarity can be discerned regarding the organisation of daily activities, cooperation across communities and the levels of household autonomy. Identified storage areas may be analysed spatially in relation to building designs and other activities, and may also be observed for their potentially dynamic relationships within the life histories of individual buildings (cf. Green *et al.* in Demirergi *et al.* 2014).

The potential of such intra-site studies in the Neolithic has been limited by the dearth of direct evidence that offer confirmation of storage functions, as well as a general lack of horizontal exposure of multiple buildings and/or of detailed phasing. The established

farming site of Çatalhöyük (above, 3.2), presents the rare opportunity to implement such types of analyses, and forms the main case site for this detailed examination of storage facilities. Meticulous sequencing of over 100 buildings has documented an unprecedented range of *in situ* storage deposits for the Neolithic period, which have enabled wider recognition of built storage features throughout the site. Several contemporaneous horizons of settlement enable direct comparisons to be made between different buildings, as well as the exploration of individual building histories through time.

This chapter will additionally present a critical review of the different forms of storage identified from early and pre-farming communities across western Asia, focusing on those recognised from well-documented and well-preserved sites. Cases with associated direct evidence, in the form of primary plant remains, will be explored in greater detail, and compared against the general temporal trends (see above) established from the wider sources of evidence.

4.2. Critical review of early storage evidence from western Asia

A variety of different storage types have been identified from early and pre-farming sites across western Asia, which may reflect different scales of use and levels of organisation, as well as indicating differing functions within society. However, the criteria used in the identification of storage facilities are rarely considered systematically, which restricts the usefulness of intra and inter-site comparisons. Additionally, much of the storage evidence has been recognised without any corresponding direct evidence, such as primary plant remains, which enable confirmations of storage functions, and are largely based on architectural form or from absence of other activities. In this critical review, the most convincing cases for food storage (i.e. with associated plant remains) will be analysed in detail, and their individual characteristics compared with those from the more ambiguous examples.

Table 4.1 - Critical review of identified storage evidence with associated plant remains in western Asia.

	Site name	Period	Description of identified storage types with plant remains	Key feature references	1. Primary plant remains - *in situ* macroremains	WILD									DOMESTICATED						UNIDENTIFIED	2. High seed concentrations - over 100 counts per litre	3. Preserved basketry	4. Fixed built container feature	5. Specialised structural form*	6. Associated rodent evidence	SCORE
							Cereals			Fruit/nut			Oil seed			Cereals		Pulses									
						Avena sterilis	*Hordeum spontaneum*	*Secale sp.*	*Taeniatherum caput-medusae*	*Triticum dicoccoides*	*Amygdalus sp.*	*Pistacia atlantica*	*Quercus ithaburensis*	*Capsella bursa-pastoris*	*Descurania sophia*	*Helianthemum sp.*	*Hordeum vulgare var. nudum*	*Triticum aestivum/durum*	*Lens culinaris*	*Pisum sativum*	*Vicia faba*	*Cereal, indeterminate*					
1	El-Hemmeh	PPNA	Pisé storage bin	Locus 790			–			–		–									+			✓		✓	2/6
2	Gilgal I	PPNA	Cache of wild oat, wild barley grains, with additional wild pistachio and acorns	House 11	✓		X	X				–	–										✓	✓				3/6
3	Jerf el-Ahmar	PPNA	Storage-like building consisting of small cells	Building EA30				–																✓	✓	✓	3/6
4	Tell 'Abr 3	PPNA	Burnt communal building with internal storage concentration	Building M1	✓			–	–																			1/6
5	Yiftahel	PPNB	Indoor clay 'silo' built on plaster floor	Locus 719	✓																X			✓		✓		3/6
		PPNB	Perishable container next to built silo	Locus 714	✓														X					✓	✓			3/6
6	'Ain Ghazal	MPPNB	Peas and lentil concentration located near internal wall, behind row of stones	House 12	✓														X	X				✓				2/6
7	Beidha	MPPNB	Two bitumen-lined baskets of carbonised pistachio	Building 48/54	✓							?												?	✓			2/6
8	Çatalhöyük	PN	Clusters of charred plant remains, likely to represent basket and hanging storage	F. 2040	✓				X					X		X								✓	✓			✓	4/6
		PN	Built clay storage bins with *in situ* contents	F. 2002-2005, F. 2502, F. 232-237	✓				X		+			X	X		X	X	X	X				✓	✓	✓	✓	✓	6/6

* i.e. bin hood, suspended floor

Concentrations of *in situ* plant remains provide the best available evidence for determining storage, by demonstrating its original stored contents. However, such high densities are usually only recovered from exceptionally preserved contexts, such as instances where building-scale burning occurs. When evidence for burning is absent, plant remains recovered from built features may merely reflect unrelated dumping deposits or collapsed material. Table 4.1 evaluates the storage evidence with accompanying plant remains from western Asia, and summarises the major species represented from associated samples. Cases where associated plant remains represent 'primary' *in situ* deposits are indicated under the first criterion. The second criterion indicates when these represent significant concentrations (over 100 items per litre[1]). Each identified example was further assessed in relation to another four criteria that may indicate storage functions, which include preserved basketry, built features, specialised structural form (i.e. hoods, suspended floors, access points), and associated rodent activity. Traces of basketry offer potential evidence for portable storage containers, particularly when in associat with primary plant remains, whereas built storage features indicate more permanent facilities (Green *et al.* in Demirergi *et al.* 2014). The final two criteria add further credibility to interpretations of plant storage by isolating potential storage functions, as well as indicating the presence of grain stores through rodent infestations.

Of the eight sites with archaeobotanical remains recovered from recognised storage contexts, six had occurrences that could be determined as representing primary *in situ* plant remains, with only five of these demonstrating any significant concentrations. Though likely to represent primary burning, the excavators of Tell 'Abr 3 (Table 4.1), noted '*une très grosse concentration de grains, dans un espace très réduit*', but actual densities were much more limited than this suggests, with only 7.2 grains of rye per litre (Stordeur & Willcox 2009; Willcox & Stordeur 2012). Two of the examples identified with associated archaeobotanical remains did not appear to represent primary burning. The charcoal rich basal fill (Locus 790) of a pisé built storage bin at El-Hemmeh contained the

[1] This arbitrary threshold relates to visible concentrations of archaeobotanical remains, as identified within unambiguous examples of Neolithic storage (i.e. *in situ* remains within built bin features).

second highest charred seed densities from the PPNA period at the site, with over 49 counts per litre compared with the average of 21 counts per litre (White 2013: 202). However, closer inspection by White (2013: 212) of the distribution of species in this deposit indicated close similarities with other hearth/ash deposits at the site, suggesting a secondary origin. The large building EA30 interpreted as a specialised communal storage facility from PPNA Jerf el-Ahmar likewise contained some of the highest densities of charred grain at the site, but with a maximum of only 7.4 grains per litre these densities are extremely limited (Figure 4.1) (Willcox & Stordeur 2012: 108). While the building was burnt, the excavators indicate that this archaeobotanical material related to secondary contexts rather than primary stores (Willcox & Stordeur 2012: 107; Stordeur 2015: 209).

The minimal number of storage examples with direct evidence makes an assessment of temporal trends difficult, with all but two of the examples being recovered from the PPNB and Late Neolithic. This can further be observed when considering the recovery of evidence for associated basketry, which is only recovered from exceptional contexts. This pattern could possibly be explained by an increased likelihood of destructive burning incidents in the later periods, which developed alongside the rising density of settlements in the PPNB period, as well as increasingly internalised cooking facilities (Wright 2000).

When assessing the range of species recovered from primary storage contexts, a variety of cereals, pulses, fruits, nuts and oily seeds can be observed. In most cases the distributions of species reflect the shift from morphologically 'wild' plants in the PPNA, to domesticated species in the PPNB storage examples. The *in situ* examples from Late Neolithic levels at Çatalhöyük stand out by demonstrating a diverse assemblage, with an extensive storage of wild resources alongside the major cultivars. However, it is worth noting that Çatalhöyük was the only site with more than two cases of *in situ* plant storage.

Only two of the sites with direct *in situ* plant storage evidence featured plant concentrations in *built* storage features; these were recovered from LN Çatalhöyük and PPNB Yiftahel. This limited evidence is particularly significant, as built container features

are one of the most common forms to be interpreted as storage facilities by excavators amongst the wider available evidence. Another notable aspect was that both of these sites also featured basket forms of storage located directly alongside formalised fixed containers; this suggests the importance of flexible storage space in addition to formal installations in the established Neolithic, which would have responded to shifting requirements in storage potential.

Specialised structural forms pertaining to protective or other functional properties useful for storage, as well as the presence of associated rodent activity, add further credibility to some of the identified examples, including those with only secondary plant remains. One of the internal cells from building EA30 at Jerf el-Ahmar (Figure 4.1) had a low narrow opening that was too small to function as a crawl hole (Stordeur *et al.* 2000; Stordeur 2015: 210). This would have eased access to stored supplies from inside its deep protective walls (up to 1.35m) (Stordeur *et al.* 2000). Small rodent droppings were also regularly recovered from the site, and were of a size corresponding to those of the domestic house mouse, suggesting the widespread storage of grain (Willcox *et al.* 2008). Charred rodent droppings were also recovered from the PPNA levels at El-Hemmeh,

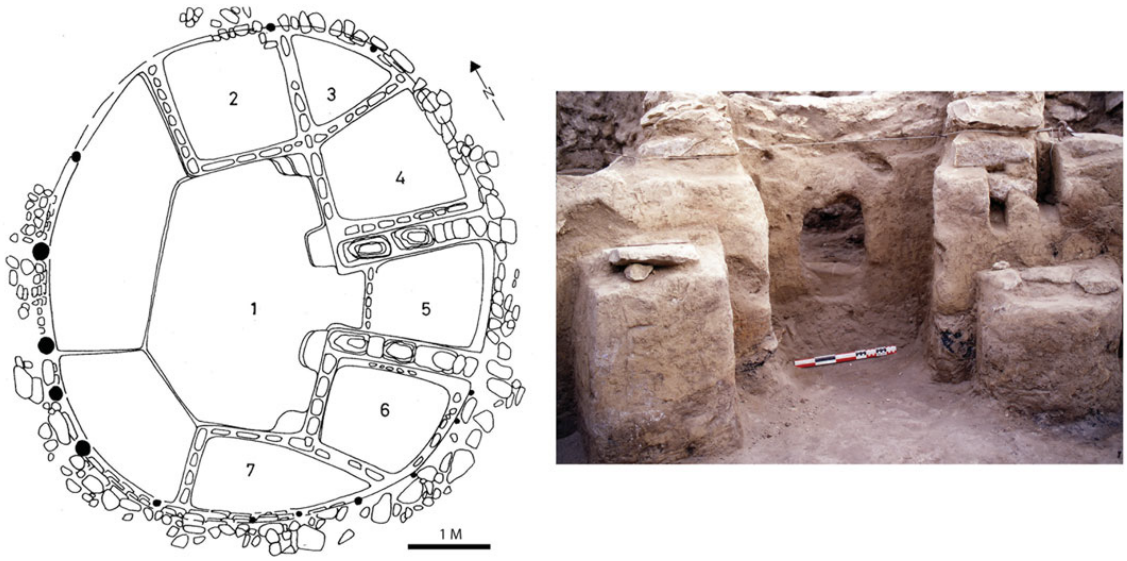


Figure 4.1 – Plan of 'communal' building EA30 from Jerf el-Ahmar with its several internal 'storage' compartments. The photograph shows the narrow opening into cell 5, which has been interpreted as an access point for its contents (Willcox & Stordeur 2012: Fig. 8).

though in smaller quantities (White 2013: 67-8). Çatalhöyük, with its range of identified storage, fulfilled both of these criteria; it had evidence for protective covered bin hoods, as well as the recovery of *in situ* rodent skeletons and droppings from sealed plant concentrations found inside storage bins (Bogaard *et al.* 2013*a*: 119).

The recovery of relevant phytolith evidence was also considered as a criterion for confirming storage functions when macrobotanical remains were absent, though only limited sites have applied these methods. A recent study at the LPPNB site Tell Seker al-Aheimar identified high levels of grass phytoliths from inside a built plaster bin feature (Portillo *et al.* 2014). However, comparison with other samples from surrounding areas in the building produced similar high levels, so did not prove significant enough to confirm grain storage. Alternatively, investigations at Çatalhöyük, identified quantified phytolith 'peaks' from inside confirmed storage bin features, identifying five additional high-integrity storage features from unburnt contexts; this highlights the potential use of such methods at other sites without charred primary macroremains (Ryan 2013: 174-5).

Only Çatalhöyük was able to meet the full range of criteria for the identification of storage facilities, with tens of examples with primary deposits, demonstrating a range of stored plant types (below, 4.3.1.1). In cases when primary burning was identified, only two other sites, Yiftahel and Beidha, had more than one example (two each) with *in situ* plant remains. This critical review highlights the unique opportunity presented by the excavations at Çatalhöyük, and will be studied in detail below (4.3). Before this, however, the characteristics of the most convincing storage examples will be compared with other potential storage features lacking direct evidence.

4.2.1. Comparison of identified storage characteristics

4.2.1.1. 'Basket' storage

Six of the sites reviewed with primary storage contexts had examples that could represent basket type storage, of which four also provided direct evidence for basket containers in the form of preserved wood/reed materials or imprints, though in most cases only small traces survive (Table 4.2). The investigation of the spatial characteristics and associated activities of these well-preserved examples, however, may offer identifiable traits for the further recognition of potential storage without associated plant remains.

The two 'basket' examples from the PPNA (Table 4.1 & 4.2) were both identified from atypical buildings that were recognised by excavators as structurally unique, as well as having distinct internal activities. At Gilgal I, a cache of wild grains and nuts was discovered from Locus 11, which was interpreted as having a non-domestic function (Noy 1989; Weiss *et al.* 2006; Bar-Yosef *et al.* 2010: 23). Locus 11 was the only sub-rectangular building to be excavated, with seven other buildings from the same horizon oval in shape (Bar-Yosef *et al.* 2010: 23). The building also contained a second bitumen-lined basket filled with 'exceptional' flint items, as well as human and bird figurines (Bar-Yosef *et al.* 2010: 21; Noy & Kozlowski 2010). The uniqueness of the building's contents, however, may be partially a result of better levels of preservation from wide-scale burning. Tell 'Abr 3 scored low (1/6) in relation to the storage criteria (Table 4.1), due to limited densities of primary plant remains and lack of visible container, but it is worth considering the 'pure' primary traces of rye within the distinctive building M1 (Yartah 2005; Stordeur & Willcox 2009: 698). This large (8m diameter) circular subterranean building has been interpreted as having communal and ritual functions; it had a stone constructed podium with built-in auroch bones, as well as benches, a large hearth, five large basins, and several limestone grinding stones, which may indicate food preparation beyond the family unit (Stordeur & Willcox 2009: 698).

Table 4.2 - Summary of storage characteristics.

Storage type	Period	Sites with primary storage contexts	Key characteristics	Potential examples without direct evidence
Basket storage	PPNA	Gilgal I, Tel Abr' 3	- Located inside 'special' buildings interpreted as having communal functions. - Found in association with other unique finds or specialised features.	- 'Special' buildings from Jerf el-Ahmar, Mureybet, Dhra, WF16.
	PPNB	Yiftahel, 'Ain Ghazal, Beidha, Çatalhöyük	- Located inside buildings interpreted as 'domestic'. - Often found next to built storage features.	- 'Ain Ghazal - Partitioned area in Building 3 - Further domestic buildings from Beidha with preserved basket evidence. - Side room spaces from Çatalhöyük with built bin features.
Built storage feature	PPNB	Yiftahel - Locus 719	- Located inside building interpreted as 'domestic'. - Clay construction, built on plaster floor.	?
	PN	Çatalhöyük - Various	- Located inside buildings interpreted as 'domestic'. - Frequently associated with side room spaces. - Grouping of features along room walls.	- Further built bin features from Çatalhöyük.

Parallels to these 'special' buildings can be seen in a number of other PPNA sites without primary plant stores, and often possess unique structural features that could offer protection for plant storage. Building EA30 from Jerf el-Ahmar (Table 4.1; Figure 4.1) was distinct in design from other neighbouring domestic buildings, and shares a number of characteristics with building M1, with its large (7.4m x 6.8m) subterranean elliptical shape, internal bench, and possible ritual associations in the form of a grinding stone with red ochre and a headless burial (Willcox & Stordeur 2012; Stordeur 2014; 2015). However, building EA30 diverges by having six internal stone-built compartments, which have been interpreted as formally built storage containers (Stordeur 2014; 2015). Despite its lack of primary plant remains, this example scored relatively highly (3/6) in relation to the storage criteria, with its small low opening to one of the cells, which may have enabled access to stored foods, and recovered rodent droppings (Willcox & Stordeur 2012). A building featuring this compartmentalised style has also been identified at PPNA Mureybet (House 47) (Table 4.2), and contains an additional hearth area alongside its internal bench feature, similar to building M1 (Stordeur *et al.* 2000).

Another form of distinctive building has been recognised at PPNA Dhra' (Table 4.2), where three purpose built 'granaries' have been distinguished from the surrounding processing/residential structures (Kuijt & Finlayson 2009). In this case, the uniqueness of the building type is based upon its structural design, rather than the nature of its internal features and associated artefacts. Structure 4 provides the clearest example of this; this 3m x 3m circular structure had a suspended floor built by placing notched stones upright along a subfloor, which supported wooden beams (Kuijt & Finlayson 2009). This design would have protected basket forms of storage from rodents and insects. Additionally, the floor was found to slope at a seven degree angle, which would have been useful for storing and gathering loose material (Kuijt & Finlayson 2009: 10967). A similar style can be determined from PPNA WF16, with evidence for suspended floors recognised from Buildings O45 and O12, the former also containing a built internal compartment (Finlayson *et al.* 2011). Phytolith analyses are currently being conducted at these two sites and may present crucial evidence for their interpretations as storage functions (E. Jenkins

pers. comm.); preliminary indications from Structure 4 at Dhra' suggest the presence of barley husks, however the significance of this signature when compared with other buildings at the site needs to be determined (Kuijt & Finlayson 2009: 10967).

By contrast, the perishable storage container examples recovered from the PPNB and later Neolithic levels appear to be associated exclusively with 'ordinary' domestic structures; this general trend has also been suggested from the wider evidence for potential built storage features (Wright 2000). The two carbonised baskets of pistachio recovered from Phase A at MPPNB Beidha (Table 4.1) were both located within typically sized and constructed buildings that were interpreted as domestic 'dwellings' (Byrd 2005a). Buildings 48 and 54 were oval, medium in size (4.2m and 3.5m diameter respectively), with plastered internal floor surfaces and walls, a central post, and were both agglomerated with other structures; all these characteristics were typical for the phase (Byrd 2005a: 75). Building 48 was slightly more distinctive, having an extra 2.4m x 1.5m rectangular 'alcove' area at its entrance, but this was not uncommon across the site (Byrd 2005a). Though devoid of built features other than a small pit in Building 54, the burnt nature of the buildings preserved a range of additional *in situ* artefacts, which were consistent with those recovered from other identified domestic units; these include a possible wooden bowl, animal bone, three stone querns and ground stone tools from Building 48, and clay animal figurines from Building 54 (Byrd 2005a). Furthermore, a number of bitumen-lined basket fragments were recovered from several other similarly constructed buildings from this phase, which may indicate further plant storage in other domestic structures.

A similar pattern can be observed from MPPNB 'Ain Ghazal (Table 4.1), where a pea and lentil concentration was identified from House 12, what Banning and Byrd (1987: 319) describe as 'a classic example of the PPNB house' (Rollefson & Simmons 1986; Banning & Byrd 1987: 319). This structure was of usual dimensions for the site and was subdivided into three room areas forming the recognised 'Pier House' style. A central internal hearth, which was also observed in other buildings, further suggests that this structure represents

a domestic unit. Notably, this identified plant store was located behind a partitioned area demarcated by a low row of stones, suggesting a dedicated storage area. Structure 700 from PPNB Yiftahel (Table 4.2), which contained traces of a lentil basket store, also appears to demonstrate usual household level activities, with a small grinding area to the south of the building and external yard hearth area. However, only three other poorly preserved structures were partially revealed during excavations, which provided only a limited horizontal exposure, so it is difficult to confirm whether this building form was typical across the site (Garfinkel *et al.* 2012).

Basket forms of storage are consistent at the household level in the examples recovered from Late Neolithic levels at Çatalhöyük (Table 4.1). Storage clusters from perishable containers were often associated with smaller side room spaces inside burnt domestic buildings, or located next to formalised built bin structures. In Building 52, a number of distinct plant concentrations, including barley, free-threshing wheat and wild mustard, were recovered from the floor of the small side room Space 93 (Bogaard *et al.* 2013*a*: 117). These were located beside four built storage bins with extensive sealed plant storage deposits, and suggest that these perishable containers may have functioned as additional storage suspended from the ceiling (Bogaard *et al.* 2013*a*: 117).

The unremarkable characteristics observed for basket-scale storage in the PPNB and Late Neolithic present limited opportunities for their wider recognition in the absence of larger burning events. Nevertheless, the cases presented may assist the further recognition of likely storage areas on a site-based level, such as the additional occurrences of preserved basketry in Beidha, or in instances with close parallels; the partitioned area in the 'Ain Ghazal 'Pier House' for instance bears a close resemblance to a partitioned area in similarly styled Building 3 at Beidha (Table 4.2), which may also represent a small storage area.

4.2.1.2. Built storage features

Investigation into the characteristics exhibited by built storage features with primary plant remains presents much greater potential for assisting wider recognition of facilities, due to their durability in the absence of large-scale burning. However, as previously noted, only two sites were able to offer such confirmed examples of built storage (Table 4.1). A clay constructed 'silo' was identified from the north-eastern corner inside 'domestic' Structure 700 at PPNB Yiftahel, which contained large concentrations of horse beans (*Vicia faba*) at its base (Garfinkel *et al.* 2012; Kislev *et al.* 2012). Though the actual size of the feature was unclear due to truncation, it appeared to cover at least $3m^2$ in area, and had surviving walls up to 0.4m in height (Garfinkel *et al.* 2012: 22). Unfortunately, its relatively poor condition offers few other physical characteristics for comparison. Its true relationship with the corner of the room is also unclear due to it being cut by a modern bulldozer trench. No other parallels could be identified from the site, which may be a result of its limited exposure.

The Late Neolithic levels from Çatalhöyük on the other hand present a vast number of built 'bin' features containing primary plant remains. As seen in basket levels of storage at the site, built bin features are all located within the inside of domestic structures, often within the smaller side room areas. This unique dataset of confirmed storage offers an unprecedented opportunity to explore the range of built storage across a single settlement, as well as offering well-preserved characteristics for wider identification. The examples so far recovered from the site will now be assessed in greater detail.

4.3. Built storage facilities at Late Neolithic Çatalhöyük

The Late Neolithic levels at Çatalhöyük provide some of the most extensive direct evidence for early storage practices in western Asia. Many examples fulfil the list of criteria for recognising storage facilities, including *in situ* archaeobotanical remains, associated rodent activity, preserved basket containers and formal built bin features (Table 4.3). A broad range of plant species can also be observed from these storage contexts, including cereals, pulses, nuts and other wild plant resources. Evaluation of the physical characteristics from demonstrated storage cases has enabled wider identification of storage facilities across the site (Green *et al.* in Demirergi *et al.* 2014), presenting one of the best opportunities to assess local scales of food storage across an individual settlement, as well as determining the range and variation of built features. Detailed phasing from several key buildings further enables investigation into the life history of built facilities throughout building sequences, reflecting the shifting requirements of individual households.

The site dates from 7100 to 5950 cal. BC, forming a large 13.5 ha mound with a densely clustered population (3,500 to 8,000 people) (above, 3.2); though the majority of excavated contexts relate to the mid to later levels, dating after c. 6700 cal. BC in the Pottery Neolithic (Hodder & Farid 2014). Surviving on-site activity areas appear to be largely focused indoors, or on upper storeys, with only limited open spaces amongst the closely packed buildings; these were frequently used as dumping areas that formed extensive middens, with emerging evidence to indicate their additional use as 'private' yard spaces in later phases (Hodder & Cessford 2004; Bogaard *et al.* 2014). There is currently no evidence for any centralised or communally accessible storage facilities, such as those seen in other contemporary Neolithic sites, with only one minor possibility of an externally located built storage bin.

Over 100 built storage 'bins' have been identified at the site in a variety of forms, which occur inside most of the houses that have been excavated (Farid 2007; Green *et al.* in Demirergi *et al.* 2014). These widespread household scales of storage present opportunities to investigate local trends and distinctions in storage capacities, and levels of household 'economic autonomy'. The remainder of this chapter will study in detail the *built* bin features with burnt *in situ* deposits that confirm their primary use as food storage facilities, by exploring trends in their associated contents and physical characteristics; the latter will be isolated from the recorded traits compiled in the recent study by Green *et al.* (in Demirergi *et al.* 2014) (Appendix 1a).

4.3.1. Range of storage contexts at Çatalhöyük

This analysis identified 19 built storage features with associated plant remains (Table 4.3); these included 14 features with primary *in situ* concentrations of macroremains, as well as a further five features that were identified from phytolith analyses. All of the features with primary charred macroremains were recovered from burnt buildings, highlighting the restrictive nature of such forms of preservation. Phytolith analyses were able to indicate additional storage facilities from several unburnt buildings, as well as reinforcing the species represented in primary storage deposits (Ryan 2013). The identified features were located within 11 different buildings, and were split evenly between the two main site areas, the North and South areas, with further examples identified from the smaller exposure areas (above, 3.2); this suggests that such storage practices were widespread across the site.

4.3.1.1. Range of plant contents

When examining the contents of such stores, a range of plant species can be determined (Table 4.3); though it is notable from assessing other primary contexts that such storage

Table 4.3 - Identified storage evidence with associated plant remains at Çatalhöyük.

> 500 counts per litre (X) 100-500 counts per litre (+) < 100 counts per litre (-)

										MAJOR SAMPLE COMPONENTS														PHYTOLITHS							
															Cereals					Pulses											
Phase/level	Area	Building no.	Space	Feature No.	Units	Brief description of identified storage types	Burnt building?	Complete in plan?	Primary plant remains - *in situ* macroremains	WILD	*Amygdalus sp.*	*Descurania sophia*	DOMESTICATED	*Hordeum vulgare var. nudum*	*Triticum monococcum/dicoccum/sp.*	Glume wheat indet. grain	*Einkorn/emmer glume bases*	*Triticum aestivum/durum*	*Lens culinaris*	*Pisum sativum*	Phytolith concentrations	Cereal husk silica skeleton	Wheat husk silica skeleton	Wild grass husk silica skeleton	Barley husk silica skeleton	Fruit/Nut	Preserved basketry	Specialised structural form*	Associated rodent evidence
G	North	1	71	215	1332, 1344, 1415	Burnt lentil bin	✓	✓	✓										X										
G	North	1	186	214	1227, 1230	Burnt wooden bin	✓	✓	✓					-															
EVI	Area E	EVI 17	-	Bin 3	Sample 24, 33	Burnt clay bin	✓	✓	✓			X																
G	North	52	93	2002	11900, 11903, 11906, 11908	Bin in the northwestern corner of space 93	✓	✓	✓		-	X		+				+			2	P	P	P	P	P			✓
G	North	52	93	2003	10284, 10292	Large bin in room corner	✓	✓	✓			X		+														?	
G	North	52	93	2004	11911, 11923	Medium-size bin	✓	✓	✓			X		+			+			+									✓
G	North	52	93	2005	11956	Small square bin	✓	✓	✓			X									✓				P	P			
South Q-T	IST	63	283	1967	11866	Rectangular plastered bin with rounded corners	✓		✓					X							✓	P							
South Q-T	IST	63	283	2330	13919	Wooden bin container	✓		✓					+							✓	P							
G	North	77	337	3092	16488	Triple bin feature with primary basal fill	✓	✓	?			+					-												✓

* i.e. covered hood, suspended floor

Table 4.3 - Identified storage evidence with associated plant remains at Çatalhöyük (continued).

> 500 counts per litre (X) 100-500 counts per litre (+) < 100 counts per litre (-)

Phase/level	Area	Building no.	Space	Feature No.	Units	Brief description of identified storage types	Burnt building?	Complete in plan?	Primary plant remains - *in situ* macroremains	MAJOR SAMPLE COMPONENTS: WILD		DOMESTICATED							PHYTOLITHS							
													Cereals					Pulses								
										Amygdalus sp.	*Descurania sophia*	*Hordeum vulgare var. nudum*	*Triticum monococcum/dicoccum/sp.*	Glume wheat indet. grain	*Einkorn/emmer glume bases*	*Triticum aestivum/durum*	*Lens culinaris*	*Pisum sativum*	**Phytolith concentrations**	Cereal husk silica skeleton	Wheat husk silica skeleton	Wild grass husk silica skeleton	Barley husk silica skeleton	Fruit/Nut	**Preserved basketry**	**Specialised structural form***	**Associated rodent evidence**
O	South	79	134	5031	18596, 18598	Low bin-like feature	✓		?					-		-											
O	South	80	135	3435	18945, 18952	Bin	✓		✓			X															
S	TPC	122	493	7182	30785, 30859, 30864	Bin in NW part of Sp. 493	✓		✓			X															
S	TPC	122	493	7198	30833, 30871	Small free-standing bin	✓		✓			X															
R	South	56	123	2085	13353, 13355	Single bin in space 123		✓											✓				P	P			
H	North	64	287	2903	14957, 14962	Bin structure		✓											✓	P				P			
Q	South	65	298	2500	13384	Plastered mudbrick bin		✓											✓					P			
Q	South	65	298	2502	13386	Plastered mudbrick bin		✓											✓					P	✓		
Q	South	65	298	2503	13387	Bin in western side room		✓											✓		P			P			

* i.e. covered hood, suspended floor

concentrations do not represent the full range of plants that were used in these buildings (Bogaard *et al.* 2013a: 127). Naked barley (*Hordeum vulgare var. nudum*) was the most frequently represented taxon and was recovered in large concentrations from nine of the identified storage bins. The presence of glume and free-threshing wheat, on the other hand, was rare despite their extensive representation in processing contexts; one bin feature, F.5031 from Building 79, contained small concentrations (<100 grains per litre) of glume wheat grain mixed with free-threshing wheat, and bin F.2002 from Building 52 represented the only other storage context of free-threshing wheat. However, alternative stores of glume wheat have been indicated from perishable storage contexts, such as the large concentrations of 'new type' glume wheat (cf. Jones *et al.* 2000) grains and phytoliths deposited on the floor of storage room Space 493 from Building 122 (Marciniak *et al.* 2013: 87).

Stored pulses were recovered from two buildings: a store of lentils *(Lens culinaris*) in Building 1, as well as a deposit of peas (*Pisum sativum*) accompanying other plant types (barley, wild mustard and glume wheat bases) in bin F.2004 in Building 52. The storage of wild plants was extensively represented, with six of the features containing large quantities of wild mustard (*Descurania sophia*), as well as a singular occurrence of wild almond kernels (*Amygdalus* sp.) in F.2002. One of these wild mustard contexts was particularly significant, with F.2005 from Building 52 packed with over 30 litres of *Descurania sophia* (Table 4.2) (Bogaard *et al.* 2013a: 117). This dedicated storage area from Building 52 contained the greatest diversity of stored plant types within a single building at the site (Bogaard *et al.* 2009).

The analysis of plant phytoliths provide further details about the life histories of household storage features (Ryan 2013: 173). Indicators for the storage of fruit/nuts were found in five bins examined without corresponding primary macroremains; this is particularly significant due to the limited representation of fruit/nuts from other primary storage contexts. A consistent signature was also recovered from the primary storage bin

F.2005 in Building 52, which contained almost pure concentrations of wild mustard (Figure 4.2); this may represent the residual signature of former storage contents. The additional examination of the three other primary storage contexts provided consistent plant signatures for the storage of cereals in Building 63, as well as for the diverse assemblage recovered from F.2002 in Building 52.



Figure 4.2 – F.2005 from Building 52, which contained 30 litres of *Descurania sophia* (wild mustard) (Çatalhöyük Online database).

4.3.1.2. Extent of evidence for rodent activity

The number of storage examples with *in situ* evidence for rodent activity (i.e. droppings, skeletal remains) was actually fairly minimal. Such indications could only be determined from inside two storage bins, F.2002 and F.2004, which were both located in Building 52. Thousands of charred rodent pellets were recovered in addition to skeletal remains from bin F.2004 suggesting a considerable infestation (Bogaard *et al.* 2013*a*: 119). A further association of rodent activity can be established from deposits in the side room space beside the bin complex F.3092 in Building 77; several rodent droppings were recovered suggesting storage in the area (Bogaard *et al.* 2013*a*: 121).

4.3.1.3. Other bin contents

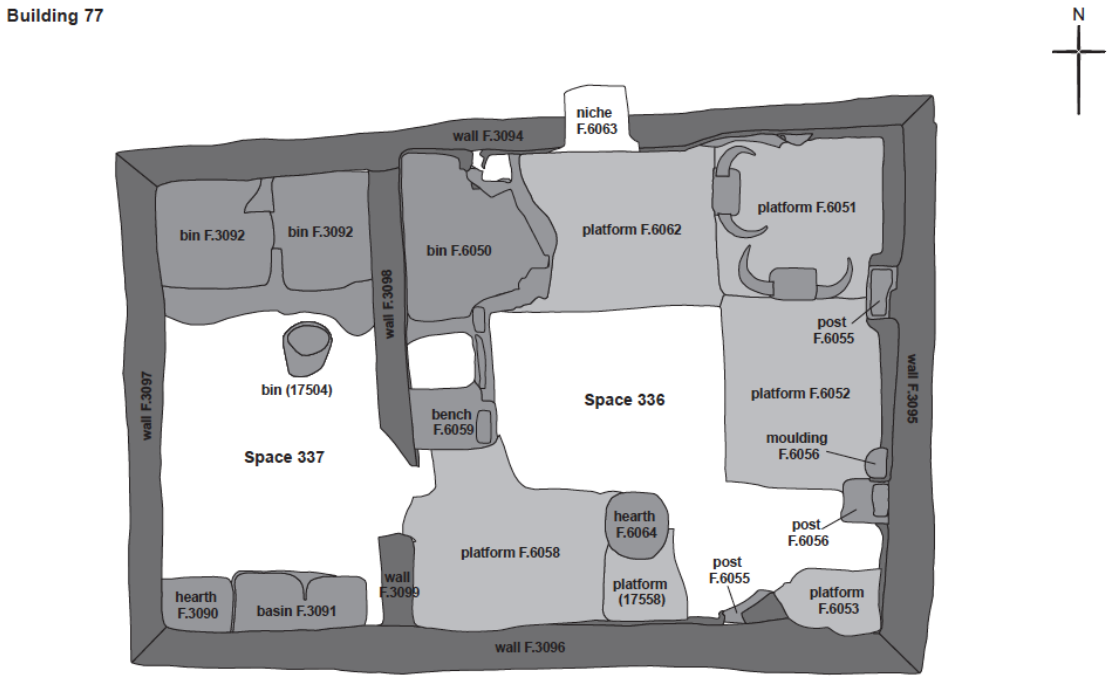
Additional *in situ* contents other than plant material were recovered from several built bin features, and suggest that some of these features served multiple storage functions besides plant material (Table 4.4). This highlights some of the difficulties involved in interpreting built features as dedicated plant storage facilities without accompanying remains. The bins from Building 52 demonstrated a range of additional stored commodities including worked bone tools, horn cores, obsidian blades and stone grinders. One of the bins, F.2003, also notably included a concentration of sheep/goat dung pellets at its base, which may have been stored for its purpose as a fuel (Bogaard *et al.* 2013*a*: 119). These pellets contained large quantities of *Sporobolus* sp. seeds, a grass from wet saline environments; such taxa may skew ecological analyses conducted on the arable weeds from such storage contexts if not distinguished as dung-derived taxa (below, 9.3 & Figure 9.51). The triple bin complex F.3092 from Building 77 also contained horn cores, antlers, and stones at its base, which were sealed under building collapse during its closure; these finds were located in separate sections of the bin from where primary plant traces were recovered, though the largely empty nature of the sections makes it difficult to determine whether they had different storage functions (Bogaard *et al.* 2013*a*: 121).

Traces of perishable containers were recovered from the insides of two bins analysed, F.2330 and F.2502. The former, from burnt Building 63, had distributions of wood charcoal that indicated a possible wooden container, although it was unclear whether it may have been more formally incorporated within the structure of the bin (Özbaşaran *et al.* 2014: 657). The bin F.2502 from unburnt Building 65 revealed clay impressions for a perishable bag/matting, which was further verified by phytolith analyses; these indicated the presence of monocot leaves alongside its other fruit/nut signature (Ryan 2011: 298). These may have been used to subdivide storage space for separate plant types (Ryan 2011: 302), or for the separation of non-food based stores; this interpretation is strengthened by the distinct clustering of plants and other objects seen in F.2004 in

Table 4.4 – Bin features with additional associated deposits.

Building no.	Feature no.	Associated deposits
52	2002	Bone tools and obsidian blades
52	2003	Large antler tool, stone grinder, obsidian blade, cow tibia, sheep horn, sheep/goat dung pellets
52	2004	Bone, worked bone and a stalactite
52	2005	Clay seal
63	2330	Remains of possible wooden container
65	2502	Reed mat/bag
77	3092	Horn core, antler and stones in NW section

Figure 4.3 – Plan of triple bin F.3092 (top left corner) in Building 77, which contained limited primary plant remains in its basal fill (u.16488) (Bogaard *et al.* 2013: 121; House 2014: Fig. 23.1).



Building 52 (Bogaard *et al.* 2009; Ryan 2011: 302). Finally, F.2005, which was also from Building 52, contained a layer of clay packing (u.11958) above the charred macroremains, sealing its internal contents; this appears to be intentional and may have acted as a way of preserving plant stores (Farid 2014: 379).

4.3.1.4. Size, shape and construction

The built 'bin' structures featured in this analysis (Appendix 1a) were some of the best examples excavated at the site, featuring deep upstanding walls up to around 1m in height; bin features are usually truncated to below half this height in poorer preserved contexts, increasing the ambiguity of their potential storage functions (Green *et al.* in Demirergi *et al.* 2014). The internal floor areas of the bins were variable, ranging from a tiny 0.07m^2 to a more sizeable 1m^2 (where this information was available); these two extremes could both be represented as part of the same triple bin complex F.3092 from Building 77 (Figure 4.3). The large compartments from this feature demonstrate the greatest storage volume observed from the site, with the smaller collapsed circular bin perhaps acting as a later addition for separate storage functions (House 2014: 492). The majority of the features analysed (12/19), however, had internal areas between around 0.2-0.4m^2.

Such agglomeration of storage features, which can be seen in F.3092, was also common throughout the examples; four of the features were grouped together as one complex (F.2002-2005) in Building 52 (Figure 4.4), with three of the other examples connected within Building 65 (F.2500, F.2502-3). F.215 from Building 1 was particularly interesting as it was directly connected to a 'basin' feature; such features have been linked with contexts of food processing, with possible indications for the handling of liquids/wet foods and cereal processing (cf. Green *et al.* in Demirergi *et al.* 2014: 94).

The bin features were typically rectilinear in form, often making the most of the space in small side room areas, though three elliptical bins were also identified: two of these

(F.3435 and the front section of F.3092) were extremely limited in internal floor areas (0.07m^2), while the other example was more typical in dimension (0.36m^2). All but two of the 19 features were built from a clay/mudbrick-based construction, which formed thin upstanding walls no more than around 10cm thick. The two exceptions included F.214 from Building 1, a feature constructed from thin wooden planks set in plaster, and F.2903 from Building 64, a plaster lined feature cut into the floor. This latter cut feature F.2903, with its shallow dimensions (0.2m), draws likeness with the form of similarly sized basin features from the site, and demonstrates some of the difficulties involved in their identification (Green *et al.* in Demirergi *et al.* 2014).



Figure 4.4 – Grouped storage bins in Space 93 from Building 52 (Demirergi *et al.* 2014: Fig. 7.1).

The built bin features were frequently plastered (16/19), though its specific application was inconsistent; some features were only plastered on the bases, while others were plastered on both the inner and outer surfaces of the bin walls. The remains of a possible superstructure could also be indicated from one of the analysed bin features: a carbonised post was inserted in the bin wall of F.2003 from Building 52. This example, however, does not represent the clearest indications for covered hoods observed from the site; several bin features without associated plant remains from Building 5 revealed surviving hood scars on their surrounding walls (Cessford 2007: 372).

4.3.2. Spatial characteristics of built storage features

When considering the spatial characteristics of the 19 storage features (Appendix 1a), several clear trends emerge in their general locations and finer spatial positioning. With the exception of Building EVI 17, which was interpreted by Mellaart as a dedicated granary (Mellaart 1963: 73) (though this interpretation is out-dated and seems unlikely),

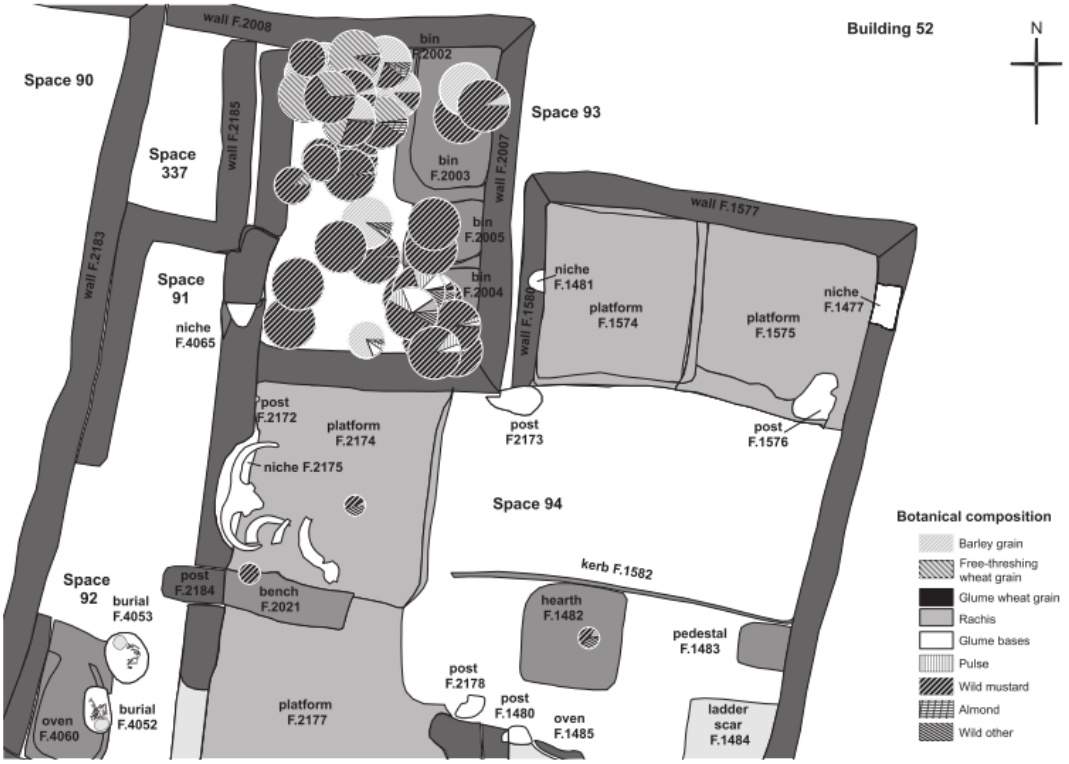


Figure 4.5 – The spatial distribution of botanical remains in B.52, highlighting the association of plant storage in side room spaces(Bogaard *et al.* 2013a: Fig. 7.23).

all of the buildings that contained these storage bin features were interpreted as individual domestics units (Hodder & Farid 2014). The size of domestic buildings across the site varies greatly (12m^2 to 63m^2), though consistent patterns in the proportions of main to side rooms space (around 20-30% allocated for side rooms) has recently been identified (Green *et al.* in Demirergi *et al.* 2014: 97-8). All but three (15/19 and one unknown) of the storage features were located within these side room areas, indicating close associations between smaller side rooms and general storage functions (cf. Bogaard

et al. 2009). This is reinforced by further clusters of plant macroremains from the floors beside built bin features, such as the extensive deposits recovered from side room Space 93 in Building 52 (Figure 4.4 & 4.5) (Bogaard *et al.* 2013*a*: 117-19). The three main room bin examples were unusual in other ways and may reflect slightly different or specialised storage functions. F.5031, from Building 79 formed a long shallow (0.12m high) rectangular feature along the northern wall of the building, while F.3435 from Building 80, was one of the two small elliptical bins (above, 4.3.1.4). The third feature to be located in the main room was the unusual double bin/basin combo F.215 (above, 4.3.1.4).

The relative locations of the identified features are fairly uniform, with all but one feature built directly against room walls. The one exception was the small freestanding bin F.7198, though this was positioned in the general vicinity of the side room corner. Many of the other features analysed also had a tendency to be located in room corners (13/19), which reduced the numbers of walls built in their construction. The association of the analysed built storage features with other activities is relatively limited, though the few examples indicate connections with food-processing areas. This can clearly be seen in the combined bin/basin feature F.215 from Building 1, with similar activities also identifiable in side room locations. Space 337 from Building 77, which contained the large triple bin complex F.3092 (Figure 4.3), contained a double basin feature at the opposite side of this small room, as well as a small hearth that indicated small-scale discard of cereal processing waste (House 2014; Bogaard *et al.* 2013*a*: 121). F.2903 from Building 64, also directly incorporated the southern side of a small hearth area in the construction of its latest remodelling phase (Yeomans 2014).

4.4. Discussion

The assessment of high integrity built storage features from Neolithic Çatalhöyük demonstrate a domestic context for formalised storage facilities at the site, while also indicating a variety of characteristics that may be used to examine storage practices more

widely across the settlement. Built storage bins were used to store of a wide range of plant types, though identified concentrations of macroremains do not reflect the full range of taxa utilised within these buildings (Bogaard *et al.* 2013*a*: 127). Applications of phytolith analyses hint at residual plant signatures from such features, and reflect the dynamic use of built storage space (Ryan 2013). Multiple plant types, as well as other storable commodities, such as dung fuel and stone tool kits, were sometimes contained within single bin spaces; traces for basketry and wooden containers indicate the internal compartmentalisation of formally built storage space with perishable bags and/or containers. There is also evidence to suggest that some stores may have been sealed with applications of clay; this may have been used for longer-term storage, and to protect against rodent infestations, which can be demonstrated by *in situ* rodent skeletal remains and droppings directly associated with bin features (Bogaard *et al.* 2013*a*: 118-9; Farid 2014: 379). The built features were typically associated with side room spaces and were similarly constructed across the site, though the scale and frequency of built features in the buildings varied, reflecting the differing storage requirements of individual households (Green *et al.* in Demirergi *et al.* 2014).

The characteristics indicated by these 19 confirmed built storage contexts also mirror those identified by the bin/basin study conducted by Green *et al*. (in Demirergi *et al.* 2014), which reassessed the criteria for identifying bins and basins features at Çatalhöyük. When 101 recognised bin and basin features were analysed, bins were able to be distinguished based on their deeper walls, rectinlinear shape, locations in side room locations, which were often in corners and in groupings of three or more, and clay core constuction (Green *et al*. in Demirergi *et al.* 2014: 94). This previous study also identified occasional deviations from these general trends (Green *et al*. in Demirergi *et al.* 2014: 94), which can also be observed from the more unusual features highlighted in this study. This analysis of high integrity plant stores strengthens the use of such characteristics for the further examination of built storage features across the site.

When comparing with the nature of storage facilities in other Late Neolithic sites from western Asia, dedicated stores appear to be either centrally located within large settlements indicating possible communal functions, such as at Sabi Abyad, or in the case of Sha'ar Hagolan reflect large-scale storage in extensive agglomerated buildings, which likely reflect coordination between 'extended' households (Duistermaat & Akkermans 1996; Ben-Shlomo & Garfinkel 2009). By contrast, the small-scale domestic context of built storage perceived from Late Neolithic levels at Çatalhöyük, indicates continuity with the emergence of increasingly 'privatised' storage facilities in the preceding PPNB period, and raises a number of questions regarding the organisation of agricultural activities at this site: do these household levels of storage also reflect household organisation of agricultural practice, or did separate households work together? The primary crop stores that have been identified in this analysis present the opportunity to examine such questions, through the analysis of their associated weed ecology. These primary *in situ* deposits, contained within formally built features, present direct connections with individual buildings, unlike secondary deposits, and can be used to compare the general ecological signatures of household agricultural practices.

Chapter 5
Archaeobotanical methods

This chapter sets out and compares the previous methods used in the recovery and analysis of archaeobotanical material from the four case study sites, as well as the procedures followed to acquire new sample data. The methodology applied for the selection of samples for ecological analysis are presented, also detailing the core procedures used to achieve refined taxonomic identifications to species level, wherever possible. The analytical methods used in the isolation of relevant weed taxa and the final ecological analysis are also detailed.

5.1 Field methods: on-site sampling strategies and sample processing

The four excavation sites analysed in this study were managed by separate research teams, and therefore reflect different approaches to the recovery of archaeobotanical material. George Willcox coordinated the archaeobotanical recovery for the three Syrian sites, Jerf el-Ahmar, Dja'de and Tell Aswad. The archaeobotanical material from Çatalhöyük, on the other hand, has been managed by a larger team since systematic excavations began in the 1990s, though methods initially employed by Hastorf (2005) have been followed throughout.

5.1.1 Jerf el-Ahmar, Dja'de and Tell Aswad

The archaeobotanical recovery methods used at each of these three sites are not yet fully published, so the following details have been compiled using a combination of preliminary reports and personal communications. A judgement sampling strategy (cf. M.K. Jones 1991) was employed at each of the three Syrian sites, with samples primarily taken from discrete contexts and areas with visible concentrations of archaeobotanical remains (i.e. charcoal filled lenses, burnt layers etc.). Sampling procedures sought to establish the function of specific features, as well as to assess the spatial distribution of particular plant species and activities across the site. There was no standard minimum sample volume; in the case of small discrete features (i.e. pits, hearths), the entire context was collected for flotation, whereas larger layers and deposits were only partially sampled, with quantities decided on a case-by-case basis (C. Douché pers. comm.). A further consideration at these sites was to acquire representative data across all phases excavated.

At Jerf el-Ahmar, a total of 266 samples was collected for archaeobotanical analysis over five of the six excavation seasons, which represent over 12,000 litres of sediment (Willcox *et al.* 2008: 315; Stordeur 2014). Layers were initially tested by processing small samples with flotation in order to detect areas of concentrated charred remains; sediments that were identified as being archaeobotanically rich were then selected for further sampling (Willcox *et al.* 2008: 314). A range of individual contexts was sampled at various volumes (ranging from 3 to 913 litres) including hearth areas, occupation, midden and demolition layers. Some exceptionally well preserved areas of the site were sampled more intensively; Room 2 from Building EA10 (interpreted as a 'kitchen' area) had been destroyed by fire and was systematically sampled using a one metre grid square system (Willcox 2002). This enabled the spatial distribution of each taxon to be accurately documented in relation to other features located within the space.

A similar judgement sampling approach was undertaken across the site at Dja'de, where 227 samples were taken over 13 seasons of excavation (Willcox *et al.* 2008: 314). These

samples represented around only half as much sediment as at Jerf el-Ahmar, with approximately 6,000 litres sampled, but had greater average densities of charred remains (Willcox *et al.* 2008: 314). A comparable range of individual contexts were sampled, with hearth deposits and ashy fills/ lenses occurring frequently across the site, as well as midden, occupation and demolition layers (Willcox *et al.* 2008: 314). These ranged from 5 to 170 litres in volume, with greater quantities taken from rich occupation layers (Willcox unpublished reports).

At Tell Aswad, 440 samples were taken over six seasons, with more than 11,000 litres of sediment processed (Stordeur *et al.* 2010; C. Douché, pers. comm.). Samples were collected strategically from a wide range of discrete contexts, including pits, hearths, storage features, basins and house floors (Willcox unpublished reports). Samples ranged from 1 to 202 litres in volume, with some of the larger samples taken from seed rich-features: for example, the fill from of the basins from Building 584.

The preservation of plant remains at these three sites was primarily by charring; therefore, the main method of recovery for plant remains was by flotation. The archaeobotanical samples at each site were processed using a simple 200-litre flotation tank, with the light fractions collected in a mesh with a 0.5mm aperture size (Willcox *et al.* 2008: 2). Finer meshes were trialled, but these were deemed impractical as they clogged too easily (Willcox *et al.* 2008: 2). However, tests comparing the mesh sizes demonstrated that no significant quantities of identifiable material were lost due to the 0.5mm aperture selection (Willcox *et al.* 2008: 2). The heavy fractions were collected in a submerged sieve with a larger aperture of 2.5mm; this sieve size reflects further compromises linked to the frequent clogging of smaller meshes, in addition to restricted timescales and limited local resources (i.e. no running water or electricity) (Willcox 2016; G. Willcox, pers. comm.). The samples were air dried slowly before being transported and sorted (Willcox 1996; Willcox & Roitel 1998). The heavy residue material has yet to be analysed and is now inaccessible; the heavy fractions are currently stored in Syria in a region now under Islamic State control (G. Willcox, pers. comm.).

5.1.2 Çatalhöyük

The archaeobotanical recovery methods at Çatalhöyük have been widely reported elsewhere (Hastorf 2005; Bogaard *et al.* 2013a; Filipović 2014), so this section will present a brief summary of the methods used at the site. At Çatalhöyük over 13,000 samples have been processed over the last two decades (from 21 seasons), representing over 220,000 litres of sediment. A systematic sampling strategy was employed, with a 'bulk' soil sample of c. 30 litres taken from every excavation unit as standard practice (Hastorf 2005: 130; Bogaard *et al.* 2013a: 93). However, the specific recovery procedures did evolve over time in accordance with what was encountered. At the site, the term 'unit' refers to what is more commonly known at other sites as a single context; this represents the basic recording element used at Çatalhöyük (Cessford and Farid in Hodder *et al.* 2007: 13). Individual units will be referred to in the text using a lowercase 'u' enclosed in brackets, for example (u.1000). Such units ideally represent single depositional events, but in practice these will sometimes include multiple events that were impossible to excavate separately (Cessford and Farid in Hodder *et al.* 2007: 13). Attempts were made to take several separate samples when units were heterogeneous or contained notable clusters, so as to isolate and document any potential variability (Hastorf & Near 1997). Such a practice was particularly relevant for some of the storage deposits examined as part of this project, as discrete clusters were discerned within some seed concentrated units (e.g. pea deposit (u.11911) from Building 52) (below, 9.1.2) (Bogaard *et al.* 2013a: 117).

During the sample collection procedure, if a single unit consisted of less than 30 litres of soil the deposit was taken in its entirety (Hastorf 2005; Cessford and Farid 2007: 13). A 100% sample was additionally taken in cases where extensive *in situ* botanical concentrations were discovered (e.g. storage deposits); these samples were dry sieved due to their limited soil matrix, which was prone to clogging. Therefore, sample volumes vary widely at the site, ranging from less than a litre up to 632 litres (with an average of 17.5 litres) (Çatalhöyük Excavation Database).

The archaeobotanical samples were processed using two flotation machines, with a capacity of around 50 gallons (c. 227 litres) and with a two-tank settling system for recycling water (Hastorf 2005: 131). The light fractions were collected in a piece of chiffon material with an aperture of less than 0.3mm, clipped inside a bucket with its base removed (Hastorf 2005: 131). This small mesh size was chosen due to the prevalence of small seeded (<0.5mm) taxa at the site, for example the small seeded wild mustard *Descurania sophia*. Heavy fractions were collected using a flexible stainless steel mesh with an aperture of 1mm that was submerged within the drum (Bogaard *et al.* 2013a: 93).

The light fractions ('flots') were air-dried in their chiffons, and were later transferred to labelled plastic bags in the archaeobotany laboratory (Hastorf 2005: 131). Using geological sieves, these were then sieved and separated into three fraction sizes to assist scanning; >4mm, >1mm and >0.3mm (Bogaard *et al.* 2013a: 93). Material that was smaller than 0.3mm was occasionally retained for phytolith analysis (i.e. if there was no separate sample), but was usually discarded, as it contained minimal identifiable taxa (A. Bogaard, pers. comm.). The 1mm fraction was subsequently split down into random subsamples of around c. 10ml using a riffle-box to enable rapid preliminary analysis (Filipović 2012: 72). The heavy fractions were processed separately by a dedicated heavy residue team, at fractions of 4mm, 2mm and 1mm, with recovered archaeobotanical remains quickly sorted and added back to the original sample for identification (Hastorf 2005: 133; Bogaard *et al.* 2013a: 94).

5.2 Previous sample assessment and analysis

As the central purpose of this research project is to refine the identification of weed taxa to improve the accuracy of ecological analyses, a large number of the archaeobotanical samples selected for this study have been previously scanned and analysed to some extent. Additional scanning and analysis was undertaken in this study to obtain maximum weed material for ecological analysis (below, 5.4). This section briefly outlines the

laboratory methods used by the former research teams for the scanning, identification and quantification of archaeobotanical material.

5.2.1 Jerf el-Ahmar and Dja'de

The archaeobotanical samples from Jerf el-Ahmar and Dja'de were analysed by a small team of researchers at C.N.R.S. Archéorient, Antenne de Jalès (southern France), which include George Willcox, Sandra Fornite and Linda Herveux, as well as doctoral student Valérie Roitel, based at Université Montpellier II (Willcox & Roitel 1998; Willcox *et al.* 2008). The light fractions of the samples were partially examined on-site to provide preliminary indications of their taxonomic compositions (C. Douché, pers. comm.). Detailed examinations of the macrobotanical remains were undertaken in the archaeobotanical laboratory at Jalès, where an extensive modern seed reference collection was available to assist accurate identifications; the collection consists of 1,500 specimens collected from various locations across the Middle East (Willcox & Roitel 1998; Archéorient 2012).

The majority of samples from the two sites was fully examined, though some especially rich samples were subsampled in order to speed up the analytical process (Willcox unpublished reports; C. Douché, pers. comm.). In order to quantify the number of items recovered from the two sites, each identifiable plant part, whether complete or fragmented, were scored as a single item (Willcox *et al.* 2008: 315). Many of the specimens were only identified to the genus level, which was attributed to the vast extent of potential species found within the region, as well as poor levels of preservation from charring (Willcox & Roitel 1998: 71; Willcox *et al.* 2008: 315). The results of these analyses were partially published in Willcox *et al.* 2008, with the main publication still in preparation. Access to the raw sample data for use in this project was granted by Willcox, and was extracted from the Origins of Agriculture project database, created by the University of Sheffield (2016).

Following the retirement of Willcox, the archaeobotanical material from these two sites was recently relocated from Jalès to Paris (summer 2015) and taken over by Margareta Tengberg, based at the Muséum national d'Histoire naturelle. Full primary analysis of samples from Dja'de formed a core part of Carolyne Douché's doctoral thesis (Université Paris I, Panthéon-Sorbonne). A number of samples taken from the site between 2006 and 2009 have been analysed solely by Douché, but as the identification of these samples was still in progress, these were not considered within the scope of this project. The Dja'de material available for analysis in this study were those examined by Willcox, which were restricted to the PPNB levels.

5.2.2 Tell Aswad

The samples from Tell Aswad were analysed in a similar way to the other two Syrian sites, with a small team of researchers carrying out preliminary on-site analysis of the archaeobotanical material. Initial examination was carried out in the first excavation season by Willcox, with samples in subsequent seasons analysed by a number of doctoral students, including Manon Savard (University of Cambridge), Hugues Pessin (Université Paris I) and Linda Herveux (Université Paris X). Detailed analysis of the samples from this site forms the remainder of Douché's doctoral thesis and are yet to be published. Access to the material was granted by Douché and supervisor Tengberg, who also provided the raw sample data.

Examination of the macroremains was undertaken by Douché in the archaeobotanical laboratory located within UMR 7209 du CNRS, at the Muséum national d'Histoire naturelle, Paris. As the samples contained only small volumes of charred material (<300ml), all of the archaeobotanical samples from the site were scanned in their entirety (C. Douché, pers. comm.). Specimens were compared with modern reference material and seed catalogues to assist identification; much of the modern seed reference collection from Jalès was also transferred to Paris along with the archaeological material from the other

two sites. The laboratory also contains a Scanning Electron Microscope, which was used to refine identifications. Nevertheless, much of the wild/weedy material has only been identified to the genus level (C. Douché, pers. comm.).

5.2.3 Çatalhöyük

Initial on-site sorting of the 10ml subsamples from the 1mm fraction was undertaken by an extensive team of archaeobotanists (including the author) who have worked at the site during the last two decades. This initial stage of analysis ('level 1 assessment') yielded approximate counts of the basic plant categories for each sample (i.e. glume wheat, wild/weedy taxa, Cyperaceae etc.), enabling targeted selection for further analysis (Bogaard *et al.* 2005); in earlier seasons (1995-2002), this assessment was more rudimentary with categories by weight (A. Bogaard, pers. comm.). Some units were designated by the excavators as priorities requiring immediate feedback, so the corresponding flots were examined in greater detail in the field ('level 2 assessment') with more quantitative data recorded, such as diversity estimates (Bogaard *et al.* 2005).

The criteria used for identifying the basic plant categories were determined using seed atlases (e.g. Berggren 1969; 1981; Anderberg 1994), archaeobotanical publications (e.g. Jacomet *et al.* 1989; Körber-Grohne 1991; Jones *et al.* 2000) and through consultation of modern seed reference collections (Selcuk University herbarium, Edinburgh Botanical Garden with *Flora of Turkey* collection, UCL collection) (Bogaard *et al.* 2013a: 94). A small modern seed reference collection was also available within the on-site laboratory, which consisted of some of the most common species identified from the site; these were largely collected during botanical field studies that were undertaken in the local area (Bogaard *et al.* 2004).

Detailed examination (full identification and quantification) of the archaeobotanical samples was carried out by several research teams and individuals over the two decades

of excavation (Hastorf 2005; Bogaard *et al.* 2013a). For the 1995-1999 seasons, a subset of samples (77 samples derived from 75 units) was fully analysed by Andrew Fairbairn (formerly Australian National University), Julie Near (University of California at Berkeley) and Danièle Martinoli (Basel University) (Fairbairn *et al.* 2005). Samples were selected to represent the full range of interpretive categories assigned to units at the site (Fairbairn *et al.* 2005: 148; Hastorf 2005: 134). These were exported from Turkey to their respective institutions, with the analysis undertaken between 2000-2001 (Asouti *et al.* 1999; Hastorf *et al.* 2000). The results of these analyses were presented in Çatalhöyük Research Project Volume 4 (Fairbairn *et al.* 2005).

A large number of the samples that were unanalysed, or only partially analysed (level 1 and 2 assessment), from the 1995-1999 seasons were examined as part of Dragana Filipović's (University of Oxford) doctoral thesis (Filipović 2012; 2014). Filipović's study further included samples taken from the BACH area excavations, which took place between the 1997-2003 seasons (Filipović 2012: 62). The study considered a wide range of context types (ovens, hearths, bins, midden etc.), but primarily targeted well defined depositional events, with significant amounts of identifiable plant remains (minimum of c. 50 identifiable items) suitable for statistical analysis (Filipović 2012: 63). A total of 94 samples (representing 92 units and amalgamated from 115 flots) were examined, with full identifications completed at the University of Oxford (Filipović 2012). The results of this study were recently published (Filipović 2014).

Direction of the archaeobotanical recovery shifted to the current UK based team in 2003, whose team leaders initially consisted of Amy Bogaard (formerly University of Nottingham), Michael Charles (formerly University of Sheffield), and Glynis Jones (University of Sheffield) (Agcabay *et al.* 2003). Most of the samples considered for analysis in this study were excavated and processed under this direction. Using the data generated from the initial stages of analysis, samples—mostly from primary deposits—were selected and exported to the UK where they were able to be examined in greater detail (Bogaard *et al.* 2013a: 93). The results of 319 archaeobotanical samples, excavated between the 2000-

2008 seasons, were published in Çatalhöyük Research Project Volume 8 (Bogaard *et al.* 2013a).

A selection of the archaeobotanical samples recovered from the Istanbul (IST) area, which was excavated by a separate team from Istanbul University between 2005-2008, were fully analysed as part of Müge Ergun's (Istanbul University) Msc dissertation, with supervision of the archaeobotanical work by M. Charles at the University of Sheffield as part of an Erasmus visit by Ergun (Ergun 2008; Ergun *et al.* in Özbaşaran *et al.* 2014). Thirty-one samples (amalgamated from 42 flots) were selected for analysis, which mostly derived from Building 63, a well-preserved building destroyed by fire (Ergun *et al*. in Özbaşaran *et al.* 2014). The selection procedure targeted well sealed and archaeobotanically rich deposits, such as a number of storage deposits, fire installations and dirty floor deposits (Ergun *et al*. in Özbaşaran *et al.* 2014). The results of the study were published in Çatalhöyük Research Project Volume 7 (Ergun *et al*. in Özbaşaran *et al.* 2014).

Subsampling was frequently used as a time saving method when examining samples very rich in charred remains, which were recovered regularly due to the site's extensive burnt *in situ* deposits (Hastorf 2005: 134; Filipović 2012: 82; Bogaard *et al.* 2013a: 94). Samples that were estimated to contain more than c. 400-500 crop items within the coarse flot (>1mm) (based on the initial phases of data analysis) were randomly subsampled until this approximate amount was reached; this approximate figure was determined in Van Der Veen & Fieller's (1982) study, which identified the minimum number of botanical items for accurately representing a given population with a high probability (Bogaard *et al.* 2013a). This procedure enabled a greater number of samples to be analysed, while permitting the targeting of dense contextually rich primary deposits without contributing unnecessary timescales. The fine flot (>0.3mm) was randomly subsampled to c. 1/8th of the corresponding coarse flot with the aim to reach a minimum of 30 wild plant remains, with further subsamples sorted until this number was reached (Bogaard *et al.* 2013a: 94). This process, however, meant that many of the samples did not reach their full weed

potential; frequently occurring wild taxa, such as *Descurania sophia*, dominated the minimum wild taxa quota, which likely prevented the full range of weed flora from being identified. Furthermore, low ratios of weeds to crop items in the seed stores meant that partial analysis of the samples was generally insufficient for retrieving adequate weed taxa (below, 5.3.1).

Final identifications were made using modern seed reference collections held at the associated institutions, as well as referring to other UK based seed collections and herbaria (University of California, University of Sheffield, University of Nottingham, UCL, University of Oxford, Royal Botanic Gardens Edinburgh) (Filipović 2012: 78; Bogaard *et al.* 2013a: 94). Lists of geographically relevant species were determined for each genus using the *Flora of Turkey* (Bogaard *et al.* 2013a: 94). In cases where related species were missing from reference collections, new accessions were ordered from botanic gardens where possible, or were collected in the field (Bogaard *et al.* 2013a). A number of botanical seed reference collections were also consulted within Turkey, including the herbarium based at the Department of Botany at Selcuk University, Konya, and the seed reference collection held at the British Institute of Archaeology at Ankara (BIAA) (Asouti *et al.* 1999; Filipović 2012: 78).

The plant remains were quantified using a system based upon the 'minimum number of individuals principle' (MNI) (Fairbairn *et al.* 2005: 148; Filipović 2012: 79; Bogaard *et al.* 2013a: 94). For the preparation of the initial 1997-1999 report, cereal grains, pulse seeds and wild seeds were counted by whole specimens and diagnostic fragments (embryo ends/ apical ends, with only the greater score used) (Fairbairn *et al.* 2005). Due to the large frequency of undiagnostic cereal fragments, these were also collected, weighed and then converted into the whole grain equivalent in order to calculate their MNI figure; the conversion figure of 0.01g was based on the mean weight of 411 grains measured from the site (Fairbairn *et al.* 2005: 148). Weight conversions were also applied to fruit and nut fragments, which were frequently recovered in a fragmented state, and were calculated with appropriate figures for each species (Fairbairn *et al.* 2005: 148).

For the 2000-2008 report and two postgraduate theses, the quantification system was simplified, following methods proposed by Jones (1991: 65-66). Only the diagnostic parts of cereal grains, pulses and weed seeds were calculated (Bogaard *et al.* 2013a: 94). Glume bases were counted by their basal attachment point, while for free-threshing wheat, only the upper 'nodal' parts of rachis segments were counted (Bogaard *et al.* 2013a: 94). Wild chaff, such as *Taeniatherum caput-medusae* rachis segments, was counted in the same manner as for free-threshing wheat, by their upper rachis segments (Bogaard *et al.* 2013a: 94). Nutshell was quantified by counting hilar scars, or dividing the number of fragments by 20 (Bogaard *et al.* 2013a: 94).

5.3 Selection of samples for present study

To assess the crop husbandry practices used at the four Neolithic sites as accurately as possible, the sample selection procedure needed to carefully consider context type in order to identify deposits with limited mixing of wild plant sources, therefore enabling the isolation of relevant weed taxa. As discussed previously (Chapter 2 & 4), *in situ* storage contexts provide the purest deposits for obtaining weed flora, which can be directly related to the specific crop types with which they were grown. While this approach could be taken for the selection of samples at Çatalhöyük, owing to its unprecedented sample coverage and extensive levels of preservation, no *in situ* storage contexts were recovered from the archaeobotanical sampling at the three earlier Syrian sites. For these sites, other primary context types (e.g. hearth fills, dirty floor layers) were prioritised for selection. Further selection criteria included minimum thresholds for both crop items and weed taxa present within a sample, which enabled samples to be statistically analysed. The specific selection criteria determined for each site are detailed below.

5.3.1 Çatalhöyük

The selection process for Çatalhöyük began during the 2013 excavation season (prior to the project commencing) in order for appropriate samples to be exported from Turkey to the UK for detailed analysis. Samples were selected from those yielded from the recent Hodder excavations as described above, which began with the 1995 season. However, with the majority of *in situ* storage deposits excavated post 2003, emphasis was given to samples recovered under the direction of the UK led team. A smaller number of storage contexts were available from the 1995-1999 period, analysed as part of Filipović's (2012; 2014) doctoral thesis.

The first selection phase was carried out using the 'level 1 assessment' data compiled within a central database, which recorded the basic plant categories of a 10ml subsample; this enabled c. 5,700 samples to be considered for analysis. With weed taxa the primary focus of this project, an initial attempt was made to isolate samples with greater numbers of wild/weed taxa. This approach, however, tended to accentuate heavily mixed context types such as heterogeneous midden deposits, rather than the desired primary deposits. It therefore became apparent that it was necessary to use contextual associations as the principal criterion for sample selection. Using the excavators notes and interpretations recorded in the excavation's central database, samples derived from storage related features (i.e. built bin features), as well as concentrated seed cluster units were targeted from the available archaeobotanical samples. Nevertheless, in order to identify *primary* crop storage contexts, it became necessary to narrow the selection exclusively to samples from buildings destroyed by fire; storage linked units from unburnt buildings were frequently indicative of secondary deposition (i.e. building collapse, dump material) (Bogaard *et al.* 2013a).

While only considering burnt buildings, a list of 100 potential storage samples (derived from 90 individual units) was composed. Using the archaeobotanical composition estimates provided by the subsample dataset and contextual records, each sample was

then assessed in relation to a number of criteria to confirm their status as primary storage. Firstly, the samples were filtered down so that only samples containing at least an estimated 100 cereal grains or pulses were included; this was to ensure selected samples represented depositional events large enough to be analysed statistically (Van Der Veen & Fieller 1982). This preliminary list of approximately 65 samples formed the starting point for the project and the corresponding samples were prepared for export. This included further fractions of samples that had been partially exported and analysed by Bogaard *et al.* (2013a), Filipović (2012; 2014) and Ergun *et al.* (in Özbaşaran *et al.* 2014).

Further selection from this shortlist was based on samples containing a high proportion (over 50%) of grains/pulse seeds compared with other plant types (i.e. cereal chaff, wild taxa). This was useful for isolating many of the primary stores, but there were a number of exceptions to consider, such as instances where concentrations of grains were preserved within their chaff (i.e. 'new type' wheat clusters from Building 77; below, 9.1.3) (cf. Bogaard *et al.* 2013a: 119). The contextual associations of the samples were examined in greater detail by referring to excavator's comments from the central database, as well as the many archive reports (http://www.catalhoyuk.com). Visibly concentrated seed clusters were confirmed as storage, whereas heavily mixed bin fills, more likely to represent secondary contexts of collapsed building material, were excluded from the study. Thin concentrated seed lenses from the bases of built storage features (above, 4.3), which appeared to relate to original stored contents, were, however, included. Densities of grains per litre were considered as a way of identifying seed clustering in deposits, but a threshold of 100 or even 50 grains/pulses per litre overly constrained the selection; it became clear that there were several different categories of storage represented within the archaeobotanical dataset, which were also likely to have been excavated differently, therefore reflecting different densities (below, 9.1.2).

For the next selection phase, samples were assessed for their potential weed richness. A minimum threshold of ten well-preserved and identifiable (at least to genus level) weed specimens was set for samples to be included in the study. This threshold was initially set

higher at 20 counts per sample, but was often difficult to achieve and excluded too many crucial storage contexts. It became clear that the most secure primary *in situ* stores related to the fewest wild taxa counts, likely a result of extensive crop cleaning prior to storage (below, 9.1.2).

Sample data from the previously analysed samples were compiled from published reports (Bogaard *et al.* 2013a; Ergun *et al.* in Özbaşaran *et al.* 2014; Filipović 2014) to provide more accurate weed count estimates. For unanalysed samples, the 'level 1 assessment' data were used in the first instance, but further scanning was required to confirm the suitability of samples with low weed counts. Several samples were predicted to contain insufficient weed taxa from the 10ml subsample, but further sorting in some cases revealed additional weed seeds in unscanned fractions. This also occurred within some of the previously examined samples, which were subsampled for analysis. Alternatively, in some cases items recorded under the 'level 1 assessment' wild/weed category yielded exclusively non-weed taxa likely derived from other wild plant sources (i.e. collected, dung, modern; below, 5.6). Following this preliminary scanning process, a final list of 33 crop stores was composed for full examination and identification (Appendix 1b).

5.3.2 Jerf el-Ahmar, Dja'de and Tell Aswad

The archaeobotanical samples from the three Syrian sites were permanently housed at the Muséum national d'Histoire naturelle in Paris, so required a different strategy for the selection of samples for further analysis. Permission was given to re-examine the previously identified weed flora, but not to scan samples any further. The weed material was assessed for its potential for refined identification during two short research trips (below, 5.7.2), and required strategic documentation of the most ubiquitous taxa for all three sites. Only a limited number of samples were derived from primary contexts (i.e. hearths, ovens), with no instances of *in situ* storage, so a context focused selection approach could not be principally used for these sites. Selection instead concentrated on

identifying samples with high proportions of cultivated grains/pulses, as well as employing a minimum threshold of 100 crop items per sample, so as to identify relevant crop-processing related activities. As with the Çatalhöyük samples, a minimum weed count of ten weeds per full sample was also used as a further selection criterion.

To make the selection, crop and weed totals were calculated using the full compositional data recorded for each sample. Likely cultivars at PPNA Jerf el-Ahmar, where there are no domesticated species, were determined by identifying wild cereal and pulse species with the greatest abundance and ubiquity across the site, while comparing with later domesticates from the other sites. The top four most ubiquitous and abundant species(/types) identified at Jerf el-Ahmar (when excluding collected fruit/nut species) were wild barley (*Hordeum spontaneum*), wheat/rye (*Triticum/Secale*), lentil (*Lens* sp.) and a *Pisum/Vicia/Lathyrus* type. *Hordeum spontaneum* dominated the assemblage, appearing in over 90% of the samples, with a total of 9,639 grains and 3,325 rachis fragments identified (Willcox *et al.* 2008). These genera were comparably ubiquitous and abundant at Dja'de, despite the emergence of new cereals, such as wild emmer (*Triticum dicoccoides*) (Willcox *et al.* 2008). Similarities were further detected in the cultivars identified at Tell Aswad, although domesticated forms, such as barley (*Hordeum vulgare*) and emmer (*Triticum dicoccum*) were predominant at this later PPN site (van Zeist & Bakker-Heeres 1982; C. Douché, pers. comm). This small list of genera (*Hordeum, Triticum, Secale, Pisum, Vicia* and *Lathyrus*) therefore formed the basis of the crop item calculations for each of the sites.

To calculate the weed totals for each sample, potentially identifiable weed taxa were isolated from the remaining wild taxa. This was achieved by systematically excluding fruit and nut species, larger tree or shrub species, as well as disregarding specimens only identified to plant family (likely to be poorly preserved). Unlike Çatalhöyük (below, 5.6), there were no previous studies to have analysed the potential for dung-derived taxa occurring at these three sites, so no taxa were excluded based on these grounds at this stage; this will be explored further during the final analyses (below, 5.8.2 & 9.4). The

specimen counts of the remaining wild/weed taxa were used to assess the weed richness of each sample, with only those containing a minimum of ten specimens considered for the final selection.

Based on these criteria a shortlist of samples was created for each site, which was used to guide the documentation process during the two research trips; the most ubiquitous weed genera present in this selection informed the priority genera for examination (below, 5.6). Owing to time constraints, the final sample selection was largely determined by the levels of preservation of the target weed flora, together with the accessibility of material during the trips; only the best-preserved weed specimens, with the potential to be further identified, were photographed and documented (below, 5.7.2.1). Not all samples could be located, which excluded a number of target samples from further analysis. Following the weed documentation process, a total of 63 samples was selected from the short-list that exceeded the set crop and potential weed thresholds for inclusion in the ecological analysis; this comprised of 20 samples from Jerf el-Ahmar, 27 from Dja'de and 16 samples from Tell Aswad (below, 9.2).

5.4 New sample analysis at Çatalhöyük

The final set of selected samples from Çatalhöyük was subjected to detailed analysis, with the principal aim to obtain full weed potential for each individual sample. While many of the primary crop stores were previously examined, several large storage samples were newly analysed as part of this study (Appendix 1b). Further fractions were also sorted from the previously reported samples to obtain maximum weed data. This section details the specific procedures that were followed for these new analyses.

5.4.1 Sorting of selected samples

While weed taxa were the primary focus of the analyses, all plant macroremains (excl. charcoal) were extracted in order to examine the full composition of each sample; this included cereal grains and chaff, legume seeds and pods, wild seeds and chaff, nutshell/fruit stone, culm nodes (reed and cereal) and tuber/parenchymous tissue. With the focus being upon storage deposits, related miscellaneous material such as rodent droppings and bones were also extracted (though only the former was quantified).

Sorting of the archaeobotanical material was conducted using a stereoscopic microscope at magnifications of x8–x40. In addition to the standard sieve size range separated during their initial processing on-site (4mm, 1mm and 0.3mm), samples were further sieved at 2mm and 0.5mm to ease the separation of weed material from grain-rich deposits. The majority of wild taxa was found between 1-2mm, with most grains and pulses filtered above 2mm. However, seed counts were recorded in relation to the initial categories to remain consistent with previously analysed samples. Following the sorting process, the extracted macroremains were separated into their respective plant categories (i.e. cereal grain, cereal chaff, wild seed, etc.) to prepare for the identification stage.

5.4.2 Subsampling

While recovering all potential weed material was crucial to this project, meticulous scanning, identification and recording of the entire sample was largely unattainable, particularly for the larger volume deposits; some of the densest samples were estimated to contain over 120,000 cereal grains. A compromise was achieved by fully scanning fractions until a minimum of 400-500 crop items were reached, with subsequent fractions analysed for 'weed only'. This process followed methods used by other researchers at Çatalhöyük (above, 5.2.3) in order to accurately estimate the full composition (cf. Van Der Veen & Fieller 1982), yet still enabling the full range of weed flora to be extracted for

identification. This form of subsampling was usually applied to the 1mm sieved material, which tended to contain the greatest number of identifiable crop remains. Charred seeds and fruit/nutshell were quickly extractable from the 4mm sieved material by the naked eye, so this part of the sample was usually scanned in its entirety. This was similarly the case for the separately processed heavy fractions, which usually produced only limited numbers of macroremains.

The 0.3-1mm portion of the sample was almost always subsampled to one eighth of the total fraction sorted for the 1mm sieve size; this fine part of the flot was extremely time consuming to examine thoroughly. The large volumes attributed to the selected crop stores produced extensive quantities for the 0.3-1mm sieved material, which largely consisted of thousands of fragmented cereal grains, with occasional chaff and wild seeds. The principle of only subsampling as much as one eighth of the scanned 1mm portion was an arbitrary rule (also employed by the previous researchers (Filipović 2012: 76; Bogaard *et al.* 2013a: 94), applied to limit the potential overestimation of one-off finds once the data was multiplied. Multiplications larger than eight however were sometimes used for grains/pulses identified within the 1mm material, so as to correlate with the further fractions scanned for weed only; the multiplication of large numbers of seeds (i.e. the 400-500 threshold) by a large factor was deemed much less problematic than the multiplication of minor counts by a large factor.

In this study, these scanning principles were applied to both the previously examined samples, as well as the new unanalysed ones. Having already met their threshold of a minimum of 400-500 crop items, the previously analysed samples were primarily scanned further for 'weed only' so as to achieve their full weed potential. Other infrequently recovered plant remains not represented by the existing scanned sample data were also extracted during this process so as to further improve the accuracy of the sample composition.

5.4.3 Identification

The extracted macroremains were individually examined under the microscope to identify their botanical family, genus, and where possible, species and subspecies/variety. Initial identifications were conducted by directly comparing with previously identified type specimens from the site, published seed atlases, as well as modern specimens from the seed reference collection, housed in the Baden-Powell laboratory in the Institute of Archaeology, University of Oxford. A comprehensive macrobotanical type collection, specific to Çatalhöyük, was created as part of Filipović's doctoral thesis, and was available for reference at the University of Oxford (Filipović 2012: 78). The collection contained a wide range of the most common plant types recovered from the site, including cereals, pulses and wild seeds, which were identified to different levels; this provided an invaluable starting point for the identification of the newly sorted material.

The following reference texts were also consulted in order to compare key morphological characteristics between particular genera and species: 'Identification of Cereal Remains from Archaeological Sites' (Jacomet 2006), 'Identification Guide for Near Eastern Grass Seeds' (Nesbitt 2006), 'Atlas of seeds and small fruits of Northwest-European plant species with morphological descriptions' (Berggren 1969; 1981) and 'Digitale Zadenatlas Van Nederland/ Digital Seed Atlas of the Netherlands' (Cappers *et al.* 2012). Archaeological material was compared directly with modern reference specimens in order to confirm or exclude potential identifications. Where necessary, modern reference material was experimentally charred—following methods by Charles *et al.* (2015)— to replicate the preservation conditions (along with their potential distortions) attributed to the archaeobotanical specimens; this process was mainly undertaken for the refined identification of weed taxa (below, Chapter 8).

The criteria used to identify specimens were based upon key morphological characteristics, such as their relative shape (i.e. laterally compressed/ dorsally compressed etc.), size range and the position and proportion of major features (i.e.

embryo, hilum etc.), as well as their surface texture, and where visible, internal structure. The use of 'type' categories (e.g. Convolvulaceae type, *Convolvulus* type) were used in the first instance to direct subsequent identification to the genus/species level. Unknown specimens identified to family only were compared with a number of different genera in order to isolate likely candidates. Lists of geographically relevant species were then compiled for each genus using the *Flora of Turkey* (Davis 1965).

Final identifications were based upon the presence of clear distinctive characteristics (below, Chapter 8 & Identification catalogue), with the degree of uncertainty clearly reflected by the categories applied. Uncertain identifications were indicated by the use of 'cf.'; this represented instances where specimens were either poorly preserved or distorted, resulting in the lack of distinctive characteristics, or where specimens appear to display characteristics of more than one type/species. If the 'cf.' was positioned before a genus name (e.g. cf. *Convolvulus* sp.) identification to that genus was deemed probable but not certain. The use of 'cf.' after the genus but before the species name (e.g. *Convolvulus* cf. *arvensis*) demonstrates the certainty of identification to the genus level, but with less certainty for the species level. Specimens that were unable to be confidently identified further remained as 'types'; this term was also used to indicate possible species level identifications (e.g. *Convolvulus arvensis* type), but where the full list of relevant species could not be directly observed (due to unavailability of modern accessions), and therefore were unable to be excluded.

The domesticated species recovered from the site were typically able to be identified to species, or at least to genus level; missing characteristics linked to poor levels of preservation were the primary limiting factor upon their final level of identification. There were however some domesticates that were consistently under identified; free-threshing wheat grains were unable to be identified to their species due to a lack of clear identification criteria, though all well preserved free-threshing wheat rachis from the site were identified as bread wheat (*Triticum aestivum* L.) (Bogaard *et al.* 2013a: 97). Wild fruit and nutshell were often recovered as small fragments, so were also rarely identified

to the species level. While it is possible that the identification of these specimens may be taken further with refined identification techniques (e.g. analysis of cell pattern using SEM), these plant types were not the primary focus of this research, so were not featured in the subsequent refined identification attempts. The majority of wild/weed taxa were only identified to the genus level during the initial identification stage and required further steps in order to achieve species level identifications; this is largely a result of the extensive number of species that needed to be amassed and consulted. A ranked priority list of weed genera was produced using the genus level identification data, which was used to inform the key genera for further species refinement (below, 5.6).

5.4.4 Quantification

To achieve an accurate record for the composition of each sample, identifiable plant remains were quantified according to the 'minimum number of individuals' (MNI) principle. The archaeobotanical material was frequently fragmented, particularly in cereal grains, which form a substantial part of the selected assemblage, so establishing a standardised counting procedure was crucial. Additionally, the methods used needed to be correlated with the recorded data from the previously analysed samples in order for the results to be comparable. The following sections detail the specific counting methods followed during the analysis, as well as the procedures used for calculating and standardising fractions to determine the full sample data.

5.4.4.1 Counting

Counting procedures closely followed those used by the previous researchers at Çatalhöyük (post 2003) (see 5.2.3) in order to remain consistent. Seeds were counted separately according to the completeness of their seed parts to minimise over-estimation. For broken cereal grains, the embryo and apical ends were each counted separately, with

only the greater of the two scores included in the final total. Grains that were split lengthways along the furrow were also counted, with two grain halves equalling one grain. The separate fragment scores were then added together with the whole grain counts in order to achieve the final total. These same principles were also employed while counting wild grasses, although typically only applied to the larger types, such as *Bromus* and *Taeniatherum caput-medusae,* which were more frequently broken. Pulse seeds likewise were often split into their separate cotyledons and were counted in a similar manner, with their two separate halves counted as one seed. For smaller pulse fragments, only sections containing the attachment point (radicle) were counted. In the quantification of non-grass wild seeds, which tend to be less clearly separated by their embryo and apical ends, seeds were regarded as countable when more than 50% of the seed was represented. However, species that were more easily recognisable as being split into separate halves (e.g. *Vaccaria pyramidata*) were quantified in this way, such as in grains and pulses.

The counting of cereal chaff differed slightly according to their type. For the glume wheats, the individual glume bases were counted as single units, with complete spikelet forks representing two counts; glume bases were only deemed countable when the basal attachment point was still present. Free-threshing wheat and barley chaff, on the other hand, were counted by their individual rachis segments, but only when the upper 'nodal' part was still intact. Wild chaff was very rare in the assemblage, but was also counted by its rachis segment as in barley and free-threshing wheat. Other chaff type material recovered from the samples included cereal and reed culm, pulse pod fragments and legume stalks. The counting of culm material was separated by their diagnostic and undiagnostic parts; culm nodes and bases were each individually counted, whereas for undiagnostic culm material, each fragment was counted with the final total divided by 20 so as to estimate the minimum number of whole units. Legume/ fruit stalks were counted as single units, though only when they appeared to be intact (with calyx preserved).

The division of fragment counts by 20 was used to quantify a number of other small fragment categories in the assemblage, which include pieces of pulse pod, undiagnostic

nutshell, and fruit skin fragments. This method presented some slight disparity with the quantification procedures used by some of the previous researchers. Filipović used separate division figures according to the type of nutshell identified; fragments were divided by 20 for almond and 15 for pistachio fragments in order to represent the single unit equivalent (Filipović 2012: 81). However, as only diagnostic fragments of *Pistachia* were recovered within the five samples selected from Filipović's study, the counts were not altered. The fragments from Ergun's study, on the other hand, had not been previously converted into single unit equivalents, so these counts were divided by 20 to relate to the figures in this study. A number of categories were not able to be converted into whole unit equivalents, so were quantified by volume (ml); such measurements were undertaken solely for the >2mm fraction and included dung, tuber/parenchymous tissue, burnt cereal mass, and charred fish bone mass.

5.4.5 Multiplication of sorted fractions

In order to calculate the final total of items for each taxon per sample, the scores from the sorted light fractions (4mm, 1mm, 0.3mm) were collated along with the counts from the heavy residue fractions. Most of the samples were subsampled to different quantities depending on the target plant type (i.e. cereal grain, weeds); these variable proportions also often differed for each separate sieved fraction size (e.g. 4mm: 1/1 scanned for all taxa, 1mm: ¼ scanned for all taxa, 1/1 scanned for 'weed only', 0.3mm: 1/8 scanned for all taxa). Before the total counts for each sieve size could be added together, the variable scanned fractions first needed to be equated. To retain maximum weed data, all subsampled parts of the fraction (typically grain/pulses) were multiplied up in order to match the full extent scanned for 'weed only', rather than dividing down the weed portion to equal the extent subsampled. For example, if half of the 1mm fraction was scanned fully for weed material, yet only one eighth of the same fraction was scanned to extract grains, the grain portion of the sample was multiplied by four in order to appropriately relate to the total counts recorded for weeds. As discussed above (5.4.2), the multiplication of large

grain counts (i.e. 400-500) by more than a factor of eight was deemed to be less problematic than for small rare taxa counts (cf. Van Der Veen & Fieller 1982), so were occasionally multiplied at greater factors of 16 or 32. Once all of the sieved fractions were correctly matched, the counts were added together to calculate the final totals for each taxon.

5.5 Amalgamation for statistical analysis

5.5.1 Sample amalgamation

Before the samples were analysed, it was first important to consider the nature of the contexts represented by the samples, and whether any of the deposition events had possibly been duplicated due to multiple sampling procedures; it is necessary to isolate single 'behavioural episodes' before being statistical analysed, otherwise false patterns may emerge from the duplicated datasets, which may give unwarranted significance to units that were repeatedly sampled (Jones 1991: 67). For the Çatalhöyük material, 13 of the selected samples shared units with another sample, with four being the largest number of samples attributed to a single unit (u.11911). Each of these samples was individually assessed for their potential to be amalgamated. This process involved careful consideration of each sample's density of archaeobotanical items and composition, as well as any corresponding excavation notes recorded within the site database, which detailed the nature of excavation, as well as justifications for multiple sampling. From this assessment, all of the selected samples were identified to represent single behavioural episodes, or were identifiable as distinct clusters formed within the unit; this meant that no samples were amalgamated in the preparation of the final dataset. One of the main reasons for keeping samples separate was linked to the differing density of items, which separated the main clusters from more residual deposits. Nevertheless, it must be noted that a small number of samples from the previously conducted analyses had already been

amalgamated in order to represent single events; this included Fl.171/329 from Building 1, and samples Fl.6594/6641 and Fl.8048/8049/8205 from Building 63. These samples were amalgamated due to their similarity in composition, density and stratigraphic deposition (Filipović 2012: 87; Bogaard *et al.* 2013a: 94).

Corresponding excavation records were not available to relate to the archaeobotanical samples at the three Syrian sites, so it was difficult to assess the potential for sample amalgamation. Nevertheless, the sample database indicated that most of the selected samples were spatially distinct from one another (i.e. area/locus), therefore likely representing separate behavioural events. Furthermore, with many of the selected samples deriving from secondary contexts, they were not treated with the same level of contextual detail as the Çatalhöyük stores in the final analyses.

5.5.2 Amalgamation of taxa

Another consideration to be made before the samples were analysed was the simplification of the numerous taxon categories identified at each of the four sites. A large proportion of the identification categories represent duplicated 'cf.' and type categories (e.g. *Polygonum aviculare* and *Polygonum* cf. *aviculare*), where poor preservation likely affected the level of certainty attributed to identification. Further duplications included instances where greater detail could be documented, such as specific varieties or preservation states (i.e. twisted barley grains, terminal spikelet, 'new type' grain in spikelet etc.). These specific identifications were amalgamated into broader groups where possible, to limit any skewing effect of rare categories upon the final analyses, though species level distinctions were retained, particularly for the wild/weed taxa (Bogaard 2004; Filipović 2014).

5.6 Selection of weed genera for further refinement

The refinement of weed identifications to the species level formed a central emphasis within this project, though such efforts were strategically directed towards specific target genera because of the time-consuming processes involved (below, 6.3). Unlike in Bogaard's (2004) functional ecological analysis of early farming in central Europe (above, 1.2.3), very few taxa in this study were able to be straightforwardly identified beyond the genus level; those successfully identified to species tended to belong to monotypic genera, such as *Vaccaria pyramidata* and *Taeniatherum caput-medusae*, or those that had received considerable attention owing to specific research questions posed by previous researchers, for example *Bolboschoenus glaucus* (cf. Wollstonecroft *et al.* 2011; Charles 2011). A total of 85 wild genera were identified from the final selected assemblage at the four selected sites, which were ranked according to a combination of factors, including the probability of their status as weeds (Appendix 1c), their ubiquity among the selected samples, as well as the number of geographically relevant species attributed to each genus (i.e. the ease of identification).

Isolating the relevant weed flora has been one of the major challenges of this project, with some of the identified wild genera more likely to derive from other sources, such as dung or from their intentional collection, rather than as crop weeds. It was critical to recognise such distinctions early on in the project so as to correctly prioritise appropriate weed genera for the development of refined identifications; these initial assumptions were later tested at a sample-by-sample basis with correspondence analysis and discriminant analysis (below, 5.8, 9.3 & 9.4). The first step towards establishing a priority list was to systematically consider each of the unidentified genera and to exclude any taxa of ambiguous origin from further consideration; a number of previous studies were used to inform this process.

At Çatalhöyük, a considerable amount of research has been previously dedicated to the identification of dung-derived taxa (Filipović 2012; 2014; Bogaard *et al.* 2013a: 104-8),

which greatly assisted in the recognition of likely contaminants among the full genera list. Such distinctions were primarily based upon correspondence analyses of 'dirty' fire spot deposits (samples containing charred dung pellets), as well as criteria outlined by Wallace & Charles (2013) regarding the specific seed characteristics able to survive digestion in an identifiable form (i.e. small seed size, hard protective seed coat). Several genera were consistently associated with preserved dung material, with some seeds physically embedded within the charred pellets (Appendix 1c) (Filipović 2012: Table 7.1; Bogaard *et al.* 2013a: 104). Furthermore, the physical seed characteristics of these genera were consistent with those linked to high survival rates, which were observed during experimental work with sheep feeding; seeds were either small (<2mm) or had highly resistant seed coats (Filipović 2012; Wallace & Charles 2013).

The exceptional preservation of primary *in situ* wild seed stores at Çatalhöyük present unequivocal evidence for the intentional collection of selected wild/weedy genera (Appendix 1c) (cf. Fairbairn *et al.* 2007). While these genera also frequently occur as arable weeds in present-day central Anatolia, it is clear that these were deliberately gathered at the site for food or other purposes (Fairbairn *et al.* 2007). The stores include a number of genera that occurred within the selected storage samples, including *Helianthemum* sp. and *Lathyrus/Vicia* sp. To prevent wasted efforts regarding the development of refined identifications, these potentially collected species were also excluded from the emerging priority list. The collected or weed status of each taxa were later individually confirmed on a sample-by-sample basis during the final analyses (below, Chapter 9).

Such extensive investigations of dung-derived and collected wild taxa had not been undertaken at the three Syrian sites, owing to limited evidence for the burning of animal dung as fuel and *in situ* storage contexts (C. Douché, pers. comm.). Therefore, the process for isolating the relevant weed taxa at these sites presented a greater challenge. Previous work by Willcox (2012) sought to isolate possible arable weed genera at the pre-domestication cultivation sites, Jerf el-Ahmar and Dja'de (as well as a number of other pre-

domestication sites in the region), by systematically excluding taxa with known uses or alternative growth habits (i.e. ruderal taxa). Edible taxa that may have been intentionally collected were discounted, including small seeded grasses, pulses and other edibles, such as *Chenopodium* and wild mustard (Willcox 2012). The final list included 19 genera with 'no known use for their seeds', which were further correlated with known weed flora from later Bronze Age sites in the region (above, 1.3) (Willcox 2012: 164). This approach is, however, far too constraining (cf. above, Chapter 2), excluding a number of the most common potential weed genera from the selected sites, such as *Bromus*, *Eremopyrum* and *Polygonum*, which are prominent weed taxa in sites of later periods (Charles & Bogaard 2001; van Zeist 2001; Cappers & Neef 2012). Instead of using this restricted and subjective approach, sources of wild taxa were alternatively explored during the later analysis stage in relation to their individual sample compositions (below, Chapter 9). However, to establish a list of priority genera early in the project, a series of factors based on sample ubiquities and identification potential were used, whilst also comparing the weed status of each genus with later sites.

To achieve a final comprehensive priority list, which took into account all four of the selected sites, the separate potential weed genera lists were combined and ranked according to their ubiquity across all sites, as well as their number of associated species. Genera that were applicable to all four sites were ranked highest, with a separate score attributed to the estimated number of samples in which a genus occurred; these ubiquity estimates were calculated by considering all available sample data from the four sites, with the greatest number of samples assigned the highest ranking. This was to ensure that refined identification efforts were most efficiently directed by maximising the number of samples that could be analysed for their functional attributes. The final criterion considered during the scoring process was the number of species associated with each genus. This information was compiled from the two relevant Floras, the *Flora of Turkey* (Davis 1965) and the *Flora of Iraq* (Guest & Townsend 1966)[1]. Species with few associated

[1] There is currently no comprehensive Flora that covers the region of Syria, so the Flora of Iraq was used as the most relevant alternative. See Chapter 8.3.1 for further justification details.

species were ranked highest, as this limited the number of species and accessions needed to be consulted to achieve positive identifications.

Following this process, the top ten scoring genera formed the main basis for further identification attempts and the development of identification keys (Table 5.1). The list informed a number of subsequent steps needed to achieve refined identifications; the selective documentation of archaeobotanical material from the three Syrian sites (below, 5.7.2.1), the compilation of relevant images from seed atlases, the sourcing of modern seed reference material, as well as providing the target species for collection of functional attributes during further FIBS field studies (below, Chapter 6). Following the finalised selection of samples for analysis within this study (see 5.3 above), the priority genera list was refined further so as to reflect the most ubiquitous genera present within the target samples.

Table 5.1 – Initial priority list, which was used to inform refined identification attempts at the beginning of the project. The list is based on the collective number of samples (between the four sites) that a genus occured, as well as the number of associated species in the *Flora of Turkey* (FOT) and *Flora of Iraq* (FOI).

No.	Genus	No. of samples	No. of species (FOT)	No. of species (FOI)	Jerf el-Ahmar	Dja'de	Tell Aswad	Çatalhöyük
1	*Polygonum*	312	27	8	x	x		x
2	*Bromus*	155	36	22	x	x	x	x
3	*Convolvulus*	122	32	-	-	-	-	x
4	*Galium*	120	99	23	x	x	x	x
5	*Chenopodium*	82	10	-	x	-	x	x
6	*Thymelaea*	63	7	2	x	x	x	x
7	*Atriplex*	58	13	10	x	x	x	x
8	*Hordeum*	57	8	8	x	x	x	x
9	*Eremopyron*	56	6	4	x	x	x	x
10	*Adonis*	55	9	6	x	x	x	x

5.7 Documentation and measurement of weed taxa

Modern and archaeological weed taxa were photographed using microscope imaging software to record accurate reference images, from which precise morphometric measurements could be taken. This was particularly crucial for documenting the archaeological weed material from the three Syrian sites, which could only be consulted for short periods during two research trips. The photographs further created a permanent record of the material for making detailed comparisons between specimens on a larger scale (i.e. for the development of identification keys).

5.7.1 Primary microscope camera: equipment, software and procedures

The majority of specimens were photographed using a 1.4 Megapixel 'Lumenera Infinity 3' microscopy camera, at the Institute of Archaeology, University of Oxford. The camera was attached to a Leica MZ7.5 stereoscopic microscope with a magnification range of x6.3–x40. High quality photographs were taken and processed using the image acquisition software 'Image Pro Insight' by Media Cybernetics (Figure 5.1); this software possesses features such as 'Extended Depth of Focus (EDF)', used to create a composite focused image from a series of photographs captured at different z planes, as well as fine calibration for taking accurate measurements.

Each of the archaeological and modern specimens was photographed at a range of different views (i.e. front/dorsal, side/lateral, back/ventral, cross-section) in order to comprehensively capture the three-dimensional shape of the seed, as well as any diagnostic features. For each view, multiple photographs were manually taken (approx. 10-20) along the extent of the z plane, which were then processed into a composite best-focus image using EDF. The finished photographs were then calibrated to display the correct scale and a series of measurements were taken.

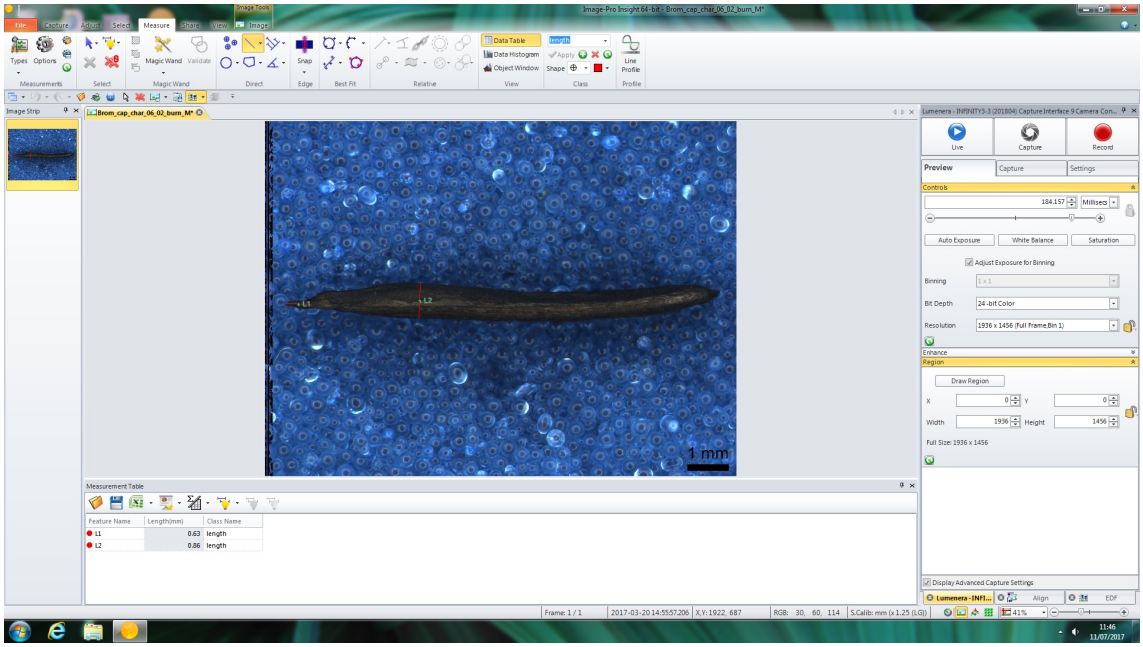


Figure 5.1 – Screenshot of the image acquisition software 'Image Pro Insight' by Media Cybernetics, which enabled high quality photographs to be taken of modern and archaeological material, which were able to be precisely measured.

5.7.2 Research Trips: equipment, software and procedures

5.7.2.1 Muséum national d'Histoire naturelle, Paris: December 2013, November 2015

Two separate research trips, consisting of two weeks each, were undertaken at the Muséum national d'Histoire naturelle, Paris, to examine and document the archaeobotanical weed material from the three Syrian sites, Jerf el-Ahmar, Dja'de and Tell Aswad. A comparable microscopy camera and computer software program was available within the archaeobotanical laboratory, which enabled high quality images to be captured and measured in a similar process to the Oxford setup. Photos were captured with the microscope imaging software 'NIS-Elements Documentation' for windows, using a microscopy camera at magnifications of x8–x80. As in the Oxford system, 'NIS-Elements Documentation' also had an EDF function, which enabled the production of composite

best-focus images. The final photographs were calibrated in order to add corresponding scale bars. There was insufficient time to undertake detailed measurements during the trips, so each of the photographs were later individually recalibrated with 'Image Pro Insight' in Oxford, using the embedded scale bar to be measured.

During these research trips, the priority genera were retrieved from the shortlisted samples (see 5.3.2 above) and assessed for their potential for refined identification, with only the best-preserved specimens fully photographed with multiple views. The initial approach was to photograph a minimum of 9 specimens for each target genus per site, representing 3 different specimens each taken from 3 separate samples; this was intended to sufficiently document the main 'types' for each genus present at the sites. Nevertheless, in practice this approach was too simplistic, owing to the wide range of 'types' observed for certain genera, the variable levels of preservation for different samples, as well as the limited prior separation of 'types' (i.e. wide type, narrow type) within the analysed material. Instead, effort was directed towards identifying and photographing as many complete specimens as possible for each genus. Notes were made for fragmented specimens that related to other photographed types, which were quickly recorded in larger group images. Some of the original shortlisted samples contained only unidentifiable material, so were excluded from further study.

5.7.2.2 Çatalhöyük Excavation Season, Turkey: June/July 2015

A number of the selected samples from Çatalhöyük could not be exported back to the UK in their entirety. Nevertheless, some samples required further scanning to achieve sufficient weed data for analysis. The outstanding fractions were sorted for weed only during a two-week research trip to the 2015 excavation season at Çatalhöyük. The identified archaeobotanical weed material was quantified and photographed in detail to enable the material to be identified further, as well as directly compared with the previously exported material. The principle camera, microscope and software setup, as detailed above, were transported to Turkey for consistent image capture. The same

procedures were undertaken as previously described (above, 5.7.1), with the best-preserved specimens for each 'type' documented in multiple views. Group images were also taken to document the further weed material from the same genus types already photographed in detail.

5.8 Analytical methods

Several analytical techniques were employed in this study to isolate the relevant arable weed data from archaeological assemblage, and to compare them with known husbandry regimes. The samples from the three Syrian sites required different treatment to those from Çatalhöyük, where context and depositional status are very clear. These samples were investigated for their crop-processing stages to provide greater context for the final ecological analyses.

5.8.1 Correspondence analysis

Correspondence analysis is a multivariate statistical technique that has been frequently used in the field of archaeobotany (as well as ecology) as a way of examining and identifying associations of different taxa deriving from different activities (e.g. dung-derived, crop-processing, collected taxa) (Jones 1991; Jones *et al.* 2000; Bogaard 2004; Filipović 2014). The technique arranges units of analysis, in this case archaeobotanical samples, along four axes according to similarities and distinctions in taxon composition among samples. For the Çatalhöyük storage material with their well-defined contexts, the method was applied to explore variation in wild taxa composition among the selected samples, as well as to isolate and exclude outlier taxa derived from non-arable sources. The outcome of this analysis was to assess potential trends in weed ecology that reflect variation in growing conditions and farming practices. While similar analyses were attempted for the three earlier Syrian sites, their limited contextual associations meant

that it could not be assumed that wild taxa were of arable origin, hence trends are not necessarily reflective of growing conditions. For these three sites the isolation of weed data was instead carried out using discriminant analysis (below, 5.8.2.1).

The software package used to perform the correspondence analyses was Canoco for Windows 4.5, and the corresponding plots were created using CanoDraw for Windows (ter Braak & Smilauer 2002). Two-dimensional scatter plots were created, which presented the two axes that best accounted for the variation between species and samples. In these plots, axis 1 refers to the horizontal axis and axis 2 the vertical axis. To illustrate the results, a separate plot is created for both the distribution of samples and the distribution of the corresponding taxon data. These two plot types needed to be analysed in conjunction to interpret trends effectively. The relative distance among the plotted data points (samples or taxa) reflect their similarity, with closer spacing indicating greater similarity. The arrangement of points along the different axes thus reflects their relationships across the samples (or taxa) as a whole. Data points located near the origin tend to reflect greater commonalities across the assemblage, whereas data points arranged at some distance from the origin reflect more unique samples or taxa. Therefore, correspondence analyses tend to emphasise rare taxa and/or samples with unusual composition. It was for this reason that any taxa occurring in one sample only were removed at the outset. While some samples also skewed the distribution of the analysis, an effort was made to retain as many samples as possible, and exclusions were primarily made from the species data.

Mineralised and silicified remains were excluded from all weed analyses as they are not exposed to the same selective biases imposed upon charred material (cf. Messager *et al.* 2010) and are therefore likely to be overrepresented within the assemblage. It is also difficult to determine whether naturally siliceous/calcareous seeds (e.g. Boraginaceae) represent ancient remains (cf. Willcox *et al.* 2008: 315) as they may be introduced to the archaeobotanical record post-depositionally (e.g. rodent activity, bioturbation) and therefore can only be distinguished by direct dating (Pustovoytov *et al.* 2004).

Genus level categories were amalgamated with corresponding identified species when only one type was identified, whereas genera exhibiting multiple species (e.g. *Polygonum convolvulus/ Polygonum aviculare*) were merged down to the genus level. This was to avoid the analysis being driven by distinctions in identification level rather than genuine patterns in composition; i.e. multiple splintered groups of species level identifications directly compared with singular genus level groups. The full list of species codes used in this analysis are available for consultation (Appendix 1d).

5.8.2 Crop-processing analysis

Two different approaches, outlined below, were used to infer the crop-processing stages of the selected samples. In addition to the crop-processing stage, crop process analysis was a means of examining the consistency of the wild seed sources so that relevant weed data were further refined for the ecological analysis. The analyses were also applied to the Çatalhöyük storage material to investigate the variation in crop and weed ratios across different categories of storage.

5.8.2.1 Identifying non-weed contaminants using discriminant analysis

Discriminant analysis is a statistical method used in this study to make direct comparisons between the archaeobotanical weed data and modern botanical data from known groups (i.e. crop-processing stages, or agricultural regimes). The analysis extracts the most successful combination of variables (the discriminant function) to discriminate between pre-defined groups. This equation can then be used to classify samples of unknown group, in this instance the archaeobotanical samples. One of the ways that this weed-based analysis was employed was to distinguish different crop-processing stages, which could be inferred independently of a sample's contextual associations. The approach developed by Jones (1984; 1987) compares archaeobotanical data directly with ethnobotanical samples

collected from the Greek island of Amorgos. Jones' (1984) ethnographic study extensively sampled the products and variable by-products generated by various processing stages for free-threshing cereals and pulses, which could be discriminated solely on the basis of their weed seeds. For the analysis to be compatible across different regions with different weed species, the physical characteristics of the weed seeds/dispersules were used as the basis of the discrimination. The seeds of the weed taxa were classified according to three main physical traits most relevant to crop-processing, which relate to their aerodynamic properties (heavy/light), size (big/small) and tendency to remain in heads after threshing (headed/free). Four known categories of product and by-product were used within the final analysis to compare with the archaeological data: fine sieve product, fine sieve by-product, coarse sieve by-product and winnowing by-product.

While providing useful compositional information for the non-primary samples analysed from the three Syrian sites, a further objective of the approach in this study was the identification and exclusion of outlier taxa within the wild assemblage that were not plausible arable weeds associated with crops. This was a critical step to ensure that only relevant arable weeds were included in the final ecological analyses. This investigation followed procedures used in Charles' (1998) study of dung-derived plant material, which examined the behaviour of non-weed taxa in relation to the four known crop-processing groups characterised in these analyses. In this adjusted analysis, two versions of the discriminant analysis were compared: with the archaeological samples entered as unclassified samples to be placed in the four ethnographic processing groups (i.e. Jones' original method), and, secondly, with the archaeological samples entered as a separate fifth group. This approach was taken so that samples containing non-arable taxa (with physical seed characteristics incompatible with any known processing stage) could be distinctly classified rather than being assigned to the closest of the four known groups (Figure 5.2). The methods used in this analysis closely followed protocols set out by Jones (1984; 1987) and Charles (1998).

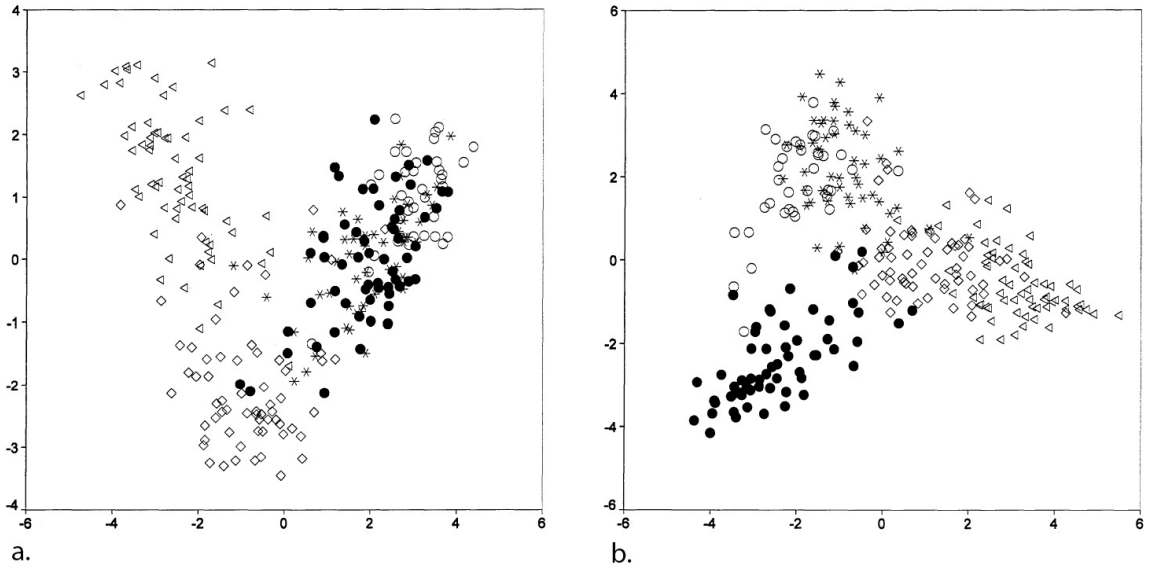


Figure 5.2 – Comparison of archaeological samples from Abu Salabikh (black points) with ethnographic samples from known crop processing stages at Amorgos. The two discriminant analyses show different results when entered as (a.) 'ungrouped' and (b.) 'grouped', indicating significant amounts of taxa from non-arable sources (i.e. dung) (Charles 1998).

Using existing studies as a guide (Jones 1987; Charles & Bogaard 2001; Charles & Bogaard 2007; Bogaard 2011; Bogaard *et al.* 2013a), each of the wild taxa was classified according to their physical characteristics, as outlined by Jones (1987) (Appendix 1e). Indeterminate classes or family level identifications that possessed highly variable seed types were excluded from the analysis. While all of the selected samples contained sufficient crop (min. 100 items) and wild/weed (min. 10 items) material owing to the selection criteria, the removal of non-weed contaminants within subsequent versions of the analyses left a small number of samples below the minimum wild/weed threshold. At this stage, these samples were removed from the analysis as they rely too heavily on the few weeds that are present (Jones 1987: 313). To increase the weed totals for the clean Çatalhöyük crop stores, which were often 'clean' and contained minimal weed material, the weed counts for subsamples were multiplied to reflect totals for the whole sample. To infer the potential status of the wild/weed taxa within the analyses, associations were collated for each taxon from Floras and previous studies to indicate their plausibility as a weed (above, 5.6; Appendix 1c). The statistical software package used to perform the analyses was IBM SPSS Statistics 24 (IBM Corp 2016).

5.8.2.2 Triangular scatter plots ('triplots'): crop and weed proportions

The discriminant analysis was complemented by a second approach to the identification of crop-processing stages, which examined the ratio of crop components (grain and rachis) to weed seeds using triangular (ternary) scatter plots, or 'triplots' (Figure 5.3). Jones (1990) developed this approach using her ethnobotanical study of free-threshing cereals from Amorgos, Greece, to aid the identification of relevant crop-processing stages. However, this method is only appropriate for assessing samples that contained one main crop type (e.g. over 70% dominance), as it assumes that the weed component derives from the crop type plotted; glume wheats (hulled) and free-threshing wheats required different processing techniques, and it is impossible to assign weed material to multiple crops in mixed crop samples (Jones 1990). Furthermore, the approach could only be applied to samples containing cereals as there is no routinely preserved chaff material to relate to pulses.

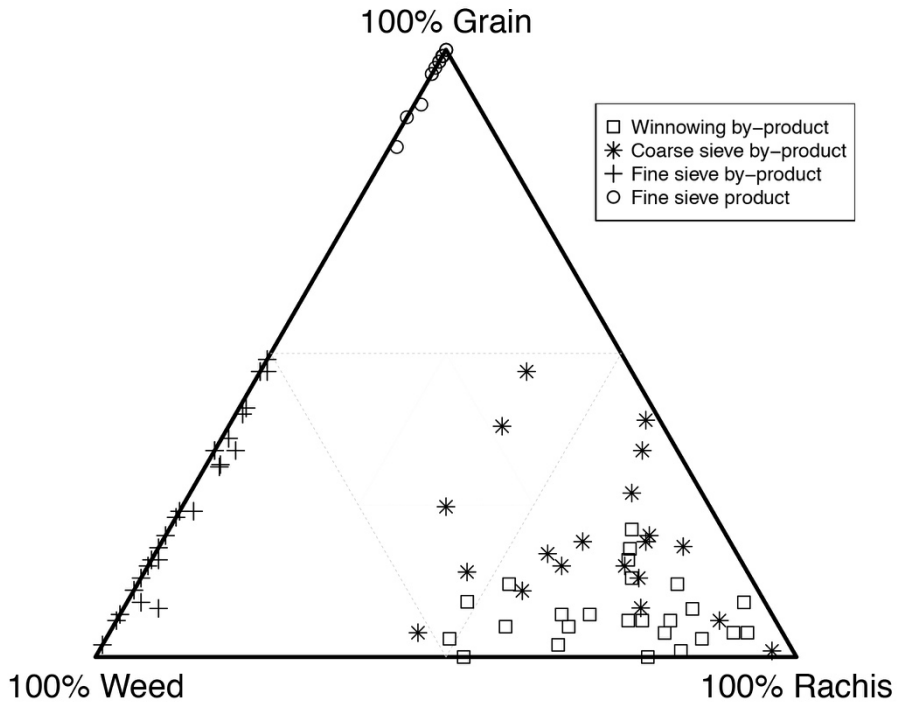


Figure 5.3 – Triangular scatter plot indicating the different proportions of grain, weed and rachis material in different free-threshing cereal products and by-products. This study of different crop-processing stages is based on modern ethnobotanical data from Amorgos, Greece (Jones 1990).

Following methods by Jones (1990) and Bogaard (2002a), each of the samples was examined to identify its main crop component, using an (arbitrary) cut-off point of 70%; with this threshold, over half (55%) of the selected samples were included in the analysis, with only minor levels of contamination. Samples that fell below this threshold were classed as 'mixed' and were excluded from the triplot analysis, along with samples dominated by pulses. Percentages were calculated for each of the three categories—'weed', 'rachis' and 'grain'—which reflected the relevant components of the dominant crop type in each sample. Since Jones' ethnobotanical data were based on six-rowed barley and durum/bread wheat, the two-rowed barley grains that dominated the archaeological samples were multiplied by three to ensure that the ratios of grain to rachis were comparable (cf. Charles & Bogaard 2001). The free-threshing wheat/rye category from Jerf el-Ahmar (likely rye based on the rachis material; cf. Willcox & Stordeur 2012) was treated comparably to barley, with grain totals also multiplied by three.

There were no ethnographic data to compare directly with samples dominated by glume wheats; these require a separate stage of spikelet dehusking, so it is unclear at which stage of the processing sequence (e.g. before or after spikelet dehusking) weeds are separated from the crop material (Bogaard 2011: 152). Therefore, grain and chaff ratios were primarily considered when interpreting crop-processing stages for the glume wheat samples. Following Bogaard (2011), the expected grain:glume base ratio was estimated for spikelet based samples. At Tell Aswad, the dominant glume wheat type was emmer, though einkorn represented around 10% of the identified wheat. Emmer has a grain:glume base ratio of 1.0 for whole two-seeded spikelets, whereas einkorn varies according to whether it is one- or two-seeded, with ratios of 0.5 and 1.0, respectively. With the einkorn indeterminate at Tell Aswad, the lower grain:glume base threshold was set at 0.75 to accommodate 10% one-seeded einkorn as well as providing a small buffer zone. To account for the charring bias against chaff material (cf. Boardman & Jones 1990), the upper grain:glume base threshold was set with a larger buffer at 1.5. At Çatalhöyük, two-seeded glume wheats were similarly dominant within the selected samples, including emmer and 'new type' wheat, with only 1.3% positively identified to einkorn. When

identified to type, one-seeded einkorn was most dominant (73%), though a third of the einkorn material was indeterminate. Furthermore, some of the samples contained many indeterminate glume bases that were difficult to distinguish between emmer and einkorn, so this increased the potential einkorn proportion to around 30% within the selected stores. To account for this potentially higher contribution of one-seeded einkorn, the lower glume:base threshold for spikelets was reduced to 0.65.

For the three Syrian sites, a series of triplots were produced to reflect the different levels of wild taxa exclusions explored within the previous discriminant analyses (above, 5.8.2.1). Comparison between these two forms of crop-processing analysis assisted with the isolation of arable components for the final ecological analysis. However, in the Çatalhöyük case, this analysis was alternatively used to observe the extent of variation among storage type, so in this case the full wild/weed totals (containing non-weed contaminants), as well as 'mixed' samples, were also incorporated within this form of analysis.

5.8.3 Discrimination of modern husbandry regimes

The isolated weed data from the archaeobotanical samples were assessed in relation to known husbandry regimes using discriminant analysis. As noted above, this form of analysis extracts the most successful linear equation combining functional ecological variables (the discriminant function) to discriminate between pre-defined groups. This equation can then be used to classify samples of unknown group, in this instance the archaeobotanical samples. In this study, the method was specifically used to infer the relative levels of labour input (low or high intensity) – in the form of weeding, tillage, manuring and (where relevant) watering – involved in cultivation practices from the selected archaeological sites, with direct reference to modern field studies undertaken as part of the University of Oxford's 'The Agricultural Origins of Urban Civilization' (AGRICURB) project (Bogaard *et al.* 2016a; 2016b) (below, Chapter 6). The analysis can be

undertaken using either quantitative or semi-quantitative data; in this study the latter was employed, with the sample data included in a presence/absence format. While a degree of information is lost in this form, it is more directly comparable with the incomplete nature of archaeobotanical datasets (Charles *et al.* 2002).

For inclusion within the final analysis, a minimum threshold of ten arable weed seeds identified to species level, or to small species groups (maximum of five species), was employed per sample. However, to maximise the number of samples analysed, a limited number of samples that contained only eight or nine weed taxa were also included when two criteria were met: the sample contained at least two identified species, so as not to not rely too heavily on one taxon, *and* its discriminant score was consistent with another sample of similar type (i.e. same stratigraphic unit, crop type). In a small number of cases, there was no functional attribute available data for the archaeobotanically identified species (e.g. *Bromus danthoniae*). Where possible, attribute data were estimated for these taxa using averages from available species data derived from the same botanical section (i.e. section *Bromus*).

The statistical software package used to perform these analyses was IBM SPSS Statistics 22 (IBM Corp 2016). Using the field data obtained as part of the AGRICURB project (Bogaard *et al.* 2016a; 2016b), an average score was determined for each functional attribute in each sample using the following formula:

$$\sum_i^n a_i k_i \Big/ \sum_i^n k_i$$

For the semi-quantitative measure, k is always equal to 1, so the numerator is the sum of the attribute values for each weed species present in a field, and the denominator is the number of species in each field. These average attribute scores were then selected as the main variables to discriminate between the known modern farming regimes according to two extremes of intensity; 'high-input' farming methods and 'low-input' farming methods

(below, Chapter 6). The success of the analysis was determined by the percentage of fields correctly reclassified with the 'leave-one-out' method, where each sample was reclassified by the discriminant function derived from all modern cases of the groups, except the one being classified. The combined species attribute data for the archaeological samples was then incorporated within this established analysis in order to classify them along the same scale. The discriminant scores calculated for each sample were then plotted within scatter plots in order to examine their relationship.

Chapter 6

Modern weed ecological studies

This chapter summarises the key methods and results of the modern weed ecological studies drawn upon within this project. The specific model used in the statistical analysis of the archaeobotanical weed flora is also detailed. The final part of this chapter features the application of this approach to assess ecological variability within the targeted weed genera, which enabled strategic approaches to refined species identifications.

6.1 Previous studies: collection of modern weed ecological data

The '*Functional Interpretation of Botanical Surveys*' (FIBS) approach (Charles *et al.* 1997; 2003; Jones *et al.* 2000; 2010; Bogaard *et al.* 1999; 2001; Bogaard 2004) was drawn upon to interpret the archaeobotanical weed dataset in this study. FIBS relates the behaviour of individual plant species to specific ecological variables through the measurement of their functional attributes, including canopy dimensions, leaf area, root type and tap root thickness, stomatal size and density (Charles *et al.* 1997) (above, 1.2.3). To relate the functional attribute data to specific crop husbandry practices, modern floristic surveys of cultivated fields were undertaken in different geographical regions, which documented the weed flora from variable regime types (Charles *et al.* 1997; 2002; Bogaard *et al.* 2016a; 2016b). Statistical analysis of the combined weed functional attributes in these modern studies has been successfully used to distinguish between a number of contrasting

Table 6.1 – The functional attributes measured and their possible ecological significance within an arable context (Bogaard *et al.* 2016b).

Functional attribute measured	Ecological attribute for which measurement is a surrogate	Relationship to habitat conditions	References
(a) Attributes relating to the duration and quality of the growth period			
Maximum canopy height and diameter	Maximum plant size, the product of growth rate and period of growth	Positively correlated with potential productivity and negatively with disturbance of habitat	Grime (2001)
Leaf area per node/leaf thickness	Plant growth rate	Positively correlated with potential productivity of habitat	Jackson (1967); Dale (1982); Givnish (1987); Jones *et al.* (2000)
Mean specific leaf area (SLA: leaf area/dry leaf weight)	Plant growth rate	Positively correlated with potential productivity of habitat	Reich, Walters, and Ellsworth (1992); Reich (1993); Wright *et al.* (2004)
(b)Attribute relating to the capacity to regenerate under conditions of high disturbance			
Length of flowering period	Duration of life cycle and potential to regenerate from seed	Positively associated with disturbance	Grime, Hodgson, and Hunt (1988); Sans and Masalles (1995); Bogaard *et al.* (2001)
Vegetative spread	Ability of perennials to regenerate vegetatively from root fragments	Positively associated with disturbance	
(c) Attribute relating to drought avoidance			
Timing of flowering	Ability to complete life cycle before dry season	Late completion of flowering associated with moist conditions	Parker (1968)
(d) Attribute relating to drought tolerance			
Mean stomatal size	Capacity to restrict transpirational water loss	Positively correlated with moist, productive conditions and negatively with droughted conditions	Salisbury (1928); Carpenter and Smith (1975); Donselman and Flint (1982); Raven (2014)
Mean stomatal density	Capacity to restrict transpirational water loss	Negatively correlated with moist, productive conditions (given the negative relationship between size and density) and positively with droughted conditions	(as above)
Epidermal cell size	Capacity to minimise loss of turgor	Negatively correlated with droughted conditions	Cutler, Rains, and Loomis (1977)
Epidermal cell wall undulation	Provides structural support in conditions of high turgor	Positively correlated with moist conditions Grime (2001)	Linsbauer (1930); Watson (1942)

husbandry regimes, including intensive and extensive cultivation, autumn and spring sowing, irrigation and dry farming, and fallowing and rotation (Jones *et al.* 2010). In this study of early farming in western Asia, this FIBS approach was employed to assess and compare the intensity of cultivation (i.e. labour inputs per unit area) in the selected sites.

6.1.1 Measurement of functional attributes

The functional attribute dataset employed within this analysis, which forms the basis of the FIBS approach, was established by the Unit of Comparative Plant Ecology, University of Sheffield (Hodgson & Grime 1990; Hodgson 1991; Hodgson *et al.* 1999). Since its application within archaeobotany (Charles *et al.* 1997), the collection of functional attribute data has accompanied the modern survey of cultivated fields. With the method focused on determining species' potential under good conditions, rather than assessing individual plant performance under variable conditions, functional measurements required the collection of multiple mature, robust specimens grown in arable fields and their margins, as well as other ruderal habitats (Charles *et al.* 1997). Table 6.1 summarises the core functional attributes that have been measured to assess cultivation intensity with this approach, as well as their potential ecological significance. Some measurements, such



Figure 6.1 – Examples of the procedures used to measure functional attributes: calculating leaf area (left), measuring of canopy dimensions (right).

as canopy height and diameter, were taken directly in the field, while others, for example, mean stomatal density, were processed and measured in a laboratory (Figure 6.1); the specific protocols for the measurement of all attributes are detailed in Jones *et al.* (2000) and Bogaard *et al.* (2001).

6.1.2 Investigating cultivation intensity: previous modern weed studies

Several FIBS fieldwork projects have been conducted to provide useful comparisons of modern flora developed under known conditions, with each study documenting a new range of agricultural regimes, crop types and climatic conditions. One of the earliest studies to assess cultivation intensity was undertaken in Evvia, Greece, which surveyed the weed flora from 60 traditionally managed cultivation plots (i.e. without chemical herbicides) prior to harvest using linear transects (Jones *et al.* 1999; 2000). These included two main regime types at either end of the cultivation (labour-) intensity scale: plots ranged from small intensively managed pulse 'gardens', which tended to be regularly hoed, manured, watered and weeded, to larger extensively managed 'fields', cultivated with an ard-plough and less frequently manured, watered and weeded. These contrasting pulse management strategies could be distinguished based on their associated weed functional attributes relating to soil fertility and disturbance using discriminant analysis: canopy height and diameter, leaf area per node:leaf thickness, specific leaf area (SLA) (leaf area/leaf dry weight), and length of the flowering period (Table 6.1). This analysis calculates the best linear combination of variables (i.e. attribute scores) to discriminate between pre-defined groups (i.e. intensive vs extensive) (above, 5.10.3) (Figure 6.2).

Subsequent field studies were undertaken to test these functional attribute-based distinctions between high and low-intensity regimes in other crop types. Weed surveys conducted in Asturias, Spain, targeted 65 spelt wheat plots that included many unusually small garden-scale plots intended for domestic consumption; these plots were intensively

tilled, weeded and heavily manured, showing similarities with the pulse gardens surveyed in Evvia, Greece (Charles *et al.* 2002). These garden-scale spelt wheat plots were correctly classified as 'intensive' using the discriminant function extracted from the Evvia study (Charles *et al.* 2002) (Figure 6.2). A further study conducted in Haute Provence, France, by the University of Oxford's 'The Agricultural Origins of Urban Civilization' (AGRICURB) project, provided complementary extensive cultivation data for 60 fields that mostly represented larger-scale, low-intensity forms of cereal production (Bogaard *et al.* 2016a). This study combined weed functional data with stable isotope analysis (carbon and nitrogen), which is another independent method of identifying crop growing conditions (cf. Bogaard *et al.* 2007; Fraser *et al.* 2011; Wallace *et al.* 2013). These low-input organic cereal fields, as well as a small number of intensively worked pulse fields, offered further cultivation regime data for a climatic region without regular irrigation practices. Comparison of the weed functional attributes associated with levels of soil fertility and disturbance correctly assigned the Provence fields at the low-input end of the intensity scale (Figure 6.4).

Smaller field surveys have also been tested using this same model. In the Sighisoara region, Romania, 17 small-scale cereal fields were surveyed, which had been treated with variable levels of manuring and hand-weeding (Hajnalová & Dreslerová 2010; Bogaard *et al.* 2016a). When assessing the relevant functional attributes for cultivation intensity, the Sighisoara fields were correctly identified as having high-input farming methods, though at lower levels than observed in Asturias; this distinction corresponds with agronomic observations and demonstrates that a range of intensity levels may be captured using this method (Bogaard *et al.* 2016a). A further low-intensity cereal production system was tested from the Kastamonu province, northern Turkey, where einkorn and emmer were grown at moderately large scales (c. 0.2 to 4.5 ha) (Karagöz 1996; Bogaard *et al.* 2016a). The 13 surveyed fields had little to no manure applied and were not weeded. Analysis of the combined functional attribute data from these fields accurately reflected low-input signatures, with some fields with lower discriminant scores than the large-scale regimes in Haute Provence, suggesting poorer growing conditions (Bogaard *et al.* 2016a).

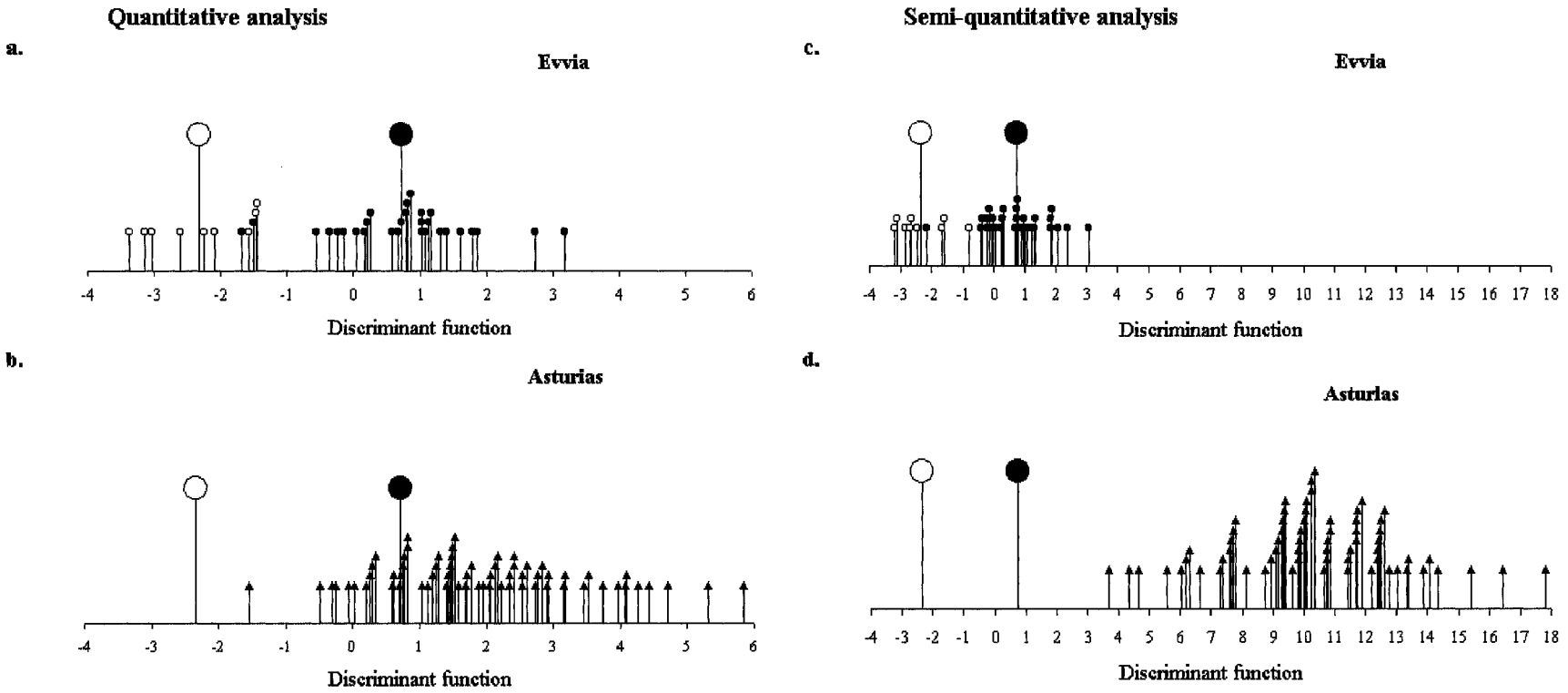


Figure 6.2 – Comparison of the pulse 'fields' (o) and pulse 'gardens' (•) from Evvia, Greece (a & c) with high intensity cereal plots (▲) from Asturias, Spain (b & d), showing both quantitative and semi-quantitative data. Larger circles indicate the positions of the group centroids for the Evvia groups (Charles *et al.* 2002: Fig. 2). While a degree of information is lost within the semi-quantitative analysis, presence/absence data are more comparable between modern survey and archaeobotanical datasets than fully quantitative data.

6.1.3 Reconstructing Agrosystems in (Semi-)arid Regions: Morocco field study

A recent field study in Morocco, also undertaken by the AGRICURB project, provided a range of climatic conditions (sub-humid/semi-arid in the north to semi-arid/arid in the south) comparable for western Asia, and offered a series of model agrosystems to compare to the archaeobotanical weed datasets in this study (Figure 6.3 & 6.4) (Bogaard *et al.* 2016b). During the spring of 2014, two trips were made to different areas of Morocco to survey a range of contrasting farming regimes, which included highly intensive oasis 'gardens', manured rain-fed terraces, and extensively managed fields. The study targeted two distinct geographical zones, located in the north and south of the country, which aimed to investigate the potential effects of climate on the previously established cultivation intensity model. A total of 60 cereal and pulse fields were surveyed for their associated weed flora, with the crop also sampled for stable isotope analysis. Varying degrees of inputs were observed across the two zones, ranging from fields with little to no manuring, weeding or irrigation, to intensive plots that were hand-dug, with intensive manuring, weeding, and irrigation practices.

Using the five main functional attributes linked to cultivation intensity, which were identified in the Evvia study (canopy height and diameter, leaf area per node:leaf thickness, SLA, length of the flowering period), in addition to stomatal characteristics, separate discriminant analyses were carried out for the north and south geographical zones to distinguish between low- and high-intensity regimes. The intensive oasis 'gardens' and extensive rain-fed terraced fields in southern Morocco were correctly discriminated from one another in 100% of cases, which was achieved for both fully quantitative and semi-quantitative (presence/absence) forms of data. Furthermore, these contrasting regimes continued to be successfully distinguished using a single functional attribute, SLA (indicating differences in growth rate), reflecting the extremity of the productivity contrast between these two agrosystems (Bogaard *et al.* 2016b). However, consideration of the discriminant scores for the northern zone revealed a clear climatic

bias. The less arid fields of the northern zone were noticeably more shifted towards the 'high-input' end of the discriminant function when compared with those surveyed from the south, regardless of regime type (Bogaard *et al.* 2016b).

The severity of the distinctions in functional attribute scores (particularly for SLA) in this Morocco study are problematic for classifying archaeobotanical samples, as subtler variations in cultivation intensity, intermediate between the two observed extremities, may be misclassified (Bogaard *et al.* 2016b). To provide a more nuanced model for the interpretation of archaeobotanical weed data from (semi-)arid regions, the field data from southern Morocco were combined with those from the previous field studies in southern Europe, including Evvia, Greece, Asturias, Spain and Haute Provence, southern France (Bogaard *et al.* 2016b). The discriminant function calculated for this refined model correctly reclassified 94% of fields (179 out of 190 fields) based on four functional attributes; SLA, canopy diameter, leaf area per node: thickness and canopy height (Bogaard *et al.* 2016b).

6.2 Selected model: combined FIBS analysis

The model used to classify archaeological samples in this study followed the combined analysis presented in Bogaard *et al.* (2016b), which was based on the presence/absence field data from four of the modern field studies, in Morocco, Greece, Spain and southern France (Figure 6.3) (Jones *et al.* 1999; 2000; Charles *et al.* 2002; Bogaard *et al.* 2016a; 2016b). The combination of these field studies gives greater resolution to the analysis by providing a more diverse spread of high- and low-input farming regimes to compare with archaeological evidence in (semi-)arid regions. Furthermore, this combination of studies balances climatic differences more successfully than the combined northern and southern Morocco study, with the discriminant function principally reflecting differences in crop husbandry; the low-input Evvian 'fields' from Greece tend to have higher discriminant function scores than the more extensively managed fields from Haute Provence, France,

despite a climatic bias in the opposite direction (i.e. higher rainfall levels in Haute Provence) (Bogaard *et al.* 2016b).

The specific protocols used in the discriminant analysis are summarised above (5.10.3). The individual field data for the modern studies can be seen in relation to the discriminant function in Figure 6.4*;* each data point refers to the combined attribute scores for a single surveyed field. The fields were classified according to two types of farming regime, high and low intensity (e.g. well-watered oasis gardens versus rain-fed terraces); this classification can be distinguished by white points corresponding to low intensity and black points corresponding to high intensity. The group centroids (weighted averages), which distinguish the separate distributions for the two regime types, are indicated by the two larger symbols.

Four attributes were needed to successfully discriminate between these two groups (94% correct reclassification, using cross-validation/leave-one-out method): specific leaf area (SLA), leaf area per node: leaf thickness, canopy height (log scale) and canopy diameter (log scale); the relative importance of these attributes in the analysis can be seen in Figure 6.3*b.* This reduced combination of functional attributes emphasises distinctions in fertility levels rather than soil disturbance, reflecting the dominant factors observed within the modern studies (Table 6.1). However, the greater contribution of growth rate (indicated by SLA) over canopy size in the discrimination of regimes reflect key functional adaptations, which enable weeds under high-intensity regimes to respond to high fertility levels under potentially high disturbance conditions (Bogaard *et al.* 2016b).

This combined intensity model may be used to classify archaeobotanical samples of various crop-processing stages. In a previous study, the potential biases of crop-processing were investigated in relation to two of the FIBS models (intensive and extensive cultivation, autumn and spring sowing), through the analysis of the arable weeds from different crop-processing (by-) products (Bogaard *et al.* 2005). While the study revealed likely biases against spring sowing indicators in fine sieve products, it was

determined that crop-processing does not introduce obvious biases for indicators of cultivation intensity (Bogaard *et al.* 2005). Nevertheless, while the specific processing stage has limited importance, archaeobotanical samples that derive from a single crop type and crop-processing stage provide especially reliable indicators for crop growing conditions (Bogaard 2004: 60).

This combined intensity model was previously used to classify 38 unmixed archaeobotanical samples from mid-late third-millennium BC Tell Brak, Syria (Charles & Bogaard 2001; Bogaard *et al.* 2016b) (Figure 6.4). The samples were distributed towards the negative end of the discriminant function (extracted from the modern field data) and were all classified as 'low-intensity' regimes with high probability (>0.9) (Bogaard *et al.* 2016b). These low discriminant scores added further rigour to the identification of husbandry regimes as opposed to merely highlighting climatic differences; many of the Tell Brak samples were lower on the intensity scale than the southern Moroccan rain-fed fields, yet rainfall levels during the Early Bronze Age would have been higher than present day southern Morocco (Bogaard *et al.* 2016b). This example of low-intensity management provides a geographically relevant case study to compare with the husbandry regimes examined as part of this study.

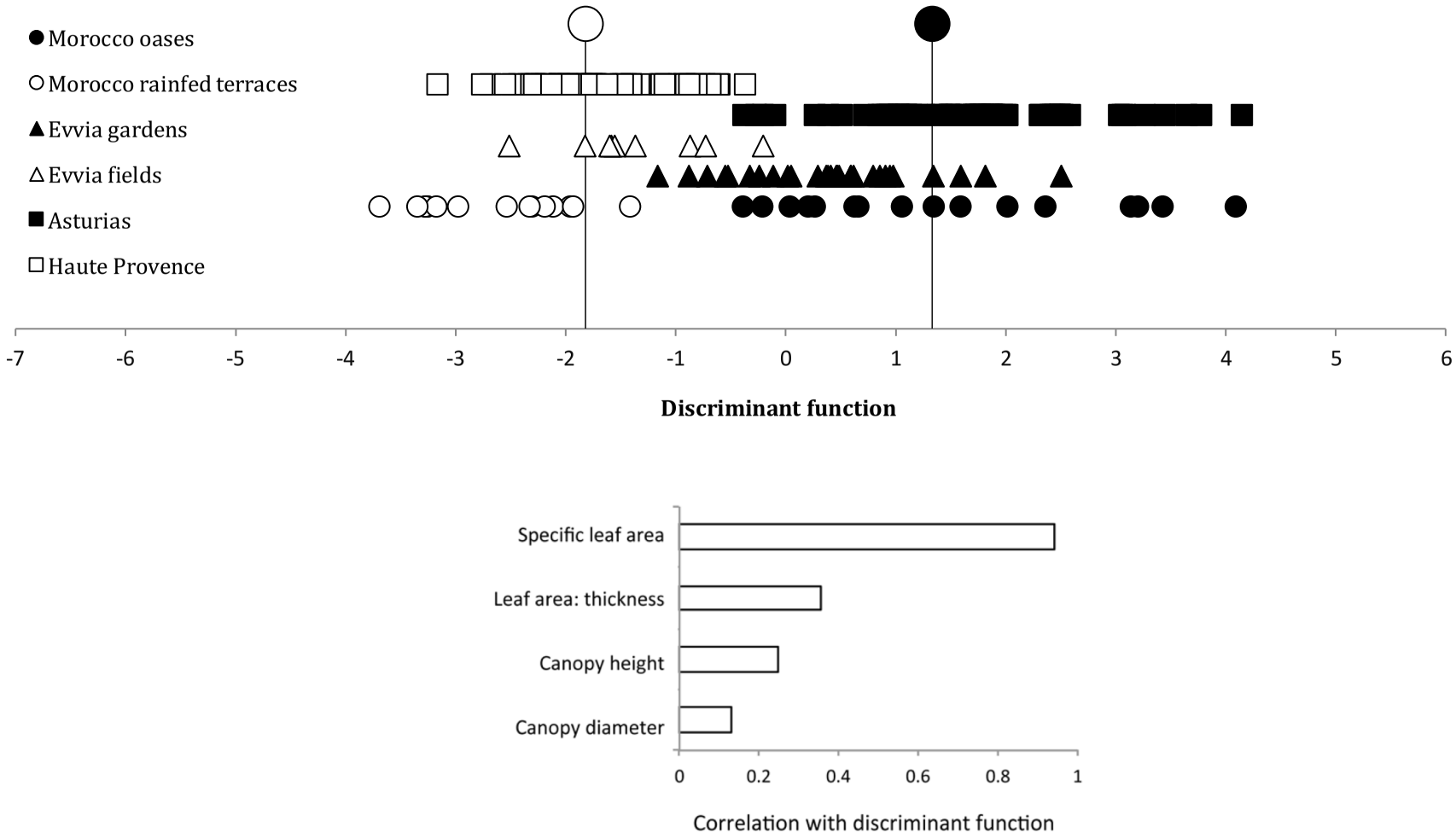


Figure 6.3 – a. Distribution along the discriminant function for the four modern field studies, including Morocco, Greece, Spain and southern France (Bogaard *et al.* 2016b). Each data point represents the combined attribute data for a single field. b. The relative importance of each attribute used to successfully classify the samples.

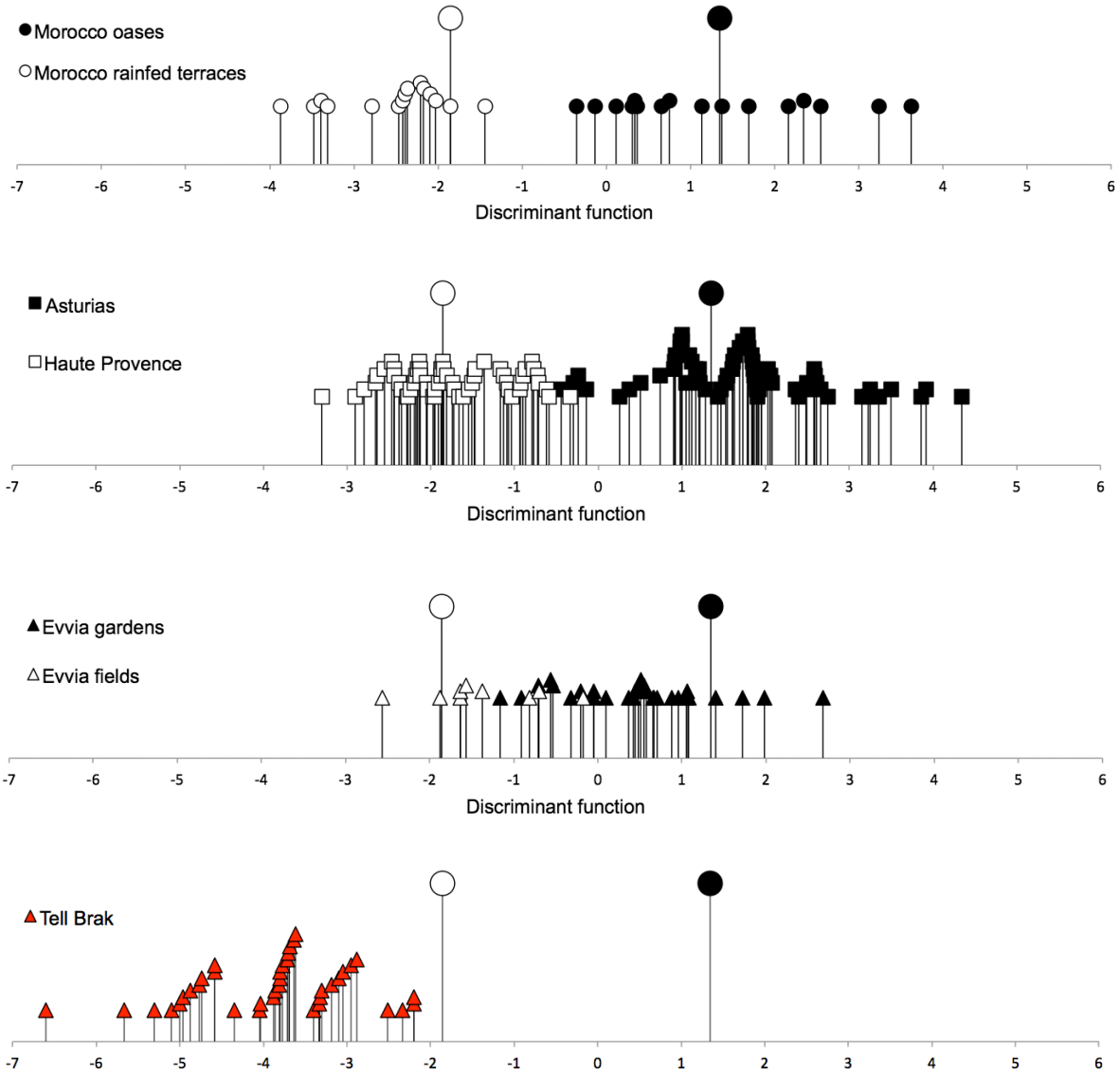


Figure 6.4 – The separate field data from each of the modern studies in the combined intensity model compared with archaeobotanical samples from mid-late third-millennium BC Tell Brak (Charles & Bogaard 2001; Bogaard *et al.* 2016b). The much lower values for Tell Brak indicate that farming methods related to low intensity regimes.

6.3 Examining ecological variability

To approach the remaining identification process strategically, ecological variation in the most frequently occurring genera was explored using the discriminant analysis approach as an investigative tool. Since species-level identifications across a diverse weed flora is a laborious process, effort must be invested primarily in genera where further identifications would make a substantial impact upon the ecological signature of interest. Moreover, when considering the wild taxa from the selected crop stores, some of the genera are much more diverse than others. *Galium*, for instance, contains over 100 different species recorded in the *Flora of Turkey*, and there were at least two different types recognised within the weed assemblage. *Adonis*, on the other hand, has only nine different species, of which only four are applicable to Çatalhöyük (see Identification Catalogue). Thus, selection of high-priority taxa must aim for a balance between species diversity and ecological resolution.

In order to illustrate meaningful ecological variation among the species of each target genus, functional attribute data for their corresponding species were incorporated within a series of discriminant analyses, which followed the format of the analyses outlined above. Instead of an archaeological sample, each data point represents the combined attribute data recorded for a single species. These were plotted in relation to the field data from the combined intensity model (above, 6.2), with the two larger symbols relating to the two group centroids (i.e. high-input and low-input). The method was tested on several key genera from the weed assemblage that had complete functional ecological data; two examples will be given here, which include the small genus Adonis (Figure 6.5), as well as the larger, frequently occurring genus Bromus (Figure 6.6).

Adonis appears to have a relatively restricted ecological signature, positioned at the low intensity end of the scale. In this case, identifications beyond the genus level may have relatively little impact upon the general ecological signature of a sample. Alternatively, the distribution for *Bromus* is highly variable between the different species, and their ecological values extend across almost the full extent of the intensity scale. Successful

identification of *Bromus* to its specific species is thus likely have a significant impact upon the ecological signature of a sample. Refinement of *Bromus* identification was therefore prioritised in this project. Furthermore, the distribution appears to form a number of small clusters, with groups of species with very similar ecological signatures. Such groupings were investigated further in this thesis as they may also bear relation to distinctive morphological traits, such as seed size or shape. In such instances, identification to small ecological groupings would be sufficient to obtain relevant ecological information.

This method has proven to be an instructive illustrative tool that highlights the key weed genera requiring further refinement. It has also usefully demonstrated how some of the genera may be similar enough in ecological signature to be included at the genus level. This approach was applied across the full extent of the weed dataset, which had available functional data, to direct and inform taxonomic identification.

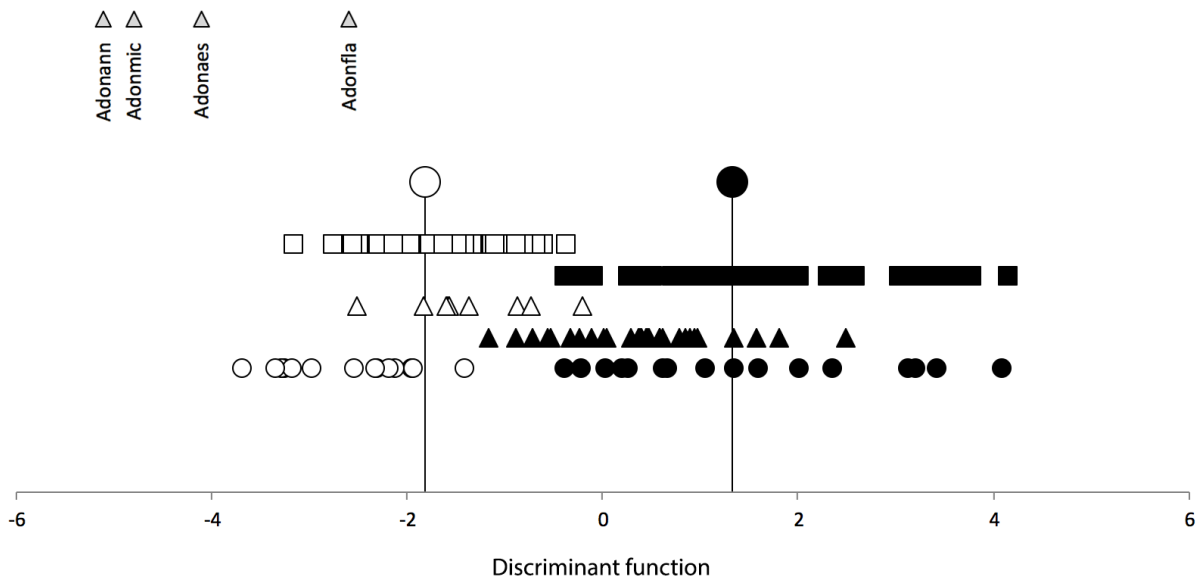


Figure 6.5 – The relationship of the different *Adonis* species to the established discriminant function for cultivation intensity.

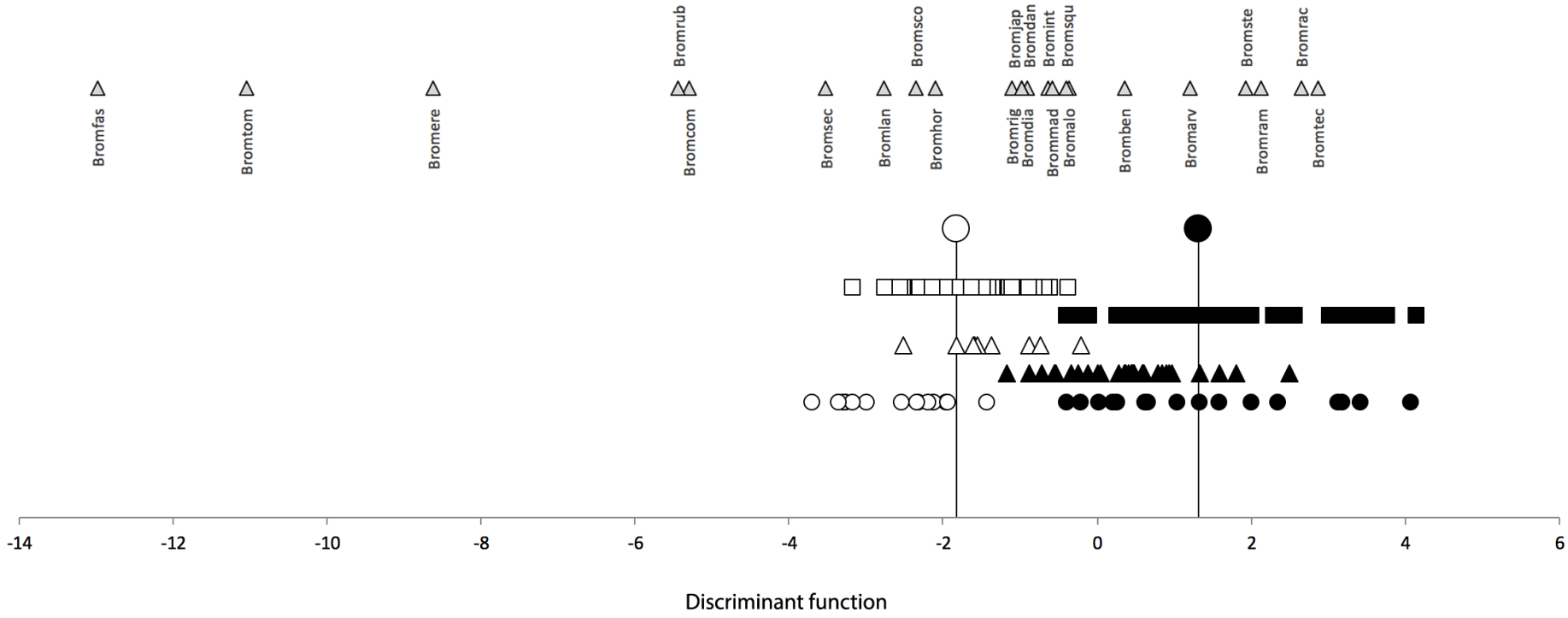


Figure 6.6 – The relationship of the different *Bromus* species to the established discriminant function for cultivation intensity.

Chapter 7
Refined identification of weed taxa

This chapter focuses on the identification of weed taxa to the species-level within archaeobotany, providing a critical assessment of the available literature as well as evaluating the various processes required to build useful and accurate identification keys.

7.1 Identification keys in archaeobotany

7.1.1 Existing identification keys

Despite over 150 years of archaeobotanical analysis, the skill of plant identification from their seeds remains a largely subjective process, with species distinctions based on subtle variants in morphology and surface pattern that are often difficult to systematically describe and quantify (Fritz & Nesbitt 2014). While a great deal of literature on seed morphology exists (cf. Nesbitt & Grieg 1990; Jensen 1998), it has been chiefly developed by botanists and is widely dispersed across many books and articles, with much of it limited to the genus level. Comprehensive species identification guides and keys that isolate distinguishing criteria visible in charred macroremains are still in their infancy (Nesbitt & Grieg 1990; Nesbitt 1991); much of the existing species-level literature developed by archaeobotanists has primarily targeted the major economic plant types, such as cereals, pulses, fruits and nuts (cf. Pearsall 2015; Hubbard 1992; Jacomet 2006; Cappers *et al*. 2009; Charles *et al.* 2010; Cappers *et al.* 2012; Neef *et al.* 2012; Cappers & Neef 2012). This narrow research focus excludes detailed identification attempts of potential arable weed taxa, that are additionally complicated by the enormous floristic diversity considered within archaeobotanical research, which today spans across the globe, with

increasing focus upon species-rich regions such as China, India and Africa (cf. Fuller 2002; Cappers 2007; Castillo & Fuller 2010).

When identifying a specimen to species the exclusion of other geographically relevant species is a crucial step (Fritz & Nesbitt 2014: 131). This is one of the main reasons why much of the literature traditionally consulted in archaeobotany (i.e. seed atlases and manuals) have tended to be poorly designed for making species-level identifications, as even when regionally specialised they are rarely exhaustive of associated species. Instead, the focus of such works has typically been to facilitate quick genus level identifications by detailing criteria for the most common, or most representative species for each genus, so as to direct further investigation with seed reference collections (Martin 1946; Berggren 1969; 1981; Beijerinck 1976; Anderberg 1994; Nesbitt 2006; Cappers *et al.* 2012; Cappers & Bekker 2013: 9). As many of these atlas studies were compiled by botanists or agronomists rather than archaeobotanists, such works are additionally biased towards weed taxa that are important for modern day distributions (e.g. invasive species), which may differ from the prevalence of species in the past (Nesbitt 1991: 21). Accurate species-level identifications require detailed studies that focus upon a single genus, such as the construction of specialist identification keys; this level of analysis enables any infra-species morphological variability to be accounted for, which otherwise may be unobservable within small-scale seed reference collections (Nesbitt & Grieg 1990). However, comprehensive coverage and documentation of the morphological variation present within each genus, or even species, can be an extremely complex and time-consuming endeavour, which is well beyond the scope of most projects.

Only a limited number of archaeobotanically focused studies have targeted species-level identifications for key weed genera, with systematic documentation of identification criteria visible in ancient macroremains. One of the most outstanding contributions was undertaken by Udelgard Körber-Grohne (1964; 1991), who prepared detailed dichotomous style identification keys for several archaeobotanically important Gramineae genera, including *Bromus*, *Alopecurus*

and *Lolium*[1]. The principal aim of this work was to assist with the characterisation of early meadow/pasture in the loess region rather than specifically targeting arable weed taxa; nevertheless, a number of key crop weed genera were featured within this project (Körber-Grohne 1991: 208). The keys detail a range of identification criteria for each species, including seed size and shape, hilum structure and cell pattern, while usefully noting the extent of variation expected within a given species; measurements are given as a range, while illustrations are provided to explain variation in seed shape, such as apical end shape (Körber-Grohne 1991). The keys also present realistic judgements for considering extremely similar species, by indicating instances where identifications should be made to species group only (Körber-Grohne 1991: 211). An extensive number of specimen measurements, sourced from various accessions, form the underlying dataset for this key, which clearly demonstrates the range of variation within each species (Körber-Grohne 1991: 196-7). However, while Körber-Grohne's keys make a valuable addition within the field of archaeobotany, they were specifically designed for the identification of waterlogged material, where Gramineae remains are usually preserved as flattened 'envelopes', so are not suitable for identifying charred material without modification (Körber-Grohne 1991: 209) (also see 8.1.1).

A similar dichotomous style identification key was developed by Elsbeth Lange (1979) for distinguishing between charred *Galium* seeds, included as part of her detailed report of the archaeobotanical material from the two Slavic settlement sites, Brandenburg and Zirzow, in eastern Germany. While principally focused upon the genus *Galium*, the key also considered a number of closely related Rubiaceae taxa (*Sherardia, Cruciata, Asperula*), which were of archaeobotanical interest for Central European sites. Measurement and analysis of the distinguishing criteria was conducted using fully ripe modern material (25 specimens per species sourced from multiple accessions), which had their outer pericarp removed to mimic the characteristics visible in archaeobotanical material. A number of distinguishing criteria were used to build the key, including general seed size and shape, the proportion and shape of the hilum opening, and cell pattern; these were presented in an easy to follow branching

[1] Körber-Grohne (1964) also produced detailed identification keys for *Juncus*, which as a non-weed will not be discussed further here.

identification key with schematic diagrams, though the underlying dataset was not published. While this key was specifically tailored towards the identification of specimens at these two sites, it still required a considerable amount of data collection and analysis in order to build, and therefore has a number of wider applications. Sadly, the key was not published separately and the raw data remain unavailable; this research instead continues to be largely hidden and inaccessible within this small-scale site report.

A slightly more recent key designed for archaeobotanical applications was published by Richard Hubbard (1992) in his 'Dichotomous keys for the identification of the major Old World crops'. While primarily focused upon carbonised cultivar species, the key also includes a limited number of associated weed species with similar morphology. The key is primarily built upon seed size and shape, but considers some surface patterning. However, there is no mention of any treatments to mimic charred specimens. While this key is not designed for weed identification, owing to the highly selective inclusion of weed species, it nevertheless offers a useful review of some of the issues involved with establishing species-level identifications. The work recognises the significant difficulties posed by extensive infra-specific variation, which is challenging to capture within a seed identification key; a factor that is often overlooked within even the most detailed identification catalogues. The work instead distinguishes among 'representative specimens' only, though the number of specimens and accessions analysed to establish these is not indicated (Hubbard 1992: 105). A further challenge highlighted by the key, is that various seed characteristics may significantly overlap, particularly among wild ancestors of cultivar species (Hubbard 1992: 106). To account for this, some parts of the key offer identifications to species group only, where it is inappropriate to identify further.

A substantial computerised identification key has been developed by Kislev *et al.* (1995; 1997; 1999) for the systematic identification of wild grass species, but after many years the key is still unavailable for general use. This project designed a multi-access style key in Microsoft Access, which was based on traditional morphometric measurements (i.e. length, breadth, thickness) and descriptions of grain characteristics, while also providing digital images to further assist comparisons. Ancient material was also incorporated, offering a useful resource to compare

identifications at different sites. A partial aim was to limit reliability on seed reference collections, which are often incomplete, as well as time consuming to assemble (Kislev *et al.* 1999). To construct the key, modern specimens were collected in the field from many countries (over 17) around the Mediterranean and in western Asia (Kislev *et al.* 1999). The insights presented by this key are therefore extremely valuable for species-level identification in archaeobotany, but two decades on the key is still not widely known and has yet to be incorporated into wider practice.

While archaeobotanically focused identification keys are extremely limited for arable weed genera, several other seed identification keys have been produced by botanists and agronomists for their own weed identification purposes. These continue to offer a range of useful identification criteria for archaeobotanical material, although they must be used with extra caution owing to the different purposes involved with their construction. One of the most substantial of these works is the *Atlas of Seeds* developed by Greta Berggren (1969; 1981) and Anna-Lena Anderberg (1994), which covers several arable weed related families (including Polygonaceae, Cruciferae, Caryophyllaceae, Ranunculaceae) across three volumes, and is frequently cited within archaeological works. The Atlas presents diagnostic dichotomous identification keys to both the genus and species-level, as well as providing detailed photographs, colour charts, and a systematic scale for describing shape. The project draws upon a wide range of characteristics to build the identification keys, which are anatomically focused and can be highly technical; these include seed size, shape (general and specific parts), colour, surface pattern and texture, and lumina of the epidermal cells. However, as this Atlas was specifically developed for use with modern seed material, these single-access keys are heavily reliant upon characteristics not usually observable in charred material (i.e. colour, surface texture and lumina, outer perianth) to separate species, so are not suitable for identifying archaeobotanical remains. Nevertheless, this substantial work offers useful reference images, descriptions, and terminology, which may greatly assist future ventures in the development of archaeobotanically focused keys.

Beyond such larger-scale ventures, there are numerous other single genera identification keys produced by botanists and agronomists to target seeds (cf. Jensen 1998); however, these are scattered across countless journals and elusive tomes, and are published in many languages, making it difficult to find those of useful quality. As with the 'Atlas of Seeds', such botanical based works are also frequently based upon characteristics only observable in fresh modern material (Fritz & Nesbitt 2014: 123). Nonetheless, it is worth reflecting upon such works when building archaeobotanically based keys, as they may offer a wealth of useful observations for consideration.

7.1.2 Why is the literature so limited?

After decades of meticulous archaeobotanical research, the limited extent of systematically produced seed identification guides may seem surprising. The existing identification keys are largely a product of the discipline's taxonomic focused past, when many archaeobotanists were first and foremost botanists, with secondary training in archaeology (Chevalier *et al.* 2014: xi). Since the 1980's, the field of archaeobotany has substantially grown and diversified, with a much greater emphasis on answering specific archaeological research questions, through detailed quantification and statistical analysis methods, as well as the application of new scientific techniques (Pennington & Weber 2004: 14). This has replaced the old-style format of archaeobotanical reports, which merely listed the plant species that were identified, with limited integration with other datasets (Madella *et al.* 2014: 3). With new avenues of research, identification is no longer the exclusive goal of archaeobotanical projects, and identification attempts are now made in a much more strategic manner.

Research interests have often constrained the time attributed to the identification of certain taxonomic groups, which has stunted advancements in their identification. Without explicit focuses upon weed ecology, wild/weedy taxa often receive only brief attention within archaeobotanical reports, with cultivars primarily relied upon to reconstruct site activities. Wild specimens are regularly identified to genus only, or are assigned to similar species that were

previously identified without thorough consideration of all potential candidates. Limited discussions of weedy taxa in reports also means there is typically little consequence from incomplete or inaccurate identifications, which has further reduced motivation for detailed identification attempts in the form of keys. While considerable attention has been allocated to developing accurate identifications for plant cultivars, systematic keys have not been widely developed to aid their identification either, perhaps owing to the small numbers of species usually considered.

In addition to changes in research focus over the last few decades, there are also several practical reasons to explain the absence of systematic seed identification guides. Firstly, archaeobotanical remains are routinely retrieved in a fragmentary or highly distorted state, owing to the various processes involved in their preservation (i.e. charring, waterlogging, desiccation), deposition, and recovery (Boardman & Jones 1990; van der Veen 2007; Charles *et al.* 2015). Since species distinctions can be extremely subtle within even fresh modern material, any missing or distorted seed characteristics present major obstacles for achieving species-level identifications. Charred macroremains, the most common form of preservation, usually lack their original seed coat colour and texture, yet these features are regarded by botanists as some of the most important seed characteristics to distinguish species (Werker 1997: 10-44). Such distortions are particularly common for oil-rich seeds, which is a frequent characteristic within major wild/weed plant families (i.e. Cruciferae, Lamiaceae). Therefore, partial identifications (i.e. to family or genus level) are ubiquitous and expected within the field (Fritz & Nesbitt 2014: 118).

Furthermore, the construction of identification keys is a lengthy and time-consuming process, requiring extensive reference material to be collated, as well as painstaking systematic documentation. Multiple accessions must be sourced and observed to account for infra-species variation (Nesbitt *et al.* 2003: 80), which may present considerable difficulties when trying to obtain specimens of rare or endemic species. A further difficulty is presented by genera that have abundant species for some geographical regions (e.g. *Galium*, with 101 species listed in the *Flora of Turkey*) (Davis 1965), which must each be carefully considered to ensure appropriate

distinctions between the species. This explains the unbalanced geographical coverage of existing keys, as well as many other comprehensive seed identification works, which centre upon some of the least floristically diverse areas (cf. Barthlott *et al.* 1996) studied by archaeobotanists, in northern and central Europe (Beijerinck 1976; Berggren 1969; Berggren 1981; Anderberg 1994; Cappers *et al.* 2012; Cappers & Bekker 2013). The highly specialised nature of such identification keys, which must relate to the local flora of the site investigated, limits their usability across different geographical regions.

While the various factors listed above may help explain the lack of systematic identification works for macroremains, it is significant to note that identification keys are extensively used by archaeologists for other plant remain types, including phytoliths, pollen, starch, and wood charcoal, and are considered a vital tool for assisting genus and species-level identifications (Twiss *et al.* 1969; Brown 1984; Kaplan *et al.* 1992; Mulholland & Rapp Jr 1992; Piperno & Pearsall 1998; Bowdery *et al.* 2001; Pearsall 2016; Kapp 1969; Kapp *et al.* 2000; Moore *et al.* 1991; Reichert 1913; Yang *et al.* 2012; Yang & Perry 2013; Fahn *et al.* 1986; Minnis 1987; Hather 2000; Heiss 2009). Similar, if not greater, challenges persist for these sub-disciplines, with distorted archaeological remains and long lists of taxa to consider, yet rather than appearing as an outdated method, identification keys are developed to disseminate valuable sources of systematically measured identification criteria, which provide useful foundations for future research. Such studies have largely been undertaken at the regional level; however there have also been attempts to create universal keys (cf. Bowdery *et al.* 2001). The continued importance of keys within these sub-disciplines may be a result of the lengthy processes involved with the compilation and analysis of reference material for these types of plant remains—i.e. extraction of starch grains, mounting of phytoliths etc.—which warrant extensive and detailed documentation. Whereas the relative ease of directly comparing large quantities of seed material may have dissuaded systematic recording of observed identification criteria.

7.1.3 Why do we need seed identification keys?

While seed identification keys may have diminished among archaeobotanical research trends of the twentieth century, there are various grounds to suggest why they still have relevance for modern archaeobotany, as well as why we should invest further resources into their development. As discussed above (above, Chapter 6), investigation of arable weeds using a functional ecological approach is a valuable way to identify farming practices in past societies, and accurate species-level identifications are fundamental to this approach. It is argued here that current procedures for the identification of wild/weedy species are often inadequate for botanically diverse regions such as western Asia. The various benefits of systematically produced keys over other identification materials (i.e. seed atlases and guides) are evident (7.1.1), and they present some of the most accurate approaches to achieving species-level identifications. Though their development is time-consuming, they also have the potential to address some of the fundamental difficulties associated with weed identification, including missing and inconsistent reference material, distortion from charring, and morphological variation.

One of the principal challenges for identifying weed specimens to their species is the difficulty associated with sourcing quality seed reference material for all potential candidate species. While it is widely accepted that the consultation of comparative reference material is essential when making identifications (Nesbitt 1991; Nesbitt *et al.* 2003; Warinner *et al.* 2011), few are explicit about the possible limitations associated with their collection or use, despite the potentially adverse effects upon the accuracy of identifications. The building of a reliable and comprehensive seed reference collection is an ambitious and potentially costly endeavour (cf. Nesbitt *et al.* 2003), particularly for diverse weed genera, which may surpass the capabilities of individual researchers or small research groups with limited funding (below, 7.2.3). The most reliable source of reference material is obtained through field collections, which enable collected herbarium specimens to be securely identified by taxonomic specialists (Nesbitt *et al.* 2003: 79). Such methods however require the organisation of multiple trips to the region of study, to account for the variable fruiting times and ecological locations of different target

species (Nesbitt 1991). While seed material may be more easily obtained from other sources, such as botanic gardens, identification errors are more common from these suppliers (7.2.3), which may remain undetected (Nesbitt *et al.* 2003: 80). These procurement challenges are further exacerbated by the global coverage of modern archaeobotanical projects, which demand increasingly extensive lists of relevant species. Even established and comprehensive regional collections may become insufficient for identification purposes if geographical research areas shift within a department. Therefore, archaeobotanists frequently rely upon reference material that is incomplete and/or may contain undetected misidentifications (Warinner *et al.* 2011: 242).

Incomplete reference collections often lead to greater reliance upon seed atlases and manuals to identify likely candidates; as previously discussed, these tend to document the most representative specimens for wild/weedy taxa and rarely detail any infra-species variation. While special research trips may also be undertaken to consult missing species in more extensive reference collections or herbaria, the material may have greater restrictions imposed upon them, prohibiting their manipulation to examine in greater detail (i.e. artificial charring), dissection). Strategic visits to external collections may also encourage rushed 'positive' identifications, or equally unwarranted exclusions of possible species; limited access periods may inhibit in-depth considerations of morphological variation among multiple accessions.

With the prevalence of these flaws within routine identification procedures, the accuracy of some published species-level weed identifications may fall into question. Many weed genera are ecologically diverse (above, 6.3), so misidentifications can have major implications for the interpretation of ecological signatures examined at a site. However, it is often impossible to isolate the extent of resources that were consulted in making species-level identifications within published reports, and therefore, the reliability of the identifications attained. While it is not uncommon for detailed identification criteria to be included in the form of 'seed catalogues' (cf. Jacomet *et al.* 1989; Maier *et al.* 2001; Bogaard 2011), the number of accessions examined, or the extent of species that were unable to be consulted, is rarely indicated.

The development of detailed seed identification keys may help to alleviate some of these reference material limitations, through the dissemination of large quantities of transparent and systematically collected data. Unlike seed atlases, the characteristic traits of a species can be reliably isolated using systematic processes, which account for infra-specific variability through the detailed measurement of various accession sources. Their presentation within a key format usefully indicates the essential features for identification, rather than bewildering users with endless descriptions. With the sharing of the underlying raw data, such keys may be further refined by other researchers, who have access to different reference collections with alternative specimen sources. Such a dataset would present an invaluable tool for those with restricted collections, by offering detailed comparative criteria for the consideration of missing and inaccessible species, as well as having the potential to highlight any inconsistencies present within individual reference collections.

A recent discipline-wide questionnaire, which was conducted by Naomi Miller (Miller 2010; 2011), highlighted some of the current appeals for 'higher standards for identification of seeds and plant parts, and access to adequate references collections, descriptions, and images'; this included specific suggestions of 'seed and plant part identification databases' (Miller 2010: 2). The recent establishment of the online reference collection site *Paleobot.org* (Warinner *et al.* 2011) and other similar websites (e.g. Willcox 2016) have gone some way to addressing these issues, by enabling high quality photographs and corresponding information to be compiled into searchable databases, but they currently fall short of including systematic recordings of seed identification criteria from known material[2]. Nevertheless, such platforms could be used as a widely accessible way of collecting and disseminating systematic measurements and observations, which would greatly assist with the tailored construction of keys required for different geographical regions.

[2] A good example of systematically recorded criteria for seeds is the open access database website 'Identification Criteria for Plant Remains Recovered from Archaeological Sites in the Central Mesa Verde Region' by Adams & Murray (2004). Yet such observations are recorded from charred archaeological material rather than known reference material, so cannot be used for the construction of keys.

The development and application of seed identification keys within standard archaeobotanical practice encourages much greater transparency within the identification process, while providing a solid foundation for achieving consistent and accurate identifications across the field. As well as being able to examine straightforwardly the distinguishing criteria used to make final identifications, the rigour behind such distinctions may also be traced: i.e. how many specimens and accessions were analysed, whether specimens were treated in order to mimic ancient material. The inclusion of such information alongside published identifications enable subsequent refinements to be made with the addition of new comparative data. While such extensive methods may be impractical for identifying routine material, they are particularly beneficial for the systematic identification of unknown wild/weedy genera. They are also useful for highlighting instances where further identification may be inappropriate; for example if groups of species have significant overlaps in morphology among many accessions.

7.2 Challenges for weed identification

Before accurate and effective identification keys can be constructed for weed taxa, there are a variety of factors with the capacity to influence the identifiability of a specimen that must first be considered. Such limitations apply to both archaeobotanical and modern material alike, but there are separate challenges linked to each of these. This section will consider each limitation in turn, with particular reference to weed seed material, as well as their implications for the construction of identification keys.

7.2.1 Weed seed morphology

One of the most significant challenges for weed identification is the inherent difficulties associated with differentiating species solely from their seed morphology. While such distinctions form the basis of archaeobotanical analysis, it must be reflected that plant species are not classified from their seed character. Plant taxonomists use a variety of factors to classify

species, for example their growth habit, leaf shape, root type and flower form, which are all unavailable to most archaeobotanists. The ability to identify plant taxa from minute charred seed specimens is regarded as rather extraordinary by some botanists; archaeobotanists Fritz and Nesbitt (2014) offer a revealing anecdote, where a former professor of botany and instructor of plant taxonomy referred to archaeobotanists as "wizards" given this apparent skill (Fritz & Nesbitt 2014: 118). Nevertheless, as seeds are one of few readily preserved plant parts, we must become acutely aware of the possible limitations that their morphology poses for identification.

Several weed species derive from monotypic genera (e.g. *Vaccaria pyramidata*) or have very distinctive morphological traits that can be easily separated from other species (e.g. *Adonis vernalis*); however for the most part morphological distinctions are very subtle at the species-level (Bewley *et al.* 2006: 685). Differences in the internal morphology of seeds can be easily explained among plant families and genera—i.e. the relative size, shape and location of the embryo (Bewley *et al.* 2006: 684)—but the function behind minute differences in external shape between species (as well as subspecies and varieties) are not fully understood (Donnelly *et al.* 1997). Such subtle differences are also extremely difficult to quantify and characterise, which is further complicated by instances of infra-species variation (Nesbitt *et al.* 2003: 79). To understand the cause of variability within a single species, as well as identifying genera with greater expected levels of variation, we must carefully consider the type of the dispersal unit together with the form of locule within the ovary (e.g. pod, spikelet, mesocarp). While general seed shape is genetically determined, their final mature form is dictated by several factors, which are closely linked to a plant's dispersal strategy; these include the available space of the enclosing locule, the total number and density of seeds, as well as the relative location within the locule (Werker 1997: 3; Bewley *et al.* 2006: 684). Therefore, it is not surprising that a single plant may generate seeds of variable form depending on their relative positioning and individual shattering points (Nesbitt *et al.* 2003: 79). Further complexity arises from species that present more than one type of fruit that are distinct in shape (heterocarpy), or seed (seed dimorphism) as part of their dispersal strategy (Cappers & Bekker 2013: 9). Such differences relate to alternative dispersal mechanisms to exploit a variety of ecological niches, or produce

staggered germination rates; such a phenomenon can be observed within prominent weed families, including Amaranthaceae, Apiaceae and Polygonaceae (Cappers & Bekker 2013).

Similar factors may also influence the relative size of the seeds produced within a species, or even within a single plant. Whilst the average seed size of a species tends to be relatively constant in modern communities, most species exhibit extensive variation around this average, which is typically fourfold (Bewley *et al.* 2006: 632). The variation within a single plant can be partially explained by evolutionary theory, where a range of seed sizes may be beneficial for the plant's regenerative strategy; large seed size is correlated with superior seedling establishment, whereas smaller seeds have the potential to disperse further from the mother plant, or may have greater persistence within seed banks (Bewley *et al.* 2006: 632; Thompson *et al.* 1993). Variances in seed size among different plants and communities have also been attributed to impacts of the maternal environment, such as nutrient availability, soil moisture content, and temperature (Werker 1997: 8; Luzuriaga *et al.* 2006; Violle *et al.* 2009).

When dealing with extensive vegetation histories in archaeobotany, we must also be aware of the possibility that seed morphology may have shifted over time. Crop mimicry is well accounted for among arable weed communities, and presents an identified source of evolutionary change in seed morphology since their initial emergence (above, 2.4) (Barrett 1983). Such modifications would have occurred through the selective pressures imposed by cultivation practices, for example hand cleaning using sieves, and winnowing, which favour seeds of similar size, shape and mass to the crop (Tominaga & Yamasue 2004). The extent to which all arable weed seeds have been affected by evolutionary changes alongside their cultivated counterparts is currently unclear, and is a subject that requires further research.

This wide range of morphological variation within the seeds of individual species presents difficulties for the construction of seed identification keys. With variable dimensions and features, there is a significant chance of overlap between the measurable traits of similar species. For some groups of species, it may not be possible to distinguish between them based

on seed morphology alone. Therefore, the development of identification keys may be crucial for recognising instances where it is inappropriate to identify further.

7.2.2 Preservation factors

In addition to the restrictions posed by seed anatomy, the various distortions linked to archaeobotanical preservation have further impacts upon the identifiability of ancient weed seeds. Most weed seeds are recovered in a charred state, with silicified seeds likely to represent alternative depositional sources (Messager *et al.* 2010). While waterlogged remains are common within European sites, they do not occur in this current study, so will not be discussed further. Even in their best preserved state, carbonised seeds lack their original colour and often their surface texture (Nesbitt *et al.* 2003: 79; Charles *et al.* 2015). Higher charring temperatures are linked to extensive distortions of seed form through the puffing up of seeds, which skews their general size and shape (Charles *et al.* 2015); this is particularly problematic for seeds with a high starch or oil content, such as grasses and crucifers (Gustafsson 2000). Outer testas, which may offer important distinctive identification criteria, are also regularly affected and usually only survive in well-preserved specimens (Charles *et al.* 2015: 7).

Taphonomic processes offer further obstacles by fragmented surviving material; this limits the usefulness of morphometric data, while important distinctive traits may be missing entirely. Charred material is extremely fragile, so broken seeds are a consistent feature of archaeobotanical samples. As with puffing, some seed types are more susceptible to breakages than others; long and thin seeds, like wild grass seeds, are frequently broken and pose additional identification challenges. To make the extensive investment worthwhile, identification keys should be primarily constructed for the identification of complete and well-preserved seed material. While it may be possible to classify broken seeds using identification keys, success is usually dependent on their direct comparison with complete specimens.

7.2.3 Sourcing seed reference material

As discussed above (7.1.3), the sourcing of quality seed reference material can be a demanding task, but is an essential prerequisite for the construction of accurate seed identification keys. Though the availability of reference material has formed a barrier for weed identification, the building of species-level keys concentrates procurement efforts upon single genera, encouraging wider acquisitions of relevant taxa, as well as obtaining multiple replicates from various sources. Nonetheless, there are significant factors linked to the sourcing of reference material that may influence seed morphology, and that should be made explicit alongside the presentation of keys.

The principal concern relates to the reduced reliability of species identifications obtained from certain sources. Seed reference collections are usually constructed from variable sources, which may include field collections, gene banks, botanic gardens, herbaria, and commercial companies (Nesbitt 1991; Nesbitt *et al.* 2003). Yet the ease of acquiring specimens from these sources is generally in inverse proportion to the reliability of the identification (Fritz & Nesbitt 2014: 130). Field collections represent the most trustworthy source of material, but are also the most labour intensive. The whole plant may be collected for identification purposes, which can be independently checked by taxonomists, and retained as a voucher specimen. Although, depending on the target genus and region, such collection trips are unlikely to recover all relevant species within one season, and may require further collaboration with experts in the regional flora. This procurement strategy is the most appropriate for examining arable weeds, as seeds collected directly from the wild or from farming contexts are more representative of recovered ancient material; as briefly discussed above (7.2.1), seed size may be influenced by the maternal environment, so it is possible that specimens 'cultivated' in a garden environment may differ from their wild counterparts (Fritz & Nesbitt 2014: 130). This however highlights a potential issue with seed material obtained from non-field sources, particularly if seed dimensions are an important component of identification keys.

Nevertheless, the time commitment and expense associated with field expeditions and the variable distribution of species in the wild often prevent the complete attainment of target species, so reference collections are frequently supplemented with alternative sources. The easiest way to acquire seed material is by ordering from botanic gardens, which issue annual exchange lists (*Index Seminum*) (Nesbitt *et al.* 2003). However, there are various criticisms of the current *Index Seminum* system that may have implications for archaeobotanical research (Richardson 1994; Aplin & Heywood 2008; Havinga *et al.* 2016). Despite recent calls for centralised exchange networks (cf. Havinga *et al.* 2016), seed exchanges are currently managed at the individual level by botanic gardens (Aplin & Heywood 2008; Havinga *et al.* 2016). Seed lists are often lengthy and must be examined separately, yet they usually offer little, if any, associated data for accessions in relation to their growing conditions, collection or origin (Aplin & Heywood 2008; Havinga *et al.* 2016). Most concerning is that very few botanic gardens indicate that the identity of its listed material has been verified, with identification errors particularly prevalent for annual species (Nesbitt *et al.* 2003: 80; Aplin & Heywood 2008). Crop species and their wild relatives are especially problematic, owing to regular instances of hybridisation (Nesbitt *et al.* 2003: 80; Havinga *et al.* 2016). Commercial seed companies that specialise in wild plants or 'heritage' crop varieties exhibit comparable limitations and should also be treated with caution (Nesbitt *et al.* 2003: 80).

A more dependable source for ordering seed material is genebanks, which specialise in the long-term storage of crops, their wild relatives, and associated weeds (Nesbitt *et al.* 2003: 80). Their role in the conservation of agricultural biodiversity necessitates greater detail for accessions of their collection methods and origin. However, while collections may have originated from a region or habitat of interest, specimens are usually grown on before storage, so as with botanic garden material their seed size may not be representative of ancient material (Nesbitt *et al.* 2003: 80). While herbarium collections provide a further opportunity to examine verified seed material, access is usually accompanied by certain restrictions that prohibit the sampling of specimens (Nesbitt *et al.* 2003: 80). Furthermore, herbarium material preferentially selects plant specimens that are in flower to assist identification, so seeds may be absent or immature (Nesbitt *et al.* 2003: 80). It is crucial that fully mature seeds are used for the construction of

identification keys, as seed form may substantially differ in partially ripe material (see Identification Catalogue). Field collections are another potential source of unripe material, and botanic gardens also occasionally distribute immature seeds (pers. observation); it is important that immature accessions are identified and excluded before they are experimentally charred and measured.

Despite the various obstacles associated with the sourcing of reliable reference material, the acquisition of multiple accessions for each species is the best way to ensure material is correctly identified. Though problematic when used in isolation, seed atlases may offer a further means of checking reference material, which can be compared as if they were another accession. With the transparent documentation of sources used for the construction of keys, any insufficiently sourced areas can be later strengthened with the locating and measurement of new material.

7.2.4 Floras and taxonomy

A final aspect to consider that may influence approaches to weed identification is the variable quality and completeness of Floras, as well as the impact of taxonomic revisions. Archaeobotanists are usually reliant upon Floras to determine lists of geographically relevant species for each target genera. Nevertheless, the alternative research interests and collection strategies behind such works are rarely reflected upon. Flora projects have been carried out for centuries and their management has taken various forms; earlier publications were often prepared by individuals or small teams, while more recent works have been developed as collaborative efforts between two or more institutions, sometimes taking decades to complete (Frodin 2004). However, not all regions have been studied equally; political instabilities have resulted in large areas of western Asia having only patchy coverage, with larger-scale research Floras such as the *Flora of Iraq* remaining incomplete after many years, while other works are now outdated (Ghazanfar & McDaniel 2016). For areas with insufficient documentation there is little option but to consult Floras of neighbouring regions. While such substitutions are unavoidable, we must be acutely aware of the limitations these temporary solutions impose

upon identification. Without direct botanical surveys for a region, it is possible that some species may be wrongly neglected from species candidate lists when building identification keys for ancient material. Another related aspect is that recorded modern day distributions may not accurately resemble those of the distant past, with some species perhaps having become locally extinct since prehistoric times (Fritz & Nesbitt 2014: 131). However, it is also unrealistic to consider all known species for a given genera to account for these potential omissions. Furthermore, absolute extinctions are also attested archaeobotanically, for example the disappearance of 'new type' wheat in prehistory, which has only recently been discovered (Jones *et al.* 2000).

Further obstacles are presented by ongoing taxonomic revisions, which postdate the publication of many large-scale Floras. Various subspecies have been separated into distinct species in recent years, while other taxa have been subsumed within different genera (e.g. *Polygonum convolulus* revised to *Fallopia convolvulus*); this highlights the importance of considering related genera to identify possible overlaps in seed morphology. There are also instances where new species have been reclassified into multiple species. A prominent example relates to the revised classification of *Bolboschoenus maritimus*, a taxon commonly identified across sites in western Asia, which has now been split into several closely related species (Wollstonecroft *et al.* 2011). The revisiting of archaeobotanical material led to specimens being re-identified as *Bolboschoenus glaucus*, which has different ecological implications to its original identification (Wollstonecroft *et al.* 2011). These frequent nomenclatural problems further complicate the sourcing of reference material, with many taxa listed under alternative synonyms. However, like the field of archaeology generally, the process for identifying specimens to species will never be perfect owing to numerous limiting factors, which are often beyond our control. For best practice when building identification keys, we should be explicit about which species were directly considered, as well as any omissions, so that decisions can be clearly traced and improved in future studies.

Chapter 8

Building identification keys

The following section will detail the methods and resources used to construct weed identification keys in this study, while closely reflecting upon some of the key challenges raised in Chapter 7. A finalised multi-access key for identifying *Bromus* specimens will be presented, as well as detailed feasibility studies for other principal weed genera.

8.1 Methods for building identification keys: *Bromus* case study

Following the selection process for further refinement (above, 5.8), the genus *Bromus* was chosen to be systematically analysed for the construction of a seed identification key for use with archaeobotanical specimens. *Bromus* occurred at all four of the archaeological sites and was the second most ubiquitous weed genus (after *Polygonum*) (above, 5.6). As a member of the grass family (Gramineae), *Bromus* caryopses lend themselves to systematic recording as they are straightforward to document and measure in multiple dimensions (length, breadth, thickness) in a consistent manner. An extensive range of reference material was available from reliable sources for this genus, including gene banks and verified field accessions collected from the target region. A further advantage was the relatively complete species coverage of functional ecological data for *Bromus* (23 species with functional attributes measured), which enabled the full variability of functional ecological traits among species to be assessed (above, 6.3). Initial investigations highlighted a diverse set of ecological signatures attributed to the genus, reflecting the

importance of their distinction to the species level; the functional characteristics of species ranged from values linked to extremely low-input farming conditions to those reflecting moderate-high input environments.

8.1.1 Previous work identifying *Bromus*

Before a new dataset was compiled it was first important to review the extent of existing identification work undertaken for *Bromus* seeds to highlight worthwhile characters and measurements to incorporate during the data collection process. The collation of measurement data from existing sources also serves as an additional independent check for the accessions utilised in the construction of this current key. *Bromus* commonly features as an arable weed on archaeological sites, so has often been included within seed identification guides. As detailed above (7.1.1), one of the most comprehensive studies to document seed morphology for individual *Bromus* species is the *Bromus* identification key presented by Körber-Grohne (1991). This key considers ten different species relevant to Central European sites, though most are equally applicable to southwest Asian contexts (Körber-Grohne 1991: 232). A useful table of traditional morphometric measurements is included, but these proportions specifically apply to artificially fossilised waterlogged material, which are not directly comparable to charred material; waterlogged *Bromus* seeds form flattened 'envelopes' so are greatly distorted from their original three-dimensional shape (Körber-Grohne 1991: 209). Descriptions of distinctive apical cell patterns are also included in Körber-Grohne's key, though the consistency of such patterns is difficult to assess without the underlying systematic data. Nevertheless, apical cell patterns were explored further using scanning electron microscopy (SEM) during the construction of this key, but it soon became apparent that in charred specimens these are completely obscured by the preservation of the sturdy outer cell layer of the pericarp (Körber-Grohne 1991: 209).

Another valuable study to attempt distinctions among individual *Bromus* species is Nesbitt's 'Near Eastern Grass Seeds' (2006), which includes specimen measurements and general descriptions. This extensive work covers 122 different grass genera in total, so was never intended as an identification guide to the species level. Nevertheless, the *Bromus* section offers a useful set of broader distinctions between 53 species from the Near Eastern region, separating them into 'short' and 'long' groups by their caryopsis length. A range of measurements was taken for eight species using fresh modern specimens, which were selectively included within the appendix, including caryopsis length, embryo and hilum length (with associated percentage), as well as further dimensions expressed as ratios; i.e. length-to-breadth ratio (L:B x 10) expressing seed narrowness in the dorsal plane, and thickness-to-breadth ratio (T:B x 100) representing the degree of lateral compression. These expressions of seed shape as a ratio have been particularly influential within this current work owing to their separation from absolute values (below, 8.1.5). Detailed drawings are also presented in Nesbitt's work for four important *Bromus* species, each with four separate views, which serve to highlight the importance of considering all dimensions for species identification. The work also acknowledges the large within-population variation for seed shape within the section *Bromus*, which has been identified within previous studies (Nesbitt 2006: 81).

Bromus was one of the wild grass genera to be included within Kislev's computerised identification key, but was unavailable for consultation in this analysis (above, 7.1.1) (Kislev *et al.* 1995; 1997; 1999). Additional information on *Bromus* seed morphology was obtainable from further sources, but was limited to the more common species from European distributions, with the extent of recorded features generally inconsistent between studies. Two similarly formed *Bromus* species, *Bromus secalinus* and *Bromus hordeaceus,* featured as a combined group in Hubbard's (1992) 'Dichotomous keys for the identification of the major Old World crops'. While a useful range of measurements is presented including length-to-breadth and thickness-to-breadth ratios, these are offered as ranges so cannot be extracted at the specimen level. The publication also omits the number of specimens analysed in the construction of this key, limiting the amount of

confidence attributed to its presented identification criteria. Nevertheless, it incorporates a number of useful terms for the main seed characters of this species group, including seed shape descriptions for the alternate views (dorsal, ventral, cross-section) and apical end shape. These categories were considered during the building of this current key (below, 8.1.5), but as the context of the Hubbard article was to differentiate among other major grass genera, they required further testing to assess their usefulness at the species level.

The online database for the 'Digital Seed Atlas of the Netherlands' includes a number of high quality magnified images of fresh and de-husked seeds for a small number of *Bromus* species, yet these were only available for the dorsal and ventral views. Dimensions for length and width were included with each specimen in the database, but only one specimen was available per species. A small number of other seed atlases (Beijerinck 1976; Bojnanský & Fargašová 2007) included basic descriptions of seed shape alongside their images, yet such details were largely generic to *Bromus* rather than reflecting the subtle differences between species. Measurements were included in some cases, but these were presented in ranges without reference to the number of specimens analysed. Further seed images were also available for 12 of the 22 *Bromus* species featured in the *Flora of Iraq*, which presented basic illustrations alongside other key plant parts. While not detailed enough to form the basis of seed identification criteria, they offer further verification for general seed shape (i.e. wide type, narrow type), particularly for species where reference material was difficult to source.

8.1.2 Finalising species lists

The first step towards building a practical identification key for use with archaeobotanical specimens of *Bromus* was to compile a comprehensive list of all potential species

candidates for the geographical region considered in this study.[1] The most reliable source of systematically documented species and their associated habitats derive from modern botanical Floras. Several Floras were consulted to account for the varied geographical regions of the selected archaeological sites. The *Flora of Turkey* (Davis 1965-85) represents the most comprehensive botanical Flora available to date from the western Asian region; it is the only complete and updated source for several archaeobotanically important plant families (e.g. Convolvulaceae, Boraginaceae, Lamiaceae) (Table 8.1) (cf. Ghazanfar & McDaniel 2016) and is frequently cited within the archaeobotanical research of neighbouring regions (Willcox 1996: 145; Willcox *et al.* 1999: 23-4; Savard *et al.* 2003: 100; Wetterstrom 2003: 391-2; Pustovoytov *et al.* 2004: 208; Riehl 2010: 40). An initial list of *Bromus* species to consider for the Çatalhöyük material was compiled using Vol. 9 from the *Flora of Turkey* (Davis 1986), which consisted of 36 species[2] in total for all Turkish provinces (Table 8.2).

The compilation of species for the Syrian sites was however less straightforward owing to the patchier coverage of botanical surveys. The *Nouvelle Flore du Liban et de la Syrie* (Mouterde 1966) represents the most recent large-scale and systematic Flora project undertaken in Syria, but but has since been regarded as outdated, with some significant taxonomic revisions missed at the time of publication (Davis 1968; Arnold *et al.* 2015; Ghazanfar & McDaniel 2016). Through an inspection of the distributions listed under each species, there appears to be a slight bias towards collections in coastal/lowland areas, perhaps reflecting a greater emphasis upon Lebanon and the Mediterranean zones of Syria in this work. While attempts were made to include the north-eastern expanses of Syria around the Euphrates region in this Flora, Mouterde acknowledges that this area—which

[1] This identification key has been specifically designed to identify *Bromus* specimens from the selected sites in Turkey and Syria, so is likely to require revision before being utilised for other regions.

[2] Only species level information was considered for the gathering of potential candidates as it was considered too difficult to distinguish sub-species and varieties from archaeobotanical seed material. The individual collection details for sub-species and varieties were amalgamated together with their corresponding species.

Table 8.1 – Approximate number of taxa in countries of the Middle East and the status of their Floras (Adapted from Ghazanfar & McDaniel 2016).

Country	No. of taxa	Floras
Turkey	9,753	Davis (ed.) Fl. Turk. Vols 1–9 (1965– 1985) – complete; Güner *et al.* (2012 – checklist)
Iran	7,300	Rechinger (ed.) Fl. Iranica (1963– 2012) – incomplete (see Akhani, 2006)
Syria	3,500	Post, Fl. Syria, Palestine & Sinai Vols 1 & 2 (1932, 1933) – complete but outdated
Iraq	3,220	Townsend & Guest (eds) Fl. Iraq (1966– 1985); Ghazanfar & Edmondson (2013 –) – incomplete
Yemen	2,838	Wood, Fl. Yemen (1997) – complete but not for S Yemen; Al-Khulaidi (2013 – checklist)
Palestine (incl. Israel & eastern Jordan)	2,700	Zohary, Fl. Palaestina Vols 1–4 (1966, 1972, 1986) – complete – being updated
Lebanon (incl. Syria)	2,606	Mouterde (1970) – complete but outdated
Jordan	2,521	No Flora – incomplete
Saudi Arabia	2,281	Chaudhary, Fl. Saudi Arabia Vols 1–3 (1999, 2001) – complete; Mandaville (1990)
Egypt	2,145	Egypt 2145 Boulos , Fl. Egypt Vols 1–4 (1999, 2000, 2002, 2005) & checklist (2009) – complete
Oman	1,211	Ghazanfar, Fl. Oman Vols 1–3 (2003 , 2007 , 2015) – incomplete
United Arab Emirates	650	Western (1989); Jongbloed (2003); Karim & Fawzi, Fl. United Arab Emirates (2007) – complete
Kuwait	407	Daoud & Al-Rawi, Fl. Kuwait Vol. 1 (1985); Al-Rawi, Vol. 2 (1987) – complete but outdated
Qatar	270	Batanouny, Fl. Qatar (1981); Norton *et al.* (2009 – checklist); Abdel-Bari (2012) – complete
Bahrain	250	Phillips (1988); Cornes & Cornes, Wild Flow. Pl. Bahrain (1989) – complete but outdated

is most relevant to two of the three Syrian sites (Jerf el-Ahmar and Dja'de)—remains insufficiently documented (Mouterde 1966: xxx). To offer a wider botanical coverage for this crucial vegetation zone, the *Flora of Iraq* (Guest *et al.* 1966-1985; Ghazanfar & Edmondson 2013) was also consulted to supplement the initial list of *Bromus* species for the three Syrian sites. This extensive project is slowly nearing completion after a lengthy hiatus linked to geopolitical changes, though the relevant Gramineae section (Vol. 9) has been available for several decades (Townsend *et al.* 1968; Ghazanfar & McDaniel 2016). While many of the *Bromus* species overlap between the two Floras (13 species feature in both) (Table 8.2), the *Flora of Iraq* offers valuable details that are omitted from *Nouvelle Flore du Liban et de la Syrie,* including altitude range and associated vegetation zone. Using the two Floras, an initial list of 30 *Bromus* species was compiled to consider for the three Syrian sites.

Table 8.2 – Comparison of Bromus species listed in relevant Floras for the selected sites in western Asia (Frodin 2004).

	Flora of Turkey	***Nouvelle Flore du Liban et de la Syrie***	***Flora of Iraq***
Vascular flora	8,800 species	3,459 species and subspecies	2,937 species
***Bromus* species**	36 species	21 species	22 species

As the taxonomy of many species has been greatly revised since the publication of these works, it was imperative to confirm the current nomenclature for each of the 46 *Bromus* species featured in the initial lists. This was carried out using *The Plant List* (2013), an authoritative online database produced in collaboration between the Royal Botanic Gardens, Kew, and Missouri Botanical Garden, which lists the current accepted Latin names for each species and their synonyms. This process identified five species records

listed as synonyms rather than their accepted names; of these, two transpired to be duplicates of others in the list and one had been reclassified to a different genus[3] so was excluded. This reduced the total list of species down to 43 *Bromus* species to consider for the inclusion in the identification key.

8.1.3 Filtering out species by vegetation zone

The full list of *Bromus* species recognised from the consulted Floras cover an extensive range of vegetation zones, some of which are both geographically and attitudinally very distant from the archaeological sites in question; the surveyed areas range from the Mediterranean coast, to arid deserts and high mountain zones. Such contrasts are particularly prominent for Turkey, which represents one of the most floristically diverse regions in southwest Asia owing to its bordering upon three major phyto-geographical regions; Mediterranean, Irano-Turanian, Euro-Siberian (Zohary 1973). It was therefore essential to filter out species with distributions limited to irrelevant vegetation zones before significant efforts were afforded to the recording of individual species traits.

Each Flora had its own system for relating individual specimen records to specific geographical locations. The *Flora of Turkey* used a straightforward grid system splitting the entire region into 29 squares, which enabled quick reference back to each locale on the map. Accompanying this grid code, each collection also included a unique accession number, place name and corresponding altitude, yet the type of vegetation cannot be easily identified. In contrast, the system used in *Nouvelle Flore du Liban et de la Syrie* was fairly limited, only referencing place names that were often difficult to locate without additional altitude or accession information. The most fitting system was presented in the

[3] The accepted name for *Bromus pumilio* is *Boissiera squarrosa*. An inspection of their seeds indicates distinctly different morphology to other *Bromus* species, with its uncharacteristic laterally compressed seed shape, so it was deemed unnecessary to consider this genus in addition to *Bromus*.

Flora of Iraq, which linked species distributions to broad vegetation zones, i.e. 'dry steppe', 'thorn-cushion', 'desert' (Figure 8.1). These zones were largely characterised by specified ranges in altitude, so could be extended to apply to neighbouring Syria. Each species in this Flora included a list of individual collections with accession number and place name; altitude was also given, but as a range for all collections.

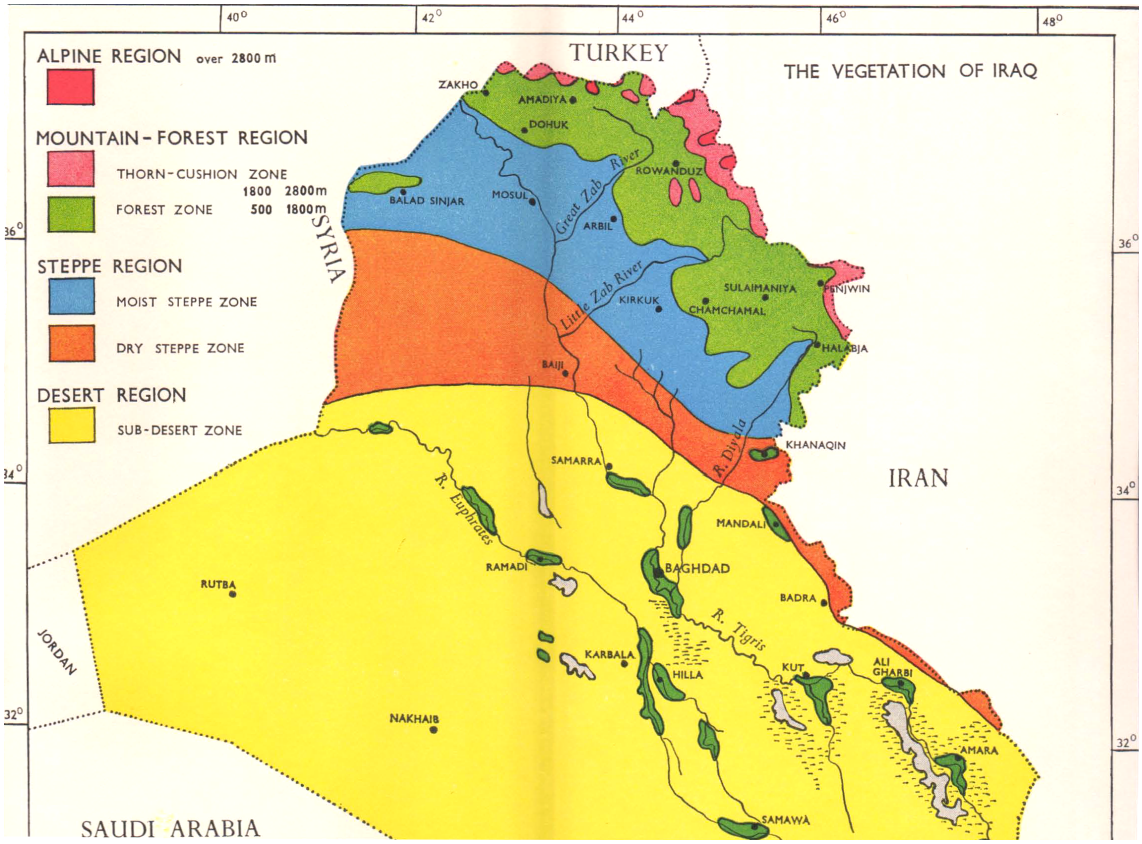


Figure 8.1 – Simplified vegetation map, which was used to characterise the zones where species occurred in the *Flora of Iraq* (Guest & Townsend 1966). These simplified zones, which were largely based on altitude, were extended into Syria to exclude taxa restricted to upland and sub-desert areas.

Few systematically recorded features were available to develop a comparable geographical filter applicable for all three Floras. Altitude was deemed the best independent variable for setting filter boundaries, which could be readily adjusted to account for shifts in vegetation since antiquity. While numerous factors may have shaped present day geographical distributions of species (e.g. grazing, later introductions), the persistence of weed populations in certain altitude ranges continues to reflect fundamental preferences in vegetation (i.e. low altitude reflecting coastal areas, high

altitude linked to mountainous zones). For species restricted to the Syrian Flora only where no elevation was specified, altitude range could be estimated using the recorded place names and regions. For this early stage of the project a broad filter was applied, which excluded species that were restricted to altitudes in excess of 500m above or below the elevation of each archaeological site; this was intentionally generous to permit informed testing and tweaking of filtering levels following the completion of the key.

Other categories were also used to filter out irrelevant species where applicable. For the Turkish Flora, the grid system was used to exclude species with highly isolated distributions, such as those endemic to regions very distant from the site and in separate phyto-geographical zones (e.g. *Bromus sipyleus*, endemic to north-west Turkey near the coast). However, this method was considered problematic when considering areas closer to the site (i.e. Central Turkey) as the grid squares do not neatly differentiate between important vegetation boundaries. The broad vegetation zones determined in the *Flora of Iraq* were also used to remove *Bromus* species constrained to extreme mountainous or arid areas. Using site elevation as a guide, the relevant vegetation zone was determined for each of the Syrian sites (Figure 8.1); Jerf el-Ahmar and Dja'de belong to the 'Moist Steppe' zone and Tell Aswad is in the 'Forest' zone. A large buffer was again employed by including species listed from adjacent zones so as to account for shifts over time. The imposing of these initial filters produced a more manageable list of 26 *Bromus* species, which were applicable across the four archaeological sites.

8.1.4 Sourcing and preparing reference material for analysis

While many modern reference specimens were already available for the genus *Bromus* in the reference collection at the Institute of Archaeology, University of Oxford, further material needed to be obtained to achieve a minimum target of three different accessions per species. As discussed above (7.2.3), it was important to acquire seed material from a variety of separate sources, though greater preference was given to accessions from gene

banks and field specimens collected from the studied regions. Nevertheless, many accessions needed to be sourced from botanical gardens in order to reach this target. A full list of seed accessions that were analysed in this study can be consulted in Appendix 2a. Modern reference material was unable to be sourced for two species, *Bromus brachystachys* and *Bromus pseudobrachystachys*, so could not be included in the identification key. Only two separate accessions could be obtained for *Bromus commutatus* and *Bromus erectus*, so additional specimens were measured from the most reliable source (i.e. USDA gene bank).

As this key was designed with the specific goal to identify archaeobotanical weed specimens, it was imperative that the reference material used to isolate identification criteria replicated comparable conditions to archaeological material. Charring has been demonstrated to have significant effects upon cereal grain morphology (cf. Charles *et al.* 2015), with the potential to grossly distort major identification criteria observed in fresh material. While similar investigations have yet to be undertaken for smaller weedy species, preliminary findings from this study indicate that *Bromus* seeds are particularly prone to lateral puffing, as well as a slight reduction in length and breadth. All modern specimens analysed for this key were experimentally charred at the Institute of Archaeology, University of Oxford following protocols outlined by Charles *et al.* (2015). Such methods involved tightly encasing seed specimens in aluminium foil and placing them in the centre of a 250ml Pyrex beaker filled with sand; this process is important to replicate the low oxygen conditions present in storage contexts (Charles *et al.* 2015: 14). The beaker was then placed inside a pre-heated muffle furnace at 230˚C for 24 hours. Following the charring process, the seeds were manually de-husked to fully expose the seed.

The number of specimens charred for each accession was largely dictated by the abundance of seed material available; consideration needed to be given to preserve sufficient quantities of reference material for future research. Random samples of ten seeds were taken from the larger accessions (over c. 50 seeds) to account for possible

breakages, with decreasing numbers charred for more limited sources. Some accessions, such as those received from Kew Gardens, were limited (c. <5 specimens) so an ideal minimum target of three charred specimens per accession could not be reached.

8.1.5 Systematic recording of reference specimens

Where possible, three of the best-preserved charred specimens were selected per accession for detailed analysis. Specimens were individually photographed to scale in multiple views using the image acquisition software 'Image Pro Insight' by Media Cybernetics (see Chapter 5.7 for methods). Before the final set of identification characters were fully determined, six different views were photographed per specimen; this included the dorsal, lateral, ventral and cross-section view, as well as two zoomed in images taken at the embryo (dorsal side) and apical ends (ventral side). This was later reduced to three views—dorsal, lateral, and cross-section view—which were concluded to be sufficient for recording the principal identification traits. As the key was designed to identify complete well-preserved archaeological specimens, the modern seeds were left whole rather than being dissected to document the cross-section. There was insufficient *Bromus* material for the archaeological specimens to be dissected, thus to present comparable conditions the cross-section was captured by photographing the seed in its end view. Extra attention was therefore required to make sure the seeds were accurately lined up in fine sand, so as not to skew the cross-section shape and dimensions.

8.1.5.1 Traditional morphometric measurements

Traditional morphometric measurements were manually taken from the seed images directly in 'Image Pro Insight', which has a fine calibration system for taking accurate measurements from magnified images. The dimensions selected for the key were length,

breadth, thickness, scutellum length[4], and where definable[5], apical end breadth (Figure 8.2). Measurements were taken at the maximum extent observed for each plane. The cross-section images served as an additional check for confirming the thickness measurements. Using these raw measurements, various dimensions were later adjusted to more effectively apply to archaeobotanical remains. This included the conversion of seed length and scutellum measurements to reflect only the main body of the seed. In *Bromus*, the fine delicate tip of the embryo frequently projects beyond the main extent of the seed body (cf. Nesbitt 2006: 33), though it was commonly broken off in the archaeological specimens analysed in this study. The inclusion of this protruding embryo tip in the key therefore would overinflate measurements as well as slightly distorting shape ratios when comparing archaeological to modern material. To account for this, additional measurements were taken between the embryo end and the beginning of the more robust part of the seed; this was clearest in the lateral view (Figure 8.2). The value was then subtracted from both the length and scutellum measurements to achieve adjusted seed 'body' measurements for comparison with archaeobotanical specimens in the key. Despite efforts to select the best-preserved specimens some accessions were more widely affected by distortion than others, so some puffed specimens were included in the dataset to reach sufficient numbers. Further adjustments were made in a small number of cases to reduce the impact of unevenly puffed seeds upon the dataset; this was achieved by retaking thickness measurements at unaffected sections where distortion was limited to isolated parts of the seed.

Following Nesbitt (2006) (see 8.1.1) and previous authors (van Zeist 1970: 48), a number of ratios were calculated from the raw measurement data to clearly express variability in caryopsis shape. These included a length-to-breadth ratio (L:B x 10) reflecting seed narrowness in the dorsal plane, thickness-to-breadth ratio (T:B x 100) expressing the

[4] Attempts were also made to record embryo length, but the visibility of this feature was inconsistent across the archaeological and modern charred specimens observed, so it was discontinued.

[5] Measurements for the apical breadth were only taken from specimens that displayed 'blunt' ends, as they offered a clear definable extent to assess the degree of tapering at the apical end of the seed.

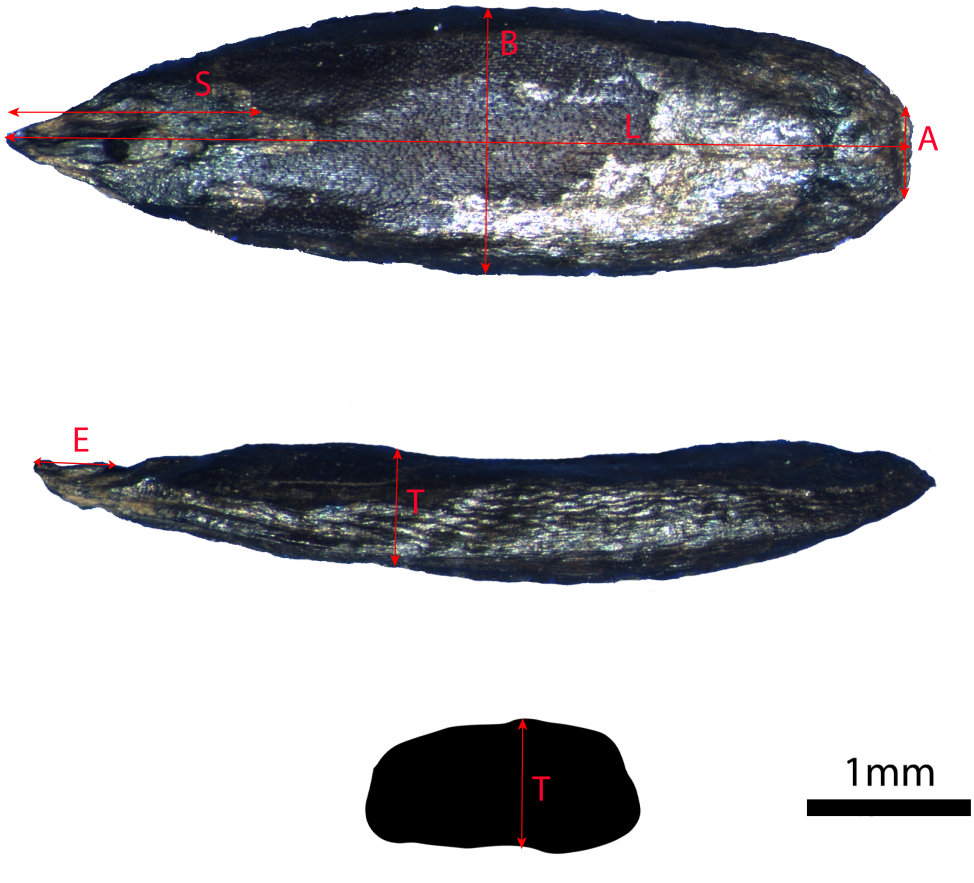


Figure 8.2 – Dimensions recorded for each *Bromus* specimen from its dorsal, lateral and cross-section view. L= length, B= breadth, T= thickness, A= apical end (blunt only), S= scutellum, E= embryo tip (used for seed body conversions).

degree of lateral compression, and length-to-thickness (L:T x 10), which represents the relative thickness of the seed. A breadth-to-apical-breadth ratio (B:AB x 10) was also developed in this study to express the extent of tapering present at the apical end of the seed. The raw values for the scutellum length were also converted in percentages in relation to the full length of the seed. All conversions were calculated separately for both the full seed length and the adjusted 'body' measurements.

While geometric morphometric analysis has been demonstrated to be a successful technique for refined archaeobotanical identification to the subspecies level (cf. Terral *et al.* 2010; Ros *et al.* 2014), the large number of *Bromus* species under investigation precluded these methods from being undertaken in this study. This technique is best

reserved for distinguishing between small numbers of candidates owing to the large numbers of reference specimens required for it to be effective. In a recent study by Ros *et al.* (2014), 300 specimens were measured (each with 41 landmarks) in order to distinguish between the two candidates two-rowed (*Hordeum vulgare subsp. distichum*) and six-rowed barley (*H. vulgare subsp. vulgare*).

8.1.6 Recording shape characters

The systematic recording of seed shape characters was a particularly challenging process that required continual revision throughout as further specimens were analysed. Distinctive characters, which could not be easily expressed through measurements, were first observed and noted while recording the traditional dimensions. Shape categories identified from previous studies, such as the apical end descriptions used in Körber-Grohne's (1991: 227) key, were used as a starting point for this process. Once the images were collected, shape characters were systematically recorded for each specimen using detailed descriptions, which were later simplified into broader categories. This was the most challenging part of the process as specimens commonly fell between identified categories. While many traits were explored, only a small number appeared useful for species level distinctions.

The characters recorded in full included: seed shape, apical end shape, dorsal side shape, prominent dorsal ridges and cross section (Table 8.3). The final categories for each characteristic were determined by reviewing all images taken for each specimen to ensure consistency throughout, as well as to make sure all distinctions were fairly represented in the fewest number of categories. As shape descriptions are often highly subjective (cf. Fritz & Nesbitt 2014: 115), the categorised shapes can be consulted in Appendix 2b, which also denotes the variation of shapes that were integrated into each category.

Table 8.3 – Shape characteristics systematically recorded for each specimen during the construction of the *Bromus* identification key.

Measured characteristic	Categories
Seed shape	Tapered towards embryo
	Tapered towards apex
	Tapered ends
	Breadth constant
Apical end shape	Blunt
	Leaf point
	Narrowly pointed
Dorsal side shape	Flat
	Sloping
	Roof like
Cross section shape	Flat semi-circle
	Lenticular
	Semi-circle
	Rectangular
	Round
	Arched
Prominent dorsal ridges	Yes
	No

8.1.7 Finalising the data

Before building the identification key, it was important to finalise the dataset by isolating the most applicable set of measurements for use with archaeobotanical specimens, as well as pruning any redundant characters. To provide direct comparisons, the best preserved archaeological *Bromus* specimens were measured in the same format as the modern charred specimens. A primary observation was that even with the length measurements adjusted to reflect the main body of the seed (above, 8.1.5) the archaeological specimens were noticeably smaller on average than the modern experimentally charred reference

material (Table 8.4). Length measurements for 16 complete archaeological specimens of variable types produced an average of only 4.5 mm, which fell below the average for the smallest specimen analysed (*Bromus commutatus*). This observation is not too surprising since much of the reference material was sourced from gene banks and botanic gardens, which are likely to grow-on plants in optimal conditions and therefore inflate seed size (above, 6.2.3). Another factor to consider is that seed size may have evolved over time; larger *Bromus* seeds may have been selected through millennia of crop processing activities (above, Chapter 2). Furthermore, within the grass family, seed size is known to be variable both between and within spikelets owing to their relative positioning and distance from the apex of the spike (Harper *et al.* 1970), so size by itself it is not the most reliable characteristic for separation. To prevent misclassifications of the archaeobotanical material a decision was made to rely upon the proportional ratio measurements, which reflect seed shape, rather than the absolute data. However, an exception was made for broader categories of length measurements (small, medium, large) to separate out the main extremes exhibited between the species.

While reviewing the modern dataset it became apparent that species with larger numbers of specimens and accessions analysed also displayed greater degrees of variability. It was therefore decided that the number of specimens included would be standardised, with eight specimens selected for each species so that variation in standard deviations reflected differences within a species rather than differences in the number of specimens/accessions analysed for each species. Effort was made to retain as many different accessions as possible, though this process also presented the opportunity to exclude the most puffed/distorted specimens recorded that may further skew the distribution of data. The individual measurements for the final selections were also checked against existing datasets, such as those included in Nesbitt's (2006) 'Near Eastern Grass Seeds', to confirm that they were broadly representative for each species.

The recorded shape characters also required refinement to exclude features with too much intra-species variability, therefore offering minimal assistance for the identification

Table 8.4 – Average adjusted seed length (body measurements – without embryo tip) by *Bromus* species. Averages are based on eight specimens for each species that were analysed for the presented key. See Appendix 2d for full range of measurements.

Species name	Average length – body only (mm)
Bromus sp. (archaeological)	4.5
Bromus commutatus	4.8
Bromus hordeaceus	5.0
Bromus scoparius	5.3
Bromus racemosus	5.4
Bromus japonicus	5.5
Bromus arvensis	5.8
Bromus squarrosus	5.9
Bromus intermedius	6.1
Bromus danthoniae	6.8
Bromus alopecuros	7.1
Bromus benekenii	7.2
Bromus fasciculatus	7.5
Bromus tectorum	7.6
Bromus lanceolatus	7.7
Bromus erectus	7.7
Bromus riparius	8.0
Bromus rubens	8.3
Bromus ramosus	8.6
Bromus tomentellus	8.8
Bromus sterilis	9.0
Bromus cappadocicus	9.3
Bromus madritensis	9.8
Bromus rigidus	11.8
Bromus diandrus	12.3

process. The characteristic 'dorsal side shape' with its three defined categories 'flat', 'sloping', 'roof like' proved to be too variable to be useful and was removed from the key. Around half of the species displayed two of three categories, with several more species exhibiting all three. Upon closer inspection, this trait appeared to be more closely linked to accession and may reflect differing stages of seed maturity. Similar morphological variances associated with seed maturity were also observed in other species analysed in this study (i.e. *Adonis*) (see Identification Catalogue). The characteristic 'prominent dorsal ridges' was also removed from the study. This feature was only applicable to *Bromus sterilis*, but its presence was inconsistent among the recorded specimens. Furthermore, the outer pericarp of *Bromus* caryopses tend to be more textured than the internal part, so preserved sections could easily be mistaken for dorsal ridges leading to misidentifications.

While the remaining three shape characters were retained for the final key, there was still a considerable degree of intra-species variation. Some of this variability could be attributed to charring and preservation. Cross-section shape was heavily influenced by the puffing up of seeds from charring, with species typically exhibiting 'flat semi-circle' cross-section shapes puffing up to display 'round' cross-sections. The varying survival of thin protruding papery ends following de-husking also presents a possible explanation for intra-species variation observed in apical end shape. However, the variation detected for general seed shape does not have any obvious external factors and is more difficult to explain.

8.1.8 Statistical analysis

Before building the identification key, consultations were undertaken with a statistical advisor to investigate the final dataset for separations between species or groups of species. It was believed this may have informed the distinction of categories in a systematic manner for use in the final key. However, as was the case with geometric morphometric analysis, such methods had only limited applications when considering so

many categories (24 species). There was insufficient data to produce significant results using appropriate multivariate analyses such as multidimensional scaling; a minimum of 20 measured specimens per species would have been required to achieve reliable results, but this number was unachievable with the limited time and resources available. The continuous measurement data was therefore categorised using simple averages and standard deviations for each measured feature, providing a set of expected measurement ranges for each species.

8.1.9 Building keys

With the raw dataset finalised, the next step was to construct a user-friendly identification key that could be applied to archaeobotanical material. Two different styles of key were experimented with; dichotomous keys and multi-access keys. Dichotomous keys are the classic form of identification key employed by Körber-Grohne (1991) and (Hubbard 1992), adapted from conventional practices used in botany (Lawrence & Hawthorne 2013: 99). As this style of key was designed for use in the field, they are very easy to present in a clear and printable format. However, a major limiting factor associated with dichotomous keys is that they are 'single-access', meaning that identification criteria must be considered in a fixed order such as in a 'decision tree' (Figure 8.3) (Hagedorn *et al.* 2010; Lawrence & Hawthorne 2013). Identification by this method often requires complete specimens that display all listed characters. As archaeobotanical specimens are frequently damaged or incomplete, this form of identification key was deemed too restrictive. The use of multi-access keys however circumvents such constraints, allowing users to determine the order and number of characters analysed; this more flexible style of identification key was selected for this study.

While printable multi-access keys exist, this type of key is best suited for use with computer-based software (Hagedorn *et al.* 2010: 60). The software package utilised for

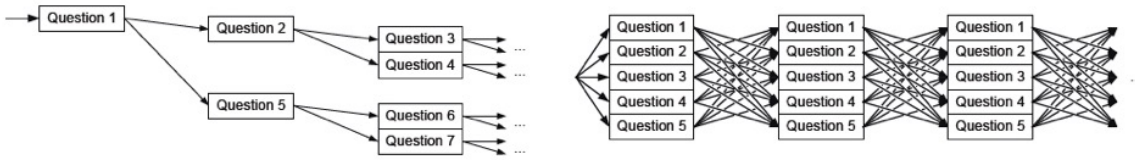


Figure 8.3 – Diagram demonstrating the differences between steps taken in a single-access key (left) and multi-access keys (right) (Hagedorn *et al.* 2010).

building and presenting keys in this study was 'Lucid 3 version 3.3', which is freely available online (see Supplementary material). It was previously used in the field of archaeobotany for the construction of interactive identification keys for charred wood remains in eastern central Australia (Barker 2005). The software assists with the building of multi-access keys (Figure 8.4), including a 'score analyser' that identifies similarities between 'entities' (i.e. species) by examining the number of differences present in their scoring (Figure 8.5). It also enables the integration of multimedia to illustrate descriptive terms and candidate species. The software package consists of two separate components – a 'Builder' and a 'Player'. The 'Builder' is where the main elements of the key are defined, with a presence/absence system to compile the corresponding raw data (Figure 8.4). The 'Player' component functions as the user interface for the key and offers various useful features to further assist the user (Figure 8.6). These include 'Find Best', an algorithm that pinpoints the best feature to address at any stage during an identification session, and 'Differences', which enables the user to inspect entity scores more closely during the identification process.

To prepare the data for entry in Lucid Builder, the continuous measurement data needed to be converted into grouped data categories to be compatible with the presence/absence system. The setting of arbitrary group boundaries required extensive testing and tweaking to prevent biases in the final key. Each recorded feature was analysed separately to assess the distribution of values; this was carried out using scatter graphs that plotted average values for each species, with error bars of one standard deviation either side. While one

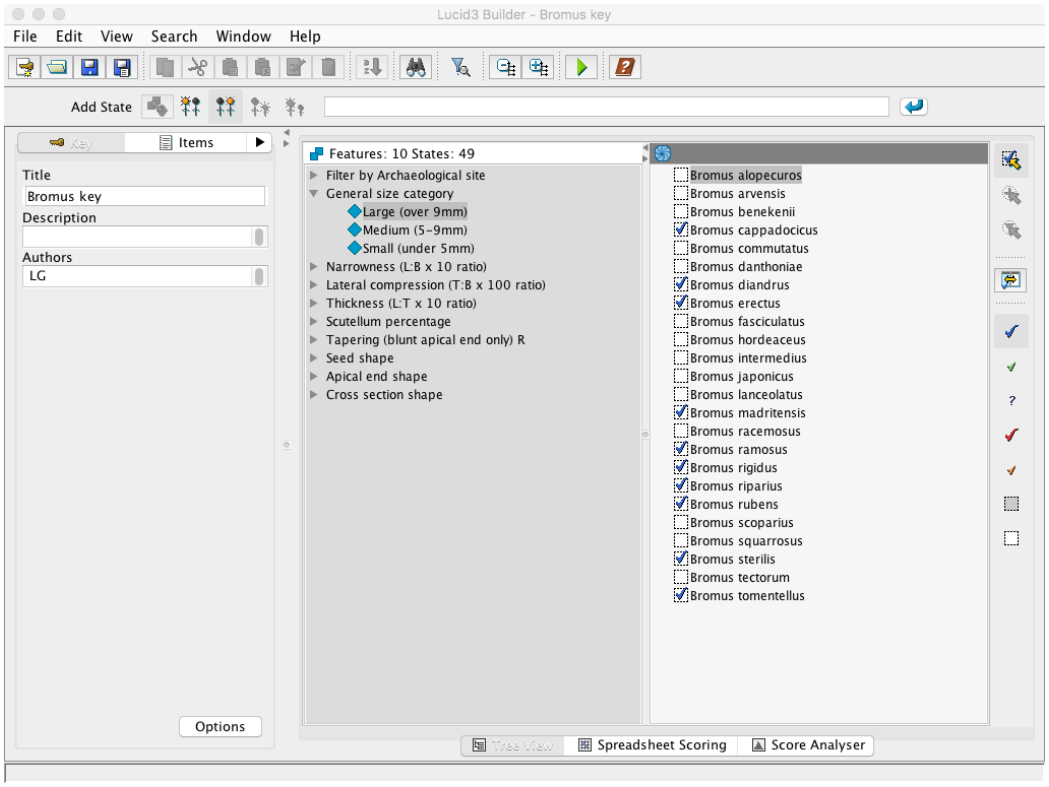


Figure 8.4 – The construction of multi-access keys with Lucid Builder.

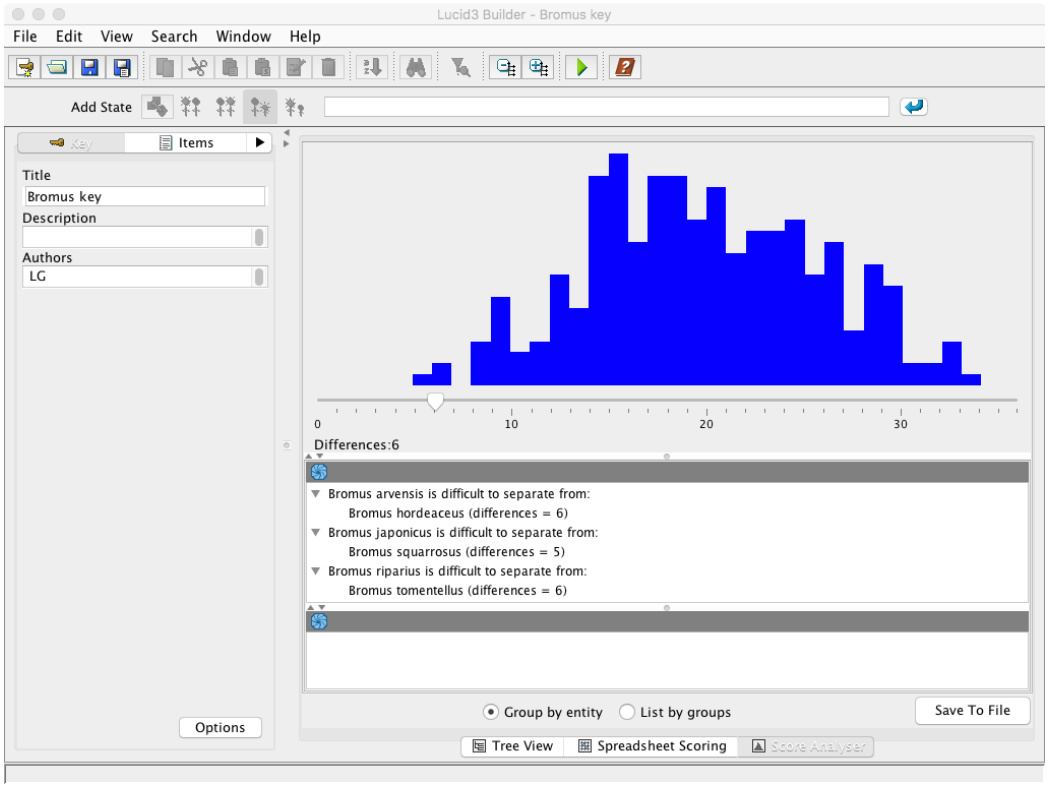


Figure 8.5 – 'Score analyser' function in Lucid Builder, which helps to highlight the extent of differences between species, as well as potential groups with similar traits.

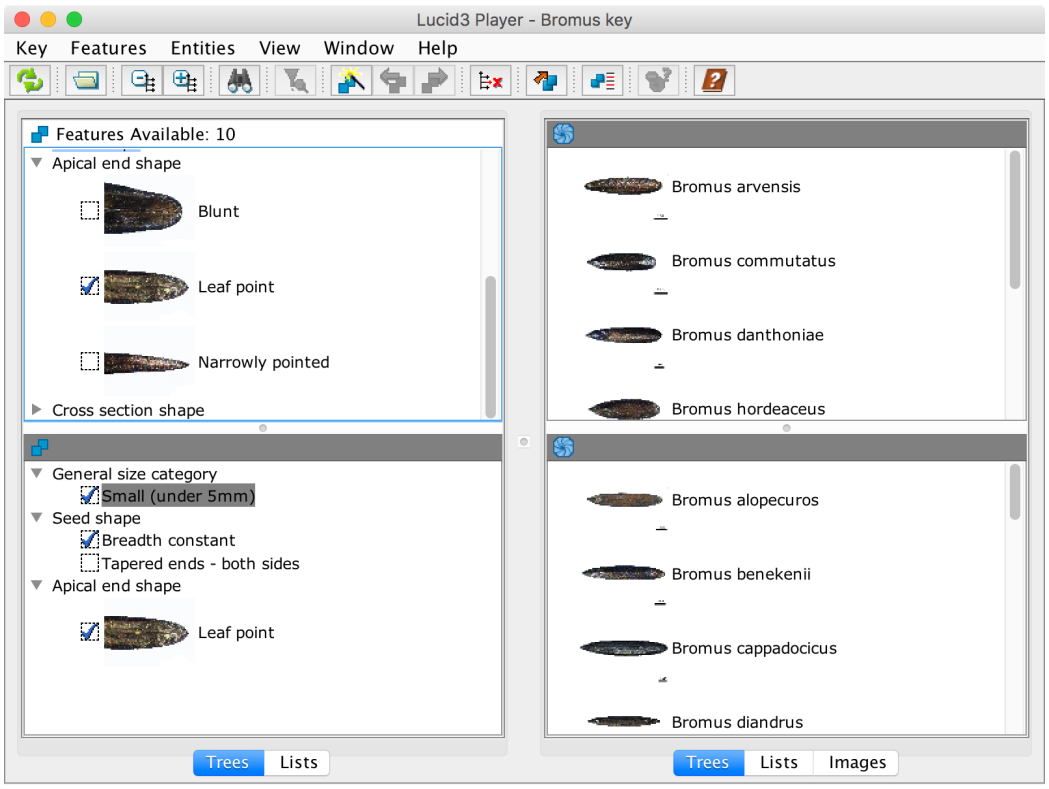


Figure 8.6 – The final *Bromus* key as presented in Lucid player. A range of features can be selected on the left side of the screen. The top-right box displays the remaining candidates, while the bottom-left box shows species that have been excluded.

standard deviation does not account for the full extent of variability observed in each species, this range was deemed sufficient to separate typically representative specimens. Trials of two standard deviations presented extensive overlaps between species that rendered many categories unusable for identification purposes. The final groupings were set at regular intervals (e.g. 30-40, 40-50) which centred around the main distribution of data; the smallest and largest categories acted as maximum and minimum thresholds (i.e. above, below "value") to restrict the total number of categories for consideration. In some cases, the furthest extent of a species' distribution fell on the boundary of two separate categories. For example, for the L:B x 10 category, the highest distribution for *Bromus scoparius* was 59.65, which fell on the boundary between categories '50-60' and '60-70'. To prevent major biases or shortcomings in the data, a species was rounded up (or down) to include the next category if the raw data reflected this group. Thus, *Bromus scoparius* was rounded up to be included in the '60-70' category as one of the recorded specimens had a value of 66.

As described above, the raw unconverted values for seed length (small, medium, large) were included in the key as an exception, with three broad categories used to separate the extremes in the data. To address the bias associated with the on average larger values for the modern material (Table 8.4), an arbitrary 1mm buffer was added to the lower extent only for each species distribution. With all of the categories finalised, presence/absence scores were entered using Lucid Builder.

While the categories for the shape characters did not require any alterations, it was clear that some categories were more typical for a species than others. For example, the 'seed shape' for *Bromus rigidus* was recorded as 'Tapered ends' for seven out of eight specimens, with a further specimen recorded as 'Tapered towards embryo'. The Lucid Builder software enables these distinctions to be reflected in the presented key by providing alternative forms of notation, so uncommon categories (less than 25%) could be denoted by a 'rare' score. While this separate form of notation does not exclude entities from the key, it directly affects the final ranking order of the 'entities remaining' in Lucid Player. To improve the ease of use of the key and to clarify descriptive terms, several images were incorporated. Shape descriptions are often subjective so it was important to provide visual examples for the key to be utilised correctly.

8.1.10 Testing the finished key

Throughout the tweaking process, the key was tested numerous times before its application to the archaeological material, firstly, to see if it could correctly identify constituent specimens of the key, and secondly, to accurately identify newly recorded modern specimens. The initial tests aimed to check the suitability of the arbitrary categories to check for errors or possible biases in the data. Two specimens were randomly selected from the raw data for each species, which were then tested blind in a randomised order. A small proportion of 'no result' outcomes was anticipated from the key owing to the use of only one standard deviation to bookmark average distributions.

These tests proved highly useful for identifying significant outliers that dominated several categories through their high standard deviations. In previous versions of the key, atypical specimens from various species were commonly misidentified as *Bromus danthoniae;* this could be traced back to a single puffed specimen yielding a uncharacteristically low L:T x 10 ratio, which skewed the overall distribution with a high standard deviation. To fix such biases, further specimens were charred and measured to replace outliers. This review process also highlighted the importance of entering all available features into the key to avoid misclassifications; while elimination down to a single species may be achieved after the assessment of two or three features, consideration of the remaining aspects may reveal that the specimen cannot be identified.

The final version of the key correctly identified component specimens 77% of the time. Of this proportion, 60% were identified to three or fewer species, while 17% presented the correct species among a larger group of potential candidate (>3 species). Specimens that were identified to larger species groups tended to possess values that fell within medium categories where the greatest amount of overlap resided. However, some of these large groups could be reduced further if species with 'rare' shape entries were isolated and removed. Of the remaining 23%, 15% of specimens presented 'no result' and 8% of specimens were misidentified. Those that returned no result were specimens that deviated from the typical set of values for one or more categories. Nevertheless, the closest matches could be still determined for no result cases using the key's 'Ranked' sorting mode, which lists the percentage of criteria matched for each entity. The proportion of misidentifications, however, present more of an issue, though a small margin of error is to be expected.

As a final test, a further ten new *Bromus* specimens were selected at random from the modern accessions in the University of Oxford reference collection to be experimentally charred, measured and identified with the key (Appendix 2c). Out of the ten newly recorded specimens, six were correctly identified to species, of which four were identified to three or fewer candidates. The remaining four specimens consisted of three with 'no

result' and one case that was misclassified. Using the 'Ranked' sorting mode, the correct species appeared as the closest match for two of three specimens, and second choice for the third specimen. The misidentification of *Bromus scoparius* was a result of its lack of tapering seed shape, which was present in the other observed specimens; with the removal of this feature, the specimen would have been identified correctly.

These tests demonstrate that this pilot identification key, though far from perfect, presents a beneficial tool for directing users towards probable *Bromus* candidates for archaeobotanical studies in western Asia. With the sourcing and inclusion of additional specimen data, it may be possible to increase the accuracy of identifications further using this model. While the current version of the key more commonly identifies groups of species candidates rather than offering definitive answers, lists of remaining entities may be refined further using site specific geographical filters (below, 8.1.11) and through careful inspection between unknown cases and the reference seed image catalogue (see Supplementary material). This image directory is intended to directly complement the key; some subtleties in seed shape could not be quantified without labour intensive methods such as geometric morphometric analysis, so the consultation of reference material remains a fundamental part of the identification process.

8.1.11 Geographical filtering

The *Bromus* species that feature in this key were already filtered according to the three geographical regions of the archaeological sites in question (above, 8.1.2), but were treated collectively, so not all species in the key are applicable for each site. Furthermore, the initial species selection (above, 8.1.3) was filtered using a generous altitudinal buffer of 500m above and below each site's elevation, so it was possible that this could be refined further. The implications and effects of smaller altitude ranges upon the species selection was explored using Geographic Information System (GIS) software. Elevation maps were generated for each target region with the archaeological sites plotted, then a series of

different altitude boundaries were calculated in relation to each site (Figure 8.7). It became clear that the original 500m buffer zone was excessively generous when solely considering topography; this range encompassed almost the entirety of Syria and the Anatolian region, only excluding coastal zones and the highest mountain peaks.

For Çatalhöyük, even a restricted 100m altitudinal buffer zone still encompassed a substantial area around the site, with a minimum distance of 30km from the site to the next altitudinal zone (Figure 8.7); this distance would take an average of 4-5 days to travel on foot (Charles *et al.* 2014:79). The suitability of this small range in altitude is further supported by recent strontium stable isotope analyses[6], which suggest that crops were most likely cultivated on the surrounding alluvial soils, extending a maximum of 25km

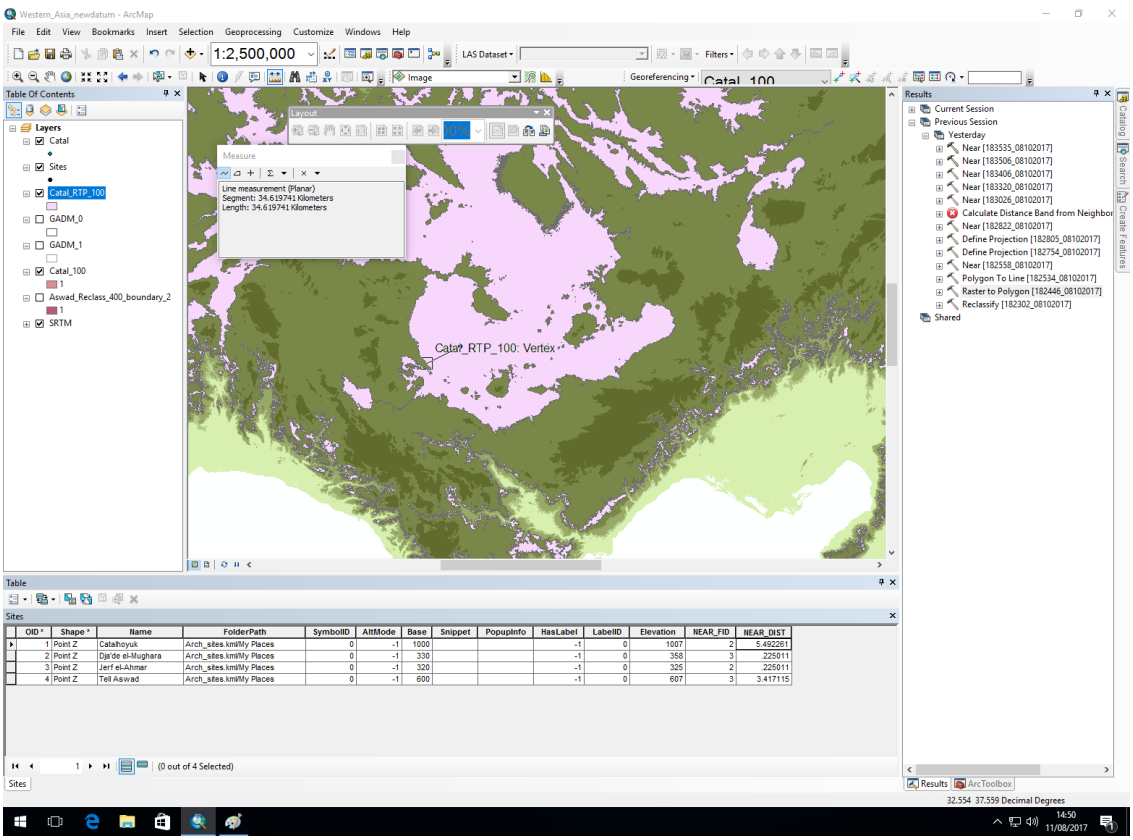


Figure 8.7 – Use of GIS to analyse distances between each site and a series of different altitude zones. This process was used to inform the final altitudinal filters for the key.

[6] This pilot stable isotope study was conducted on two of the crop store units from Building 52 that have also been analysed within this study (Charles *et al.* 2014: 77).

from the site (Charles *et al.* 2014). The site of Tell Aswad is similarly located in the middle of a large flat plain, with approximately 20km to the edge of a 100m buffer zone (>3 days travel, cf. Charles *et al.* 2014:79). The use of these smaller buffer zones for Jerf el-Ahmar and Dja'de was however more problematic owing to their positioning within the Euphrates river valley. The boundary of a 100m buffer zone was less than 2km from each of the sites, so a larger 300m altitude buffer was selected as more appropriate.

Table 8.5 – Final altitude buffer used to filter *Bromus* species for each site, including an arbitrary buffer of 200m to account for shifts in vegetation since the Neolithic.

Site name	Topographic buffer	Final altitude buffer range
Jerf el-Ahmar	300m	500m
Dja'de	300m	500m
Tell Aswad	100m	300m
Çatalhöyük	100m	300m

Nevertheless, one of the main rationales behind maintaining an overly generous buffer zone is to minimise the impact of potential shifts in species' distributions over time, as well as research biases within Flora projects. It is problematic to assume that species distributions have remained static since the Neolithic and therefore resemble those presented in modern Floras. Shifts in climate, as well as thousands of years of human activity—i.e. cultivation practices, overgrazing and deforestation—have dramatically shaped the Anatolian and Syrian landscapes, and therefore, the overall composition of plant communities (Davis 1965: Vol. 1, 66). Moreover, while modern Flora works remain our primary source of systematic documentation for examining species distributions, they act as a guide rather than a definitive account of all populations, so may not reflect full altitudinal ranges. Although the extent of such biases upon the data is difficult to quantify, it was important to retain an additional buffer range in excess of that suggested by the topography. After a series of arbitrary ranges were tested, an additional buffer of 200m above and below site elevation was added to the topographic buffer for each site (Table 8.5).

With the geographic filters finalised, the list of relevant species was updated for each site. An additional 'Filter by archaeological site' category was added to the identification key in Lucid Builder to enable irrelevant species to be discarded from the analysis; this feature was designed to be selected at the beginning of an identification session. However, when using the 'ranked' sorting mode (above, 8.1.9), each of the highest-ranking specimens must be individually checked for their geographical relevance as this mode gives equal weighting to each measured category. It was at this stage that the key was ready to be applied to the archaeological material.

8.2 Presentation and application of the *Bromus* key

The final version of the *Bromus* identification key for use in western Asia can be accessed in the supplementary material. The underlying presence/absence dataset behind the key can also be examined in Appendix 2d.

8.2.1 Examining differences using Score Analyser

The key was examined in Lucid Builder using the feature 'Score analyser' (Figure 8.5) to assess the extent of separation between the presence/absence scores of the 24 species entered, therefore evaluating the identification potential of the key. The analysis also highlights groups of species that are most difficult to distinguish. The slider on the graph generates groups of entities whose scoring differ by less than a nominated number of features. This analysis was undertaken with the 'Filter by archaeological site' feature removed to isolate similarities in seed morphology only. There was a minimum of five differences among the scoring of all 24 species, which was represented by the lowest threshold on the slider; this lowest number of differences was observed between the two species *Bromus japonicus* and *Bromus squarrosus*. When the slider was moved up to eight

differences, four main groups of species were displayed that were difficult to distinguish (Table 8.6). A brief examination of the ecological signatures for each species indicate that Group 1 is the most problematic owing to the extensive ecological variability of the species (above, 6.3). However, depending on the site, several of the species could be separated further when the geographical filtering was reapplied. This quick assessment of the underlying presence/absence data establishes that it is possible to identify *Bromus* specimens to the species level using the current version of the key.

Table 8.6 – The species listed below were indicted as difficult to separate by the 'Score analyser' function, with at most 8 differences between them. Using the combined FIBS model (above, 6.3), ecological signatures were calculated for each species to explore variability between the groups. *There was no functional data available for two species, so average values were calculated by averaging data for the species from the same botanical section.

	Discriminant function	Average values*	Section
Group 1 (Average Difference = 7)			
Bromus cappadocicus	No data	-4.3	Pnigma
Bromus ramosus	2.1		
Bromus riparius	No data	-4.3	Pnigma
Bromus sterilis	1.9		
Bromus tomentellus	-11.1		
Group 2 (Average Difference = 8)			
Bromus madritensis	-0.6		
Bromus rubens	-5.4		
Group 3 (Average Difference = 8)			
Bromus sterilis	1.9		
Bromus tectorum	2.9		
Group 4 (Average Difference = 6)			
Bromus arvensis	1.2		
Bromus hordeaceus	-2.1		
Bromus japonicus	-1.0		
Bromus squarrosus	-0.4		

8.2.2 Application to the archaeological material

The data for the recorded archaeological specimens (above, 5.7.1) were refined to apply to the final categories used in the identification key. Incomplete measurements from broken specimens (mostly seed length) were highlighted in red to prevent the calculation of inaccurate proportional ratios. In some cases, only the very tip of the embryo end was missing, so the full seed length could be estimated and used for ratio calculations. In a small number of specimens where preservation was exceptional, the protruding embryo tip was preserved. As the key was specifically designed to exclude this delicate tip, the measurements needed to be adjusted to reflect the main 'body' of the seed, as in the modern specimens (above, 8.1.5).

The identification key was primarily used to analyse complete *Bromus* specimens as they produced the clearest results. Prior to the identification process, the recorded images and raw data were carefully examined and compared, with each specimen assigned to preliminary 'types' (i.e. likely separate species). They were then entered separately into the key, with their individual outputs recorded (Appendix 2e). Where distorted features were present, for example specimens that were extensively puffed, the outputs were compared with and without the associated characteristics. The outputs were later assessed to finalise the *Bromus* types for each site. Further comparisons were provided from the analysis and identification of well-preserved specimens of corresponding types, which were sourced from additional samples at each site[7]. A total of eight types were identified in total; three for Jerf el-Ahmar, two for Dja'de, one for Tell Aswad, and three for Çatalhöyük. To identify the remaining fragmentary material, specimens were related to the finalised *Bromus* types through direct comparisons of the raw measurement data and recorded images.

[7] During the initial scanning (above, 5.3.1) and recording (above, 5.7) phases, several well-preserved *Bromus* specimens were identified, but originated from samples later excluded from the final selection. A few complete specimens were photographed and analysed to assist with the identification of comparable *Bromus* types from the selected crop stores.

The final species identifications were achieved for each *Bromus* type through close examination of reference material for the suggested candidates. Many specimens had several potential candidates to consider; as demonstrated by the modern tests (above, 8.1.10), specimens that possessed a series of medium values tended to be more difficult to distinguish to species. For some types, such as Çatalhöyük's Type 1, a single species (*Bromus danthoniae*) appeared consistently across the outputs of all specimens analysed, so the occasional specimen with less well-defined outputs did not present an issue. For other types, some species could be excluded through comparison across all types identified. For example, *Bromus tectorum* could be excluded from the output group for Type 3 at Jerf el-Ahmar through its distinction from Çatalhöyük's Type 3 that was identified as *Bromus tectorum*.

A total of six species/types were identified across the four sites using the identification key (Appendix 2e). *Bromus danthoniae* was the most common species, which was identified at three out of four of the sites and assigned to 22 analysed specimens. There was one type present at Jerf el-Ahmar and Dja'de (JF 2 & DJ 2), which could only be identified to a suggested species group/type based on its closest match: *B. tectorum/sterilis type.* This very distinctive type produced no result when all characteristics were entered and had an unusually elongated embryo end in the three specimens observed, which could not be recognised within the image database. While *Bromus tectorum* and *Bromus sterilis* were the closest matches based on proportional measurements, there were many features which did not fit (i.e. cross-section, scutellum percentage). Owing to the duplication of this type across two nearby sites, it is possible that this either represents *Bromus brachystachys*, for which reference material could not be sourced, or alternatively an unknown species endemic to Northern Syria that has not been observed.

8.2.3 Ecological signatures

The ecological signatures for the final *Bromus* species identifications were assessed using discriminant analysis (above, 5.10.3) (Table 8.7; Figure 8.8). In this analysis, the functional attribute data were isolated for individual species, with each species treated as a 'sample' to be compared with the modern survey data; a detailed description of this specific analysis can be found in Chapter 6.3. Despite *Bromus danthoniae* being the most abundant *Bromus* species, there were no functional attribute data available for this species. Unlike many of the other species, the geographical distribution of *Bromus danthoniae* is restricted to western Asia, whereas much of the functional data has been accumulated from specimens collected across Europe and in Morocco (above, 6.1). An estimated value was calculated for this species by averaging the functional attribute data for all species from the section *Bromus*. The ecological signatures were relatively homogenous for this section compared with the full spectrum, so the impact of this estimation should not be too great. For the *Bromus tectorum/sterilis type*, the raw attribute data for the two species was averaged.

Table 8.7 – Ecological signatures (discriminant function) for each of the identified *Bromus* species/types in relation to the combined FIBS cultivation intensity model (Chapter 6). *The estimated discriminant function for this species was calculated by averaging the attribute data for all species from the Section *Bromus*.

Final ID	Discriminant function	DF based on averaged values
B. danthoniae	No data	-0.98*
B. hordeaceus	-2.10	-
B. japonicus	-0.98	-
B. sterilis	1.94	-
B. tectorum	2.87	-
B. tectorum/sterilis type	-	2.40

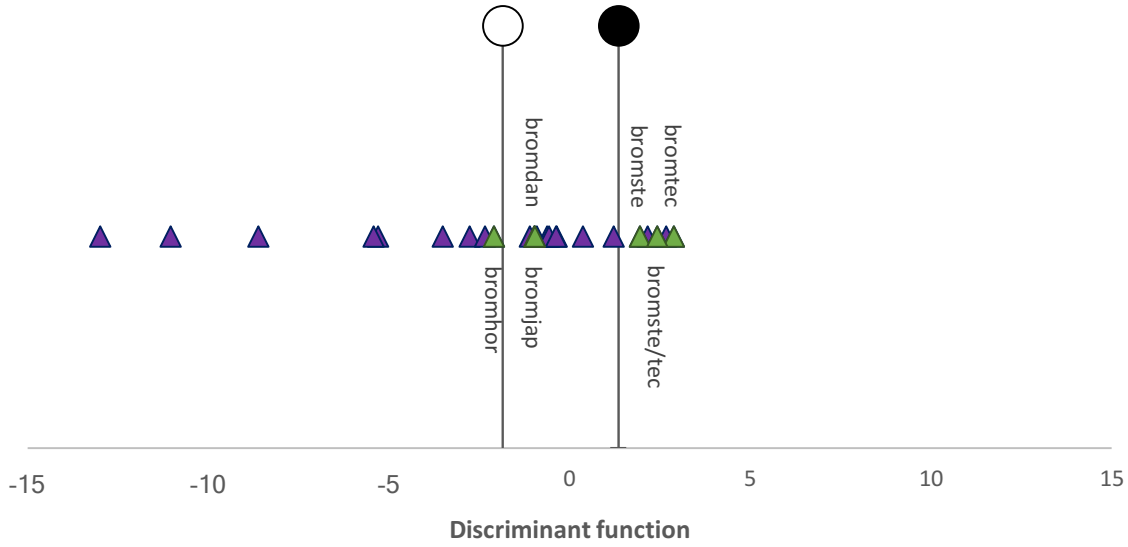


Figure 8.8 – Ecological signatures for the different *Bromus* species identified from the four sites (green), compared with the full ecological distribution for *Bromus* (purple).

When comparing the identified *Bromus* species to the full ecological distribution for this genus (Figure 8.8), the archaeological specimens reflect the higher input end of the scale (above, Chapter 6). Upon closer inspection, there appears to be two distinct clusters of species; *Bromus tectorum* and *Bromus sterilis* are at the highest end of the input scale, and *Bromus danthoniae*, *Bromus japonicus* and *Bromus hordeaceus* are grouped together around the 'extensive' lower input group centroid. These refined identifications were incorporated with the other species level data to establish the final ecological signature for each selected sample. Decisions made for the identification of a range of other weed taxa are detailed separately in the Identification catalogue.

8.2.4 Aspects for future work

The development of this identification key has been a highly instructive tool for the identification of archaeological *Bromus* specimens from Syria and Turkey. Nevertheless, there remains a lot of work to make the key more widely accessible, such as the inclusion

of additional species for use across broader geographic regions. Successful use of the key also requires a certain amount of expertise that is difficult to express within user instructions. The puffing up of *Bromus* seeds from charring generates some of the greatest pit-falls as it has the potential to distort several features at a time. While features affected by puffing were excluded during the identification process for this project, such distortions may be missed by unfamiliar users. Furthermore, while the multi-access format of the key is straightforward to use, there is currently no way of weighting the most important features within the scoring system (e.g. Narrowness L:B x 10 ratio). Future versions of the key will need to be tweaked further to account for such issues. The incorporation of further accession data (ideally up to 20 specimens) would also greatly improve the reliability of the key.

Chapter 9

Results

This chapter presents an overview of the compositions for each of the selected samples. Where specified, these samples are related to their specific archaeological contexts within each of the four study sites. The results of the statistical analyses are also presented: this includes correspondence analysis and two forms of crop-processing analysis, which were used to isolate the relevant weed flora for the final weed analysis. The final part of this chapter presents the results for the functional ecological analysis, where cultivation intensity will be explored.

9.1 Overview of assemblage: Çatalhöyük

9.1.1 General summary

A total of 33 storage samples reached the minimum criteria for analysis (above, 5.3.1) (Appendix 1f), which derived from 25 separate excavation units and seven different burnt buildings (Table 9.1). These buildings span across four different excavation areas, and represent four separate phases of the mound from the mid to later levels (Table 9.2). The majority of these samples, however, were located within three particularly well-preserved burnt buildings in the North area, from phase North G (20/33).

All of the samples examined were preserved *in situ* by charring, but a small number of silicified and mineralised remains were also present in some of the samples. The few silicified exceptions include hackberry (*Celtis*) stones, seeds of the Boraginaceae family, and *Lemna,* an aquatic genus from the duckweed family; these are naturally

siliceous/calcareous. *Bolboschoenus glaucus* was the only species that occurred in a mineralised form and this was present in one instance (Fl.6052). There was also only one occurrence of material recovered in phytolith form: 'new type' glume bases in one sample (Fl.10922) from a storage area of particularly exceptional phytolith preservation in the TPC area, where spikelets had been reduced to ash.

The density of archaeobotanical items per litre is highly variable across the selected storage samples, ranging from ten to 25,705 items per litre (excluding *Descurania sophia*[1]). Two-thirds (21/33) of the storage samples' densities fall above the site average (365±1204 items per litre (319 samples[2]) excluding *D. sophia*) (Bogaard *et al.* 2013a). Some of the variation in storage densities can be explained by the different types of flotation sample taken from the site; while some of the flotation samples were targeted to extract concentrated seed clusters, others were taken to collect the remainder of a unit as part of the routine bulk samples (30 litres per unit). Variation in sample volume across the selected samples is quite considerable, ranging from 0.35 to 148 litres. However, the observed differences in seed densities are also a reflection of the different types of storage sample observed at the site, e.g. residual storage versus seed clusters (below, 9.1.2).

9.1.1.1 Buildings and phases in analysis

While a very large number of buildings (over 100) have been excavated at Çatalhöyük, only seven of these contained primary *in situ* plant stores with sufficient weed material to include in this project; this limits the extent to which wider comparisons that can be made between the different phases of the site when considering storage deposits alone. Nevertheless, the selected samples present a unique opportunity to explore the ecological

[1] *Descurania sophia* is an abundant species of wild mustard at Çatalhöyük. Its tiny (<0.3 mm) seeds pervade in large numbers across many of the samples recovered from the site, including two thirds of the selected storage samples. While it may have been a common crop weed, this is difficult to determine due to the general 'background noise' linked to its collected, and potentially cultivated, status. For this reason, it has been removed from the following analyses so as not to skew the proportion of genuine weed taxa present in the crop stores.

[2] This site average includes 15 of the selected storage samples, which were previously examined for the Bogaard *et al.* 2013 report, as well as other crop stores that contained insufficient weed material.

Table 9.1 – Number of selected storage samples according to site area, building number and phase.

Building no.	*Level*	*No. samples*
North area		
52	North G	9
1	North G	5
77	North G	6
South area		
79	South O	2
80	South O	3
IST area		
63	South Q-T	4
TPC area		
122	Late Neolithic (South S)	4
	TOTAL	33

Table 9.2 – Current understanding of the relationship between levels in the South, North and TPC Areas (Hodder 2014; Bogaard *et al.* 2017; Çatalhöyük Research Project phasing, autumn 2017).

Mellaart	South	North	TPC
0, I, II, III	TP 6 levels		B109 & B.115
	T	J	B.110 & B.150
	S	J	B.150 & B. 122
	R	I	
	Q	H, I	
	P	H	
VIA	O	G	
VIB	N	G	
VII	M	G	
VIII	L	F	
IX	K	F	
X	J		
XI	I		
XII	H		
Pre XII	G		

signatures of plant stores in well-documented contexts, with many of the samples deriving from three roughly contemporaneous buildings in a 'neighbourhood' of the North area. A number of different storage clusters was also recovered from two adjacent buildings in the South area from an approximately contemporary level. Furthermore, the selected storage deposits enable ecological signatures of different crop types to be examined across four different phases of the mound.

9.1.2 Storage types

All of the deposits selected for this analysis were from primary *in situ* contexts from burnt buildings, but several factors needed to be studied to confirm these as 'storage contexts'. A consideration needed to be made of their individual context types and relationships (i.e. containment within built storage features), as well as their sample composition (i.e. grain-rich). Five separate categories of crop storage were identified from the samples, which reflect a variety of deposit types, sample volumes and overall seed densities (Table 9.3). These observations demonstrate the inadequacies associated with the sole use of minimum grain thresholds to identify storage contexts, as they do not account for less dense residual storage signatures that form a large proportion of the crop stores. The primary characteristics used to distinguish samples as 'storage' were a high proportion of grains/pulses compared with chaff and wild taxa, and close spatial relationships with formalised built storage facilities (above, 4.2). The five different categories of storage identified will now be outlined.

9.1.2.1 Storage type 1: Preserved within bin

This first category concerns homogeneous crop stores that were contained within the boundaries of formalised built storage features and were recovered in very large concentrations. The cut-off point for this purest form of storage was set at a minimum of 10,000 crop items for the total sample, concentrated to at least 1,000 items per litre, and

composed of over 95% grain. The four samples that met these criteria represented instances where built bin features were still partially full at the time of the burning event. These were the clearest indications of storage at the site and were very clean in sample composition, each consisting of one dominant crop—in these cases, naked barley— with limited wild taxa or chaff material. Sample Fl.10921 from Building 122, was particularly exceptional in extent, containing over 120,000 naked barley grains, which is equivalent to 4kg of grain in terms of fresh weight (Figure 9.1) (Ergun *et al.* in Özbaşaran *et al.* 2014: 657).



Figure 9.1 – Storage type 1: bin F.7182 from Building 122, an example of *in situ* naked barley grain storage preserved within a built bin feature.



Figure 9.2 – Storage type 2: separate clusters of peas (u.11911) within built storage bin F.2004, Building 52 (Çatalhöyük Online database).

Table 9.3 - Selected storage samples from Çatalhöyük by their identified storage type, including further information regarding their total number of crop items (100% of sample), densities per litre, and crop/grain/wild taxa percentages. All totals and percentages exclude *Descurania sophia* (see footnote 1) and fruit/nut taxa.

Storage type	Flot no.	Unit no.	Feature no.	Building no.	Total crop items	Density crop items/ litre	% crop	% grain	% wild/ weed
1 - Preserved within bin									
	10921	30859	7182	122	128,130	25,626	99.7	99.6	0.3
	144	1344	215	1	87,562	2,085	99.6	99.5	0.4
	10961	30871	7198	122	83,968	10,496	99.3	99.0	0.7
	8048, 8049, 8205	13962	1967	63	13,010	1,446	97.7	97.0	2.3
2 - Preserved in bin - cluster									
	6050	11911	2004	52	9,222	1,537	53.9	30.1	46.1
	6019	11900	2002	52	6,194	364	98.8	95.3	1.2
	6052	11903	2002	52	5,671	247	99.7	99.2	0.3
	6049	11908	2002	52	4,256	1,270	98.5	98.4	1.5
	6070	11911	2004	52	2,183	2,183	52.8	21.7	47.2
	6059	11908	2002	52	2,046	341	97.5	97.5	2.5
	6051	11911	2004	52	1,207	805	84.1	13.1	15.9
	6056	11911	2004	52	462	924	89.0	30.8	11.0
3 - Residual storage in bin									
	7906	13919	2330	63	7,964	996	89.5	87.9	10.5
	11922	22709	7198	122	5,422	361	89.1	33.4	10.9
	535	1442	34	1	3,220	22	88.9	21.1	11.1
	6638	11866	1967	63	1,656	414	94.4	94.2	5.6
	516	1442	34	1	1,182	21	87.3	47.0	12.7
	9176	18596	5031	79	837	70	32.8	26.7	67.2

Storage type	Flot no.	Unit no.	Feature no.	Building no.	Total crop items	Density crop items/ litre	% crop	% grain	% wild/ weed
3 - Residual storage in bin									
(continued)	9159	18598	5031	79	770	385	38.8	38.8	61.2
	6594, 6641	12417	1984	63	466	8	80.3	74.7	19.7
	171.329	1314	215	1	463	9	86.2	72.8	13.8
	135	1349	27	1	204	24	68.0	36.0	32.0
4 - Seed cluster									
	10922	30785	-	122	40,911	8,182	99.5	94.6	0.5
	8413	16480	-	77	10,642	484	99.9	60.7	0.1
	9256	18945	-	80	4,044	1,011	95.8	91.8	4.2
	6026	10309	-	52	3,200	5,333	97.3	96.8	2.7
	8415	16480	-	77	2,233	558	99.4	48.5	0.6
	8416	16480	-	77	1,381	1,381	90.7	20.4	9.3
	9271	18952	-	80	1,234	88	86.2	77.0	13.8
	9255	18949	-	80	336	168	79.1	45.6	20.9
5 - Prepared food									
	8486	16498	-	77	23,889	281	97.4	91.2	2.6
	8614	17519	-	77	2,167	361	91.6	57.8	8.4
	8505	16498	-	77	414	1,183	95.9	92.2	4.1

9.1.2.2 Storage type 2: Preserved in bin - cluster

This second storage type similarly features *in situ* grain deposits contained within formalised storage features (Figure 9.2), but were instead identified and excavated as small distinct seed clusters by excavators. While some samples were almost as rich in crop items as the first storage type with a maximum of 9,222 crop items, the samples included in this category were more variable in their number of crop items and density. Rather than having a minimum threshold, the samples in this group were mainly distinguished by their contextual associations with other deposits and positioning within their associated built structure. These included multiple discrete samples (sometimes of the same unit) taken from the internal space of a single storage feature, which represent the division of different crop types or alternatively separate collection events of the same crop type; these clusters are most likely linked to the use of perishable materials to partition formal storage space, such as the use of material bags or wooden containers that did not survive the burning event. Samples of the same unit that fall in this category therefore need to be treated separately when considering their ecological signatures without being amalgamated. This type of storage was only observed within the storage bins of Space 93 in Building 52, including examples of both mixed crop storage and stores of the same crop type in discrete clusters (Bogaard *et al.* 2013a).

9.1.2.3 Storage type 3: Residual storage in bin

This third category of crop stores to be identified from the inside of formalised storage features distinguishes the more limited basal deposits recovered from largely empty built 'bin' features. This was the most common storage type observed and represents around a third of the samples identified (10/33). These deposits denote the residues of previous stores that were either almost all used up or deliberately emptied before the burning event. While this category had some of the lowest density of crop items per litre (6 samples below 100 items), this may be partially a reflection of the greater soil volumes generally taken for this sample type (average of 21±21 litres compared with an average of

9.5±14 litres for all storage types); a standard 30 litre sample was taken from units with no visible concentrations. These samples were not as easily recognisable as concentrated seed lenses, but their frequent instances of grain and primary contextual associations confirms their status as storage.

9.1.2.4 Storage type 4: Seed cluster

This fourth storage type recognises isolated concentrations of grain-rich deposits excavated separately from formalised bin features, but which were located near formalised storage facilities or within side room areas (Figure 9.3). Such clusters were generally recovered in small volumes (average of 3±2 litres) but were high in seed density, distinguishing them as likely storage contexts. These deposits may represent storage that was hung from the ceiling and collapsed during burning events, or smaller-scale moveable storage that was kept inside baskets or wooden containers (Bogaard *et al.* 2013a).



Figure 9.3 – Storage type 4: clusters of 'new type' glume wheat (u.16480) in Building 7 (Photographs by Jason Quinlan) (House 2014: 499).

9.1.2.5 Storage type 5: Prepared food

The fifth and final storage category to be identified was 'prepared food'. This category includes two unusual seed cluster units (u.16498, u.17519) that were located within the main room of Building 77 (Bogaard *et al.* 2013a). Both units contained a mixture of pea

and barley, as well as fused clumps of fish remains that suggest their status as prepared foods. While it may be debated whether this context type should be treated alongside storage in this analysis, the grain-rich composition of these samples and inclusion of likely crop weeds present an equally useful example for investigating ecological signatures.

9.1.2.6 Distribution of storage types by building

When considering the distribution of these different storage types among the seven buildings (Table 9.3) there are relatively few broader trends, with each building seeming to have its own scenario for the types of storage deposits that were preserved. Residual bin stores, the most common storage type, were recovered from each of the four areas though not from every building. Building 52 stands out as the only example with such highly partitioned bin stores, with eight of its nine deposits identified as distinct clusters contained within two storage features. Two of the seven buildings (B. 77, B. 80) only contained stores in the form of uncontained seed clusters, despite having built storage facilities available; Building 77 contains the largest bin complex yet identified from the site, but these appear to have been emptied before the burning event (Bogaard *et al.* 2013a: 121; Green *et al.* in Demirergi *et al.* 2014). Additionally, while Fl.9256 was actually recovered from the inside of bin F.3435 in Building 80, the excavators interpreted the deposit as a fallen cluster rather than original bin contents (Regan in Hodder 2010: 17). The greatest variation of storage types was found in Building 122, which were also of the same dominant crop type (naked barley); this group of three storage types provide the best opportunity to explore differences in weed representation among potentially separate harvesting events.

9.1.3 Summary of crop types

In addition to the variety of storage types observed, a range of different crop species were stored among the selected deposits (Table 9.4; Figure 9.7). These include naked barley, glume wheat (hulled wheat), free-threshing wheat, pea and lentil. The most prevalent crop

stores within the study were those dominated by naked barley (13/33). Stores of barley tended to be the purest in composition, with minimal chaff and weed material; more than half of these samples (8/13) consisted of over 80% naked barley grain. It is likely that these naked barley stores consisted mainly of the two-row variety (*Hordeum vulgare* convar. *distichon* var. *nudum*), as there were only very rare instances of twisted grains (1% of classified naked barley grains) indicative of the six-row form. A slightly higher percentage of six-row chaff was recognised (11.5% of fully identified specimens) amongst the identified naked barley chaff in the stores, but these counts were relatively minimal (6/42 identified chaff specimens) with the two-row form continuing to dominate.

The second most common crop stores were storage deposits that predominantly consisted of glume wheat (8/33). Three of these samples represented almost pure concentrations of glume wheat (over 90%), while the remaining samples were more mixed in composition and were accompanied by smaller quantities of other cereals, such as free-threshing wheat and naked barley (Figure 9.5). The three purer glume wheat samples from Building 77 contained relatively high quantities of chaff material, with one sample (Fl.8416) containing as much as 70% chaff. This chaff-rich sample was determined as a storage cluster due to its direct relationship with the two more grain-rich samples of the same unit

Table 9.4 – Number of selected storage samples per main grain type.

Main grain type	No. samples
Naked barley	13
Glume wheat	8
Pea	7
Free-threshing wheat	3
Lentil	1
Naked barley/ pea	1
Total	33

Table 9.5 – Dominant crop composition of the selected storage samples at Çatalhöyük (excluding *Descurania sophia* (see footnote 1) and fruit/nut). The two dominant classes are determined by an arbitrary threshold of ≥70%, while the main grain type reflects the most abundant grain within the sample. Indeterminate grain identifications (i.e. cereal indet., wheat indet.) have been proportionally reassigned based on confirmed identifications to determine the main grain type.

	Full sample					Grain only						
Flot number	Crop %	Wild/ weed %	Grain %	Dominant class	Dominant crop class	Barley %	Free-threshing wheat %	Glume wheat %	Wheat indet. %	Cereal indet. %	Pulse %	Main grain type
10921	99.7	0.3	99.6	Crop	Barley	100.0	0.0	0.0	0.0	0.0	0.0	**Barley**
6052	99.7	0.3	99.2	Crop	Barley	98.3	1.7	0.0	0.0	0.0	0.0	**Barley**
10922	99.5	0.5	94.6	Crop	Barley	97.8	0.0	2.2	0.0	0.0	0.0	**Barley**
10961	99.3	0.7	99.0	Crop	Barley	99.8	0.0	0.2	0.0	0.0	0.0	**Barley**
6019	98.8	1.2	95.3	Crop	Barley	99.8	0.0	0.0	0.1	0.0	0.1	**Barley**
8048/8049/8205	97.7	2.3	97.0	Crop	Barley	86.7	0.0	0.2	0.2	12.6	0.2	**Barley**
9256	95.8	4.2	91.8	Crop	Barley	97.8	0.0	0.1	0.0	0.0	2.1	**Barley**
6638	94.4	5.6	94.2	Crop	Barley	95.8	0.0	0.0	2.9	1.0	0.2	**Barley**
7906	89.5	10.5	87.9	Crop	Barley	74.5	2.4	0.1	2.1	20.8	0.1	**Barley**
11922	89.1	10.9	33.4	Crop	Mixed	88.3	0.0	9.4	0.8	0.8	0.6	**Barley**
535	88.9	11.1	21.1	Crop	Glume wheat	53.4	0.5	5.2	4.7	33.0	3.1	**Barley**
516	87.3	12.7	47.0	Crop	Mixed	64.2	5.3	5.3	6.9	13.8	4.4	**Barley**
6594/6641	80.3	19.7	74.7	Crop	Barley	86.4	0.9	0.9	3.2	3.6	5.0	**Barley**
8413	99.9	0.1	60.7	Crop	Glume wheat	0.0	0.0	99.0	1.0	0.0	0.0	**Glume wheat**
8415	99.4	0.6	48.5	Crop	Glume wheat	0.0	0.0	99.4	0.2	0.0	0.4	**Glume wheat**
8416	90.7	9.3	20.4	Crop	Glume wheat	0.0	0.0	92.9	7.1	0.0	0.0	**Glume wheat**

	Full sample					Grain only						
Flot number	Crop %	Wild/ weed %	Grain %	Dominant class	Dominant crop class	Barley %	Free-threshing wheat %	Glume wheat %	Wheat indet. %	Cereal indet. %	Pulse %	Main grain type
171/329	86.2	13.8	72.8	Crop	Mixed	3.1	3.1	6.1	7.4	62.9	17.4	**Glume wheat**
9255	79.1	20.9	45.6	Crop	Mixed	1.0	7.7	29.4	61.9	0.0	0.0	**Glume wheat**
135	68.0	32.0	36.0	Mixed	Mixed	5.6	13.0	18.5	11.1	46.3	5.6	**Glume wheat**
9159	38.8	61.2	38.8	Mixed	Mixed	0.1	5.5	39.1	55.3	0.0	0.0	**Glume wheat**
9176	32.8	67.2	26.7	Mixed	Mixed	1.2	3.7	23.3	68.5	2.9	0.4	**Glume wheat**
8486	97.4	2.6	91.2	Crop	Pea	10.5	0.1	0.2	0.1	0.0	89.0	**Pea**
8505	95.9	4.1	92.2	Crop	Pea	7.0	0.0	0.0	0.0	0.0	93.0	**Pea**
6056	89.0	11.0	30.8	Crop	Mixed	5.6	0.0	5.0	0.0	1.9	87.5	**Pea**
9271	86.2	13.8	77.0	Crop	Pea	1.5	0.0	3.3	1.1	1.5	92.7	**Pea**
6051	84.1	15.9	13.1	Crop	Glume wheat	5.9	0.0	4.8	4.8	0.0	84.6	**Pea**
6050	53.9	46.1	30.1	Mixed	Mixed	0.9	0.0	0.6	0.1	0.3	98.1	**Pea**
6070	52.8	47.2	21.7	Mixed	Mixed	0.9	0.0	4.0	0.9	0.0	94.2	**Pea**
6049	98.5	1.5	98.4	Crop	FT wheat	0.0	54.1	0.0	45.9	0.0	0.0	**FT wheat**
6059	97.5	2.5	97.5	Crop	FT wheat	4.7	95.3	0.0	0.0	0.0	0.0	**FT wheat**
6026	97.3	2.7	96.8	Crop	FT wheat	2.0	53.8	0.0	37.4	6.3	0.5	**FT wheat**
144	99.6	0.4	99.5	Crop	Lentil	0.0	0.0	0.0	0.0	0.0	100.0	**Lentil**
8614	91.6	8.4	57.8	Crop	Mixed	48.7	0.0	0.0	0.0	1.8	49.5	**Barley/Pea**
AVERAGE	86.6	13.4	66.4									

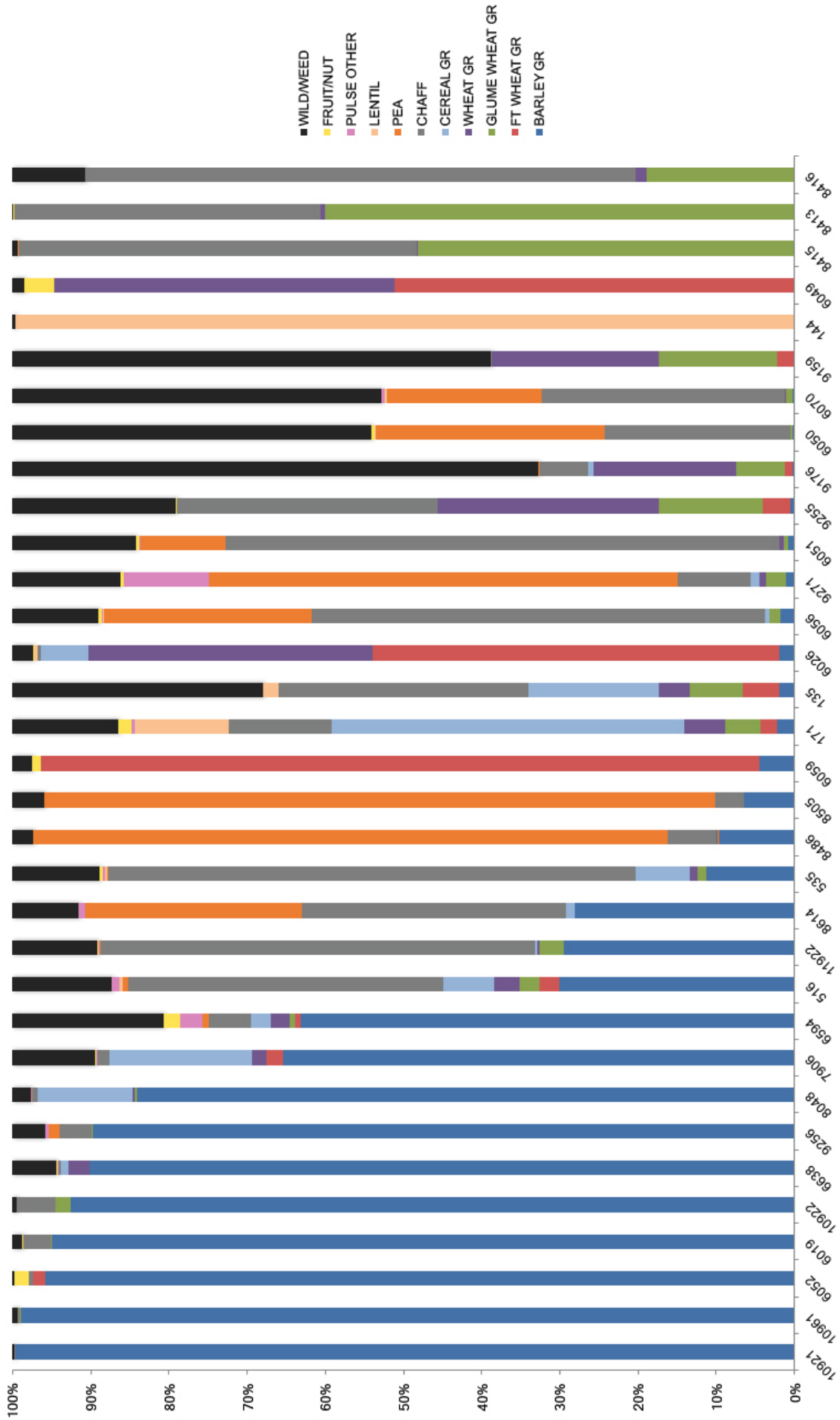


Figure 9.4 – Species composition of selected storage samples at Çatalhöyük, with crop types based on the grain/seed component. Chaff, wild/weed, and fruit/nut are indicated separately.

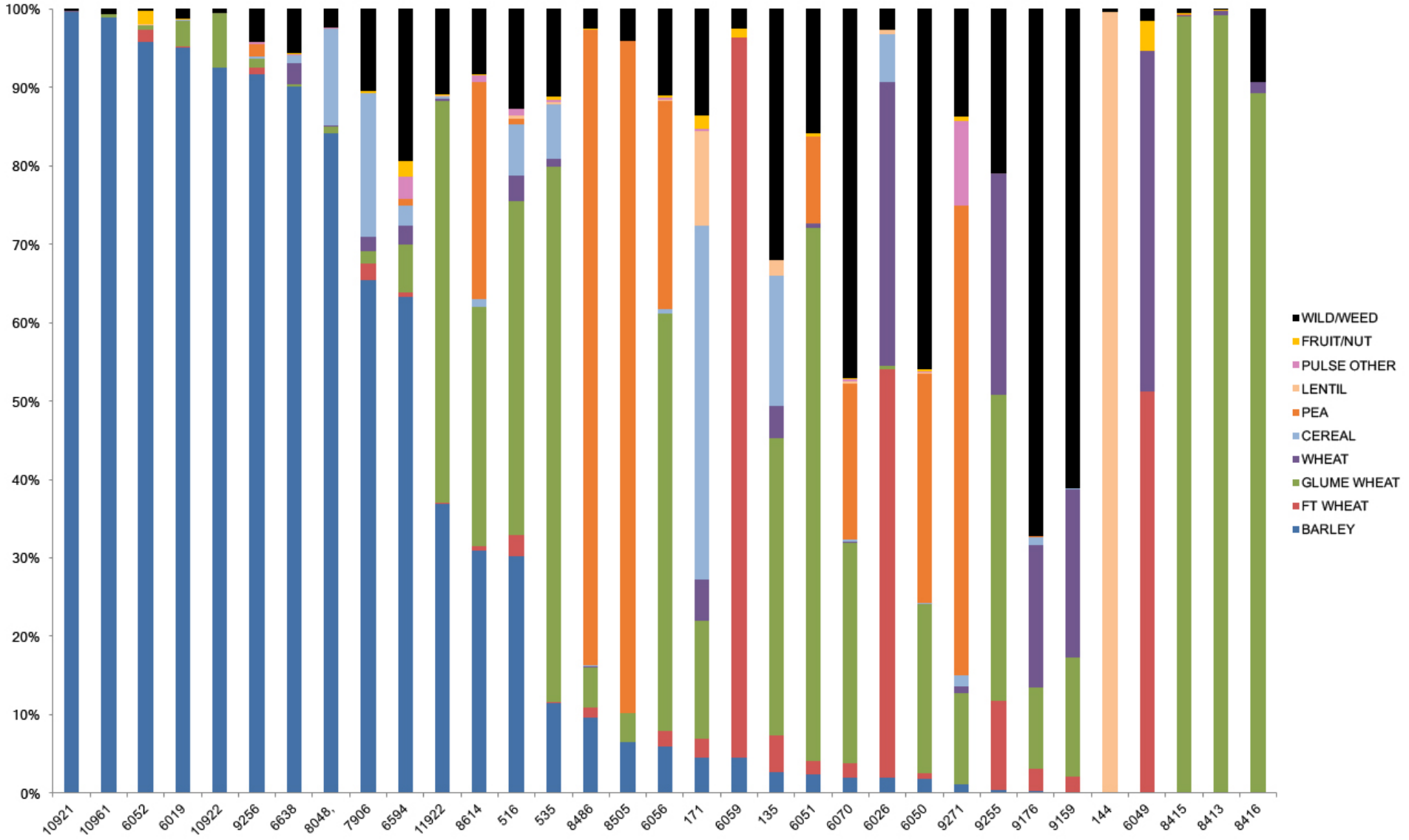


Figure 9.5 – Species composition of selected storage samples at Çatalhöyük, with crop types based on both grain/seed and chaff. Proportions of of wild/weed and fruit/nut are also indicated.

(u.16480: Fl.8413 and Fl.8415), as well as its contextual association beside a storage bin complex. The large quantities of chaff material in these samples relate to the storage of wheat grains in their spikelets; direct evidence for this was recovered from Fl.8413 (Figure 9.6). The slightly higher proportion of chaff in Fl.8416 may indicate that the unit was in the process of being dehusked (Bogaard *et al.* 2013a: 120). This sample also contained a greater proportion of wild/weed taxa than the rest of the unit, perhaps relating to the concentration of sieved by-product from processing. Unit 16480 therefore provides a useful trio of samples to directly test the effect of crop-processing on ecological signatures. The glume wheat grain identified from these three samples was of the 'new type' variety (*Triticum sp*.), with trace instances of einkorn and emmer, but the majority (90%) of the glume wheat identifications remained indeterminate. The chaff material was identified much further, with 88% identified as 'new type' and 11% attributable to einkorn/emmer.

While glume wheat was identified as the more dominant type of wheat among the five mixed wheat samples (between 78–89% of identified wheat), the proportion of free-threshing wheat is likely to be underrepresented owing to the more easily recognisable identification characteristics of glume wheat compared with free-threshing wheat (e.g.



Figure 9.6 – Glume wheat spikelets embedded in collapsed bin wall fragments (u.16480) (Bogaard *et al.* 2013a: Fig. 9.27).

glume lines, elongated shape). Furthermore, the poor preservation of grains in some of the samples (particularly in Fl.171/329 and Fl.135) limited the identification of many grains beyond wheat or cereal indeterminate. Of those that were identifiable within these mixtures, the predominant species of glume wheat (96.6%) was emmer grain (*Triticum dicoccum*), with only limited amounts of 'new type' wheat (1.9%) and einkorn (*Triticum monococcum*) (1.5%) recovered. The free-threshing wheat at the site cannot be identified to species based on the grain alone, but the presence of small amounts of rachis material within three of the samples (Fl.9176, Fl.9255, Fl.171/329) indicates that it was of the bread wheat type (*Triticum aestivum*). The level of non-crop contaminants was quite variable among the mixed samples, with some samples relatively grain rich (Fl.171.329 – 73% grain), while others contained substantial amounts of wild/weed material. Two samples from Building 80 (Fl.9176 and Fl.9159) each contained over 1,000 counts of the wild taxon *Helianthemum* (9.3); concentrations of this genus were discovered in Mellaart's earlier excavations and is thought to have been intentionally collected (Fairbairn *et al.* 2007).

The next most abundant crop stores within the selected samples were those dominated by peas (*Pisum sativum*) (7/33). Like glume wheat, these stores were frequently contaminated by other crop types and sometimes contained significant proportions of wild/weed taxa; only three of the samples contained over 70% pea when considering all crop material. The most common crop contaminant was glume wheat chaff, most notably of the einkorn/emmer type (65.8% of identified chaff). There was also a small amount of naked barley grain in each of the pea samples, ranging from 0.2–10%. These frequent contaminants, plus the occasional presence of pea pod material (Fl.9271), suggest that peas tended to be stored in a semi-clean state (without fine-sieving) at Çatalhöyük and were also likely to share processing/storage areas with other crop types (Bogaard *et al.* 2013a: 114). The processing stages for each of the crop stores will be discussed in greater detail below (9.3).

Three of the selected crop stores were predominantly composed of free-threshing wheat. These samples were very pure in composition with an average of 93±5% free-threshing wheat grain (when indeterminate wheat grain is classified as free-threshing wheat[3]). The limited crop contaminants include small quantities of naked barley grain, as well as trace amounts of glume wheat chaff, pea, and lentil. As with the mixed free-threshing and glume wheat deposits, identification of the wheat to species was not possible from the grains, and in these instances, there was no identified chaff material to confirm the type of free-threshing wheat. Nevertheless, the pattern across the site as a whole suggests that it is of the bread wheat variety (*Triticum aestivum*) (Bogaard *et al.* 2013a: 97).

The two rarest storage types to be observed were a single lentil deposit (Fl.144) from Building 1 and a mixed pea and naked barley sample (Fl.8614) from Building 77. The single lentil (*Lens culinaris*) store to be included within this analysis, which was the only significant lentil concentration from the Hodder excavations (Bogaard *et al.* 2013a), was extremely pure in composition, consisting of 99.4% lentil seed. The few crop contaminants within the sample included one-off grains of barley, one-seeded einkorn and einkorn/emmer, a few indeterminate wheat grains and a limited amount of barley and glume wheat chaff. There were also small amounts of lentil stalk (0.06%) recovered from the deposit, but there was no larger pod material such as was found in some of the pea stores.

The final mixed pea and barley sample represents one of the three identified 'prepared food' samples, indicated by the inclusion of fused fish remains and wild mustard, as well as fused botanical remains (Bogaard *et al.* 2013a: 121). While the other two samples in this category were dominated by peas with a small proportion of barley, Fl.8614 was evenly split between the two crop types for the grain part of the sample. A third of the full crop component consisted of a further mixture of barley and glume wheat chaff and there was a relatively small proportion (8%) of wild/weed taxa. The limited amount of naked barley

[3] Poor preservation of cereal grains often limits their identification beyond the genus level due to lacking or ambiguous features (i.e. glume lines, grain form), but in samples containing one dominant species the indeterminate grain can often be proportionally reassigned for analytical purposes.

chaff indicates the presence of both the two and six row varieties, but no twisted grains were identified from the sample. The glume wheat chaff contaminants consisted of a mixture between emmer and einkorn wheat.

9.1.3.1 Comparison with general site signature

It must be noted that the abundance of crop types observed within the storage assemblage do not directly reflect the full spectrum and distributions of crop types across the site as a whole, and instead merely represent the stores that were present during instances of burning that also contained enough wild/weed material to be analysed. The most ubiquitous crop type to be observed across all analysed samples from the 2000-2008 seasons is glume wheat rather than barley, and occurs within 88% of samples; this is largely due to extensive evidence for the storage and dehusking of wheat spikelets on-site (i.e. glume bases) (Bogaard *et al.* 2013a: 95). Nevertheless, some similarities remain, with naked barley continuing to be one of the dominant crops across the site as a whole, appearing in 70% of the samples (Bogaard *et al.* 2013a: 95). Free-threshing wheat and pea also occurred relatively frequently within the wider samples, occurring in 57% and 34% of the samples respectively (Bogaard *et al.* 2013a: 95-7). The single store of lentil also similarly mirrors the slightly rarer distribution of lentil at the site, which occurs in only 18% of the analysed samples (Bogaard *et al.* 2013a: 97).

Some of the crop species that occur at Çatalhöyük were not represented as primary concentrated storage deposits; despite appearing in 14% of the 2000-2008 samples, there were no stores of bitter vetch (*Vicia ervilia*) identified from the recent excavations at the site, though it did occur in trace amounts within six of the selected stores (Bogaard *et al.* 2013a: 97). There is some mention of bitter vetch stores that were identified during the earlier excavations by Mellaart in the 1960s, but these were not available for analysis (Helbaek 1964: 122; Fairbairn *et al.* 2005: 139). There were also no large concentrations of chickpea (*Cicer arietinum*) recovered; this reflects the trend across the site more generally, with it only occurring in a minority (5%) of samples in small numbers (Bogaard

et al. 2013a: 97). This is similarly the case for the rare distribution (3%) of the hulled variety of barley (*Hordeum vulgare*) across the site, for which there were only limited quantities detected from three of the storage deposits; this distribution is largely connected with chronological trends (see below) (Bogaard *et al.* 2013a: 97; 2017). When considering the individual species of glume wheat, both 'new type' and einkorn wheat are underrepresented by the identified storage deposits. While the glume bases of 'new type' glume wheat are dominant across the wider site samples (59%), there were only three storage samples of 'new type' grain identified, which originated from one building (B.77) (Bogaard *et al.* 2013a: 96). Equally, no dominant stores of einkorn grain were identified from the recent excavations despite appearing in 28% of recently excavated samples; however, two likely stores of einkorn were recognised from the earlier Mellaart excavations (Bogaard *et al.* 2013a: 97; 2017: 12).

It must also be noted that a number of storage deposits dominated by collected wild plants were also recognised alongside the crop stores from within Building 52; these included over 30 litres of wild mustard (*Descurania sophia*) (u.11956) that filled bin F.2005, as well as a cluster of wild almonds (*Amygdalus*) (u.11906) within bin F.2002 (Bogaard *et al.* 2013a: 117). While wild mustard may have been 'cultivated' at the site (cf. Fairbairn *et al.* 2007), this study only concerns the ecological signatures of established cultivar species, such as cereals and pulses, so these storage types were not included within the analysis.

When considering the wider temporal trends of different crop ubiquities at Çatalhöyük, the storage samples seem to reflect the general patterns observed from their specific phases. A recent study compiled data from 630 samples from both the East and West Mounds; these spanned from phases South G to South T, and North F to North I in the East Mound (Table 9.2), and included 125 samples from the Chalcolithic period in the West Mound (Bogaard *et al.* 2017). There are two main site wide trends concerning the dominance of barley varieties from the early to late phases. Naked barley is the dominant form throughout the East Mound sequence, but the hulled variety begins to emerge in small proportions in the later phases (South Q-T), before becoming the dominant barley

type in the West Mound (Bogaard *et al.* 2017). A second observation is the shift from a dominance of six-row barley in the earliest phases (South G-J/ North F-G) to an almost total replacement by two-row barley by the mid to late phases (South M-T/ North H-I) (Bogaard *et al.* 2017). The phases included in this analysis lie in the mid to late stages of these changes (Table 9.1). Building 63 is phased roughly to South Q-T, which mirrors the levels where hulled barley begins to appear. Such changes can be partially detected within two of the storage deposits with limited numbers (10–14 grains) of hulled barley recovered amongst naked barley stores Fl.6638 and Fl.6594/6641. The only other sample to include traces of hulled barley was Fl.11922 from Building 122, which notably is from the latest Neolithic phase excavated from the East Mound. The trend regarding the shift to two-row naked barley varieties was also consistent in the barley crop stores, with only minimal evidence for six-row types detected in the phases following phase North G.

One of the major trends to be observed from the distribution of wheat types through time—based on the ubiquity of the chaff, which is more prevalent and more easily identifiable—is a relatively abrupt shift from a predominance of emmer wheat in the earliest phases (South G-O) to a predominance of 'new type' wheat in the later phases (South P-T); a comparable shift in species dominance also occurs in the North Area, but appears to follow a slightly distinct trajectory (Bogaard *et al.* 2017). The three wheat stores derived from phase South O are consistent with this general trend, consisting of predominantly emmer mixed with free-threshing wheat, though as previously discussed the full extent of free-threshing wheat was difficult to determine due to poor levels of preservation, with much of the grain only identified to wheat indeterminate. The two mixed glume and free-threshing wheat stores from Building 1 in phase North G had similar issues with poor levels of preservation, but the most frequent wheat to be identified in these deposits was emmer wheat, with a limited level of einkorn and 'new type' wheat. The three glume wheat only stores from this level in Building 77 consisted solely of 'new type' wheat, which corresponds with the pattern of its increasing dominance from this phase onwards in the North area.

A final trend in crop shifts that has been observed across the site-wide assemblage is a shift from a reliance upon lentil in the early phases to a greater dominance of pea in the later phases (Bogaard *et al.* 2017). This change is also paired with a decreasing reliance upon bitter vetch, supplanted by lentil in phase South K (Bogaard *et al.* 2017). In the South Area, the clearest shift can be detected from South P onwards, and in the North Area, , the shift again follows a slightly separate pattern with the main change occurring in phases North H-I (Bogaard *et al.* 2017). A single pea store was recovered from the centre of these changes, from Building 80 in South O, just as pea begins to dominate in the subsequent phases. In the North Area, the selected storage samples also highlight this period of transition, with representation of both lentil and pea stores in phase North G. While the density of the lentil store was particularly substantial (approx. 43,600 lentils), discrete pea stores were more numerous, with seven pea deposits recovered from this level.

9.1.3.2 Distribution of crop types by building

While the number of storage samples selected in this analysis is skewed towards the buildings in the North Area, the different crop types are to some extent usefully distributed between the seven different buildings under investigation (Table 9.6). In four of the seven buildings, there are stores of at least three different dominant crop types available for ecological analysis. This will be particularly useful for examining the variation of ecological signatures between different crop species located within the same building. Additionally, stores of naked barley are represented across all the different areas/phases and are present within all but one of the buildings (B. 79), enabling barley signatures to be explored further among different households, as well as considering temporal trends. There are also instances where similar crop stores can be directly compared between neighbouring buildings to investigate the potential for collaboration; comparable mixtures of glume and free-threshing wheat are present in both adjacent Buildings 79 and 80 in the South Area. Further opportunities are presented by the North Area, which enables the comparison of specific crop types between different buildings of the same phase, for instance the various separate pea stores recovered from Building 52 and Building 77.

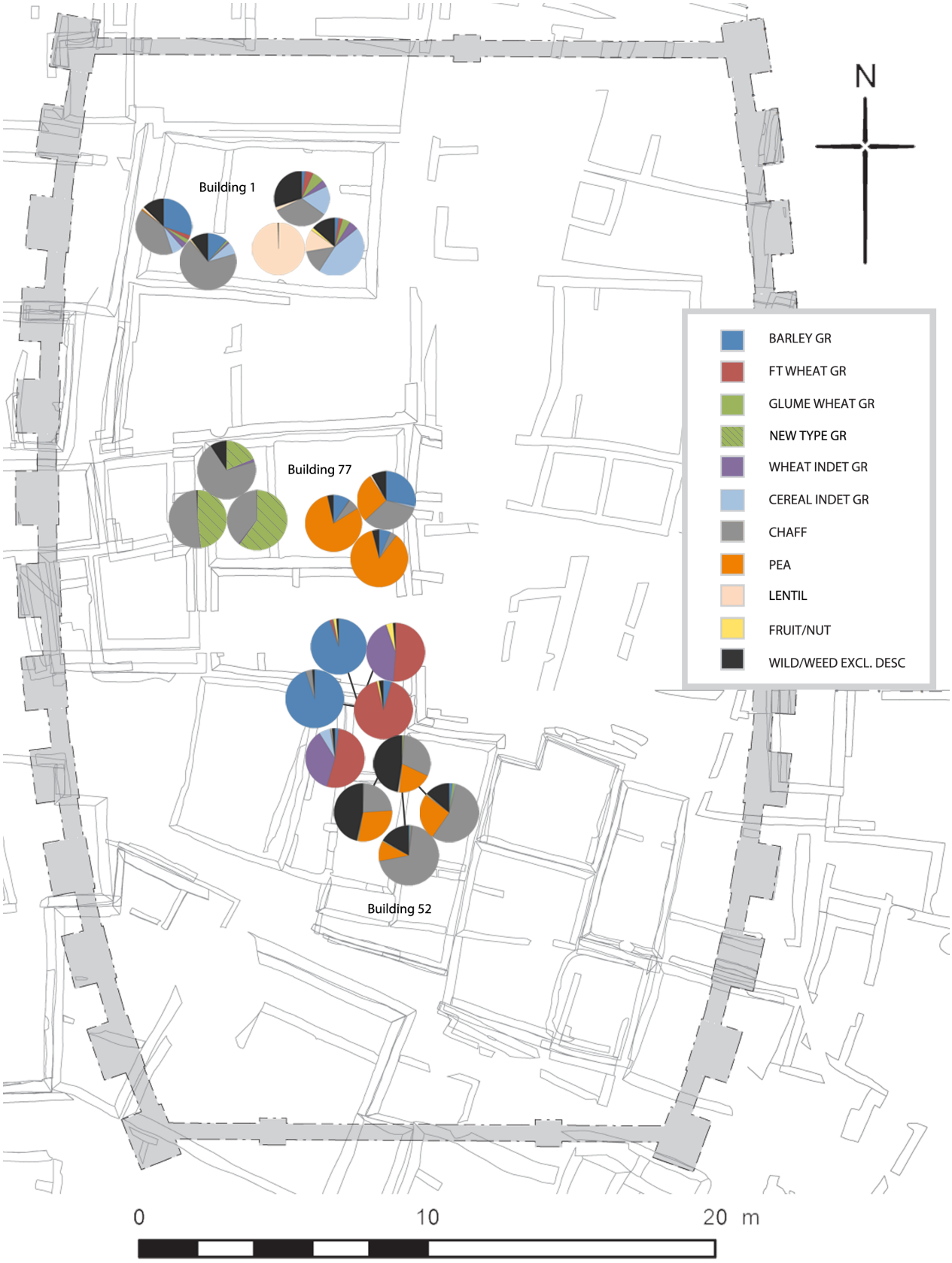


Figure 9.7 – Distribution and composition of storage samples from the North Area (Farid 2014).



Figure 9.8 – Distribution and composition of storage samples from the South Area (Farid 2014).

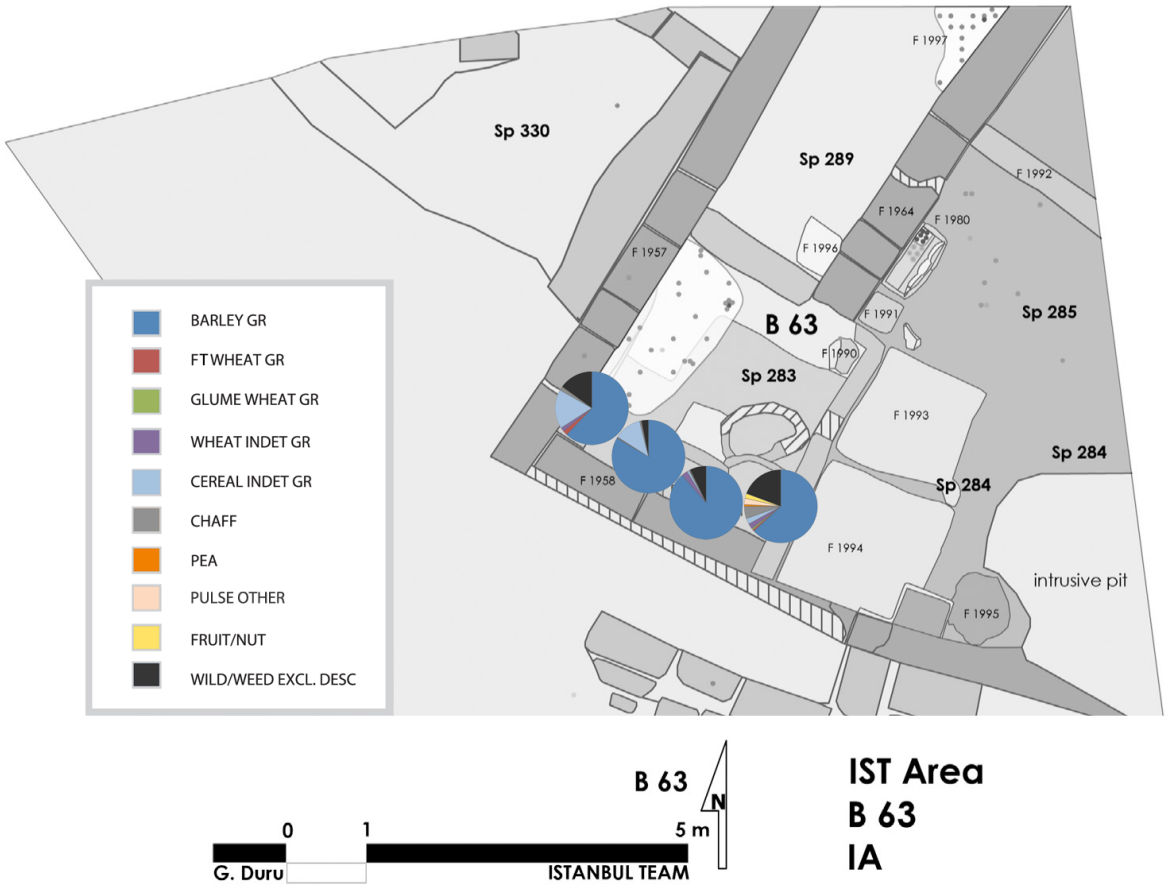


Figure 9.9 – Distribution and composition of storage samples from the IST Area (Özbaşaran *et al.* 2014).

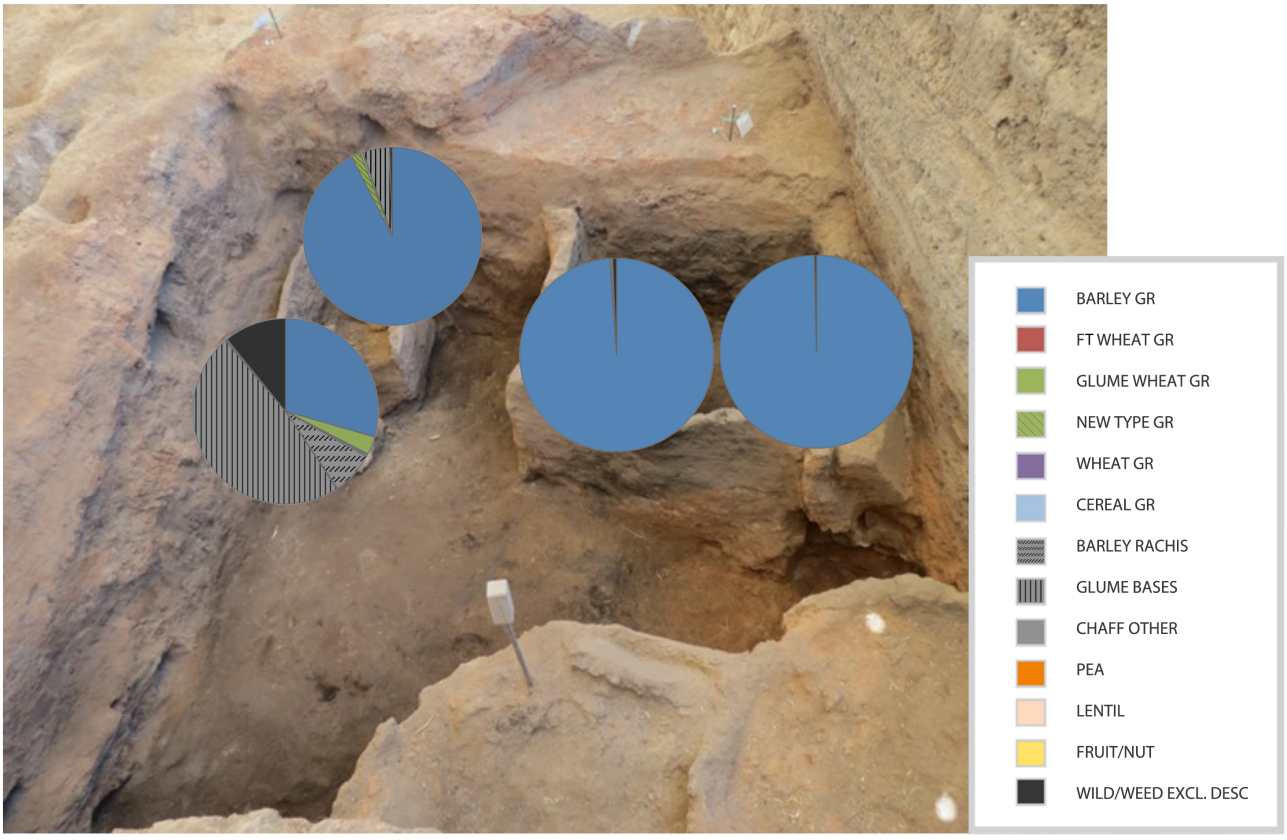


Figure 9.10 – Distribution and composition of storage samples from the TPC Area.
N.B. Full plan to follow.

Table 9.6 – Dominant crop types of selected storage samples by building.

Building no.	*Dominant crop type*	*No. samples*
North area		
1	Naked barley	2
	Glume wheat	2
	Lentil	1
52	Pea	4
	Free-threshing wheat	3
	Naked barley	2
77	Glume wheat	3
	Pea	2
	Naked barley/ pea	1
IST area		
63	Naked barley	4
South area		
79	Glume wheat	2
80	Naked barley	1
	Glume wheat	1
	Pea	1
TPC area		
122	Naked barley	4
	TOTAL	33

9.1.4 Fruit and nut taxa

A limited proportion of wild fruit and nut taxa were identified from the majority (27/33) of the selected crop stores (Table 9.7), but this did not exceed 4% of the full sample and had an insignificant average of 0.5±0.8% across the samples. The most ubiquitous genus was hackberry (*Celtis*), which occurred in 13 of the selected stores. These small nutlets have a high ubiquity (57%) across the whole site (Bogaard *et al.* 2013a: 97), but are likely

to be overrepresented due to their siliceous nature, which readily preserves without charring (above, 9.1.1). For charred fruit and nut remains, the most ubiquitous genus was *Pistacia* (10/27), some of which were identifiable to the species terebinth (*Pistacia terebinthus*). However, this collected genus was only found in limited quantities within the selected samples, with a maximum of 9.6 items identified from one of the pea stores (Fl.6050) in Building 52. This same store room contained other i*n situ* nut species; notable concentrations of wild almond (*Amygdalus*)—the most abundant of the nut/fruit taxa (Table 9.7)—were recovered from three of the studied seed clusters from Bin F.2002 (Bogaard *et al.* 2013a: 117-9). While such concentrations are of interest to discussions relating to wild plant storage, this study is primarily concerned with the storage of crops and their associated farming practices. Therefore, this collected wild category has been omitted from the sample summaries (i.e. wild/weed and crop percentages) and subsequent statistical analyses.

Table 9.7 – Fruit and nut items within the selected storage samples from Çatalhöyük.

Common name	Latin name	Family	Total items	Max	Ubiquity	
					No.	%
Hackberry	*Celtis*	Ulmaceae	49.5	14	13	39
Pistachio	*Pistacia*	Anacardiaceae	16.1	9.6	10	30
Terebinth	*Pistacia terebinthus*	Anacardiaceae	7.0	3	3	9
Almond	*Amygdalus*	Rosaceae	96.3	42.5	6	18
Almond/plum	*Amygdalus*/*Prunus*	Rosaceae	6.5	3	5	15
Acorn	*Quercus*	Fagaceae	7.6	5	4	12
Nutshell, indet.			2.4	0.8	7	21
Fruit stone/ nutshell, indet.			23.6	16	10	30
Fruit skin, indet.			2.9	1.2	4	12
		TOTAL	211.9			

9.1.5 Wild/weed taxa

While potential weed taxa are the focus of this study, wild/weed species only occur in limited numbers in most of the selected crop stores. The percentage of wild taxa within the samples ranges from 0.1 and 67% (excl. *D. sophia*), but most samples reflect the lower end of this scale with around half (16/33) containing between 2–15% wild taxa and a further nine samples representing less than 2%. The handful (4/33) of samples that contained more than 35% wild taxa included large concentrations of one or two species (e.g. *Helianthemum, Juncus*) that likely reflect either collected taxa or were derived from other sources (i.e. dung); these will need to be excluded from the ecological analyses (below, 9.3). The average proportion of wild taxa for all of the selected stores is 13±18%, which is considerably lower than the wider site average of 42±40% (Bogaard *et al.* 2013a). The smaller proportions of wild taxa in these storage contexts is likely to be a result of crop-processing methods prior to storage, such as sieving and hand cleaning, which may have removed many of the weed contaminants at an earlier stage (below, 9.4.1.4). Some of the highest proportions of wild taxa at the site more generally can be found in contexts such as external fire spots and midden layers, with their averages of 64±27% and 50±22% wild taxa, respectively; crop-processing waste is regularly discarded within these contexts and they often contain evidence for the burning of animal dung, which may contribute considerable numbers of remains of wild taxa (Bogaard *et al.* 2013a; Wallace & Charles 2013).

The ubiquity and abundance of the wild/weed assemblage was examined (Table 9.8). Fifty-three wild genera were identified from the selected storage samples that derived from 25 different plant families. Arbitrary thresholds were used to characterise the taxa into three basic ubiquity groups; taxa that occurred in over 50% of the sample were classed as frequent, those between 10-50% were classed as common, and taxa that occurred in less than 10% of the samples were classed as rare. This separated the identified genera into four frequent taxa, 15 common taxa, and 34 rare taxa (Table 9.8).

Table 9.8 – Ubiquity and abundance of the wild/weed assemblage (to genus level) within the selected samples from Çatalhöyük. Max no. refers to the maximum number of items within a single sample.

		Ubiquity		Abundance	
Genus	**Family**	**n**	**%**	**Total items**	**Max no.**
		Frequent			
Polygonum	Polygonaceae	25	76	288	55
Bolboschoenus	Cyperaceae	22	67	194	32
Vaccaria	Caryophyllaceae	19	58	518	179
Convolvulus	Convolvulaceae	17	52	191	75
		Common			
Bromus	Gramineae	13	39	64	32
Taeniatherum	Gramineae	13	39	68	26
Galium	Rubiaceae	12	36	57	17
Phragmites	Gramineae	11	33	101	32
Juncus	Juncaceae	10	30	4310	3312
Carex	Cyperaceae	9	27	52	11
Helianthemum	Cistaceae	8	24	2624	1488
Hordeum	Gramineae	7	21	80	38
Aeluropus	Gramineae	6	18	38	8
Artemisia	Compositae	4	12	68	32
Conringia	Cruciferae	4	12	57	32
Cephalaria	Dipsacaceae	4	12	6	2
Sporobolus	Gramineae	4	12	113	80
Sideritis	Labiatae	4	12	71	53
Teucrium	Labiatae	4	12	372	137
		Rare			
Silene	Caryophyllaceae	3	9	26	17
Atriplex	Chenopodiaceae	3	9	24	8
Chenopodium	Chenopodiaceae	3	9	70	48
Salsola	Chenopodiaceae	3	9	73	68
Crypsis	Gramineae	3	9	40	24
Lemna	Lemnaceae	3	9	24	8
Rumex	Polygonaceae	3	9	20	18
Thymelaea	Thymelaeaceae	3	9	34	32
Alisma	Alismataceae	2	6	16	8
Aegilops	Gramineae	2	6	5	4
Agrostis	Gramineae	2	6	10	8
Eragrostis	Gramineae	2	6	56	32
Eremopyrum	Gramineae	2	6	5	3
Mentha	Labiatae	2	6	24	16

Cicer	Leguminosae	2	6	4	3
Malva	Malvaceae	2	6	2	1
Adonis	Ranunculaceae	2	6	5	4
Bellevalia	Asparagaceae	1	3	1	1
Heliotropium	Boraginaceae	1	3	8	8
Lithospermum	Boraginaceae	1	3	0.5	0.5
Suaeda	Chenopodiaceae	1	3	2	2
Centaurea	Compositae	1	3	8	8
Scirpus/Eleocharis	Cyperaceae	1	3	1	1
Geranium	Geraniaceae	1	3	1	1
Alopecurus	Gramineae	1	3	2	2
Phalaris	Gramineae	1	3	8	8
Stipagrostis	Gramineae	1	3	96	96
Triticum	Gramineae	1	3	15	15
Linum	Linaceae	1	3	8	8
Lavatera	Malvaceae	1	3	1	1
Fumaria	Papaveraceae	1	3	1	1
Androsace	Primulaceae	1	3	8	8
Ranunculus	Ranunculaceae	1	3	0.3	0.3
Asperula	Rubiaceae	1	3	8	8

Before these wild genera could be analysed further to investigate farming practices, the relevant arable weeds needed to be isolated from alternative sources of deposition. While these *in situ* stores were purposefully selected to reduce mixing of plant material from separate taphonomic processes, as well as to specifically target crop weeds in their most evident form, a degree of contamination (i.e. dung flora, collected wild taxa) was still detectable. The deposition statuses for each of the wild/weed taxa will be explored in greater detail below using statistical analyses (below, 9.39.4). Nevertheless, brief summaries will be made for the most ubiquitous and abundant taxa identified from this category.

The most common wild/weed genus identified was *Polygonum*, which occurred in 76% of the samples, and could be identified to species in many instances (*Polygonum aviculare* and *Polygonum convolvulus*) (see Identification catalogue). The status of this wild taxon is complex, with indications of it as a likely arable weed (Bogaard *et al.* 2013a: 103), while also having direct associations with the charred remains of animal dung at the site

(particularly the *Polygonum aviculare* form) (Filipović 2012: 159). Consideration of the habitat preferences and physical seed properties of this genus suggest it could belong to either category; both identified species are common arable weeds in the region, but *Polygonum aviculare* has small hard-coated seeds that readily survive animal digestion (Davis 1965; Wallace & Charles 2013). This genus occurred in moderate numbers within some of the purest barley grain stores from Building 122 (Table 9.3) where a distinct dung flora was absent, so the status of this genus was examined on a sample by sample basis within the statistical analyses.

The second most ubiquitous wild genus identified was the sedge *Bolboschoenus,* which was universally identified as *Bolboschoenus glaucus*, and occurred within 67% of the selected store samples. This species is one of the most abundant wild taxa across the site as a whole, occurring in 69% of the 2000-2008 samples, and is commonly associated with dung pellets (Bogaard *et al.* 2013a: 97, 107). However, like *Polygonum*, the species occurred in limited frequencies within two of the purest naked barley stores. In this instance, a further category must also be considered; phytoliths and plant impressions indicate that sedges were commonly used as a material for matting and cordage at Çatalhöyük (Ryan 2011), so *Bolboschoenus* seeds may have easily become incorporated into crop stores via these alternative sources. The distinctly wet and marshy habitat preferences of *Bolboschoenus* compared with other field weeds identified at the site cast further doubt upon its status as a weed in these assemblages.

Vaccaria was the next most abundant genus within the stores, which was easily identifiable to species (*Vaccaria pyramidata*) as a monotypic genus, and occurred within 58% of the selected crop stores. While also a common species across the site as a whole, it was much less ubiquitous than *Bolboschoenus,* occurring in only 28% of all samples (Bogaard *et al.* 2013a); this distribution is much more consistent with genuine crop weeds rather than the pervading wild taxa from other sources of deposition, such as collected species and the burning of dung.

The final genus to be identified with a frequent occurrence within the samples was *Convolvulus,* which was present within 52% of the storage samples. Many of the specimens were identified to a *Convolvulus arvensis* type, which is a perennial weed well-adapted to highly disturbed ground such as cultivated fields (Davis 1965). Its status as an arable weed is the most likely scenario for this large seeded genus, the seeds of which are too large (>2mm) to survive animal digestion processes (Wallace & Charles 2013) and has no known ethnographic uses.

9.2 Overview of assemblage: Jerf el-Ahmar, Dja'de and Tell Aswad

A total of 63 samples was selected from the three Syrian Pre-Pottery Neolithic sites to be examined in this ecological analysis. In addition to the weed content, the basic composition of each sample was also explored to identify their dominant crop component and associated crop-processing stage (below, 9.4) to provide greater context for these analyses. However, as the raw sample data produced by Willcox and Douché are currently unpublished, comprehensive accounts will not be presented for the crop material.

9.2.1 Sample summary: Jerf el-Ahmar

For the ecological analysis at Jerf el-Ahmar a total of 20 samples was selected and analysed. These derived from 15 separate stratigraphic units excavated at the two main excavation areas (East and West), which include deposits from three building structures as well as other external areas across the site. The selection covers three of the four distinct phases of occupation identified at the site, with the final transitional phase (PPNA/PPNB) excluded (Stordeur 2015: 25). Of the 20 samples, 11 samples originated from the early phase (Phase ancienne), four from the mid phase (Phase moyenne), and five from the late phase (Phase récente) (Table 9.9).

In contrast to the Çatalhöyük material, none of the selected samples derive from *in situ* crop stores and instead represent contexts of more mixed origin and species composition (Table 9.9 & 9.12). However, one of the samples analysed was taken from an *in situ* occupation layer in a building destroyed by fire (EA47) (Stordeur *et al.* 2010). The samples were largely taken from extensive building collapse layers (14/20), with the occasional occupation layer (2/20), midden deposit (2/20) and fire pit (2/20). The density of archaeobotanical items per litre is relatively restricted for the selected samples, ranging from 2 to 46 items per litre with an average of 9.6±9.9 items per litre. This is reduced

Table 9.9 – Context and basic sample composition for the selected samples at Jerf el-Ahmar.

Site Phase	Sample no.	Building no.	Context	Total no. crop items	Density crop items/ litre	% Crop	% Wild/weed
Early (ancienne)							
	JF579	-	building collapse	440	7.3	78.9	21.1
	JF480	-	building collapse	348	17.4	47.9	52.1
	JF433	-	occupation	347	5.8	69.5	30.5
	JF444	-	building collapse	344	5.7	49.8	50.2
	JF441	-	building collapse	231	2.9	62.3	37.7
	JF639	-	midden	213	4.3	80.1	19.9
	JF545	EA37	fire pit	184	4.6	79.0	21.0
	JF578	-	building collapse	173	1.4	65.3	34.7
	JF483	-	fire pit	153	2.2	58.0	42.0
	JF246	-	building collapse	143	2.4	48.1	51.9
	JF284	-	midden	112	3.7	24.2	75.8
PPNA (moyenne)							
	JF227	-	building collapse	249	3.1	83.6	16.4
	JF226	-	building collapse	248	2.6	81.0	19.0
	JF252	-	building collapse	187	2.3	84.6	15.4
	JF622	EA47	occupation	165	8.3	77.5	22.5
Late (récente)							
	JF544b	EA30	building collapse	476	7.9	85.5	14.5
	JF563	EA30	building collapse	217	1.7	64.2	35.8
	JF631	EA30	building collapse	212	3.0	71.1	28.9
	JF610	EA30	building collapse	143	3.6	73.7	26.3
	JF564	EA30	building collapse	103	1.2	67.3	32.7

further when considering crop items only, which ranged from 1.2 to 17.4 crop items per litre, with an average of 4.4±3.7 items per litre. Nevertheless, these figures exceed the site wide averages of 3.3±4.4 botanical items and 1.5±1.9 crop items per litre (269 samples). While *in situ* seed concentrations were excavated from within the 'kitchen' area (Room 2) uncovered in burnt building EA10 (cf. Willcox 2002), these clusters mainly consisted of *Brassica/Sinapis* (wild mustard) seed, which did not reach the minimum threshold of 100 crop items for selection (above, 5.3.2).

9.2.1.1 Buildings and phases in analysis

Of the 20 selected samples, seven were collected from the internal spaces of three separate buildings (Table 9.10). Five of these samples derived from the large circular building EA30 in the West area, with a further two samples taken from the small circular buildings EA37 and EA47 that lie to the eastern extent of the site. The large circular building EA30 was of principal interest within this analysis owing to its interpretation by the excavators as a 'communal storage' structure (Willcox & Stordeur 2012) (above, 3.1.1.1). Though there were no *in situ* concentrations of plant remains, the samples taken from the small partitioned cells (Figure 9.11; Table 9.10) contained higher frequencies of cereals when compared with average densities across the site (1.3±1.7 per litre) (Willcox & Stordeur 2012: 107); cell 2 contained up to 7.5 cereal (7.9 crop) items per litre, which matches some of the lowest densities observed in the 'residual storage' category at Çatalhöyük (9.1.2).

The sample analysed from circular building EA47 (Figure 9.12), which was destroyed by fire, was also interpreted as a possible storage context owing to its higher than average cereal density (Willcox & Stordeur 2012: 109). However, while this sample was grain-rich, evidence for storage is more limited in this instance; only a small amount of grain was recovered (92 grains - less than one tablespoon) without any formal structures to reinforce interpretations of storage.

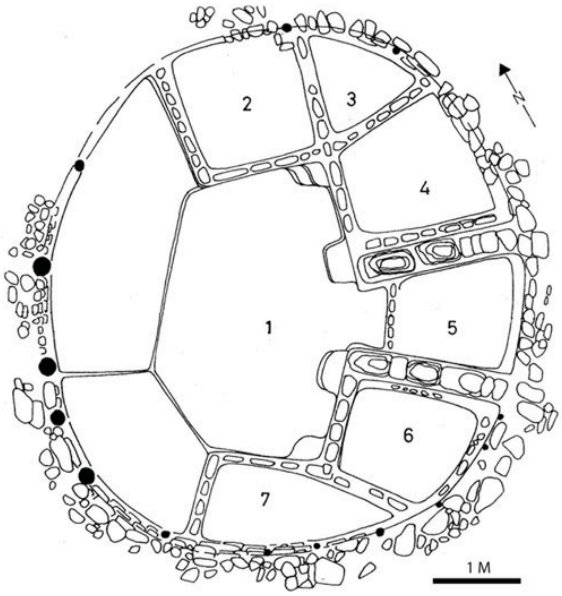


Figure 9.11 – Communal building EA30 (Willcox & Stordeur 2012: Fig. 8).

The single deposit from building EA37 was excavated from an internal hearth/ fire pit located within this small truncated structure. The arrangement of stone rubble within the centre of this building suggests a possible radial subdivision surrounding a central polygonal space (Stordeur 2015: 146). The excavators highlight parallels with the cell partitions present within the later EA30 building and suggest this earlier example as a possible 'prototype' for this style of building (Stordeur 2015: 141). With the hearth area adjoining this central demarcated space it is possible that this area may have formed a dedicated space for food processing and preparation.



Figure 9.12 – Burnt building EA47 at Jerf el-Ahmar from the middle phase of the occupation (Stordeur 2015).

Table 9.10 – Samples associated with building structures within the selection from Jerf el-Ahmar and their associated cereal densities (Willcox & Stordeur 2012).

Area	Level	Building no.	Room	Sample no.	Context	Density of cereal items/ litre
West	2/W - Late	EA30	1	JF564	building collapse	1
			2	JF544b	building collapse	7.5
			2	JF563	building collapse	1.5
			4	JF610	building collapse	3.2
			5	JF631	building collapse	2.8
East	5/E - Early	EA37	-	JF545	fire pit	3.4
	3/E - Middle	EA47	-	JF622	occupation	4.9

9.2.1.2 Summary of crop types

In this pre-domestication site, the distinction between crops and wild/weedy taxa is much more ambiguous. Nevertheless, likely cultivars were distinguished by identifying wild relatives of known cereal and pulse domesticates that were abundant across the samples (above, 5.3.2). Of these recognised cultivars, wild barley (*Hordeum spontaneum*) was the dominant crop class (≥70%) for over half (13/20) of the selected samples from Jerf el-Ahmar, with a further two samples containing a predominance of wheat/rye (*Triticum/Secale*) and five samples containing a mixture of crop types (<70%), including combinations of barley and wheat/rye, as well as barley and pulse mixes. The predominant pulse species was lentil (*Lens*), which formed over 70% of the pulse component in 13 samples. *Pisum*/*Vicia*/*Lathyrus* was the second most abundant pulse type, with one sample containing 90% for the pulse component. Bitter vetch (*Vicia ervilia*) also occurred in limited numbers across half of the samples (9/20). Fragments of fruit/nut were ubiquitous across the selected samples (19/20), though occurred in insignificant quantities; when calculated to represent their MNI (fragments divided by 20 to estimate whole equivalent– cf. above, 5.6) they represented a maximum of two percent of the cultivar/collected portion of the samples.

Table 9.11 – Number of selected samples per dominant crop class.

Dominant crop class (≥70%)	No. samples
Wild barley	13
Wheat/rye	2
Mixed	5
Total	20

Table 9.12 – Dominant crop composition of the selected samples at Jerf el-Ahmar (excluding fruit/nut). The two dominant classes are determined by an arbitrary threshold of ≥70%, while the main crop type reflects the most abundant crop within the sample.

Site Phase	Sample no.	% Crop	% Wild/ weed	Dominant class	Dominant crop class	Main crop type
Early (ancienne)						
	JF639	80.1	19.9	Crop	Barley	Barley
	JF545	79.0	21.0	Crop	Mixed	Barley
	JF579	78.9	21.1	Crop	Wheat/rye	Wheat/rye
	JF433	69.5	30.5	Crop	Barley	Barley
	JF578	65.3	34.7	Mixed	Wheat/rye	Wheat/rye
	JF441	62.3	37.7	Mixed	Barley	Barley
	JF483	58.0	42.0	Mixed	Mixed	Wheat/rye
	JF444	49.8	50.2	Mixed	Mixed	Barley
	JF246	48.1	51.9	Mixed	Barley	Barley
	JF480	47.9	52.1	Mixed	Barley	Barley
	JF284	24.2	75.8	Wild/weed	Barley	Barley
PPNA (moyenne)						
	JF252	84.6	15.4	Crop	Mixed	Barley
	JF227	83.6	16.4	Crop	Barley	Barley
	JF226	81.0	19.0	Crop	Barley	Barley
	JF622	77.5	22.5	Crop	Mixed	Wheat/rye
Late (récente)						
	JF544b	85.5	14.5	Crop	Barley	Barley
	JF610	73.7	26.3	Crop	Barley	Barley
	JF631	71.1	28.9	Crop	Barley	Barley
	JF564	67.3	32.7	Mixed	Barley	Barley
	JF563	64.2	35.8	Mixed	Barley	Barley

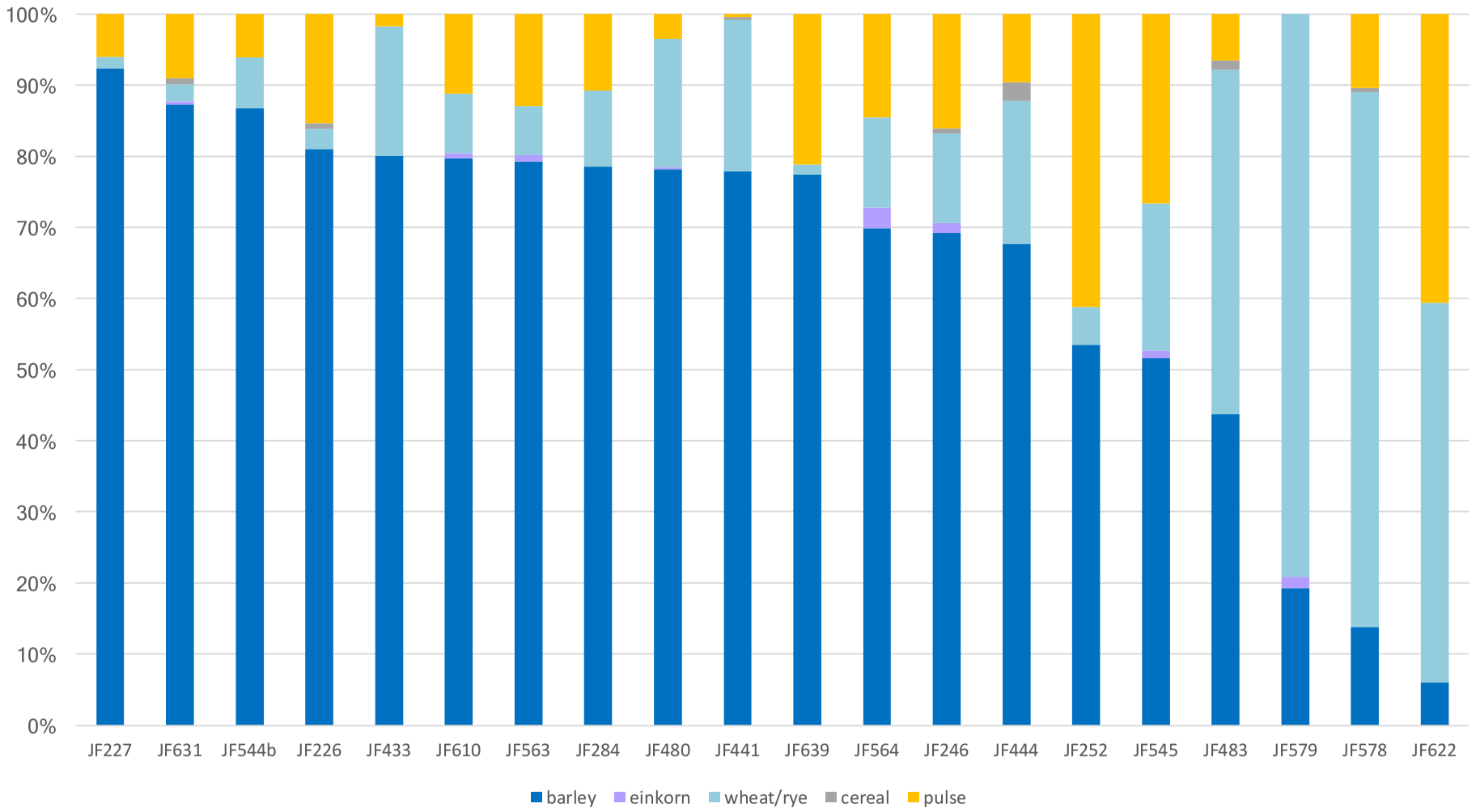


Figure 9.13 – Percentages of crop types in selected samples from Jerf el-Ahmar.

9.2.1.3 Wild/weed taxa

Owing to the secondary nature of the contexts selected from Jerf el-Ahmar, the proportion of wild/weedy taxa was much greater than observed in the primary storage deposits at Çatalhöyük. The percentage of wild taxa ranged from 15 to 76%, with an average of 32±16% across the 20 samples; this was noticeably above the site wide average of 20±17% (269 samples). This larger wild/weed average might be explained by the selection of crop rich samples (over 100 items), which could have isolated crop-processing activities, and therefore sieved weed discard material.

The ubiquity and abundance of the wild/weed assemblage was explored (Table 9.13). Thirty-two wild genera were identified from the selected samples, which derived from 18 separate plant families. Using arbitrary ubiquity thresholds (above, 9.1.5), the assemblage featured nine frequent genera, 15 characterised as common, and a further eight genera that were rare in occurrence. The most ubiquitous wild genus was a *Silene/Gypsophila* type, which occurred in 90% of the samples, though a list of applicable species for these two closely related genera were not available at the time of analysis[4].

The most abundant wild genus identified within the selected samples was the wild/weed form of *Hordeum* (*Hordeum murinum/bulbosum*) (Willcox *et al.* 2008: 317), which was also the third most ubiquitous type identified across the samples (17/20). The status of this wild type is ambiguous at Jerf el-Ahmar; while these wild grasses are commonly identified as weeds in modern contexts, they may have been intentionally gathered as a food source in these early pre-domestication contexts (Willcox *et al.* 2008: 317). The abundance of this taxon, and of similarly abundant wild grass species (e.g. *Taeniatherum*), was assessed on a sample-by-sample basis to identify possible instances of intentional collection; for example, a 30-litre sample that contained 184 *Hordeum murinum/bulbosum* grains was deemed as a possible instance of collection (cf. below, 9.4.1.1). The expected

[4] Volume five of the *Flora of Iraq*—which includes Caryophyllaceae—was only published in 2016, so *Silene/Gypsophila* was not selected for refined identification. Furthermore, the *Flora of Turkey* lists 119 species for *Silene*, so was deemed a difficult type to refine further.

deposition status for each genus—i.e. weed, collected, dung—will be explored in greater detail below (9.4.1.1; Appendix 1c).

Table 9.13 – Ubiquity and abundance of the wild/weed assemblage (to genus level) within the selected samples from Jerf el-Ahmar. Max no. refers to the maximum number of items within a single sample.

		Ubiquity		Abundance	
Genus	**Family**	**n**	**%**	**Total items**	**Max no.**
		Frequent			
Silene/Gypsophila	Caryophyllaceae	18	90	273	57
Taeniatherum	Gramineae	17	85	78	10
Hordeum	Gramineae	16	80	403	184
Polygonum/Rumex	Polygonaceae	14	70	60	9
Astragalus	Leguminosae	14	70	50	12
Bromus	Gramineae	13	65	62	22
Capparis	Capparaceae	11	55	141	68
Polygonum	Polygonaceae	11	55	68	17
Bellevalia	Asparagaceae	11	55	42	8
		Common			
Galium	Rubiaceae	9	45	29	18
Adonis	Ranunculaceae	8	40	20	8
Asperula	Rubiaceae	7	35	13	5
Centaurea	Asteraceae	5	25	5	1
Androsace	Primulaceae	4	20	16	10
Aegilops	Gramineae	4	20	12	8
Heliotropium	Boraginaceae	4	20	7	3
Bolboschoenus	Cyperaceae	3	15	7	3
Thymelaea	Thymelaeaceae	3	15	6	3
Erodium	Geraniaceae	3	15	4	2
Ornithogalum	Asparagaceae	3	15	3	1
Eremopyrum	Gramineae	3	15	3	1
Glaucium	Papaveraceae	2	10	8	7
Poa	Gramineae	2	10	4	3
Stipa	Gramineae	2	10	2	1
		Rare			
Ziziphora	Lamiaceae	1	5	24	24
Fumaria	Papaveraceae	1	5	2	2
Lolium	Gramineae	1	5	1	1
Coronilla	Leguminosae	1	5	1	1
Medicago	Leguminosae	1	5	1	1
Trigonella	Leguminosae	1	5	1	1
Verbascum	Scrophulariaceae	1	5	1	1
Tribulus	Zygophyllaceae	1	5	1	1

9.2.2 Sample summary: Dja'de

A total of 27 samples was selected to be analysed from the PPNB levels at Dja'de[5]. These were sampled from 21 individual stratigraphic units, which represent eight separate excavation trenches positioned across the site. However, there is insufficient information to relate the archaeobotanical samples to any specific building structures excavated at the site. Most of the selected samples represent the PPNB III phase (20/27), with the remaining samples from preceding the PPNB II (7/27) phase (Table 9.14) (above, 3.1.2).

Contextual information was only available for 11 of the 27 selected samples, but those that were specified originated from a range of sources; these include four burnt ashy lenses, fire pits (2/11), midden material (2/11), an occupation layer (1/11), a pit (1/11) and building collapse (1/11). The density of items per litre is on average much greater among the selection at Dja'de than at Jerf el-Ahmar, ranging from 2.9 to 89.6 archaeobotanical items per litre with an average of 21.6±21.1 items. However, it must be noted that the sample volume was unspecified for nine of the samples. This average is halved when considering crop items, with an average of 10.2±11.1 items per litre, ranging from 2.2 to 50.5 crop items per litre across the selection.

9.2.2.1 Summary of crop types

The identification of cultivars at this pre-domestication site was approached similarly to Jerf el-Ahmar, through the isolation of the most abundant cereals and pulse species (above, 9.2.1.2). The samples at Dja'de were much more mixed in composition, with over half (15/27) containing variable mixtures of pulses, wild barley (*Hordeum spontaneum*) and wheat/rye (*Triticum/Secale*). Lentil (*Lens*) was the most abundant species among these mixes, which had an average of 41±20% across the 15 mixed samples. Wild barley followed second, with an average of 31±14% across the mixed samples, while wheat/rye had a more limited average of 13±15%. The next most common sample type (9/27) within

[5] The sample data for the earlier PPNA levels at Dja'de were unavailable for this analysis.

Table 9.14 – Context and basic sample composition for the selected samples at Dja'de.

Site Phase	Sample no.	Site area	Context	Total no. crop items	Density crop items/ litre	% Crop	% Wild/ weed
PPNB II							
	DJ253	A	-	230	-	54.9	45.1
	DJ105	B	ash lens	606	50.5	67.5	32.5
	DJ282	CD	-	527	7.5	56.2	43.8
	DJ271	SB	-	486	16.2	86.2	13.8
	DJ381	SB	-	243	6.1	82.4	17.6
	DJ396	SB	-	120	-	58.0	42.0
	DJ178	ST	pit	996	-	49.3	50.7
PPNB III							
	DJ145	B	midden	275	13.8	80.9	80.9
	DJ037	B	-	265	6.3	37.4	37.3
	DJ077	B	ash	216	2.2	78.8	78.8
	DJ036	B	-	143	7.2	25.1	25.1
	DJ070	C	-	629	7.0	92.8	92.3
	DJ067	C	-	255	3.6	83.9	83.9
	DJ068	C	-	232	7.7	52.4	52.4
	DJ112	C	-	144	-	67.0	67.0
	DJ066	C	-	120	4.0	74.1	74.1
	DJ127	C	-	107	-	84.3	84.3
	DJ137	EW	occupation	128	-	28.8	28.8
	DJ135	SB	building collapse	265	3.8	55.9	55.5
	DJ134	SB	midden	244	12.2	37.3	37.3
	DJ100	SB	-	129	3.2	31.8	21.7
	DJ123	SF	-	422	7.0	40.8	40.3
	DJ176	SF	lentil	120	-	66.7	66.7
	DJ235	ST	burnt layer	392	19.6	51.9	50.2
	DJ239	ST	-	174	5.8	39.9	39.7
	DJ167	ST	fire pit	140	-	59.3	58.9
	DJ168	ST	fire pit	137	-	46.0	45.3

Table 9.15 – Number of selected samples per dominant crop class.

Dominant crop class (≥70%)	No. samples
Pulse	9
Barley	3
Mixed	15
Total	27

Table 9.16 – Dominant crop composition of the selected samples at Dja'de (excluding fruit/nut). The two dominant classes are determined by an arbitrary threshold of ≥70%, while the main crop type reflects the most abundant crop within the sample.

Site Phase	Sample no.	% Crop	% Wild/ weed	Dominant class	Dominant crop class	Main crop type
PPNB II						
	DJ271	86.2	13.8	Crop	Pulse	Pea/*Vicia*/*Lathyrus*
	DJ381	82.4	17.6	Crop	Mixed	Barley
	DJ105	67.5	32.5	Mixed	Mixed	Lentil
	DJ396	58.0	42.0	Mixed	Pulse	Lentil
	DJ282	56.2	43.8	Mixed	Mixed	Barley
	DJ253	54.9	45.1	Mixed	Mixed	Lentil
	DJ178	49.3	50.7	Mixed	Mixed	Lentil
PPNB III						
	DJ070	92.8	7.2	Crop	Mixed	Lentil
	DJ127	84.3	15.7	Crop	Pulse	Lentil
	DJ067	83.9	16.1	Crop	Pulse	Lentil
	DJ145	80.9	19.1	Crop	Pulse	Pea/*Vicia*/*Lathyrus*
	DJ077	78.8	21.2	Crop	Pulse	Lentil
	DJ066	74.1	25.9	Crop	Pulse	Lentil
	DJ112	67.0	33.0	Mixed	Mixed	Lentil
	DJ176	66.7	33.3	Mixed	Barley	Barley
	DJ167	59.3	40.7	Mixed	Mixed	Barley
	DJ135	55.9	44.1	Mixed	Pulse	Lentil
	DJ068	52.4	47.6	Mixed	Pulse	Lentil
	DJ235	51.9	48.1	Mixed	Mixed	Lentil
	DJ168	46.0	54.0	Mixed	Barley	Barley
	DJ123	40.8	59.2	Mixed	Mixed	Lentil
	DJ239	39.9	60.1	Mixed	Mixed	Lentil
	DJ037	37.4	62.6	Mixed	Mixed	Lentil
	DJ134	37.3	62.7	Mixed	Mixed	Lentil
	DJ100	31.8	68.2	Mixed	Mixed	Wheat/rye
	DJ137	28.8	71.2	Wild/weed	Barley	Barley
	DJ036	25.1	74.9	Wild/weed	Mixed	Lentil

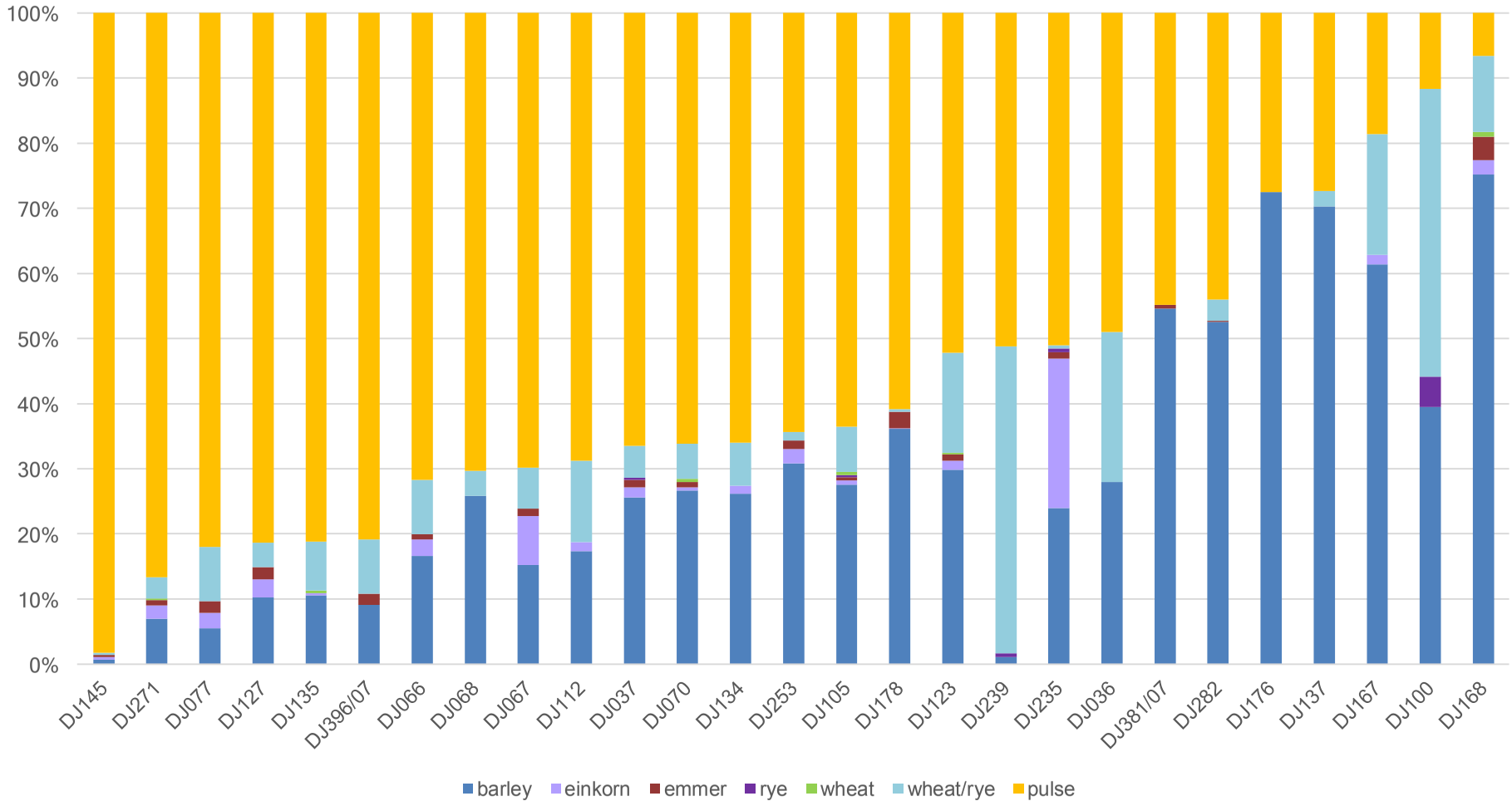


Figure 9.14 – Percentages of crop types in selected samples from Dja'de.

the selection were samples predominantly formed of pulses (≥70% of the sample), which also primarily consisted of lentil; the pulse component was formed of over 70% lentil within six of the pulse dominant samples. The remaining three pulse dominant samples comprised of one sample formed of over 70% Pea/*Vicia*/*Lathyrus* type, with a further two samples containing uneven mixtures of the two main pulses, lentil and pea/*Vicia*/*Lathyrus* type. While only three of the 27 samples were formed of over 70% wild barley, it continued to be the most dominant cereal species identified among the selected samples. Fragments of fruit/nut were ubiquitous across the selected samples (26/27), but their MNI counts were relatively minor forming a maximum of 16% of the non-wild/weed component.

9.2.2.2 Wild/weed taxa

The percentage of wild/weed taxa among the selected Dja'de samples was very similar to Jerf el-Ahmar, which again likely reflects the largely mixed and secondary nature of the selected deposits. Percentages ranged from 7 to 75%, with an average of 41±19% across the 27 selected samples, slightly exceeding the site wide average of 40±25% (196 samples). When the ubiquity and abundance of the wild/weed assemblage was examined, 39 different wild/weed genera were identified, which derive from 21 different plant families. These were broken down into seven genera classified as frequent (above, 9.1.5), 18 recognised as common and a further 14 taxa that were classified as rare.

The most ubiquitous, and furthermore most abundant, genus in this wild/weed group was *Atriplex*, which occurred in 85% of the selected samples with a total count exceeding 880 specimens. While a common arable weed in modern fields (Davis 1965), the large concentrations of this genus throughout (14 samples with more than 20 items each) the selection suggest that this wild type was likely intentionally collected at Dja'de (Willcox *et al.* 2008: 317) (below, 9.4.1.2). The seeds of many *Atriplex* species are edible and have been interpreted as a food source in earlier sites (Colledge & Conolly 2010: 135).

Table 9.17 - Ubiquity and abundance of the wild/weed assemblage (to genus level) within the selected samples from Dja'de. Max no. refers to the max number of items within a single sample.

		Ubiquity		Abundance	
Genus	**Family**	**n**	**%**	**Total items**	**Max no.**
		Frequent			
Atriplex	Amaranthaceae	23	85	888	171
Hordeum	Gramineae	23	85	366	44
Taeniatherum	Gramineae	22	81	884	357
Capparis	Capparaceae	19	70	77	16
Astragalus	Leguminosae	19	70	193	47
Centaurea	Asteraceae	17	63	146	38
Silene/Gypsophila	Caryophyllaceae	14	52	104	21
		Common			
Glaucium	Papaveraceae	11	41	256	130
Bromus	Gramineae	10	37	26	8
Onobrychis	Leguminosae	10	37	65	25
Galium	Rubiaceae	10	37	16	4
Eremopyrum	Gramineae	9	33	15	3
Adonis	Ranunculaceae	9	33	22	5
Alyssum/Lepidum	Cruciferae	8	30	196	170
Aegilops	Gramineae	8	30	15	5
Bellevalia	Asparagaceae	6	22	13	6
Erodium	Geraniaceae	6	22	52	33
Stipa	Gramineae	6	22	210	90
Heliotropium	Boraginaceae	5	19	6	2
Fumaria	Papaveraceae	5	19	6	2
Trigonella	Leguminosae	4	15	15	8
Polygonum/Rumex	Polygonaceae	4	15	7	3
Rumex	Polygonaceae	4	15	10	3
Hyoscyamus	Solanaceae	4	15	5	2
Poa	Gramineae	3	11	12	10
Polygonum	Polygonaceae	3	11	3	1
		Rare			
Ajuga/Teucrium	Lamiaceae	2	7	3	2
Lathyrus	Leguminosae	2	7	2	1
Medicago	Leguminosae	2	7	3	2
Asperula	Rubiaceae	2	7	2	1
Ornithogalum	Asparagaceae	1	4	1	1
Valerianella	Caprifoliaceae	1	4	1	1
Gypsophila	Caryophyllaceae	1	4	2	2
Bolboschoenus	Cyperaceae	1	4	7	7
Echinaria	Gramineae	1	4	1	1
Lolium	Gramineae	1	4	1	1
Ziziphora	Lamiaceae	1	4	3	3
Androsace	Primulaceae	1	4	1	1
Verbascum	Scrophulariaceae	1	4	1	1
Tribulus	Zygophyllaceae	1	4	1	1

Alternatively, *Atriplex* may have been collected for use as fuel (Willcox *et al.* 2008: 317), which would have concentrated the seeds within ashy deposits and fire pits.

Similar collected interpretations were also indicated for the second most abundant genus, *Taeniatherum* (also the third most ubiquitous), which was identified in comparable numbers across 81% of the selected samples. However, the counts for *Taeniatherum* were much more concentrated, with only five of the 22 samples containing more than ten items, so it is possible that this taxon also occurred as an arable weed. Isolation of the relevant arable crop weeds from the identified wild taxa was explored further with the use of crop-processing analyses (below, 9.4.1.2).

9.2.3 Sample summary: Tell Aswad

Only 16 samples reached the minimum crop and weed thresholds for ecological analysis at Tell Aswad. These were taken from 15 individual stratigraphic units located across the site, which collectively represented the three separate occupation phases identified (Stordeur *et al.* 2010: 43). Only two of the samples could be related to defined buildings at the site, but details of this corresponding architecture have not yet been published. Of the 16 selected samples, the majority (10/16) are from the latest PPNB phase (PPNB récent), with a further three samples from the early PPNB horizon (PPNB ancien) and three from the intermediate phase (PPNB moyen).

Many of the samples relate to specific structural features (Table 9.18); samples were taken from four separate 'cuvette' (basin) contexts, two burials, a potential 'silo', and a pit rich in faunal remains. The remaining samples were taken from floor and occupation layers, a mudbrick wall, and two distinct burnt layers. The Aswad samples had the highest density of archaeobotanical remains of the three Syrian sites, ranging from 4 to 103 items per litre with an average of 23.7±23.6 items. Around half of this average was formed of crop remains, with an average density of 12±17.6 crop items per litre, which ranged from 1.3 to 69.7 crop items per litre across the selection. The sample representing the top of this scale (AW02/72) was of particular interest owing to its comparatively high crop density, number of crop items and contextual association (basin fill). Two fills were also excavated from a potential storage silo (F.219), but these were much more limited in their total number of crop items and seed density.

9.2.3.1 Summary of crop types

With the emergence of fully domesticated species at Tell Aswad, it was more straightforward to identify cultivars at this site. The selected samples largely consisted of mixed crop types, with half (8/16) of the samples falling below the 70% species

Table 9.18 – Context and basic sample composition for the selected samples at Tell Aswad.

Site Phase	Sample no.	Building no.	Feature no.	Context	Total crop items	Density crop items/ litre	% Crop	% Wild/ weed
PPNB ancien								
	AW06/39	Ext. EA9	728	occupation	814	6.8	67.3	32.7
	AW06/52	EA42	689	mud wall	227	3.8	21.4	78.6
	AW06/32	-	334	floor	184	3.1	53.0	47.0
PPNB moyen								
	AW05/22	-	584	basin	3401	17.3	61.3	38.7
	AW02/72	-	141	basin fill	1811	69.7	69.7	30.3
	AW02/81	-	176	basin	434	21.7	68.1	31.9
PPNB récent								
	AW04/08 BIS	-	-	burnt layer	569	-	35.9	64.1
	AW02/86	-	219	fill - silo?	399	11.1	68.0	32.0
	AW04/04	-	509	burial	350	3.4	14.9	85.1
	AW02/80	-	167	pit	342	-	84.0	16.0
	AW04/30 BIS	-	-	burnt layer	253	6.3	26.9	73.1
	AW02/98	-	219	fill - silo?	206	10.3	61.7	38.3
	AW04/14	-	514	burial	184	3.1	20.9	79.1
	AW04/30	-	-	burnt layer	160	1.3	12.1	87.9
	AW05/11	-	167	pit	127	9.1	85.8	14.2
	AW05/21	-	575	basin	114	1.8	53.0	47.0

dominance threshold (Table 9.20). These mixtures reflected differing ratios of domesticated barley (*Hordeum vulgare*), emmer (*Triticum dicoccum*), pulses (*Lens* and *Pisum/Vicia* type), as well as limited proportions of einkorn (*Triticum monococcum*) (Figure 9.15). Three further samples contained over 70% wheat for the crop component. While glume wheats were identified in these samples (mostly emmer (88-93% of identified wheat) with einkorn forming the remainder), the samples predominantly consisted of indeterminate wheat grain. An additional two samples were also dominated by wheat, but much of the material was sufficiently preserved for them to be classified as glume wheat samples. These also primarily contained domesticated emmer (88-100%),

with a small amount of einkorn present in one sample. The remaining three samples consisted of two barley dominant (*Hordeum vulgare*) samples and one poorly preserved sample only identifiable to indeterminate cereal.

While only two of the 16 samples were dominated by barley, this species continued to be the most abundant crop type observed across the selection (43%), with emmer following second (22%). Barley was frequently the main species within the mixed samples and it was also recovered in large concentrations (maximum of 2043 items) within the two barley dominant samples. While none of the samples were dominated by pulse species, this category represented 12% of the total crop material. The pulses primarily consisted of a *Pisum*/*Vicia* type (42%), with lentil (*Lens*) the second most abundant. While most of the samples only contained small proportions of pulses (11 samples <15% pulse), two of the mixed samples had pulses as the main crop, with one sample distinguishable to *Pisum*/*Vicia* type. Fruit and nut taxa formed a slightly larger component than the two earlier Syrian sites, which consisted of fig (*Ficus*) and *Pistacia,* but these taxa did not exceed 20% of the non-wild/weed portion of the samples.

Table 9.19 – Number of selected samples per dominant crop class.

Dominant crop class (≥70%)	No. samples
Wheat indet.	3
Glume wheat	2
Barley	2
Cereal indet.	1
Mixed	8
Total	16

Table 9.20 – Dominant crop composition of the selected samples at Tell Aswad (excluding fruit/nut). The two dominant classes are determined by an arbitrary threshold of ≥70%, while the main crop type reflects the most abundant crop within the sample.

Site Phase	Sample no.	% Crop	% Wild/ weed	Dominant class	Dominant crop class	Main crop type
PPNB ancien						
	AW06/39	67.3	32.7	Mixed	Barley	Barley
	AW06/32	53.0	47.0	Mixed	Mixed	Glume wheat
	AW06/52	21.4	78.6	Wild/weed	Mixed	Pea/*Vicia*
PPNB moyen						
	AW02/72	69.7	30.3	Crop	Wheat	Wheat
	AW02/81	68.1	31.9	Mixed	Cereal indet.	Cereal indet.
	AW05/22	61.3	38.7	Mixed	Mixed	Barley
PPNB récent						
	AW05/11	85.8	14.2	Crop	Glume wheat	Glume wheat
	AW02/80	84.0	16.0	Crop	Glume wheat	Glume wheat
	AW02/86	68.0	32.0	Mixed	Wheat	Wheat
	AW02/98	61.7	38.3	Mixed	Wheat	Wheat
	AW05/21	53.0	47.0	Mixed	Mixed	Barley
	AW04/08 BIS	35.9	64.1	Mixed	Mixed	Barley
	AW04/30 BIS	26.9	73.1	Wild/weed	Barley	Barley
	AW04/14	20.9	79.1	Wild/weed	Mixed	Barley
	AW04/04	14.9	85.1	Wild/weed	Mixed	Barley
	AW04/30	12.1	87.9	Wild/weed	Mixed	Pea/*Vicia*

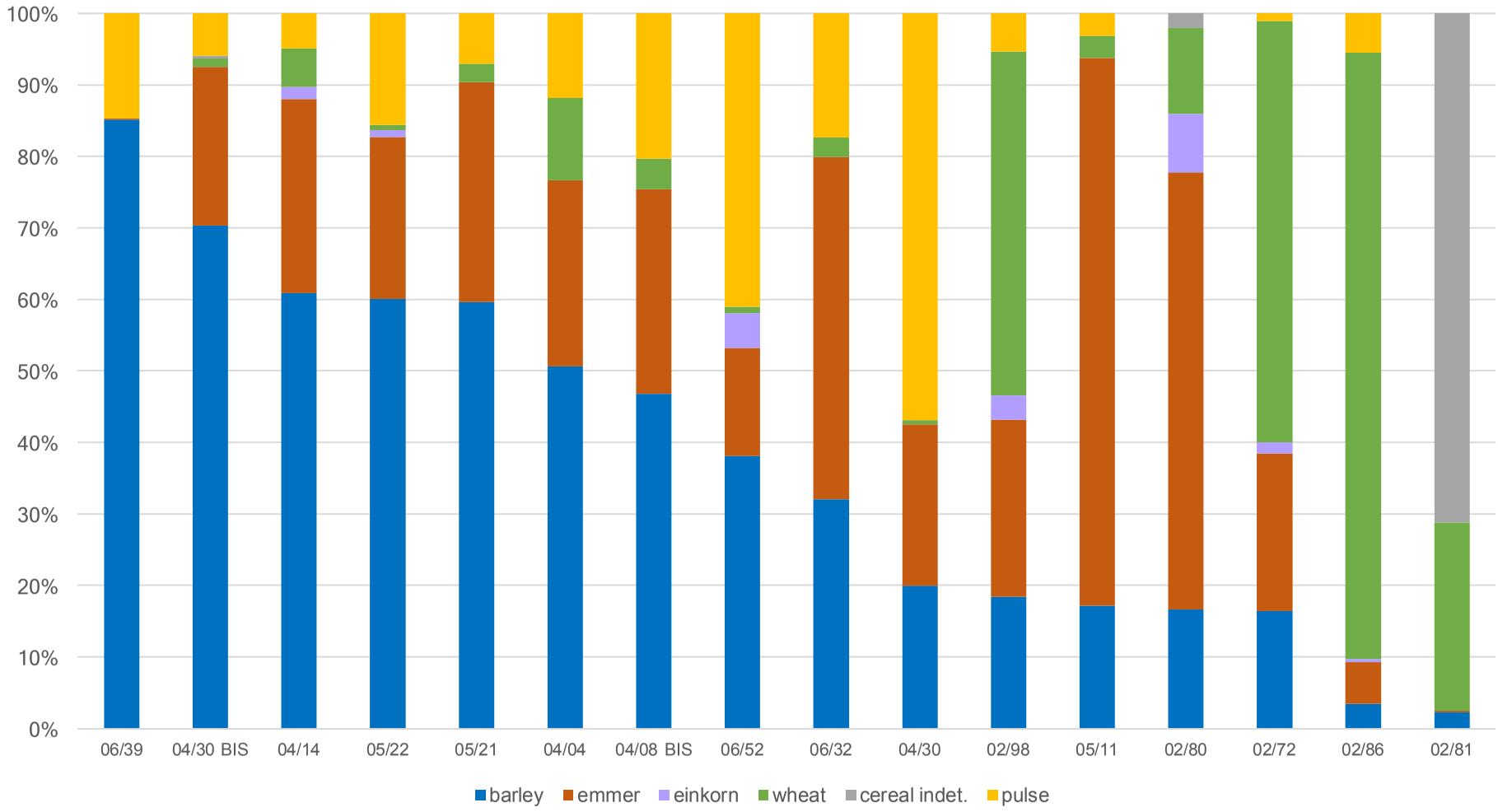


Figure 9.15 – Percentages of crop types in selected samples from Tell Aswad.

9.2.3.2 Wild/weed taxa

The proportion of wild/weedy taxa in the selected samples at Tell Aswad was the highest observed among the four sites analysed[6]. Percentages ranged from 14 to as much as 88%, with a sizeable average of 50±25% wild/weed taxa among the selected samples. Despite this notably high average, it fell below the overall site average of 60±29% wild/weed taxa (159 samples). The pervasiveness of wild taxa at this later pre-pottery Neolithic site suggest other sources of deposition likely contributed to the wild total besides crop weeds. When the ubiquity and abundance of wild/weed taxa was explored for the selected samples, a total of 40 different genera were identified, which represented 19 different plant families. With the arbitrary thresholds in place (cf. above, 9.1.5), 13 genera were classified as frequent, 18 as common, and a further nine genera were identified as rare.

The most ubiquitous wild/weed taxon was *Bolboschoenus glaucus*, which occurred in 100% of the selected samples, and was furthermore the most abundant taxon with over 2,000 specimen counts across the selection. The dominance of this wet-loving species is likely to reflect aspects of the local environment as the site is located at the edge of a lake (Stordeur *et al.* 2010), but its mode of deposition across the site is debatable (below, 9.4.1.3). *Trigonella* was the second most ubiquitous genus in the selection, occurring in 88% of samples and with the second highest abundance score, exceeding 1,800 counts in total. The marginal habitats (marshy, steppes) of the most abundant wild taxa further support the notion that other major sources of wild taxa, such as animal dung or other fuel sources, are represented within the assemblage in addition to arable weeds. The statistical analysis of the wild data component is therefore essential to correctly determine the relevant arable crop weeds for ecological analysis (below, 9.4).

[6] The collected taxon *Descurania sophia* was excluded from the sample statistics at Çatalhöyük, as their pervasiveness considerably skewed the overall datasets.

Table 9.21 - Ubiquity and abundance of the wild/weed assemblage (to genus level) within the selected samples from Tell Aswad. Max no. refers to the maximum number of items within a single sample.

		Ubiquity		Abundance	
Genus	**Family**	**n**	**%**	**Total items**	**Max no.**
		Frequent			
Bolboschoenus	Cyperaceae	16	100	2082	1011
Trigonella	Leguminosae	14	88	1880	685
Carex	Cyperaceae	13	81	383	141
Lithospermum	Boraginaceae	11	69	527	168
Medicago	Leguminosae	11	69	92	32
Melilotus	Leguminosae	11	69	36	12
Eremopyrum	Gramineae	10	63	58.5	30
Hordeum	Gramineae	10	63	103	72
Astragalus	Leguminosae	10	63	46	10
Bromus	Gramineae	9	56	58	14
Polygonum	Polygonaceae	9	56	23	6
Capparis	Capparaceae	8	50	420	385
Scirpus	Cyperaceae	8	50	854	460
		Common			
Phalaris	Gramineae	7	44	21	10
Arnebia	Boraginaceae	6	38	87	64
Adonis	Ranunculaceae	6	38	21	14
Galium	Rubiaceae	6	38	13	6
Vaccaria	Caryophyllaceae	5	31	7	3
Ornithogalum	Asparagaceae	4	25	11	5
Lolium	Gramineae	4	25	37	19
Linum	Linaceae	4	25	11.5	7
Androsace	Primulaceae	4	25	5	2
Aizoon	Aizoaceae	3	19	34	30
Heliotropium	Boraginaceae	3	19	13	10
Chenopodium	Chenopodiaceae	3	19	9	5
Poa	Gramineae	3	19	11	9
Atriplex	Amaranthaceae	2	13	2	1
Bellevalia	Asparagaceae	2	13	2	1
Silene	Caryophyllaceae	2	13	3	2
Onobrychis	Leguminosae	2	13	13	8
Vicia/Lathyrus	Leguminosae	2	13	4	2
		Rare			
Brassica	Cruciferae	1	6	1	1
Erodium	Geraniaceae	1	6	1	1
Phragmites	Gramineae	1	6	21	21
Lathyrus	Leguminosae	1	6	1	1
Trifolium	Leguminosae	1	6	1	1
Abutilon	Malvaceae	1	6	74	74
Malva	Malvaceae	1	6	2	2
Asperula	Rubiaceae	1	6	1	1
Thymelaea	Thymelaeaceae	1	6	1	1

9.3 Correspondence analysis: Çatalhöyük

To isolate relevant weed data from the identified storage deposits, as well as to investigate variation in wild taxon composition, the first weed based analysis was conducted using correspondence analysis (above, 5.8.1). This method was used in conjunction with previous assessments at the site (Bogaard *et al.* 2013a; Filipović 2014) to distinguish and remove taxa that derived from non-arable sources. After this initial step, the plotted samples were classified according to their identified categories established above (9.1) from the overview of the assemblage, which included dominant crop type, building number and storage type. Sample patterning in correspondence analysis was examined in relation to these classifications to interpret potential similarities in the weed component.

In an initial correspondence analysis, the simplified wild data from all 33 storage samples were included, comprising 34 different taxa (Figure 9.16; Appendix 1d). In Figure 9.16*a*, the majority of the wild taxa are clustered together towards the negative (left) end of axis 1. On the positive (right) side of axis 1 there is a small separate group of three genera that pull away from the main distribution. There is also a third group of four genera towards the negative ends of axes 1 and 2 (bottom left). Figure 9.16b shows the abundance of *Helianthemum* across the selected samples, and highlights two samples with over 1,000 items each; these are positioned at the positive end of axis 1. *Helianthemum* appears to be the main driver for this distribution, and is also likely to represent deposition as a collected wild plant rather than as a weed (cf. Fairbairn *et al.* 2007). To identify the clustering of samples based on ecological similarity rather than deposition source, *Helianthemum* was excluded from the following analyses.

With the removal of *Helianthemum*, three more taxa were removed as outliers from subsequent steps of the analysis, which include *Salsola*, *Conringia* and *Crypsis*. These taxa were unusually prominent due to their relatively high numbers within a restricted number of samples, but *Salsola* and *Crypsis* were also identified as taxa likely derived from animal dung, with their strong associations with dung pellets and other dung-derived taxa in alternative contexts at the site (Filipović 2012: 189; Bogaard *et al.* 2013a).

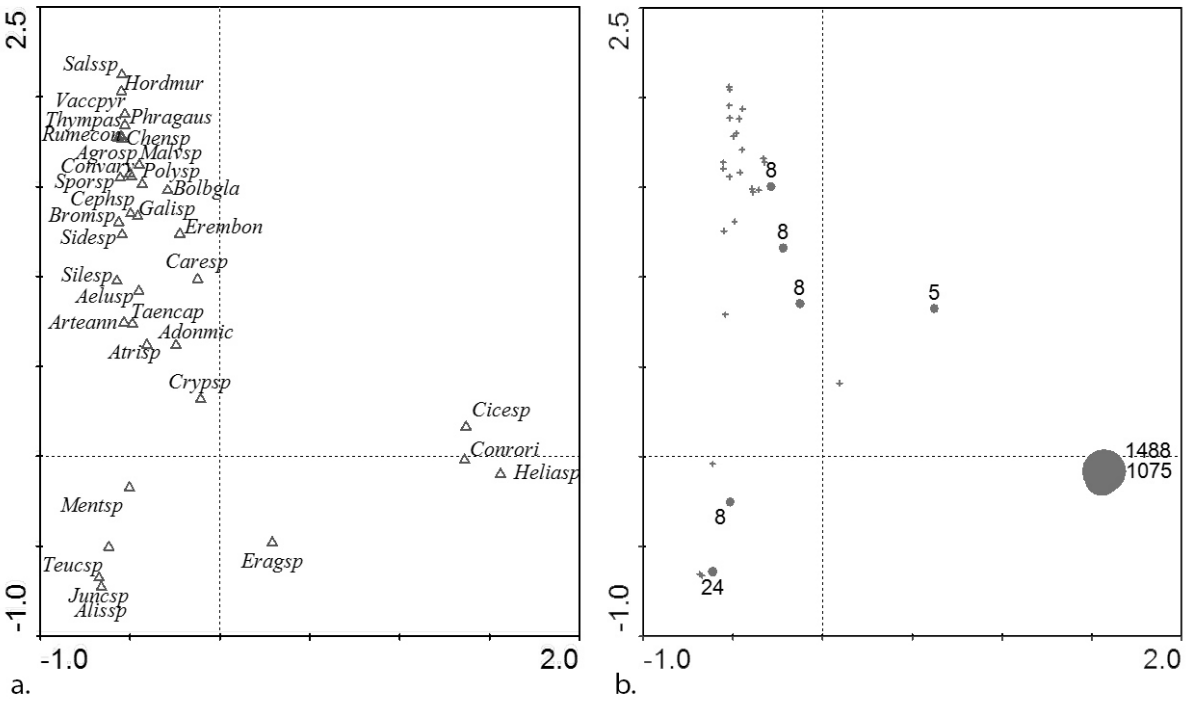


Figure 9.16 – Correspondence analysis plot of 33 samples on the basis of 34 wild taxa that occur in at least two of the samples.
a. Wild taxon distribution with labelled data points indicating genus.
b. Sample distribution with labelled data points representing abundances of *Helianthemum* sp.

This adjusted correspondence analysis yielded a more even distribution of samples and taxa along axes 1 and 2 (Figure 9.17a), but a small cluster of taxa located towards the negative end of axis 1 appeared to be distinguished based on their similarities in depositional source rather than weed composition. Figure 9.17*b* shows this same distribution coded according to predicted deposition type. The categorisation of dung-derived taxa was based on the extensive studies conducted by Filipović (2012; 2014) and Bogaard *et al.* (2013a), which identified a series of taxa that were strongly associated with known 'dirty' samples containing concentrations of preserved dung fragments (Appendix 1c). Moreover, taxa identified as collected plants based on the occurrence of unusually large concentrations, co-occurrences of taxa and properties such as edibility, influenced this analysis. Two genera from the mint family (Lamiaceae), *Teucrium* and *Mentha* were identified as likely collected taxa on this basis. Appendix 1d details the full list of categories used for predicted deposition type in this analysis.

The coded taxon distribution plot (Figure 9.17*b*) demonstrates the regular occurrence of dung-derived taxa, even within some of the purest crop stores. Some of this contamination may be linked to previous stores of dung for use as fuel inside the same bin features (above, 4.3.13). This practice was attested within bin F.2003, one of the storage features adjacent to many of the crop stores selected from Building 52, which contained a concentration of preserved sheep/goat dung pellets filled with *Sporobolus* seeds; such primary deposits demonstrate the multi-functional nature of storage facilities at Çatalhöyük (Bogaard *et al.* 2013a: 117). Clustering at the negative end of axis 1 can be distinguished as a group of samples that contain large concentrations of the two remaining collected taxa, and an abundance of *Juncus*, generally considered a dung-derived taxon (Bogaard *et al.* 2013a; Filipović 2014) (Figure 9.17*c*).

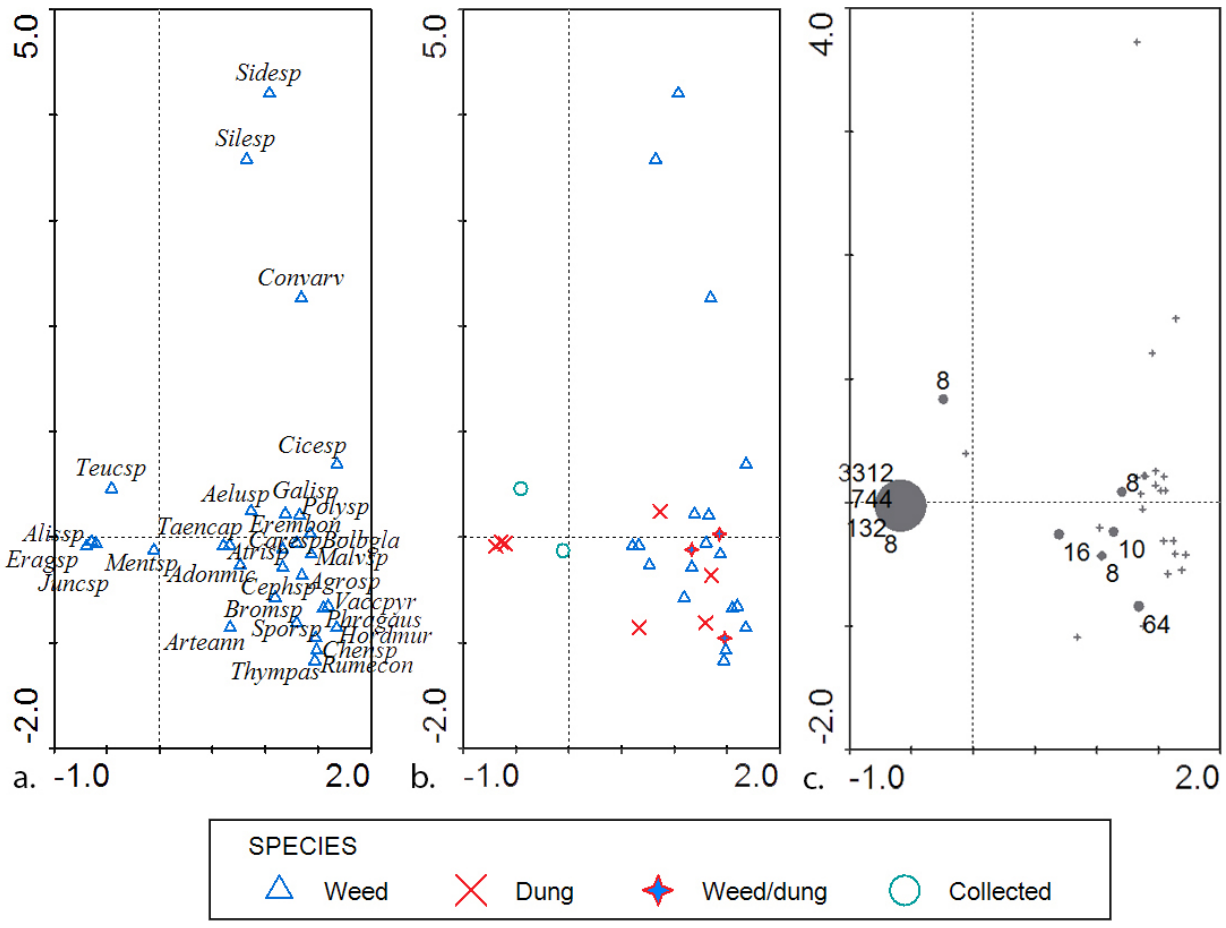


Figure 9.17 – Correspondence analysis plot of 33 samples on the basis of 30 taxa that occur in at least two of the samples. a. Wild taxa distribution with labelled data points indicating genus. b. Wild taxa distribution coded by deposition type. c. Sample distribution with labelled data points representing abundances of *Juncus* sp.

Such influences are confirmed when considering these distributions in relation to storage type. Figure 9.18 codes the samples according to the storage categories that were outlined previously (above, 9.1.2) and reveals similarities between the wild taxa compositions and storage type. The residual crop stores form a concentrated cluster towards the positive end of axis 1. There are also two distinct groups identified for the category of storage clusters that were recovered from the inside of bin features; the group positioned around the negative end of axis 1 directly corresponds to the identified concentrations of collected and dung taxa. The types of crop store recovered therefore seem to at least some extent reflect the degree of mixing from non-harvest depositional sources.

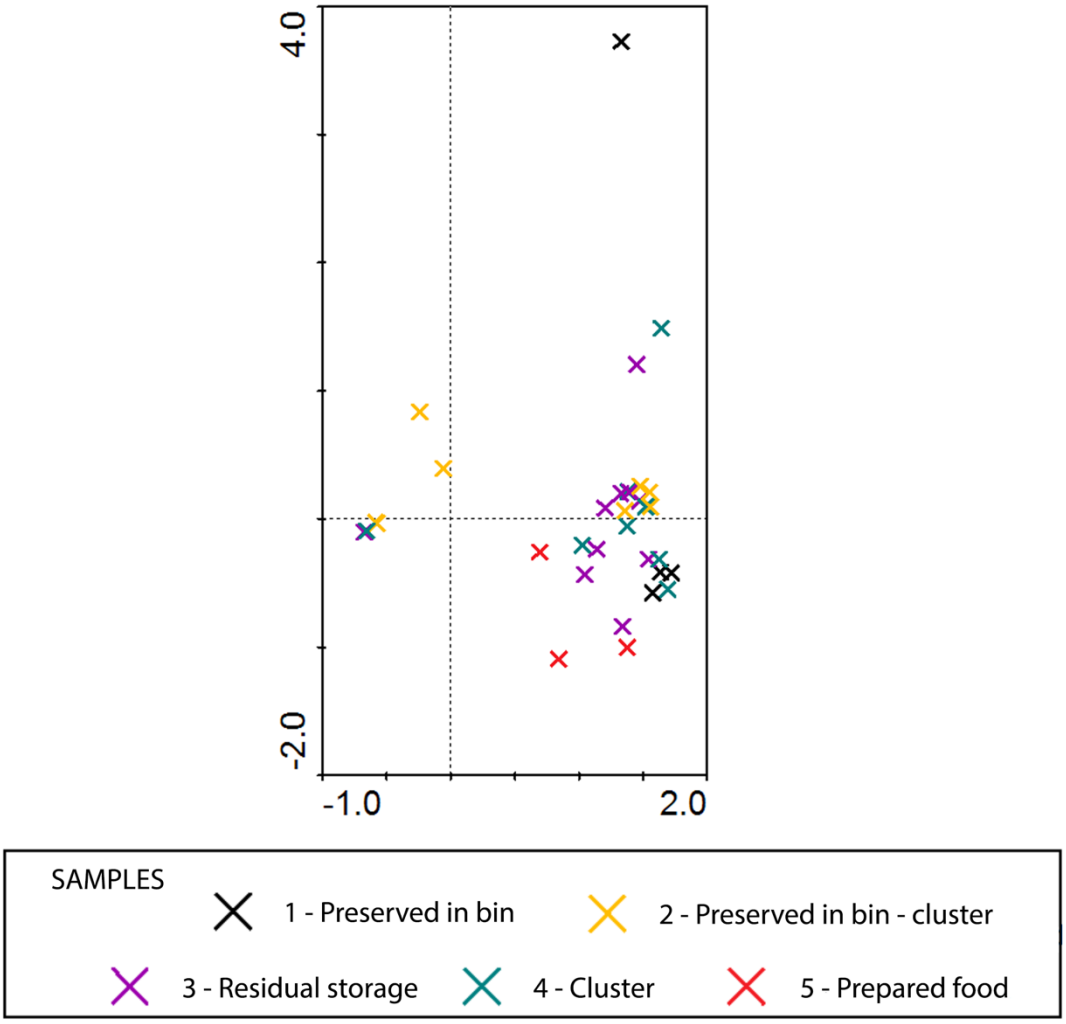


Figure 9.18 – Correspondence analysis plot of 33 samples on the basis of 30 taxa that occur in at least two of the samples. Sample distribution coded by identified storage type.

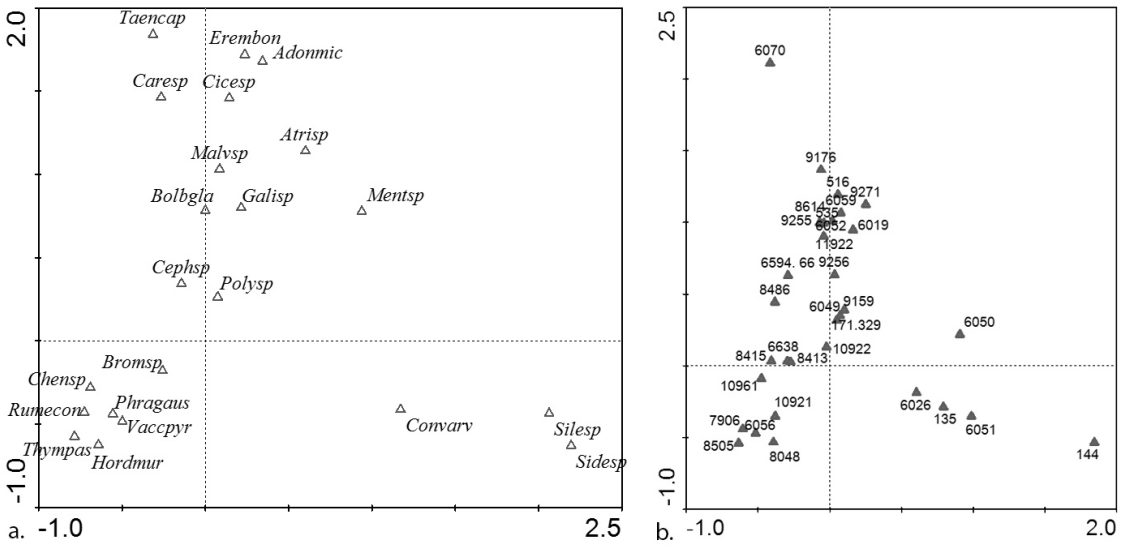


Figure 9.19 – Correspondence analysis plot of 32 samples on the basis of 22 potential weed taxa with dung and collected removed. a. Wild taxa distribution with labelled data points indicating genus. b. Sample distribution with labelled data points indicating sample number.

To isolate ecological variation in arable weed composition only, collected and dung-derived taxa were removed from the subsequent analyses, though a small number of taxa with ambiguous categories (weed/dung, collected/weed) were still incorporated (Appendix 1d). The weed only correspondence analysis was based on 32 of the 33 samples and 22 weed taxa (Figure 9.19a–b). When examining the taxon distribution plot (Figure 9.19a), there appear to be three distinct groups of taxa, with two main groups clustered at either end of axis 2, with a third group which lies towards the positive end of axis 1. The group at the negative end of axis 2 is tightly clustered, whereas the group towards the positive end is more dispersed. To correlate sample types with these observed trends, the plot was coded separately according to crop type, building number and storage type.

Figure 9.20 shows the samples in this weed only plot coded by dominant crop type. A couple of outliers can first be noted, positioned at the positive ends of axis 1 and 2. Interestingly, the sample that lies to the positive end of axis 1 is the single lentil deposit, Fl.144, which appears to be relatively distinct in its weed composition. When the distribution in Figure 9.20a is compared with the weed taxon distribution plot (not shown), it suggests that the lentil sample is particularly associated with a weed flora

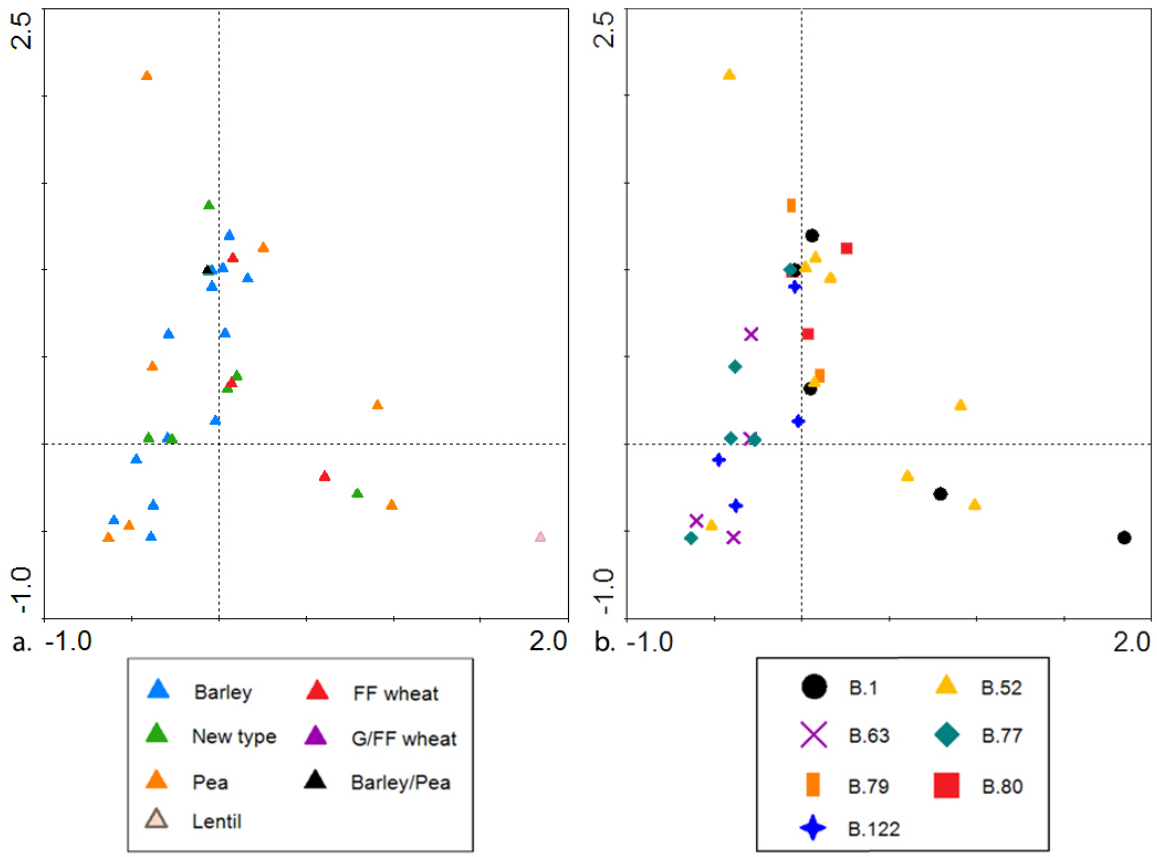


Figure 9.20 – Correspondence analysis plot of 32 samples on the basis of 22 potential weed taxa with dung and collected removed. a. Sample distribution coded by crop type. b. Sample distribution coded by building number.

consisting mainly of *Convolvulus*, *Silene*, and *Sideritis*. The second outlier, positioned to the positive end of axis 2, Fl.6070, is a pea sample from Building 52. Figure 9.19a suggests that it contained an unusually high proportion of *Taeniatherum caput-medusae* relative to other species. The main distribution of samples is positioned much closer to the origin of both axes, with a few recognisable trends when examining the different crop types. Naked barley appears to form two distinct clusters, which are separated along axis 2. Conversely, the pea samples seem to be highly variable in composition and are generally dispersed across both axes. The glume wheat-dominated samples are also quite variable, though are mainly centred around the origin. The three free-threshing wheat samples appeared distinct from one another in their weed composition, despite two of the samples being sampled from the same excavation unit; these two samples were identified as distinct

clusters by the excavators. Finally, the sole barley/pea sample appears to be closely linked to the barley group situated at the positive end of axis 2.

Examining the distribution of samples according to building adds further clarity to these observed patterns (Figure 9.20b). The two separate barley groups can be largely distinguished by their associated buildings, with the cluster at the negative end of axis 2 representing stores from Buildings 63 and 122, and the positive end group being linked to barley deposits from Buildings 1, 52 and 80. The distribution of glume wheat stores seem to be independent from building number, but it is interesting to note the close similarity between the stores from neighbouring Buildings 79 and 80 at the upper part of axis 2. Of particular significance is that the weed flora appears to be consistent between these two buildings, regardless of crop type, all samples from both buildings being concentrated around the positive end of axis 2. Building 77 also appears to be somewhat grouped together regardless of crop type ('new type' wheat, pea, pea/barley), with most of its

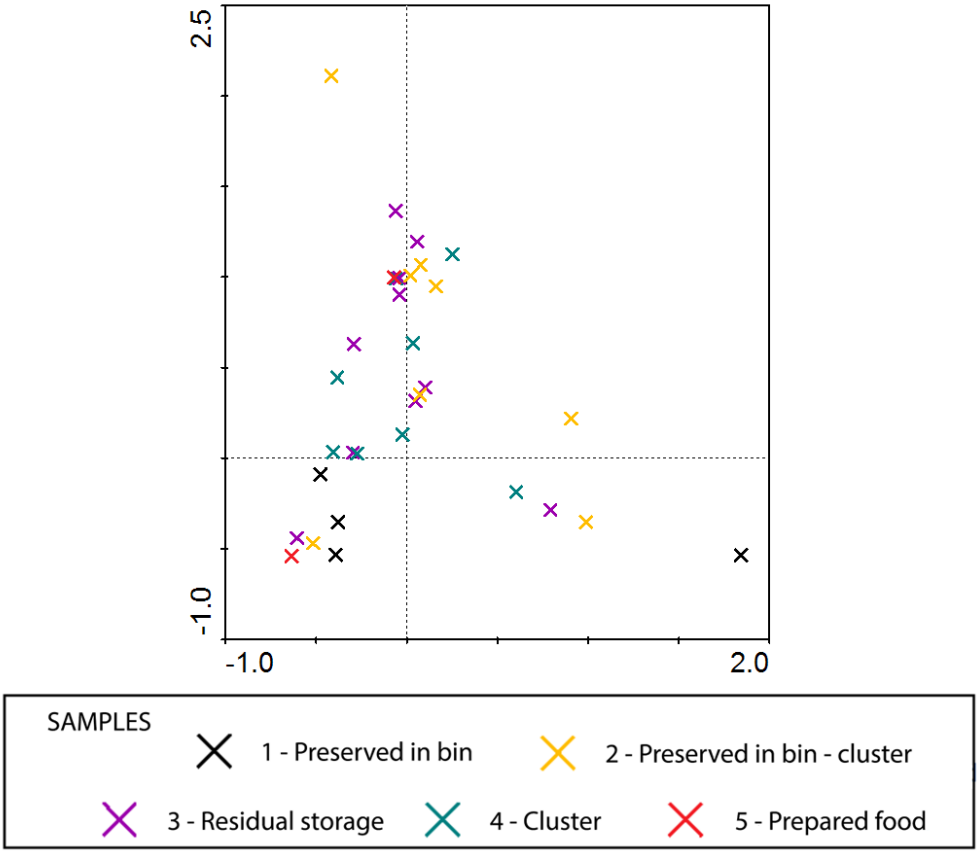


Figure 9.21 – Correspondence analysis plot of 32 samples on the basis of 22 taxa with dung and collected removed. Sample distribution coded by identified storage type.

samples grouping towards the negative end of axis 1. By contrast, the distribution for Building 1 seems to be more driven by crop type, with the samples quite widely spread across the plot; the two closely positioned samples are both barley samples. Similarly, Building 52 was notably diverse in its weed composition, with samples spread along both axes. This building also had the most diverse crop stores, but there were no observable clusters related to crop type within it.

Figure 9.21 shows the same weed taxon plot coded by storage category. In contrast to the previous analysis that included collected and dung-derived taxa (Figure 9.18), there are now only limited trends relating to storage type, which adds further reliability to the patterns observed by building number and crop types as evidence of genuine variation in arable weed composition and potentially ecology. Three of the storage type 1 samples, 'preserved in bin', were very similar in composition, though they all consisted of barley, with two of the samples from Building 122 and a third from Building. The fourth sample from category 1, Fl.144, was more strongly distinguished by it being a lentil sample. With the dung-derived and collected taxa removed, the residual bin stores were no longer closely related in composition and were widely spread across the plot. The two groups identified earlier for storage type 2, 'preserved in bin – cluster', were also no longer distinguishable.

This series of correspondence analyses has shown that similarities in the isolated weed flora are most closely correlated with building, and to a lesser extent crop type. These patterns will be explored further when examining the specific ecological signatures of the weed flora. These analyses also demonstrate the importance of identifying and excluding wild taxa from non-arable sources, as they obscure the patterning of greatest interest for this research.

9.4 Crop-processing analysis

To assist with the isolation of relevant arable crop weeds, as well as to provide further information on the status of the samples from the three Syrian sites, the selected samples were analysed using two different forms of crop-processing analysis (above, 5.8.2). Firstly, the physical characteristics of the wild/weed assemblage was analysed using discriminant analysis, which compared certain physical properties (i.e. small/big, light/heavy, headed/free) of the wild seeds from each sample with ethnobotanical data compiled by Jones (1984). This was then complemented by a second analysis, which examined the ratio of crop components (grain and chaff) to the weed seeds of each sample using triangle scatter plots, which could be further compared with ethnobotanical data (Jones 1990) to aid the identification of relevant crop-processing stages. The results of these two analyses were compared to determine trends in crop-processing stages for each site, as well as to inform the appropriate level of wild taxa exclusions from the final ecological analysis. Similar analyses were additionally undertaken for the Çatalhöyük material to test the previous identifications of wild contaminants within these *in situ* crop stores, together with the investigation of crop cleaning levels among the different categories of storage.

9.4.1 Identifying non-weed contaminants using discriminant analysis

9.4.1.1 Jerf el-Ahmar

Following the methods outlined above (5.8.2.1), the wild/weed assemblage from Jerf el-Ahmar was directly compared with the four crop-processing categories determined from the Amorgos dataset (Jones 1984; 1987). Though all the selected samples from this early site had assigned contextual information, their mainly non-primary deposition (i.e. building collapse, midden) means that their contexts are not reliable indicators of their crop-processing stage (Jones 1987). With livestock yet to be domesticated in this early Pre-Pottery Neolithic site (Gourichon 2004), the expected route of non-arable

contamination within the wild assemblage was through intentional collection rather than dung-derived taxa. Nevertheless, it has been argued that dung may have been used for fuel since the Epipalaeolithic (cf. Miller 1996; Hillman *et al.* 1997; Arranz-Otaegui *et al.* 2016), so should not be ruled out. Large amounts of wild mustard (*Brassica/Sinapis* sp.) were demonstrated to be collected at the site through the preservation of charred seed cakes (Willcox 2002); however, this known collected type did not occur within the selected samples (Table 9.13). A small number of ruderal taxa were also indicated from the assemblage (*Androsace maxima* and *Tribulus terrestris*) (Willcox 2012: 164); however these taxa are also known to invade cultivated fields so could also have been brought to site as a weed (A. Bogaard, pers. comm.).

The initial discriminant analysis, which considered all wild/ weed taxa (Table 9.22; Figure 9.22a & 9.23a), closely resembled the distribution of the Amorgos samples and suggested a mixture of crop-processing stages were represented within the samples, but with notable clustering towards the centre of the 'winnowing by-product' group. To assess the potential contribution of non-arable taxa, which may have skewed this first analysis, a second version was conducted where the archaeological samples were entered as a separate fifth group (above, 5.8.2.1) (Figure 9.22b). Comparison between the two versions of the analysis (ungrouped and separated group) revealed minimal alteration to the distribution of the ethnobotanical groups and archaeological samples, suggesting there were negligible contaminants from non-arable sources within the selected archaeobotanical assemblage. Therefore, the grouped version of the analysis was no longer considered within the subsequent removal stages.

While significant influences from non-arable sources (e.g. dung flora) could not be detected at Jerf el-Ahmar, it remained important to identify even limited instances of non-weed contaminants before conducting the final ecological analysis. Upon inspection of the wild assemblage, two taxa were considered as being potentially collected within the selected samples: *Capparis* and *Hordeum murinum/bulbosum*. While possible as a weed in specific contexts (Hillman 1991: 29), *Capparis* is widely identified as a collected type in

other sites (Rivera *et al.* 2002). The frequent occurrence of *Capparis*, which was also the third most abundant taxon within the wild/weed assemblage, warranted this genus for removal in its entirety from the second analysis (Table 9.22). *Hordeum murinum/bulbosum* was highlighted by its high abundance and ubiquity scores (above, 9.2.1.3; Table 9.13). This taxon may have been collected for consumption in these early pre-domestication contexts; however, it is also a typical arable weed within later sites. When investigated on a sample by sample basis, one sample (JF284) had a particularly high density of this species type (6.1 per litre), which paralleled some of the highest concentrations of cereal grain observed within the selection (Table 9.10). Yet all other instances of the taxon reflected minimal concentrations (less than 1 per litre), suggesting it could have been an arable weed.

Three further analyses were conducted to explore the impact upon the distribution of samples when these suspected collected taxa were removed in different degrees, with the fourth analysis also testing the exclusion of potential ruderal taxa (Table 9.22). The second analysis (Figure 9.23b), which excluded *Capparis* as well as large concentrations of *Hordeum murinum/bulbosum* (over 5 per litre[7]), presented a slight shift in sample distribution; the archaeological samples shifted slightly towards the 'fine sieved by-product' cluster, with many samples reflecting a mixture of crop-processing stages. However, a greater shift was observable within the third analysis (Figure 9.23c), where all *Hordeum murinum/bulbosum* specimens were removed (Table 9.22); in this analysis, the archaeological samples more closely reflected the 'fine sieved by-product' group. By contrast, the fourth analysis (Figure 9.23d), which excluded possible ruderal taxa, was only marginally affected.

With all four of the analyses reflecting weed-traits consistent with arable products and by-products, it was difficult to establish the appropriate level of wild taxa exclusions without considering trends in sample composition (i.e. ratios of grain to chaff and weed). To

[7] This was set above Willcox and Stordeur's (2012: 107) three cereal items per litre, which they used to identify possible storage contexts at Jerf el-Ahmar.

determine the correct analysis to inform the final ecological analysis, these four distributions were compared with a series of triangle scatter plots, which were based on the different degrees of wild taxa exclusions (below, 9.4.2.1).

Table 9.22 – Different taxon combinations examined in the Jerf el-Ahmar discriminant analyses

	Group	Species excluded	Selection notes	Reason
1	All wild taxa	None	-	-
2	Collected removed	*Capparis*	All	Likely to be collected
		Hordeum murinum/bulbosum	JF284	Large concentration (over 5 counts per litre) suggesting possible collection
3	Collected removed 2	*Capparis*	All	Likely to be collected
		Hordeum murinum/bulbosum	All	Possibly collected
4	Collected and ruderal removed	*Capparis*	All	Likely to be collected
		Hordeum murinum/bulbosum	All	Possibly collected
		Androsace maxima	All	Ruderal?
		Tribulus terrestris	All	Ruderal?

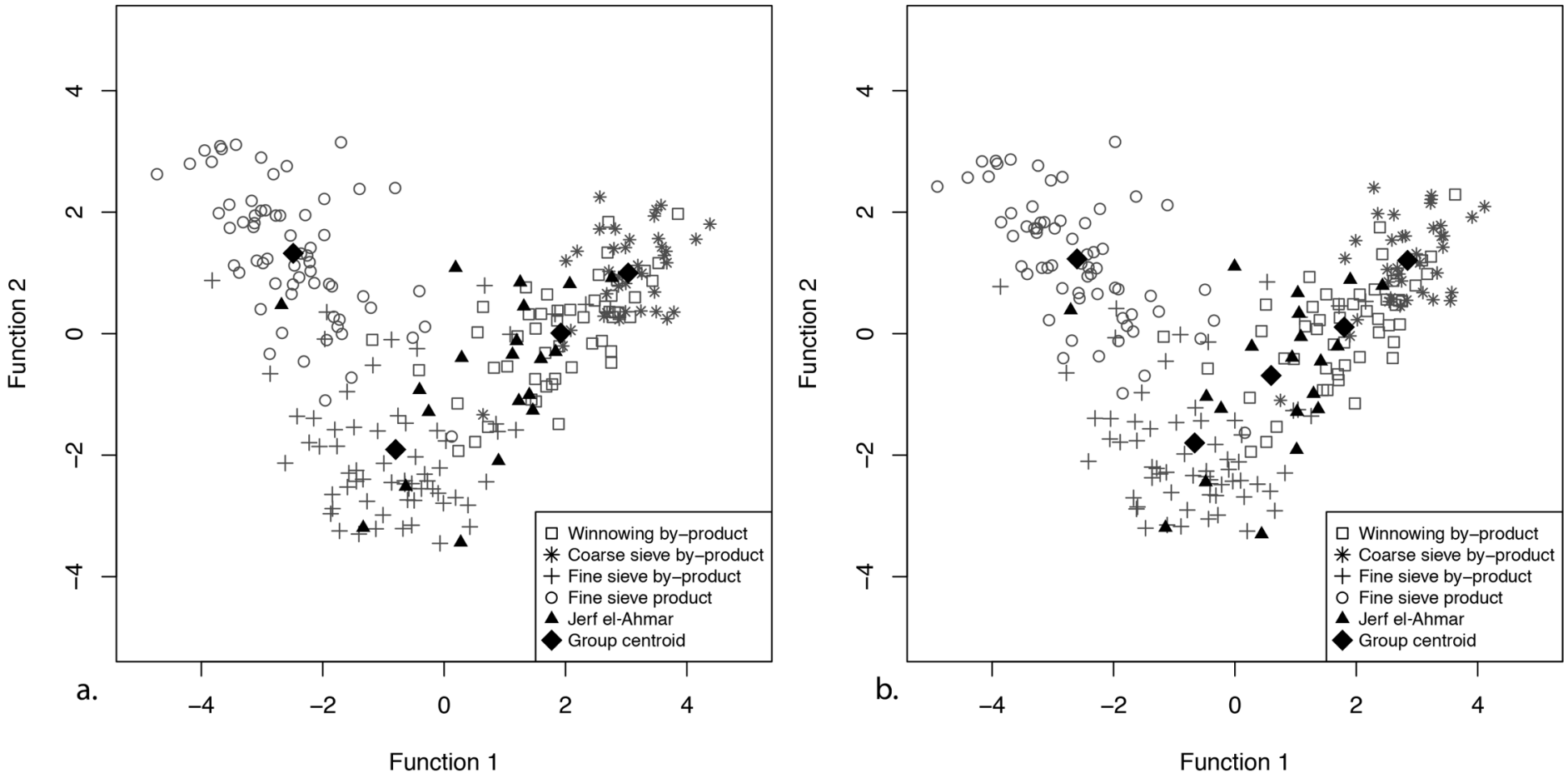


Figure 9.22 – Discriminant analysis of Jerf el-Ahmar and Jones' (1984) ethnographical crop processing samples, (a.) classified with regard to the ethnographic data (ungrouped), and (b.) with the Jerf el-Ahmar samples entered as a separate fifth group following Charles (1998).

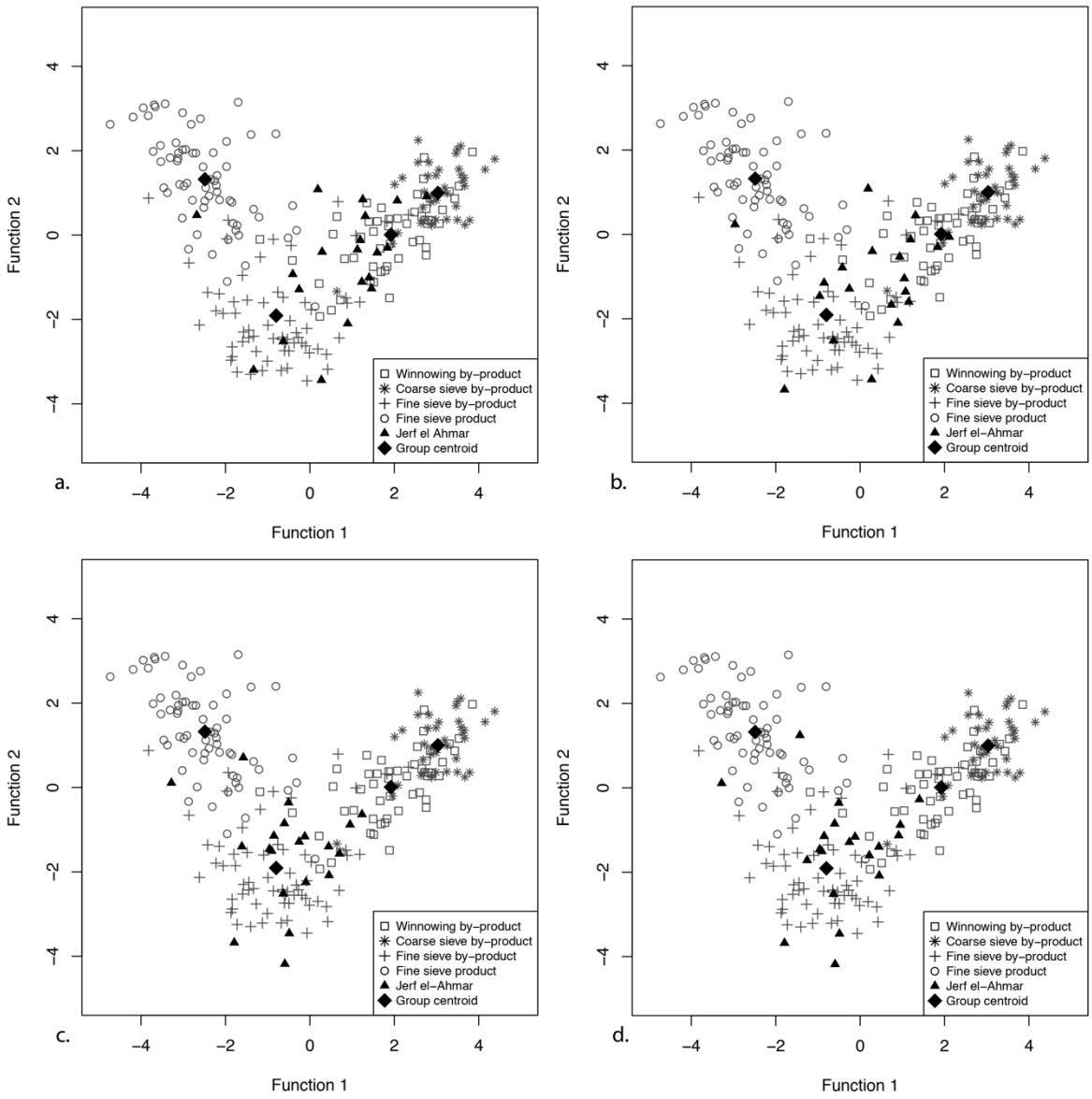


Figure 9.23 – Ungrouped versions of the discriminant analysis comparing samples from Jerf el-Ahmar and Jones' (1984) ethnographical crop processing samples. The four analyses relate to the different levels of species removals: a. All wild taxa, b. Collected removed (large concentrations only), c. Collected removed (all) & d. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.22.

9.4.1.2 Dja'de

With much of the contextual information missing from the samples examined from Dja'de, the analysis of crop-processing stages was an important step for providing greater background information for the ecological analysis. A brief examination of the crop component (Table 9.16) revealed that half of the samples were of mixed crop type (pulses and cereals), so a mixture of crop-processing stages was deemed a likely outcome of the discriminant analysis. Animal husbandry was still in its earliest stages at this early PPNB site (Helmer *et al.* 2005), with the animal bone assemblage predominantly consisting of wild gazelle and equids (Gourichon 2004: 317), so a dominance of dung-derived taxa was not expected to be a source of non-arable contamination. With no instances of *in situ* plant concentrations, such as the compacted seed cake discovered at Jerf el-Ahmar, potential collected taxa were examined and identified on a sample by sample basis. The wild/weed assemblage contained three possible ruderal taxa (*Androsace maxima*, *Hyoscyamus* sp. and *Tribulus terrestris*) adapted to marginal environments (rocky screes, steppe, sandy places) (Willcox 2012: 164), but which also sometimes occur in cultivated or fallow fields so their status as weeds could not be ruled out (Davis 1965).

In the initial analysis where all taxa were included (Table 9.23; Figure 9.24a & 9.25a), the archaeological samples were spread widely across the overall distribution with most overlapping the Amorgos crop-processing groups. A small number of samples were located within the 'void' between clusters, suggesting a mixture of crop-processing stages; this was expected owing to the mixed nature of the crop content in many of the samples. While there was no clear clustering of samples towards any single crop-processing group, most samples were classified as 'fine sieve by product' (13/27), with fewer samples identified as 'winnowing by product' (7/27) and 'fine sieve product' (6/7), while only one sample was classified as 'coarse-sieved by product'. A near identical arrangement was reproduced when the archaeological samples were entered as a separate fifth group (Figure 9.24b), suggesting that, similarly to Jerf el-Ahmar, there were insignificant

quantities of wild contaminants from non-arable sources. Therefore, only the ungrouped versions were considered in the subsequent analyses.

Though the distribution was consistent with arable weed-traits, the wild/weed assemblage was explored further for possible contaminants. One taxon that was particularly prominent was the wild grass *Taeniatherum caput-medusae*, which was the second most abundant and third most ubiquitous taxon within the assemblage (9.2.2.2). Three samples contained large concentrations of this species, which exceeded four items per litre; this equated to as much as 357 items in one sample, suggesting likely instances of intentional collection. However, *Taeniatherum caput-medusae* also commonly occurs as an arable weed at other sites (e.g. Bogaard *et al.* 2013a; Fairbairn 2014), including at Jerf el-Ahmar. Further instances of this taxon at Dja'de were in much smaller quantities, occurring at less than one item per litre, so it is possible that it derived from multiple sources.

Other suspected collected taxa were also identified, including *Capparis* and the wild mustard *Alyssum/Lepidium,* the latter of which was particularly abundant within one sample (170 items)*;* the collection of wild mustard is attested at neighbouring Jerf el-Ahmar (Willcox 2002). *Atriplex* was another candidate to be suspected from non-arable sources; though a common arable weed, the high ubiquity and abundance of this taxon across the selected samples cast doubt upon its status as a crop weed (above, 9.2.2.2). Analogous to *Bolboschoenus glaucus* at Çatalhöyük (above, 9.1.5), *Atriplex* was pervasive across most of the samples and was the most abundant wild taxon at the site. While this wild type may have been collected as food, its high frequencies within a number of burnt layers (3-4 counts per litre) support the interpretation that this taxon may have been utilised as a fuel source (Willcox *et al.* 2008: 17).

Table 9.23 details the various taxa and quantities that were removed within each of the subsequent analyses. The second analysis (Figure 9.25b) which targeted and removed large concentrations of taxa (over 4 per litre) from ambiguous sources, as well as probable

collected species, resulted in a noticeable shifting of samples towards the central space between groups, which can be interpreted as a 'mixing of different processing stages' (cf. Charles 1998: 116). In the third analysis (Figure 9.24c), when all occurrences of the wild/weedy grasses *Taeniatherum caput-medusae* and *Stipa* were removed, the distribution is altered further with samples beginning to cluster towards the 'winnowing by-product' group. A fourth analysis (Figure 9.24d), which investigated the impact of ruderal taxa upon the distribution, presented negligible changes to the distribution.

Similarly to Jerf el-Ahmar, all four versions of the analysis were consistent with arable products and by-products, or mixtures between these stages. Therefore, to establish the correct level of wild taxa exclusions from the weed assemblage, these results were compared with the outcomes of the triangular scatter plots (below, 9.4.2.1), which investigated patterns within the sample compositions.

Table 9.23 – Different taxon combinations examined in the Dja'de discriminant analyses.

No.	Group	Samples removed (less than 10 weeds)	Species excluded	Selection notes	Reason
1	All wild taxa	None	None	-	-
2	Collected removed	None	*Capparis*	all	Likely to be collected
			Alyssum/Lepidum	all	Likely to be collected
			Atriplex	all	Ubiquitous and abundant, likely non-arable source
			Taeniatherum caput-medusae	over 4 per litre	Large concentrations, possible collections
			Stipa	over 4 per litre (DJ235)	Large concentrations, possible collections
3	Collected removed 2	DJ176	*Capparis*	all	Likely to be collected
			Alyssum/Lepidum	all	Likely to be collected
			Atriplex	all	Ubiquitous and abundant, likely non-arable source
			Taeniatherum caput-medusae	all	Large concentrations, possible collections
			Stipa	all	Large concentrations, possible collections
4	Collected and ruderal removed	DJ112, DJ176	*Capparis*	all	Likely to be collected
			Alyssum/Lepidum	all	Likely to be collected
			Atriplex	all	Ubiquitous and abundant, likely non-arable source
			Taeniatherum caput-medusae	all	Large concentrations, possible collections
			Stipa	all	Large concentrations, possible collections
			Androsace maxima	all	Ruderal?
			Hyoscyamus	all	Ruderal?
			Tribulus terrestris	all	Ruderal?

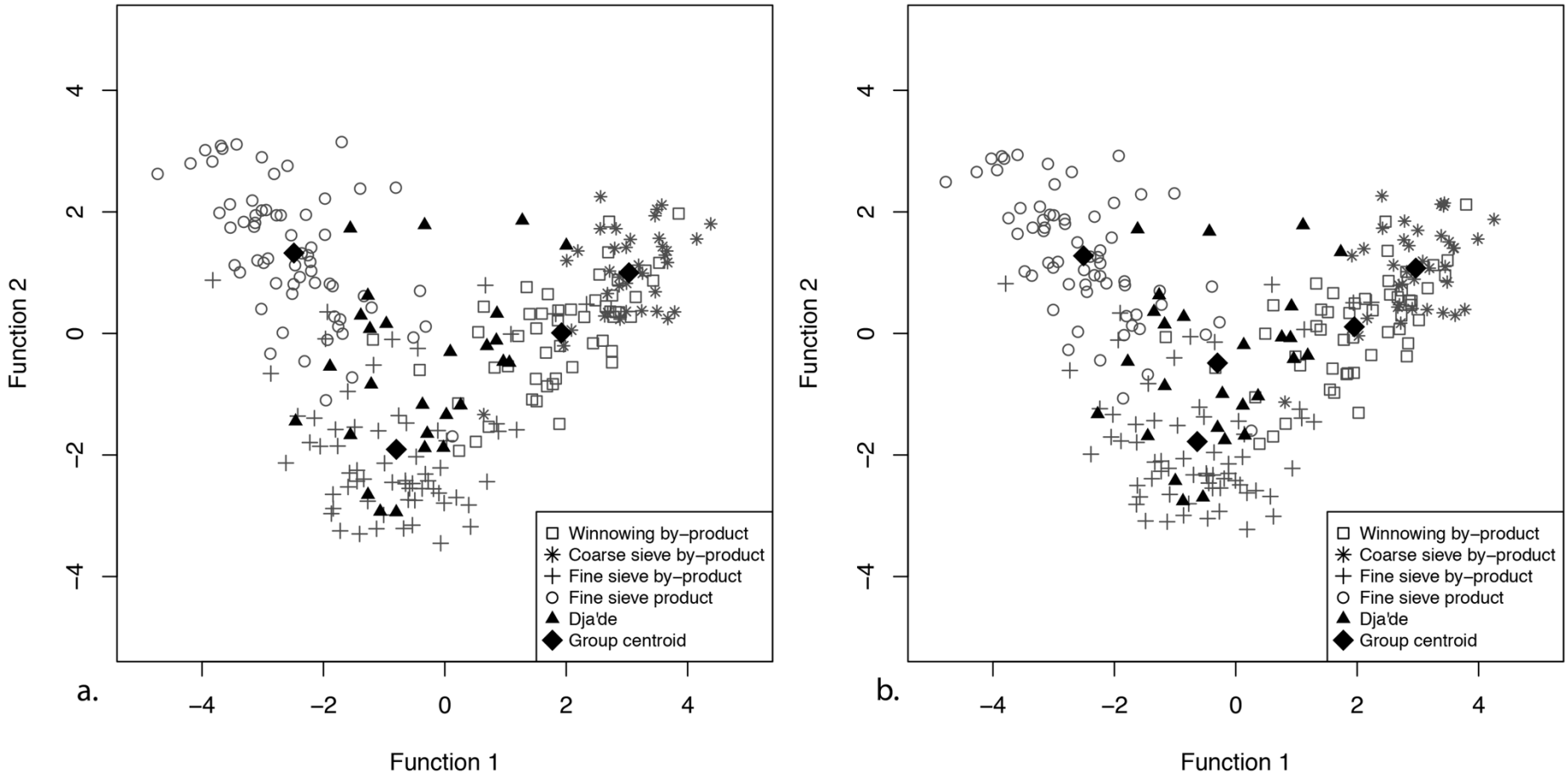


Figure 9.24 – Discriminant analysis of Dja'de and Jones' (1984) ethnographical crop processing samples, (a.) classified with regard to the ethnographic data (ungrouped), and (b.) with the Dja'de samples entered as a separate fifth group following Charles (1998).

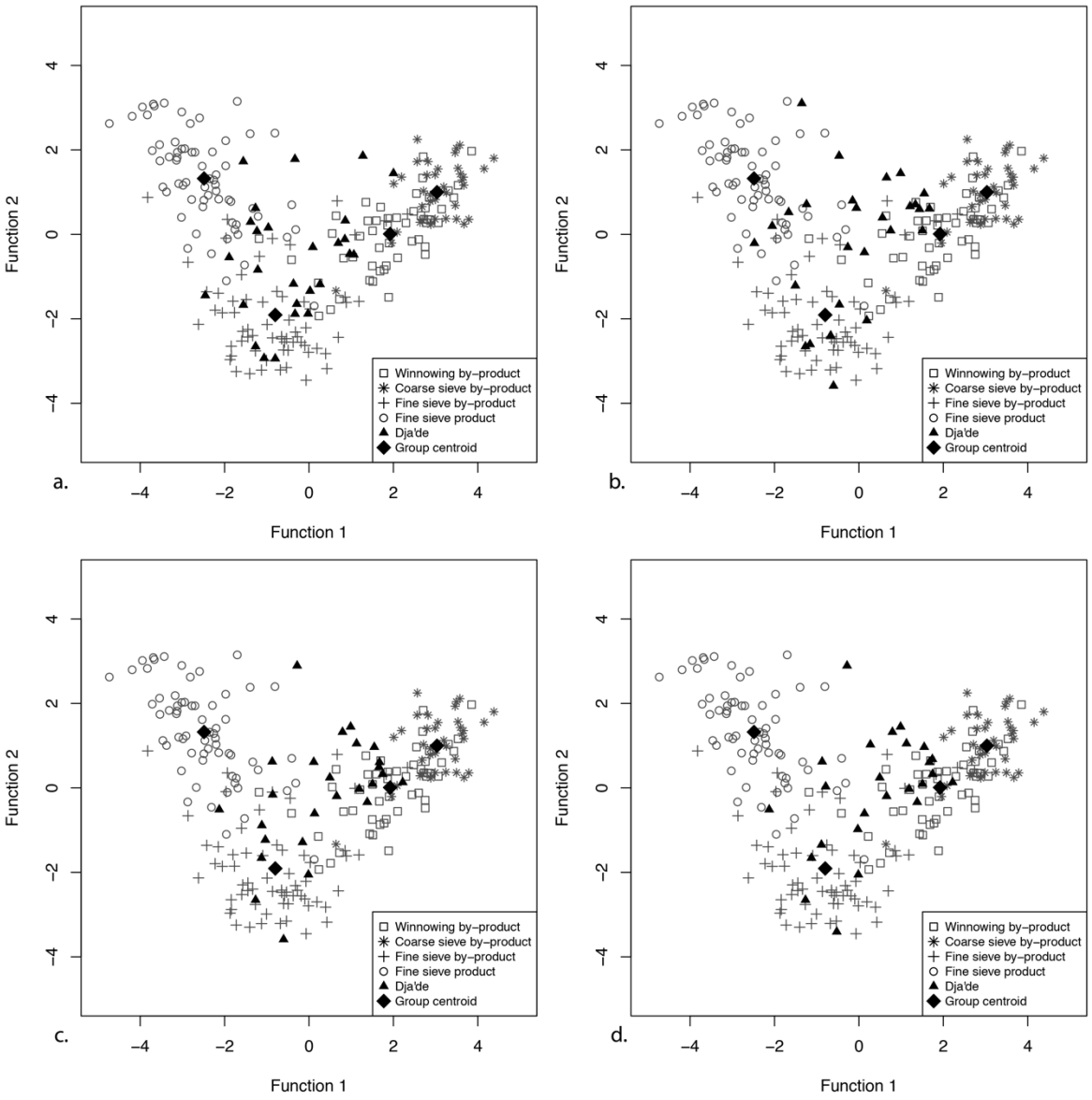


Figure 9.25 – Ungrouped versions of the discriminant analysis comparing samples from Dja'de and Jones' (1984) ethnographical crop processing samples. The four analyses relate to the different levels of species removals: a. All wild taxa, b. Collected removed (large concentrations only), c. Collected removed (all) & d. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.23.

9.4.1.3 Tell Aswad

The selected samples from Tell Aswad derived from a range of different context types, which were variable in crop density, but were of non-primary deposition. Therefore, these crop-processing analyses were crucial for providing greater understanding of their composition and origin. When considering possible sources of non-arable taxa, the potential for the use of dung for fuel is greatly increased at this PPNB site, where fully domestic goats were abundant within the faunal assemblage (Helmer & Gourichon 2008). However, unlike Çatalhöyük, only minimal charred dung material has been positively identified within the archaeobotanical assemblage (Douché 2016 pers. comm.); two samples contained small quantities of coprolite material, probably from caprines. As at the other Syrian sites, a small number of possible ruderal taxa were identified, which included *Aizoon hispanicus* and *Androsace maxima*. While *Aizoon hispanicus* is unlikely to occur as an arable weed, adapted to deserts and saline ground (Zohary & Feinburn-Dothan 1966), *Androsace maxima* is commonly found in cultivated fields (Davis 1965). A considerable amount of *Lithospermum* (*Lithospermum arvense/ Lithospermum tenuiflorum*) and *Arnebia decumbens* were also present within the assemblage as possible ruderals, but these had been excluded at the start of this analysis due to their silicified preservation (cf. above, 5.8.1). There were no primary contexts to demonstrate the intentional collection of wild species at Tell Aswad, but the large concentrations of certain taxa within the assemblage suggests the likely presence of non-arable sources.

In the initial analysis where all taxa were included (Table 9.24; Figure 9.26a & 9.27a), the 16 Tell Aswad samples were tightly clustered towards the bottom edge of the Amorgos distribution at the periphery of the 'fine sieved by-product' group. When the same data was entered as a separate fifth group (Figure 9.26b), the archaeological samples became even more distinct from the known crop-processing stages, suggesting the likely inclusion of non-arable sources within the analysis. Only 19% of the samples were classified as one of the crop-processing categories, all with low probability ($p<0.9$).

The wild/weed assemblage was examined closely for potential contaminants. There were several taxa that were both ubiquitous and occurred in large numbers within some of the samples (above, 9.2.3.2). To account for the variation in sample size (14 to 196 litres) weed counts were calculated to represent their number per litre to identify significant concentrations. The likely collected taxon *Capparis* was identified at a high concentration within one sample (15 items per litre), which was associated with a basin feature.

The next largest concentration was of *Bolboschoenus glaucus*, which occurred at a concentration of ten items per litre in one sample, with a total exceeding 1,000 items. This was the most ubiquitous *and* most abundant wild taxon at the site, which was present within 100% of samples, with a total sum of 2,082 specimens across the selection. This distribution is reminiscent of the Çatalhöyük assemblage, where *Bolboschoenus glaucus* was prevalent and likely derived from several non-arable sources, including dung burning and building material (above, 9.1.5). This species is adapted to saline and freshwater wetland environments (Davis 1965; Charles 2011), which reflects the local habitats of the two nearby lakes (W. van Zeist & Bakker-Heeres 1982). *Bolboschoenus glaucus* has been considered by some as a potential food source (Wollstonecroft & Erkal 1999; Wollstonecroft *et al.* 2008) that may have supplemented cereals, but the species is also known to occur as an arable weed (Wollstonecroft *et al.* 2011; M. Charles, pers. comm.). While the specific status of this taxon is unclear at Tell Aswad, the pervasiveness and large numbers of this species casts doubt on its primary origin as an arable weed within the assemblage. The closely related taxon *Scirpus* cf. *lacustris*, which was additionally recovered in relatively large concentrations, was treated in a similar manner.

A further two taxa, *Trigonella astroites* and *Carex*, were also pervasive within the assemblage and occasionally found in large numbers (over 100 items), but with slightly more restricted concentrations (3.5 items per litre). While both taxa are known as crop weeds, their similarly pervasive distribution within the samples suggest they entered the assemblage via alternative sources. *Trigonella astroites* is adapted to open steppe vegetation and bare limestone slopes (Guest & Townsend 1966), while the numerous species of *Carex* can be found at a range of habitats; though like other Cyperaceae, many

species are commonly associated with wet places. Both taxa were identified as dung-derived at Çatalhöyük (Filipović 2014) and could have been similarly exploited by herds of grazing goats at Tell Aswad.

The inference that there may be dung-derived taxa within the assemblage is further supported when considering *Bolboschoenus glaucus, Scirpus* cf. *lacustris, Trigonella astroites* and *Carex* in combination. These four taxa form over 80% of the wild/weed assemblage in seven out of nine cases where samples exceeded 200 items. Further taxa associated with dung deposits at Çatalhöyük, such as small-seeded legumes (Bogaard *et al.* 2013; Filipović 2014) (Table 9.24), were also detected, but occurred in much smaller quantities. A series of analyses were undertaken with different levels of exclusions to accurately isolate the arable components of the wild assemblage (Table 9.24).

There were minimal shifts in the distribution of samples within the subsequent discriminant analyses until *Capparis* and all four of the likely non-arable/possible dung-derived taxa were fully removed (Table 9.24; Figure 9.27d). The archaeological samples in this fourth version of the analysis finally resembled the Amorgos dataset, with most samples overlapping with the 'fine sieved by-product' category. When the samples were entered as a fifth group, 50% of the samples were classified as one of the four crop-processing categories, of which 56% were classified with high probability ($p>0.9$). In the fifth and sixth versions of the analysis, further adjustments were made to explore the impact of further removals, such as other possible dung-derived taxa present in smaller quantities and potential ruderal species. In the fifth analysis (Figure 9.27e), the distribution was pushed towards the centre of the four crop-processing groups, reflecting a mixture of crop-processing stages, whereas the removal of ruderal taxa in the final analysis (Figure 9.27f) presented only minor changes to the overall distribution.

The last three analyses all reflected weed-traits consistent with arable products and by-products, so were taken forward to be compared with the triangular scatter plots (below, 9.4.2.1). The identification of consistencies between the sample composition and the weed-based analysis helped to inform the correct level of taxa exclusions for the subsequent ecological analysis.

Table 9.24 – Different taxon combinations examined in the Tell Aswad discriminant analyses.
***Each analysis includes the exclusions from the previous stage.**

No.	Group	Samples removed (less than 10 weeds)	Additional species excluded*	Selection notes	Reason
1	All wild taxa	None	None	-	-
2	Collected/ other removed	None	*Capparis*	all	Likely to be collected
			Bolboschoenus glaucus	over 4/litre	Ubiquitous and abundant, likely non-arable source
			Scirpus cf. *lacustris*	over 4/litre	Ubiquitous and abundant, likely non-arable source
3	Collected/ other removed 2	None	*Bolboschoenus glaucus*	all	Ubiquitous and abundant, likely non-arable source
			Scirpus cf. *lacustris*	all	Ubiquitous and abundant, likely non-arable source
4	Collected and dung removed	AW05/11	*Trigonella astroites*	all	Ubiquitous and abundant, likely dung-derived
			Carex	all	Ubiquitous and abundant, likely dung-derived
5	Collected and all dung	AW05/11	*Medicago radiata*	all	Possibly dung-derived
		AW05/21	*Poa bulbosa*	all	Possibly dung-derived
			Astragalus	all	Possibly dung-derived
			Melilotus	all	Possibly dung-derived
			Trifolium	all	Possibly dung-derived
			Leguminosae, small-seeded	all	Possibly dung-derived
6	Collected, dung and ruderal	AW05/11	*Aizoon hispanicus*	all	Ruderal?
		AW05/21	*Androsace maxima*	all	Ruderal?

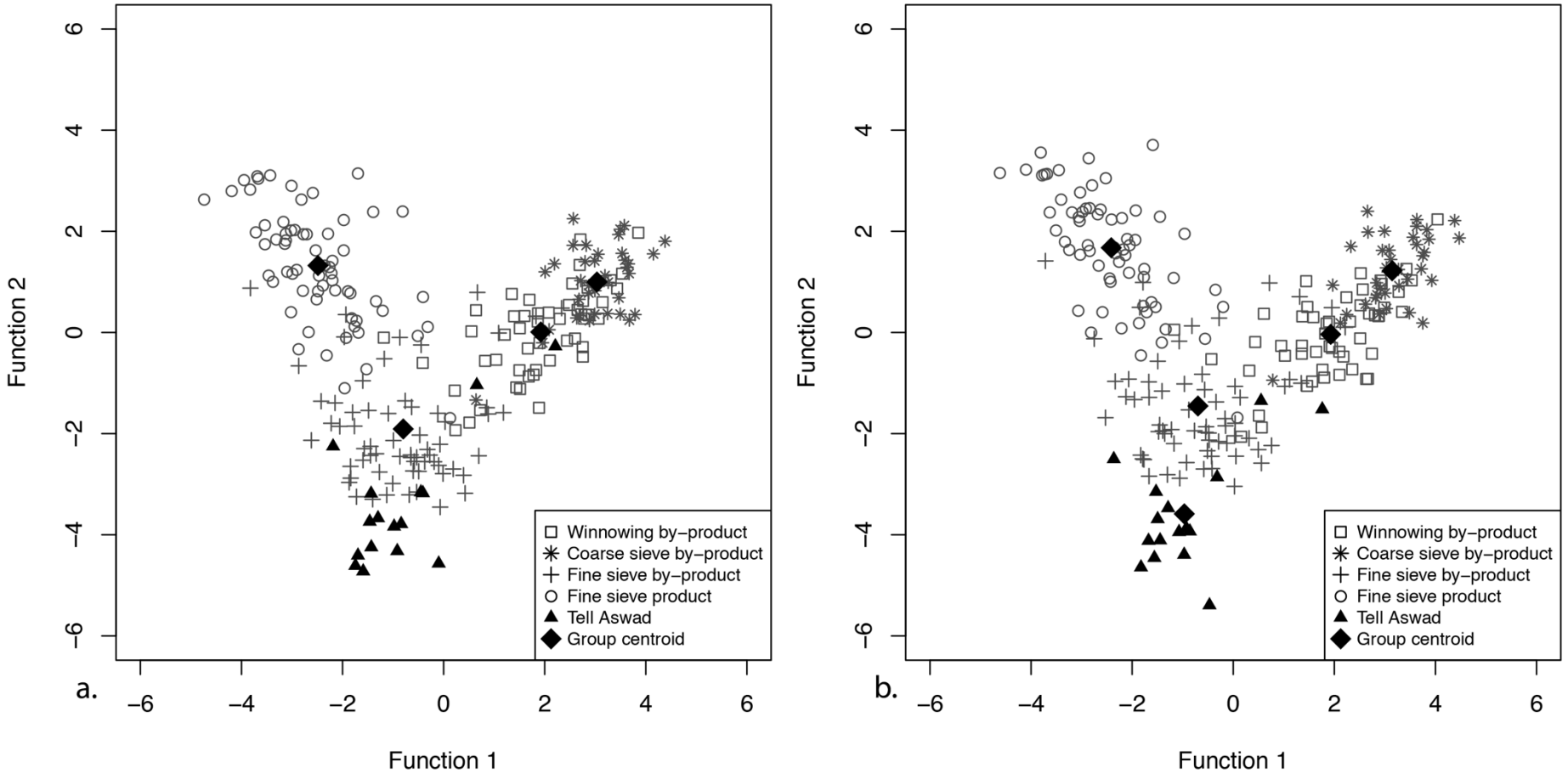


Figure 9.26 – Discriminant analysis of Tell Aswad and Jones' (1984) ethnographical crop processing samples, (a.) classified with regard to the ethnographic data (ungrouped), and (b.) with the Tell Aswad samples entered as a separate fifth group following Charles (1998).

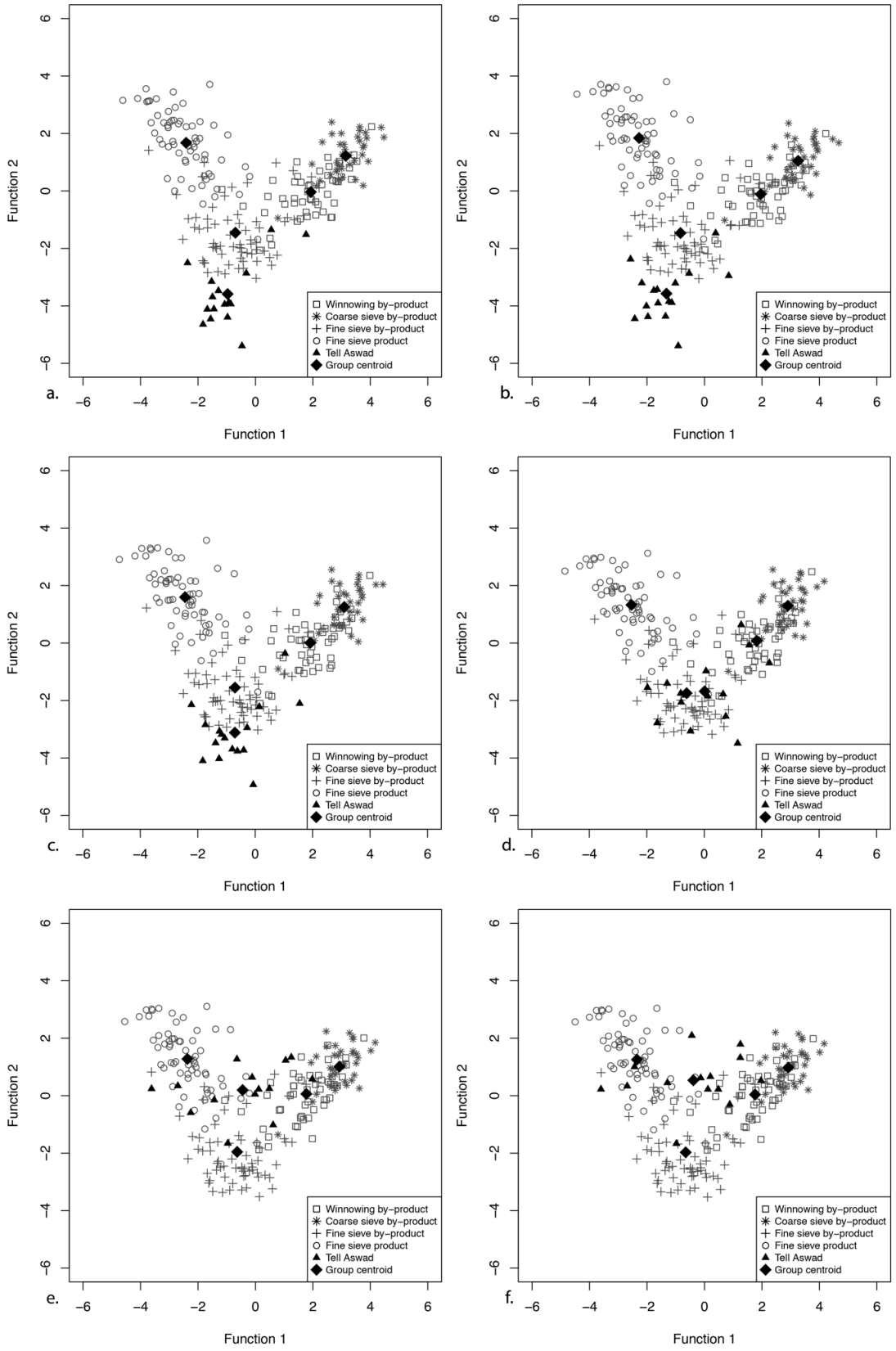


Figure 9.27 – Fifth group versions of the discriminant analysis, following Charles (1998) comparing samples from Tell Aswad and Jones' (1984) ethnographical crop processing samples. The six analyses relate to the different levels of species removals: a. All wild taxa, b. Collected removed (large concentrations only), c. Collected removed (all), d. Collected (all) and dung (large concentrations) removed, e. Collected (all) and dung (all) removed & f. Collected (all), dung (all), and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.24.

9.4.1.4 Çatalhöyük

With the arable components previously determined at Çatalhöyük (above, 9.3), the physical weed traits were tested against the Amorgos ethnobotanical data to check the consistency of the isolated weed material, as well as to assess variation in crop cleaning levels among the different categories of storage. With concentrated grain counts and primary storage contexts, the samples were expected to fall within or between the 'fine sieve product' and 'fine sieve by-product' groups, reflecting differing levels of grain cleaning prior to storage. The selected stores were demonstrated to contain a small number of collected wild taxa, as well as contamination from a suite of dung-derived taxa. Four versions of the discriminant analysis were undertaken, which explored the distribution of samples with different levels of exclusions (Table 9.25; Figure 9.29).

In the initial analysis (Figure 9.28a & 9.29a) where all wild/weed taxa were considered (excl. *Descurania sophia*), the distribution of samples largely overlap with the 'fine sieve by-product' and 'winnowing by-product' crop-processing categories. Thirteen samples were classified within this second group, contradicting the high grain content of the samples. Winnowing by-products are characterised by small, free, light seeds (Jones 1984: 55), which offers an explanation for these misclassified crop-processing stages, with two-thirds of the taxa listed with these features identified either as collected or dung-derived. When the archaeological samples were entered as a separate fifth group in this first analysis (Figure 9.28b), it became clear that the wild/weed assemblages were highly distinct from the Amorgos arable weed compositions when all taxa were included.

The subsequent analyses experimented with the removal of collected, dung-derived, and more ambiguous (though likely dung) taxa. The removal of all probable non-arable contaminants was required before the Çatalhöyük samples closely resembled the ethnobotanical crop-processing categories (Figure 9.29d). When the archaeological samples were ungrouped, most samples were assigned within the expected categories; 86% of the remaining stores were classified as either 'fine sieve product' or 'fine sieve by-

product'. The small proportion of samples (14%) classified as 'winnowing by-product' included two samples from the 'prepared food' storage category, one from 'preserved in bin – cluster' and one from the 'residual storage' category. However, while the distribution of samples did not dramatically shift, when the storage samples were entered as a separate fifth group they were still preferentially classified as archaeological samples (86%) rather than the crop-processing categories. This might be explained by consideration of the group centroid for the archaeological samples (Figure 9.29d); its positioning between the two stages 'fine sieve product' and 'fine sieve by-product' might suggest that some of the crop samples were only partially cleaned before storage, reflecting this intermediate category.

When the archaeological samples were coded according to storage type (Figure 9.30; cf. above, 9.1.2) a few patterns were detected. The residual storage category was the most variable in weed composition, which mirrors the results of the previous correspondence analysis (9.3). By contrast, the four stores from the cleanest 'preserved within bin' category were relatively clustered together and occupy the borderline between the 'fine sieve product' and 'fine sieve by-product' groups, perhaps indicating partial sieving. The remaining sample types appeared more variable in their extent of crop cleaning, but most samples reflected the general distributions of the two predicted groups. Furthermore, the four samples classified as 'winnowing by-product' (see above) were still within the outer confines of the 'fine sieve by-product' distribution.

Table 9.25 – Different taxon combinations examined in the Çatalhöyük discriminant analyses.
***Each analysis includes the exclusions from the previous stage.**

No.	Group	Samples removed (less than 10 weeds)	Additional species excluded*	Reason
1	All wild taxa	9255, 8415	*Descurania sophia*	Very high number - known to be collected
2	Collected removed	9255, 8415	*Helianthemum*	Collected
			Teucrium	Collected
3	Collected and dung removed (excl. ambiguous)	9255, 8415	*Aeluropus*	Dung
		8416	*Alisma*	Dung
			Alopecurus	Dung
			Artemisia	Dung
			Crypsis	Dung
			Eragrostis	Dung
			Juncus	Dung
			Salsola type	Dung
			Scirpus/Eleocharis	Dung
			Sporobolus	Dung
			Stipagrostis type	Dung
			Suaeda	Dung
4	Collected and all dung (incl. ambiguous)	9255, 8415	*Bolboschoenus glaucus*	Dung?
		8416	*Carex*	Dung?
		6052, 6059	*Heliotropium*	Dung?
			Chenopodium	Dung?

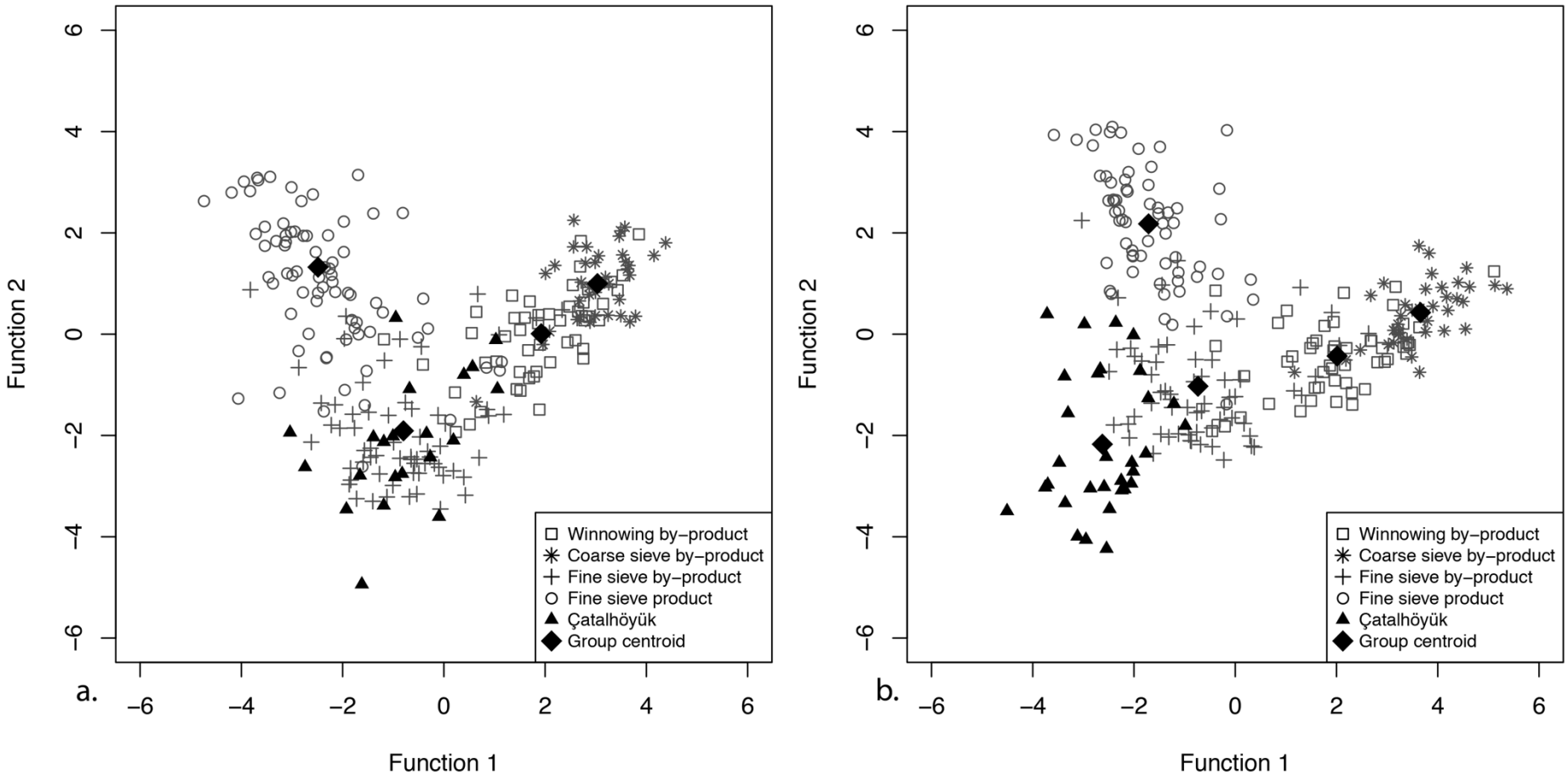


Figure 9.28 – Discriminant analysis of Çatalhöyük and Jones' (1984) ethnographical crop processing samples, (a.) classified with regard to the ethnographic data (ungrouped), and (b.) with the Çatalhöyük samples entered as a separate fifth group following Charles (1998).

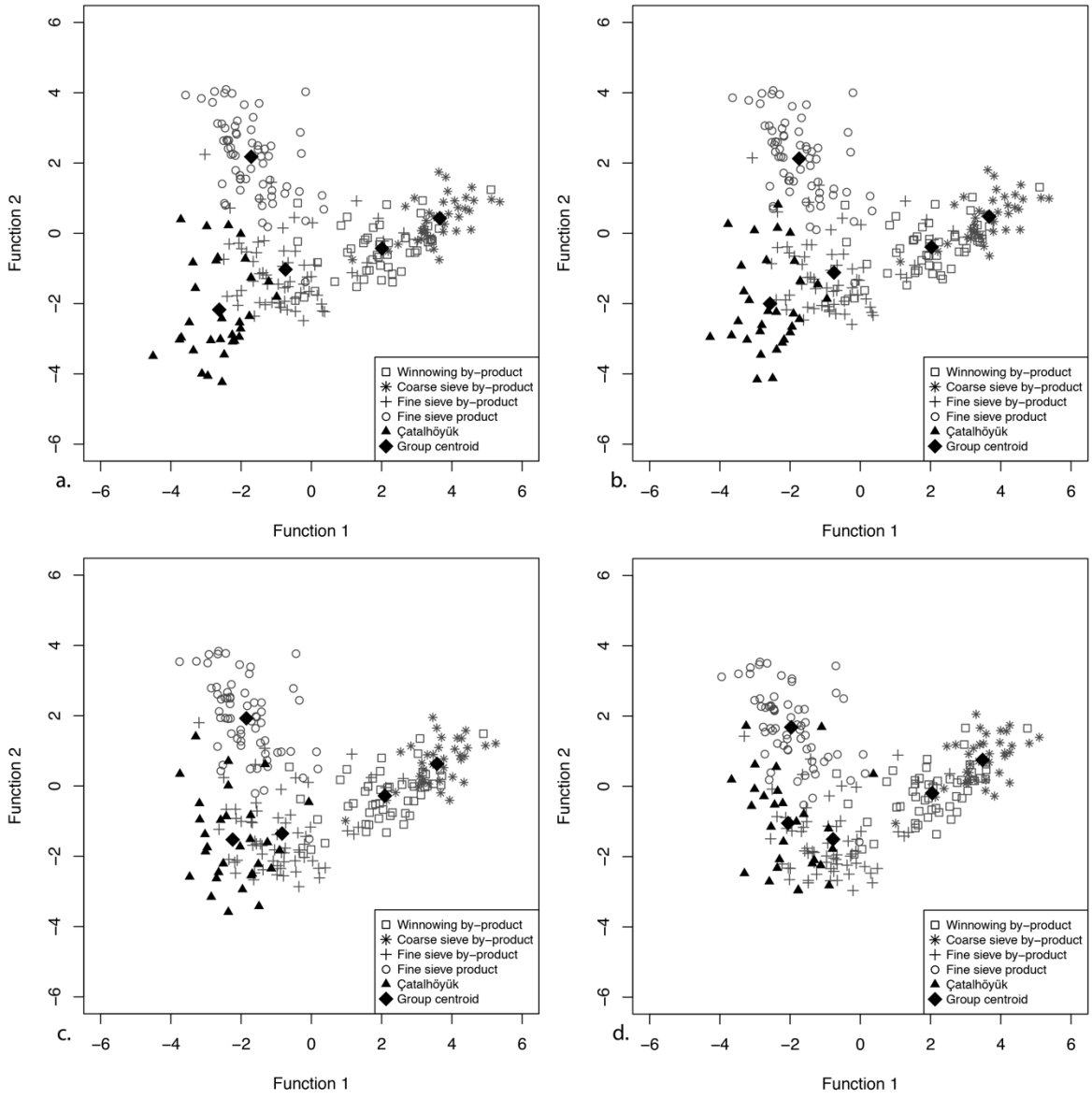


Figure 9.29 – Fifth group versions of the discriminant analysis, following Charles (1998) comparing samples from Çatalhöyük and Jones (1984) ethnographical crop processing samples. The four analyses relate to the different levels of species removals: a. All wild taxa, b. Collected removed, c. Collected and dung (excl. ambiguous taxa) removed & d. Collected and dung (incl. ambiguous taxa) removed. A full list of the taxa excluded can be consulted in Table 9.25.

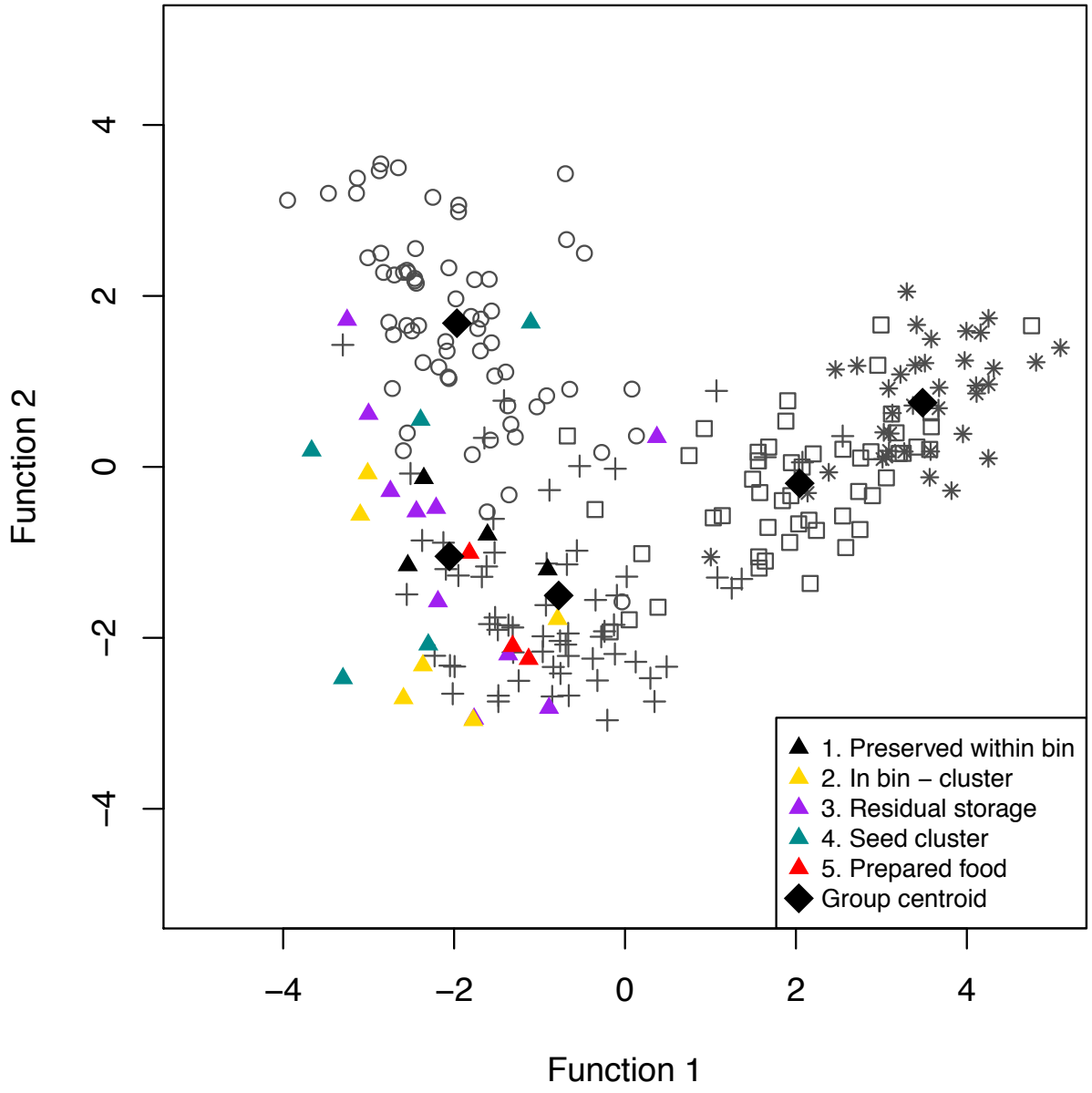


Figure 9.30 – Final fifth group version of the discriminant analysis (analysis 4) coded by storage type.

9.4.2 Triangular scatter plots (triplots): crop and weed proportions

An alternative method used to assess crop-processing stages was triangular (ternary) scatter plots, or 'triplots', which illustrated the relative proportions of grain, chaff and weed material within the samples (above, 5.8.2.2). These were undertaken for samples dominated by one cereal type (≥70%) to minimise contamination from multiple crop types. Using the various results of the discriminant analyses as a basis for the level of exclusions (above, 9.4.1), the isolated weed material was explored in relation to the crop component in a series of triplots at each of the four sites. These distributions were then compared with ethnobotanical data (Figure 9.31) (cf. Jones 1990), as well as the results of the preceding discriminant analysis, to assess trends in crop-processing stages; the identification of consistencies between these two forms of analyses informed the appropriate level of wild taxa exclusions for the final ecological analysis. Furthermore, this combined approach enabled the extent of mixing to be identified within the selected samples and therefore the resolution of ecological analysis that could be achieved. At Çatalhöyük, where context types were well-defined, the method was also used to further inform distinctions between the five identified categories of storage.

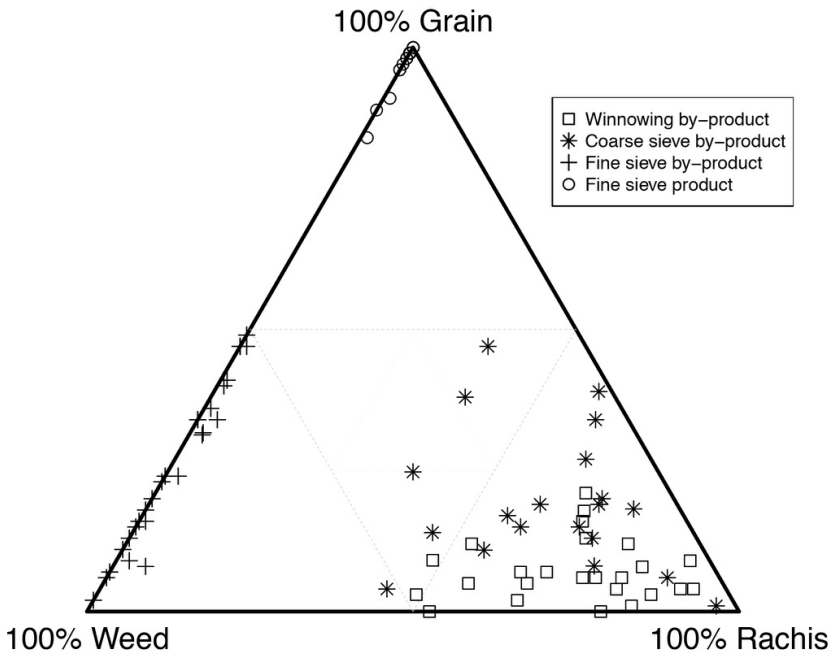


Figure 9.31 – Triplot displaying proportions of grain, rachis and weeds for Jones' (1990) ethnobotanical dataset, which examined different crop-processing stages for free-threshing cereals.

9.4.2.1 Jerf el-Ahmar, Dja'de and Tell Aswad

Jerf el-Ahmar

Comparison of the relative proportions of grain, rachis and weed based on each of the four different levels of wild taxa exclusions (above, 9.4.1.1), revealed only minor revisions to the overall distribution of the Jerf el-Ahmar samples (Figure 9.32). Only one sample's proportions (JF284) was substantially altered by the removal of wild taxa; the exclusion of a *Hordeum murinum/bulbosum* concentration in the second weed-trait analysis reduced the sample's weed proportion by 20%, shifting the sample further towards the 100% grain end of the plot. Therefore, the general trends observed within the triplot were used to inform the appropriate level of wild taxa exclusions.

When compared with the ethnobotanical data (Figure 9.31), most samples concentrate towards an intermediate stage between the cleaned 'fine sieved product' and 'fine sieved by-product' groups, suggesting the mixing of late processing stages, while a few divergent

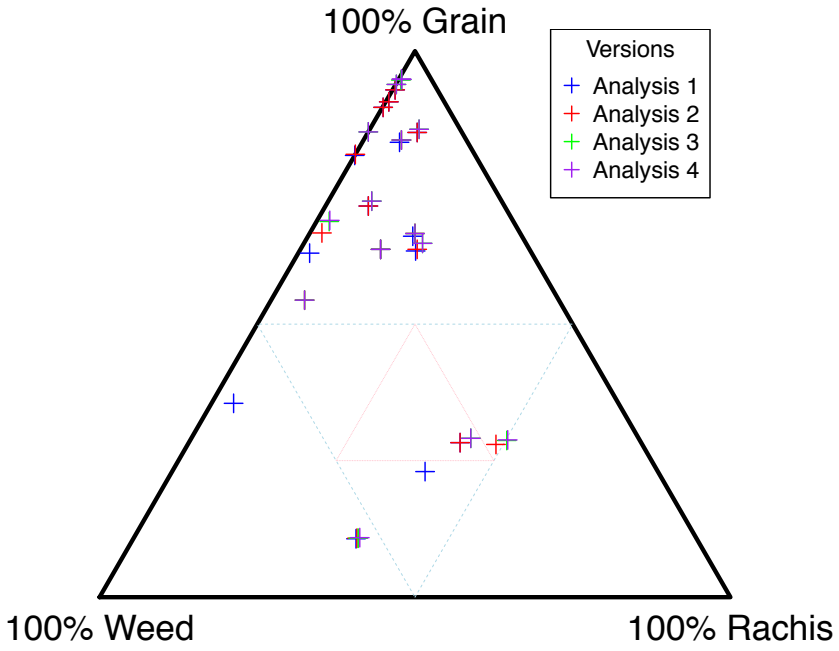


Figure 9.32 – Triplot displaying the proportions of grain, rachis and weed for each sample from Jerf el-Ahmar, based on the increasing wild exclusions of the four crop-processing discriminant analyses: 1. All wild taxa, 2. Collected removed (large concentrations only), 3. Collected removed (all) & 4. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.22.

samples contained significant proportions of rachis and were closer to the 'coarse by-product' and 'winnowing by-product' categories. Only a few samples clearly overlap with the ethnobotanical groups, with some samples deviating towards the centre of the plot; this suggests that many of the samples were likely of mixed crop-processing stage. This mixed distribution most closely mirrors the results of the second weed-trait discriminant analysis (Figure 9.23b), where many of the samples clustered at the edges of the modern crop-processing groups. Alternatively, the samples in the third and fourth discriminant analyses began to cluster towards the 'fine sieve by-product' group, which contrasts with the low proportions of weed seeds observed within the assemblage; 12 samples were identified as 'fine sieve by-product' in the third analysis, of which 83% were classified with high probability. Therefore, the second discriminant analysis was selected to determine the extent of wild taxa exclusions.

The crop-processing stages of the samples was explored further through the coding of the triplot by crop type (Figure 9.33). The two wheat/rye dominated samples were relatively similar in composition with a high grain content and almost no rachis material, placing

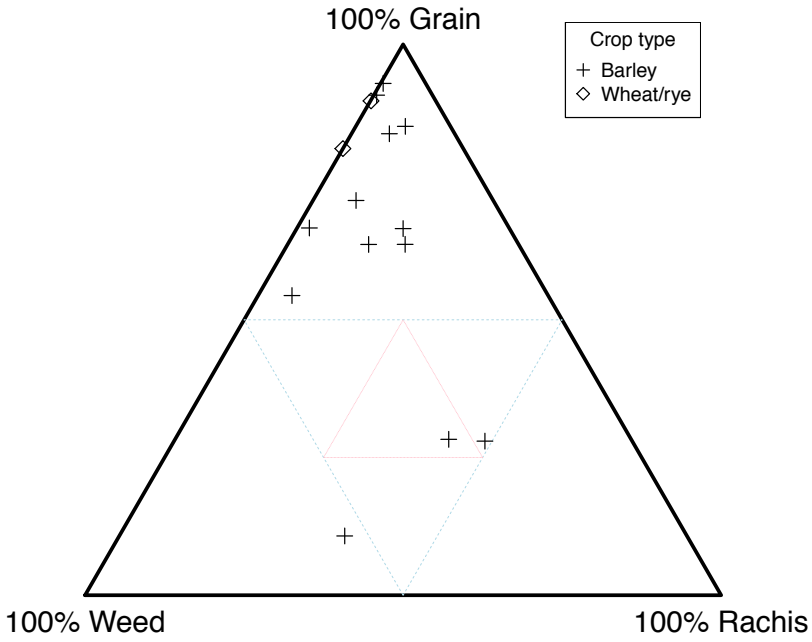


Figure 9.33 – Triplot displaying the proportions of grain, rachis and weed for each sample from Jerf el-Ahmar (based on weed content from the second version of the discriminant analysis), coded by crop type.

them within the 'cleaned product' group. The remaining samples were dominated by wild barley and reflected the full range of the distribution observed at Jerf el-Ahmar. Despite the likely mixing of crop-processing *stages* within the assemblage, only a small number of samples (25%) were excluded from the triplot due to mixing of crop *types*. The likelihood that potentially different growing conditions of different crop types were mixed, therefore, is limited.

Dja'de

Only three of the Dja'de samples were compatible with this type of analysis, as most samples were either of mixed crop type, or were dominated by pulse species, so were without associated chaff material. The three relevant samples were dominated by wild barley and contained negligible rachis material, with the samples plotted along the axis between '100% weed' and '100% grain' (Figure 9.34). However, the ratio of weed to grain in this small selection varied, ranging from predominantly weed to over 90% grain. Comparison of the four different levels of wild taxa exclusions (Figure 9.34), examined in the previous discriminant analysis (above, 9.4.1.2), presented a slight shifting of samples towards the 100% crop end of the triplot.

When this distribution was compared with the ethnobotanical data, one sample overlapped with the 'cleaned product' group, another sample corresponded with the periphery of the 'fine sieved by-product' group, while the remaining sample reflected an intermediate stage between these two groups. With such a small selection, it is difficult to establish any wider trends in crop-processing stages at Dja'de using this analysis, but the fact that many samples were too mixed in crop type to be included proved instructive.

When revisiting the previous weed-trait analyses (above, 9.4.1.2), three main patterns in sample distribution could be discerned; a predominance of samples classified as 'fine sieve -product' in the first analysis, a heavily mixed arrangement between groups in the second analysis, and a clustering towards 'winnowing by-product' in the third analysis. While not

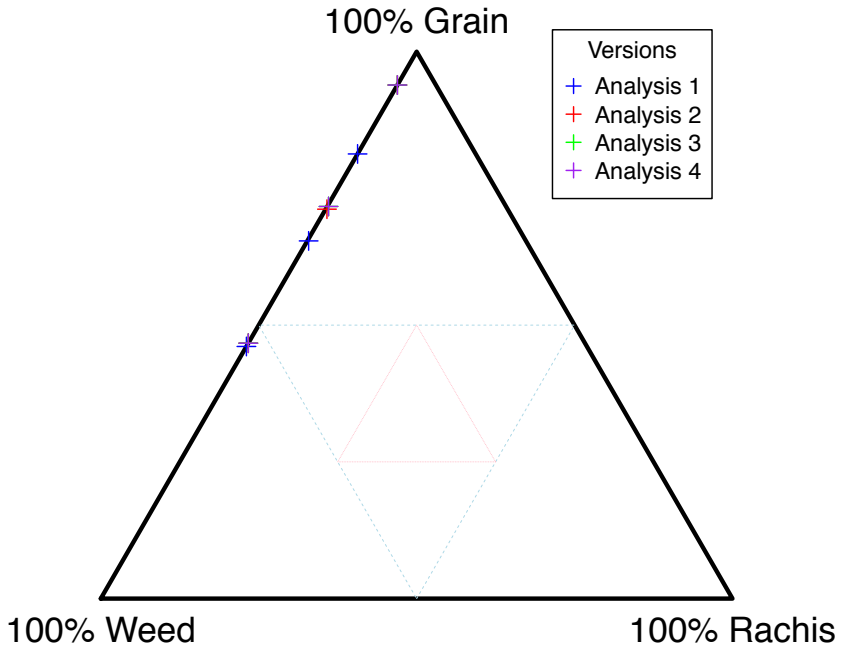


Figure 9.34 – Triplot displaying the proportions of grain, rachis and weed for the three clean barley samples at Dja'de, based on the increasing wild exclusions of the four crop-processing discriminant analyses: 1. All wild taxa, 2. Collected removed (large concentrations only), 3. Collected removed (all) & 4. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.23.

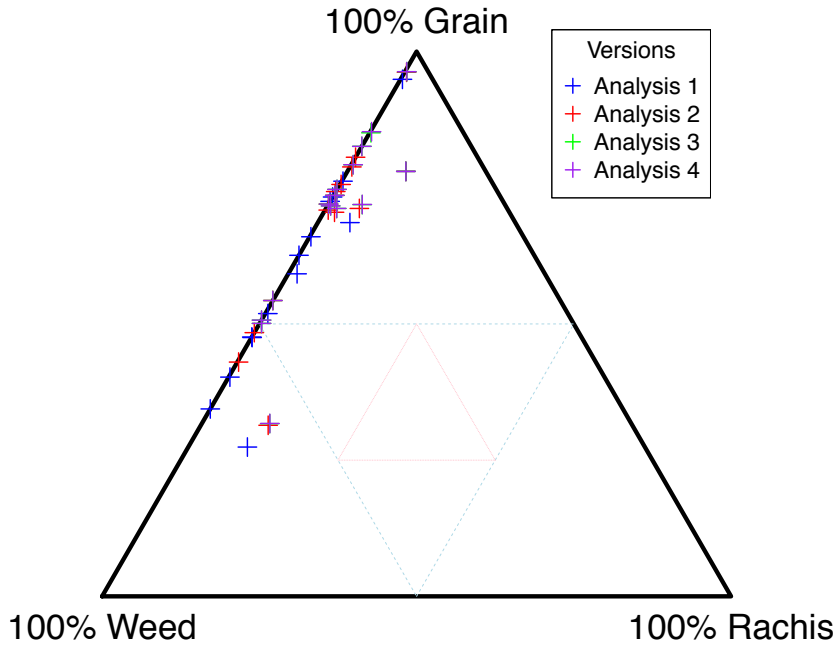


Figure 9.35 – Triplot displaying the proportions of grain, rachis and weed for the mixed samples at Dja'de, based on the increasing wild exclusions of the four crop-processing discriminant analyses: 1. All wild taxa, 2. Collected removed (large concentrations only), 3. Collected removed (all) & 4. Collected (all) and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.23. This plot is not directly comparable with ethnobotanical data.

directly comparable with the ethnobotanical groups, the relative proportions of grain, rachis and weed within the 'mixed' pulse/cereal samples (Figure 9.) continued to reflect similar proportions to the three cleaner barley samples across the four versions of taxa exclusions. The samples contained insignificant quantities of rachis material throughout and there is a greater trend towards larger proportions of grain in relation to weed content.

The concentration of samples midway between 100% weed and 100% grain in the triplots, combined with the largely mixed indications from the crop types, are most consistent with the second discriminant analysis, where many of the Dja'de samples were situated within the voids between the defined crop-processing groups (Figure 9.25b). Furthermore, the limited rachis material identified throughout the assemblage, even when cereals were dominant within the mixtures (Figure 9.), contrasts with the 'winnowing by-products' signature suggested by the third analysis (Figure 9.25c). Therefore, the second version of the analysis was used to inform the identification of arable components for the Dja'de samples.

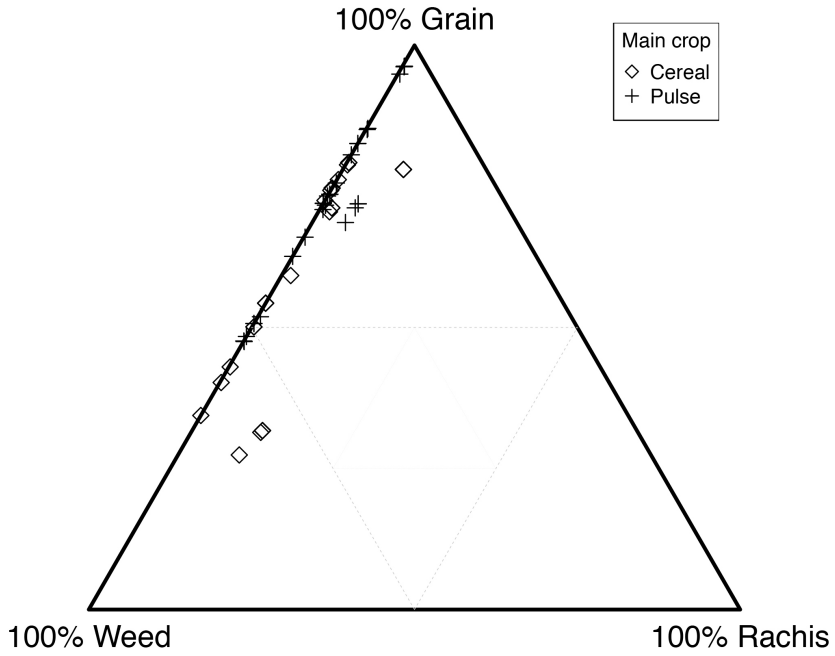


Figure 9.36 – Triplot showing mixed samples only from Dja'de (based on weed content from the second version of the discriminant analysis), coded according to main crop type (i.e. cereal or pulse). This plot is not directly comparable with ethnobotanical data.

Tell Aswad

Half of the samples from Tell Aswad contained more than 70% of a single cereal type and were able to be assessed using triplots. When the variable levels of wild taxa exclusions were compared between the final three discriminant analyses (Figure 9.37; cf. above, 9.4.1.3) there were minimal impacts upon the relative proportions of weed, rachis and grain. Therefore, the composition of the samples could be used to infer the most appropriate level of wild taxa exclusions for the ecological analysis.

The eight samples gravitated towards the '100% grain' part of the distribution, but varied greatly in their lesser proportions of weed and rachis. Five of the eight samples analysed were dominated by glume wheats (3 indeterminate wheat, 2 emmer wheat) (Figure 9.38), for which no ethnographic data was available (above, 5.8.2.2), so their crop-processing stage was primarily inferred from their grain:glume base ratio (Figure 9.39). All of the

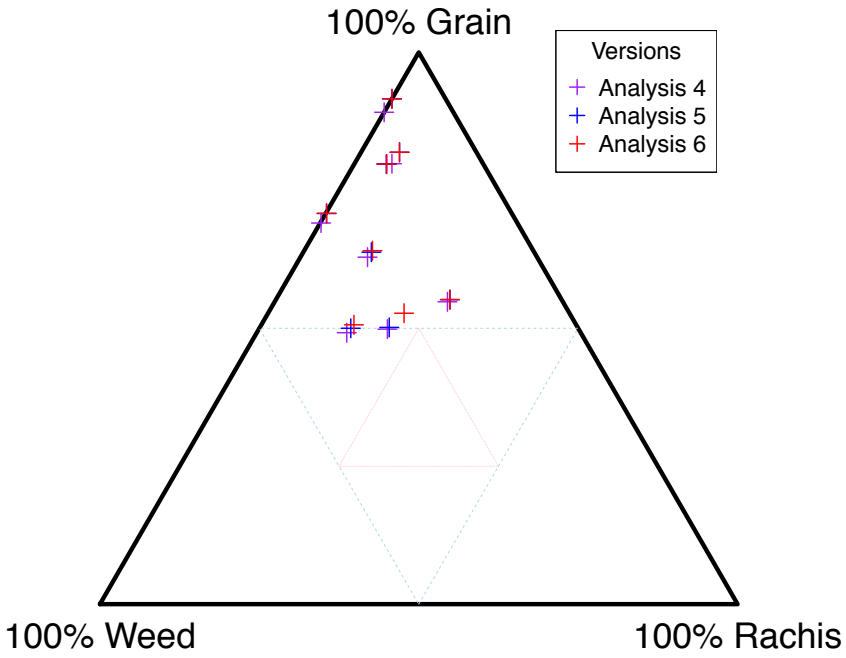


Figure 9.37 – Triplot displaying the proportions of grain, rachis and weed for each sample at Tell Aswad, based on the increasing wild exclusions of the three final discriminant analyses: 4. Collected (all) and dung (large concentrations) removed, 5. Collected (all) and dung (all) removed & 6. Collected (all), dung (all), and ruderal removed. A full list of the taxa excluded can be consulted in Table 9.24.

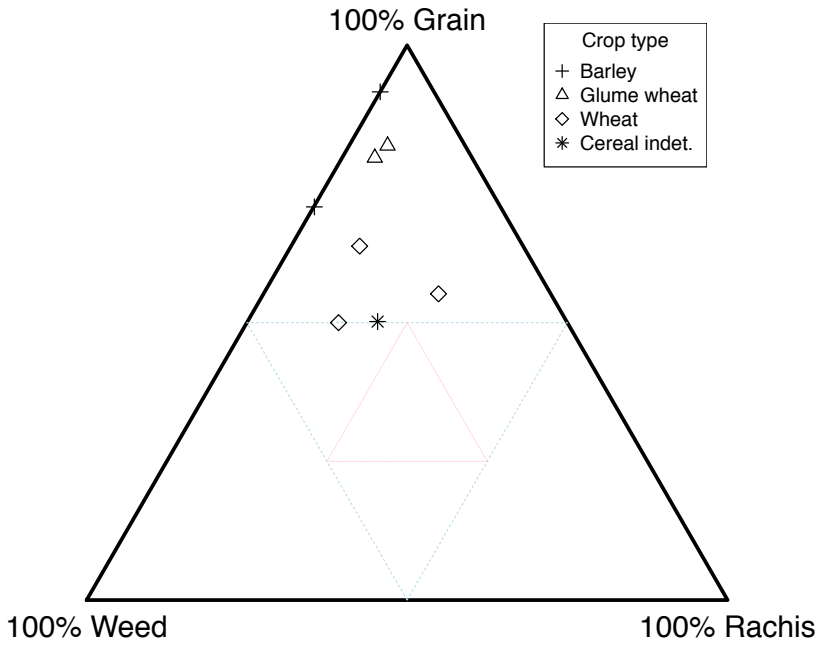


Figure 9.38 – Triplot displaying the proportions of grain, rachis and weed for each sample from Tell Aswad (based on weed content from the fifth version of the discriminant analysis), coded by crop type.

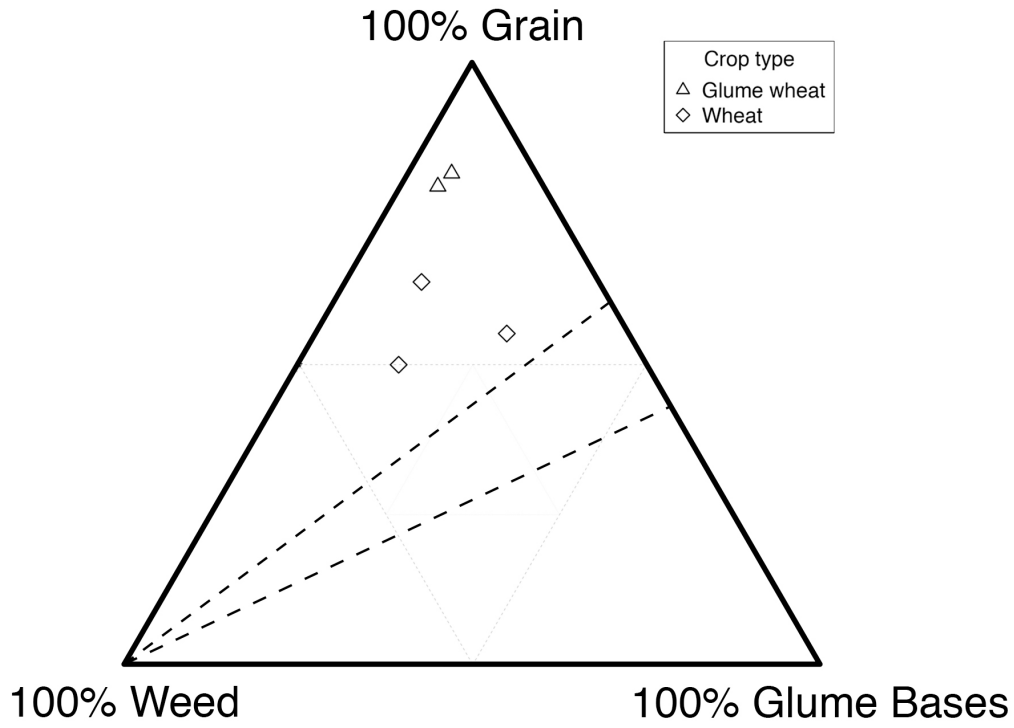


Figure 9.39 – Triplot showing the proportions of weeds, grain and glume bases of glume wheat samples at Tell Aswad. The dashed lines indicate the lower and upper cut offs for the spikelet like ratios following Bogaard (2011) (above, 5.8.2.2).

wheat samples fell within a high grain:glume base range, though the levels of cleaning clearly varied, with two of the poorer preserved wheat samples approaching ratios suggestive of 'spikelet' contexts. The two emmer samples contained few glume bases or weeds, overlapping with the edge of the 'cleaned product' group established for free-threshing cereals. A further barley sample also fell clearly within the 'cleaned product' category (Figure 9.38), but the remaining barley and cereal indeterminate samples reflected much more mixed crop-processing signatures, with the latter located near the centre of the triplot.

Two main trends in crop-processing stage could be observed within the fourth, fifth and sixth versions of the previous discriminant analyses (above, 9.4.1.3). The fourth version (Figure 9.27d), which excluded abundant and ubiquitous taxa, potentially dung-derived, reflected a clustering of samples around the 'fine sieve by-product' category. For free-threshing cereals, this crop-processing stage is characterised by low grain and chaff content, with large proportions of weed material. This contrasted with the composition of the two barley samples (Figure 9.38), which more closely reflected the 'cleaned product' group, characterised by high grain to weed content. Furthermore, some of the wheat samples contained significant proportions of glume bases (Figure 9.39), reflecting almost spikelet ratios; this further contrasts with the composition expected for 'fine sieve by-product'.

The fifth (Figure 9.27e) and sixth (Figure 9.27f) versions presented a clustering of samples towards the centre of the four groups, reflecting a mixture of crop-processing stages, while a small number of samples were identified as 'fine sieve product'. This was more consistent with the patterns suggested by the triplots, with a small number of samples with high grain proportions indicative of the cleaned 'fine sieve product' group, while most were located between groups, suggesting a mixing of crop-processing stages. With the final analysis only having minimal impact upon the overall distribution, the fifth version was selected to inform the level of wild taxa exclusions for the ecological analysis. Reference between the adjusted triplot and the previous weed-based analysis highlighted

a very clean and grain-rich barley sample (AW06/39), whose weed traits were also consistent with cleaned 'fine sieve product'; this sample taken from an occupation layer was of particular interest for the subsequent ecological analysis. The remaining samples were assessed at a broader scale (i.e. phase, crop type) (below, 9.5.3).

Site comparison and summary

Figure 9.40 compares proportions of the isolated weeds, grain and rachis within the selected samples examined from Jerf el-Ahmar, Dja'de and Tell Aswad. A general lack of rachis material was shared across all samples analysed, with most samples dominated by grain and weed seeds. The samples at Jerf el-Ahmar were most varied in composition and contained the largest proportions of rachis material. When compared with the ethnobotanical data, the combination of these two crop-processing analyses revealed that most samples were of mixed crop-processing stage. While this mixing of arable products and by-products does not limit the investigation of cultivation intensity (cf. Bogaard *et al.* 2005), it does mean that individual 'behavioural events' (Jones 1991) cannot be compared.

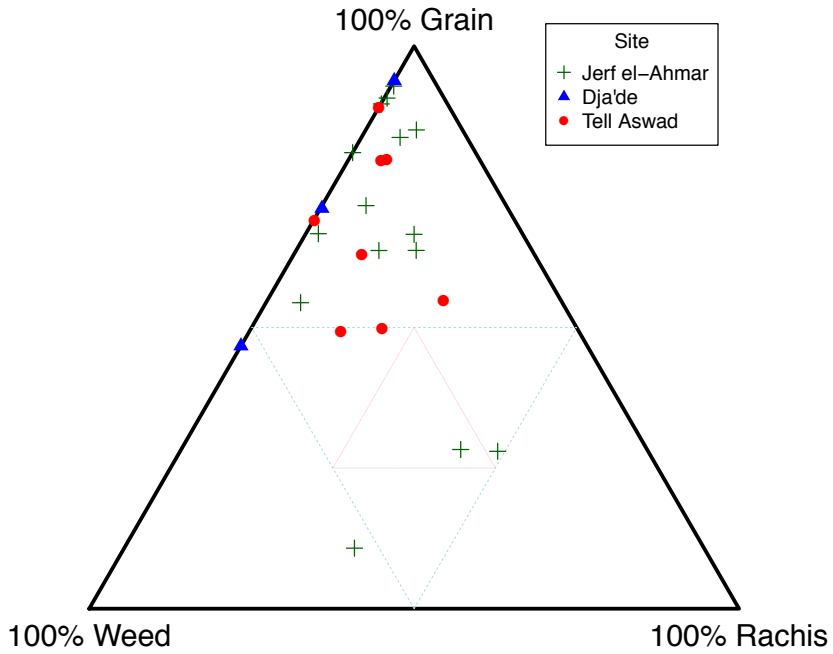


Figure 9.40 – Triplot comparing the relative sample compositions across the three Syrian sites, Jerf el-Ahmar, Dja'de and Tell Aswad.

9.4.2.2 Çatalhöyük

For the Çatalhöyük samples, the triplot method was primarily used to explore the extent of crop cleaning levels and post-depositional contaminants in relation to the categories of storage (9.1.2), as well as their dominant stored grain type. Therefore, samples classified as 'mixed' (<70% dominance) when all crop material was considered, as well as pulse dominated samples, were also included within the analysis to fully explore such variations, but were not directly related to the ethnobotanical data. Furthermore, the original totals for two-row barley grain were used (above, 5.8.2.2) so that the genuine proportions of grain, chaff and wild taxa could be investigated. While grain proportions were an important distinction among the observed storage categories (9.1.2), the extent of chaff and other wild contaminants were not yet fully quantified.

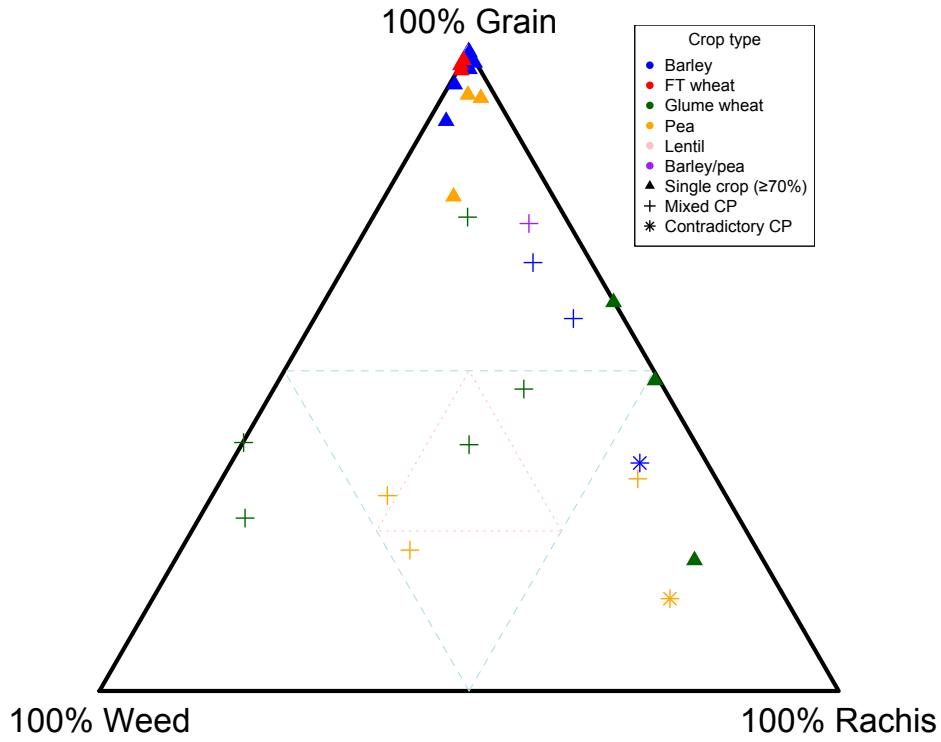


Figure 9.41 – Triplot exploring levels of grain cleaning by crop type (colours) in the stores at Çatalhöyük. The different symbols relate to their crop-processing class (Table 9.5). The class for two samples contradicted with their dominant grain (*). This plot is not directly comparable with ethnobotanical data.

Figure 9.41 shows the proportion of grain, chaff and wild/weed taxa within the 33 crop stores. Unlike the previous analyses, all crop and wild material were included within the ratios rather than just those associated with the dominant crop. This analysis therefore emphasised distinctions in general sample purity, rather than isolating the crop-processing stage of the main crop. The samples are colour coded by their dominant stored grain (Table 9.5), while their symbols referring to their crop-processing classification (i.e. ≥70% one crop or mixed) based on both grain and chaff. In two samples, the crop-processing classification was inconsistent with the dominant stored grain; these samples (barley and pea) contained large quantities of glume wheat chaff and were separately coded.

The samples were highly variable in their composition, but most samples dominated by a single crop type were grain-rich with few contaminants. A few notable exceptions to this were the three 'new type' wheat samples from Building 77, which contained whole spikelets and were in the process of being dehusked (Bogaard *et al.* 2013a: 120). Figure 9.42 shows these samples in relation to the grain:glume base ratio determined for the Çatalhöyük material. One of the samples falls clearly within this threshold, while one sample is slightly purer in grain, and the third is much more chaff rich. These adjacent deposits located within the side room area of Building 77 likely represent several stages of cleaning glume wheat spikelets, either for storage or for food preparation. The remaining chaff and weed rich samples were of mixed crop types, suggesting greater degrees of mixing from other sources. The pea and glume wheat samples were more commonly classified as mixed, whereas the free-threshing cereals, barley and free-threshing wheat, as well as the single lentil deposit, were in most cases extremely grain-rich. A few of the barley samples contained larger proportions of chaff material, but this represented contamination from other crop types, most notably glume wheat.

When the distribution is explored in terms of storage category (Figure 9.43), several notable patterns emerge, which mirror some of the earlier observations from the

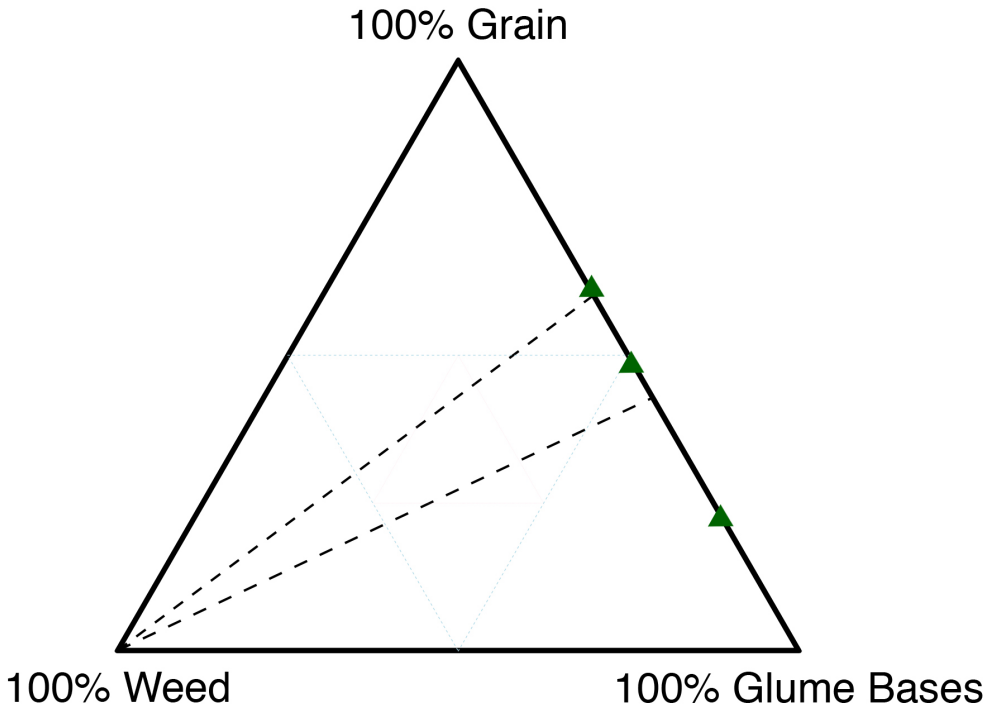


Figure 9.42 – Triplot showing the proportions of weeds, grain and glume bases for the three 'new type' wheat stores from Çatalhöyük. The dashed lines indicate the lower and upper cut offs for the spikelet like ratios following Bogaard (2011) (above, 5.8.2.2).

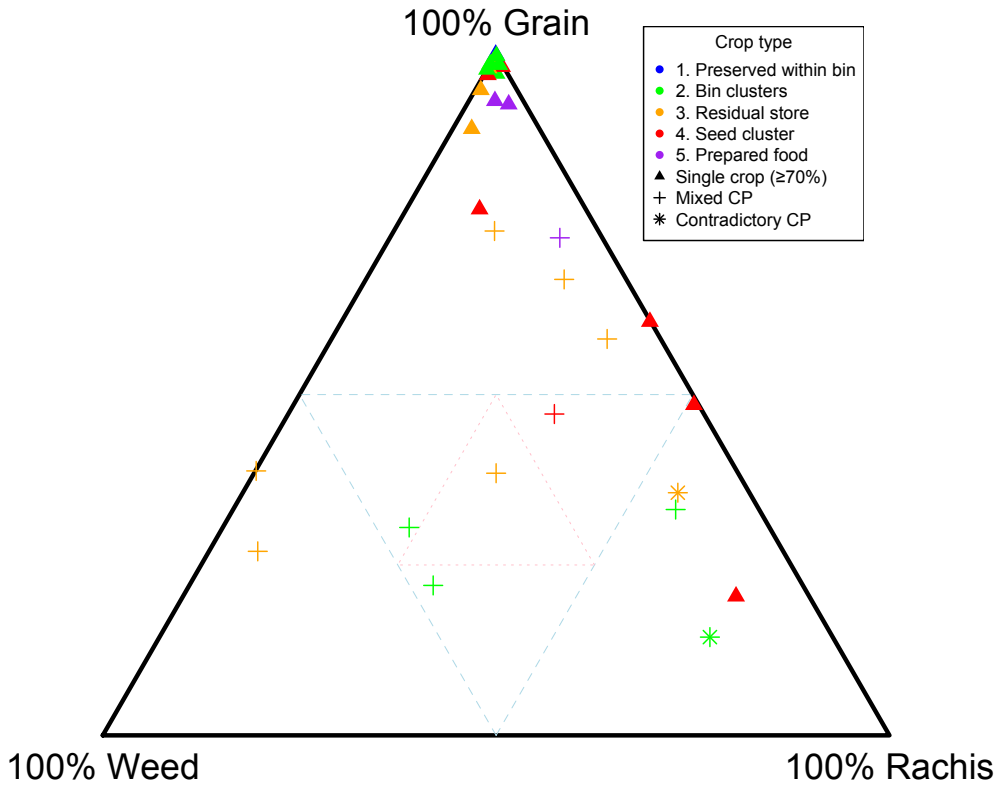


Figure 9.43 – Triplot exploring levels of grain cleaning by storage type (colours) in the samples at Çatalhöyük. The different symbols relate to their crop-processing class (Table 9.5). The class for two samples contradicted with their dominant grain (*). This plot is not directly comparable with ethnobotanical data.

correspondence analysis. All samples from the first storage category 'preserved within bin' were located at the tip of the distribution, clearly within the 'cleaned product' if compared with the ethnobotanical samples. However, this is hardly surprising as high grain density and sample purity were principal aspects for this categorisation. There are three distinct groups for the 'preserved in bin – cluster' category: one group was pure in grain, a second contained large proportions of wild taxa, while a third was more dominant in chaff material. Similar distinctions were observed in the composition of the wild/weed material of samples in this category (above, 9.3). Comparison with Figure 9.41 reveals that these dirtier samples were all dominated by pea, suggesting these stores were particularly contaminated by other sources. The 'seed clusters', which were identified separately from formal storage features, were mostly grain rich except for the three 'new type' wheat samples, and a fourth glume wheat sample mixed with free-threshing wheat grains and wheat chaff. The 'prepared food' category, which were taken from the same area of Building 77, were predominantly grain-rich with one mixed sample contaminated with glume wheat chaff. The most variable in composition was the 'residual storage' category, which reflected all parts of the distribution. Many of the samples were also of mixed crop type and may need to be considered more carefully when examining their ecological signatures.

Figure 9.44 investigates the crop-processing stages of the cereal stores classified as containing more than 70% of a single crop type, which enabled around half of the samples (16/33) to be analysed. The weed material included in these ratios was based on the isolated weed material from the fourth version of the discriminant analysis (above, 9.4.2.2) and considered the chaff material of the dominant crop only. Apart from the three 'new type' samples (see above), all of the remaining samples clearly overlapped within the 'cleaned product' group determined by the ethnobotanical samples. The persistence of small seeded weed taxa within the assemblage, indicated by the overlapping of the 'fine sieve by-product' group in the discriminant analysis (above, 9.4.2.2), may be linked to the varying thoroughness of the final cleaning stage, or the use of hand cleaning methods that missed some of the smaller seeds.

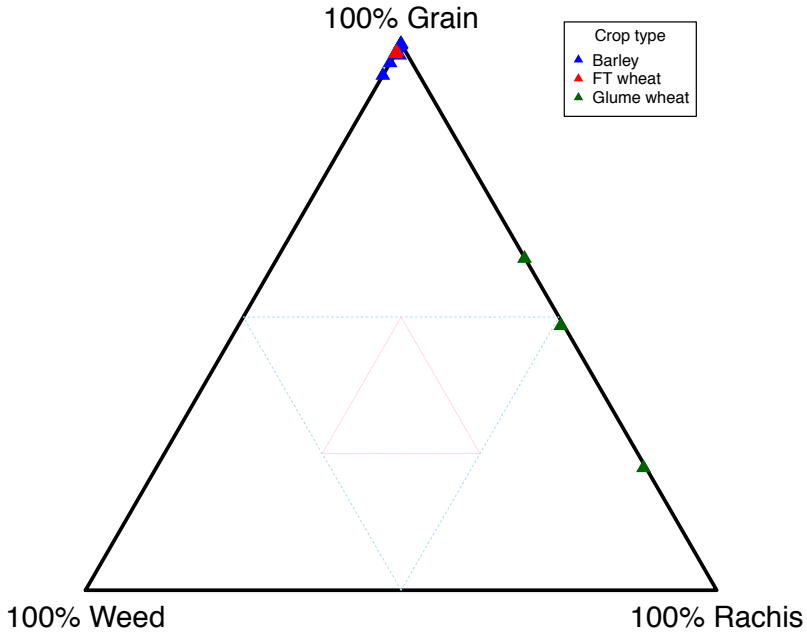


Figure 9.44 – Proportion of grain, weed, rachis in the 16 stores from Çatalhöyük dominated (≥70%) by a single cereal type.

9.5 Assessing the intensity of cultivation

For the final ecological analysis, the isolated weed data from the archaeobotanical samples were examined in relation to contrasting modern husbandry regimes to assess and compare the labour intensity of arable cultivation. This analysis was based on the combined presence/absence field data from four of the modern field studies, in Morocco, Greece, Spain and southern France, which were classified according to two types of farming regime, high and low intensity (e.g. in southern Morocco, well-watered oasis gardens versus rain-fed terraces) (Bogaard *et al.* 2016a; 2016b) (above, Chapter 6). Discriminant functions were extracted to distinguish the modern farming regimes based on their weed functional attributes, which were used to classify the archaeobotanical samples (above, 5.8.3).

With many of the samples from the earlier Syrian sites of mixed status or limited contextual information, the analysis of these sites was treated at broader scales, with ecological signatures primarily investigated by crop type and site phase. However, a small number of grain-rich contexts with greater contextual associations were examined in closer detail. The grain stores from Çatalhöyük were suitable for more detailed contextual analysis, with ecological signatures compared between phase, building, crop and storage type.

9.5.1 Jerf el-Ahmar

Nineteen of the 20 samples from Jerf el-Ahmar contained the minimum threshold of ten arable weeds and were assessed for their ecological signatures using discriminant analysis (above, 5.8.3). Table 9.26 shows the list of 18 isolated weed species/taxa that were used within the analysis, which was based on the second version of the crop-processing discriminant analysis (above, 9.4.1.1); this version excluded likely collected wild taxa from the samples. Figure 9.45 shows the discriminant scores for high and low intensity farming

regimes from the modern field studies (top) compared with the discriminant scores for each of the 19 Jerf el-Ahmar samples (bottom). Table 9.27 and Table 9.28 summarise the classification of the archaeobotanical samples by the discriminant function by phase and crop type.

The Jerf el-Ahmar samples are centrally distributed along the intensity gradient and represent a wide range of intensity scores, from low-intensity levels to discriminant scores indicative of growing conditions maintained with high labour intensity. Despite this variation within the full assemblage, most samples were classified as 'low-input' (Table 9.27); 84% of samples were classified within the low-input group, of which 69% were classified with high probability ($p>0.9$). When compared with the modern field data, the archaeological samples cluster towards the centre of the three low intensity regimes, but most closely reflects the distribution of the Evvia fields, suggesting moderate to low levels of soil fertility and disturbance. Three of the samples were classified as 'high-input', which mirrored the discriminant scores of 'garden' style plots.

When the distribution was examined by site phase (Table 9.27; Figure 9.46), there were marginal indications for greater cultivation intensities throughout the three phases, but this observation was only detected in the highest scores. Potential distinctions in husbandry practices were more clearly observed when coded by crop type (Figure 9.47). The two wheat/rye samples had noticeably higher discriminant scores than the main distribution of barley samples. A further mixed crop sample that contained mostly wheat/rye (though below the 70% threshold) was also located towards the high-input end of the Jerf el-Ahmar distribution. Nevertheless, the limited sample number means that these observations should be treated with caution; further wheat/rye samples are needed to investigate the consistency of this trend.

While closer examinations by context type are inappropriate for these largely mixed samples, it is interesting to note the overall similarity of the intensity scores observed from building EA30 (i.e. all samples examined from the late phase). Furthermore, one of

the EA30 samples (JF631, room 5) deviates from this grouped distribution, with a distinctly high input signature comparable to the Moroccan oases and Evvia gardens; this is the highest input observed from the Jerf el-Ahmar selection.

Table 9.26 – The 18 taxa used to investigate the intensity of cultivation at Jerf el-Ahmar. When taxa were not identified to species, average functional attribute values were calculated based on other identified specimens.

Species/ taxa present in assemblage	Merged species
Adonis cf. *annua*	
Adonis annua/aestivalis type	
Androsace maxima	
Bolboschoenus glaucus	
Bromus sp.	*B. danthoniae, B. sterilis, B. tectorum*
Bromus danthoniae	
Bromus sterilis	
Bromus tectorum/sterilis type	
Eremopyrum bonaepartis type	
Hordeum bulbosum	
Hordeum murinum/bulbosum	
Lolium sp.	*L. rigidum, L. multiflorum, L. persicum, L. remotum, L. temulentum*
Medicago radiata	
Poa bulbosa	
Polygonum aviculare type	
Taeniatherum caput-medusae	
Thymelaea passerina	
Tribulus terrestris	

Table 9.27 – The classification of archaeobotanical samples (n=19) by high and low input regimes, showing samples in relation to site phase, classified with high probability (≥0.90) and low probability (<0.90).

Archaeobotanical samples	High input		Low input		Average DF
Site phase	*With high probability*	*With low probability*	*With high probability*	*With low probability*	
Early		1	5	4	-1.36
Middle	1		2	1	-1.22
Late	1		4		-1.23
TOTAL	2	1	11	5	

Table 9.28 – The classification of archaeobotanical samples (n=19) by high and low input regimes, showing samples in relation to crop type, classified with high probability (≥0.90) and low probability (<0.90).

Archaeobotanical samples	High input		Low input		Average DF
Crop type	*With high probability*	*With low probability*	*With high probability*	*With low probability*	
Barley	1		8	3	-1.54
Wheat/Rye		1		1	-0.04
Mixed	1		3	1	-1.21
TOTAL	2	1	11	5	

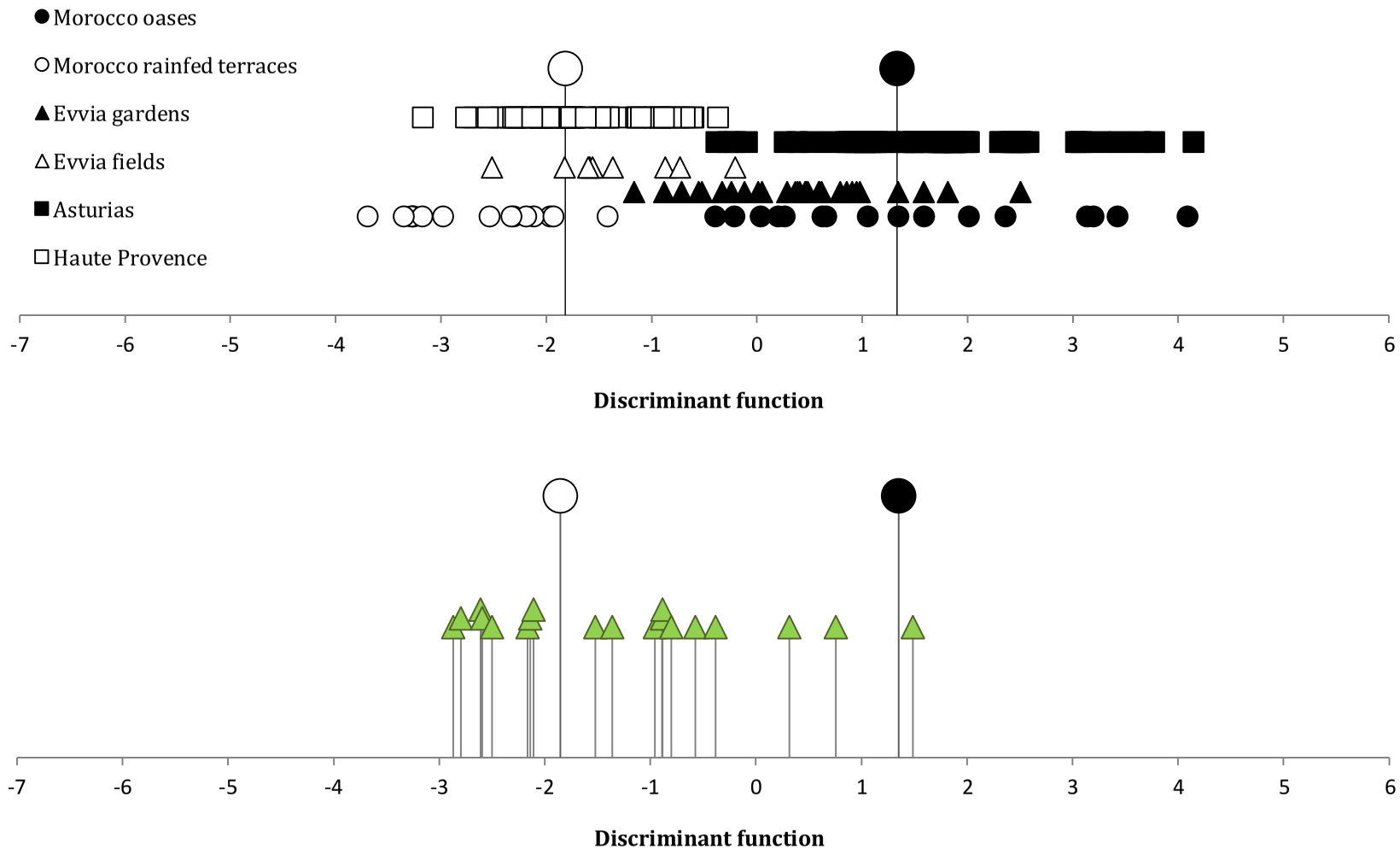


Figure 9.45 – The relationship of the Jerf el-Ahmar samples (bottom - green) to the established discriminant function and modern regimes (top). This discriminant analysis is based on 19 samples and 18 taxa. The two lines represent the group centroids for low-input (white) and high-input (black) regimes.

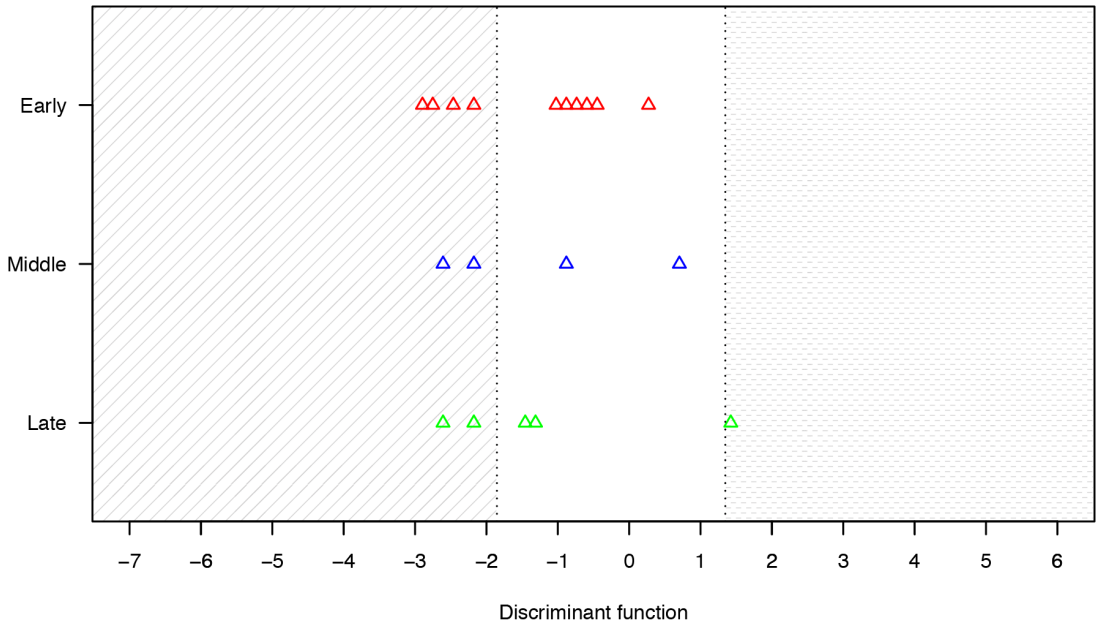


Figure 9.46 – The relationship of the Jerf el-Ahmar samples to the established discriminant function, coded by site phase. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. All samples from the late phase relate to the large communal building EA30.

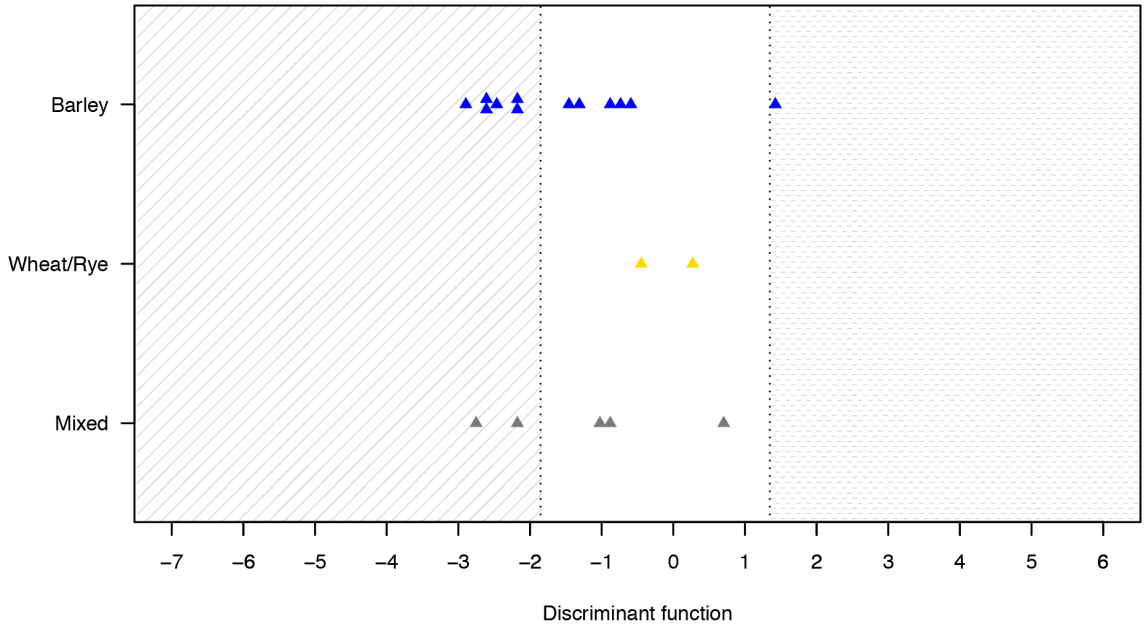


Figure 9.47 – The relationship of the Jerf el-Ahmar samples to the established discriminant function, coded by crop type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

9.5.2 Dja'de

Over two-thirds (20/27) of the samples from Dja'de contained ten or more arable weed seeds and were eligible to be examined in relation to the modern farming regimes. To maximise the number of samples within the analysis, a further sample (DJ112) that contained only nine weed seeds was also included, as its discriminant score was consistent with other 'mixed' pulse samples from the same phase and site area (above, 5.8.3). The discriminant analysis of the archaeological weed data was conducted based on 18 species/taxa (Table 9.29), which were determined from the second version of the crop-processing discriminant analysis (9.4.1.2). Figure 9.48 compares the discriminant scores for each of the qualifying Dja'de samples directly with the high and low intensity farming regimes surveyed in the modern field studies. The classification of the archaeobotanical samples by the discriminant function are shown in relation to phase (Table 9.30) and crop type (Table 9.31).

When the Dja'de samples are compared with the modern field data (Figure 9.48), the archaeobotanical samples represent a wide range of growing conditions; the low-input end of the assemblage aligns with the most extensive rain-fed terraces surveyed from southern Morocco, whereas a small number of samples reflected high inputs characteristic of 'garden' style cultivation. When classified (Table 9.30), the majority of samples were assigned to the 'low-input' group; 81% of samples were identified as low-input, of which 88% were classified with high probability. Though highly variable, there is a distinct clustering of discriminant scores towards the centre of the low-input Evvia field scores, indicating moderate to low levels of soil fertility and disturbance.

The examination of the discriminant scores by site phase (Table 9.30; Figure 9.49) revealed a notable shift towards higher intensity regimes between the middle and late phases. There were minimal correlations when the assemblage was analysed by crop type (Figure 9.50; Table 9.31), though the ability to observe such trends was hindered by the small number of samples dominated (≥70%) by a single crop type. Nevertheless, the pulse

dominant samples, which were most common within the assemblage, were relatively high-input compared with the overall distribution. These clustered together towards the centre of the two group centroids, mirroring the Evvia fields. The two barley samples also indicated higher inputs when assessed in relation to the overall assemblage, but did not form a coherent group.

Table 9.29 – The 18 taxa used to investigate the intensity of cultivation at Dja'de. When taxa were not identified to species, average functional attribute values were calculated based on other identified specimens.

Species/ taxa present in assemblage	Merged species
Adonis cf. *annua*	
Adonis aestivalis/annua type	
Androsace maxima	
Bolboschoenus glaucus	
Bromus sp.	*B. japonicus, B. sterilis, B. tectorum*
Bromus japonicus	
Bromus tectorum/sterilis type	
Eremopyrum bonaepartis type	
Galium tricornutum type	
Hordeum murinum	
Hordeum murinum/bulbosum	
Lolium sp.	*L. rigidum, L. multiflorum, L. persicum, L. remotum, L. temulentum*
Medicago radiata	
Poa bulbosa	
Polygonum aviculare type	
Rumex crispus type	
Taeniatherum caput-medusae	
Tribulus terrestris	

Table 9.30 – The classification of archaeobotanical samples (n=21) by high and low input regimes, showing samples in relation to site phase, classified with high probability (≥0.90) and low probability (<0.90).

Archaeobotanical samples	High input		Low input		Average DF
Site phase	*With high probability*	*With low probability*	*With high probability*	*With low probability*	
PPNB II		1	5	1	-1.80
PPNB III	2	1	10	1	-1.06
TOTAL	2	2	15	2	

Table 9.31 – The classification of archaeobotanical samples (n=21) by high and low input regimes, showing samples in relation to crop type, classified with high probability (≥0.90) and low probability (<0.90).

Archaeobotanical samples	High input		Low input		Average DF
Crop type	*With high probability*	*With low probability*	*With high probability*	*With low probability*	
Barley	1		1		0.05
Pulse		1	4	1	-1.18
Mixed	1	1	10	1	-1.57
TOTAL	2	2	15	2	

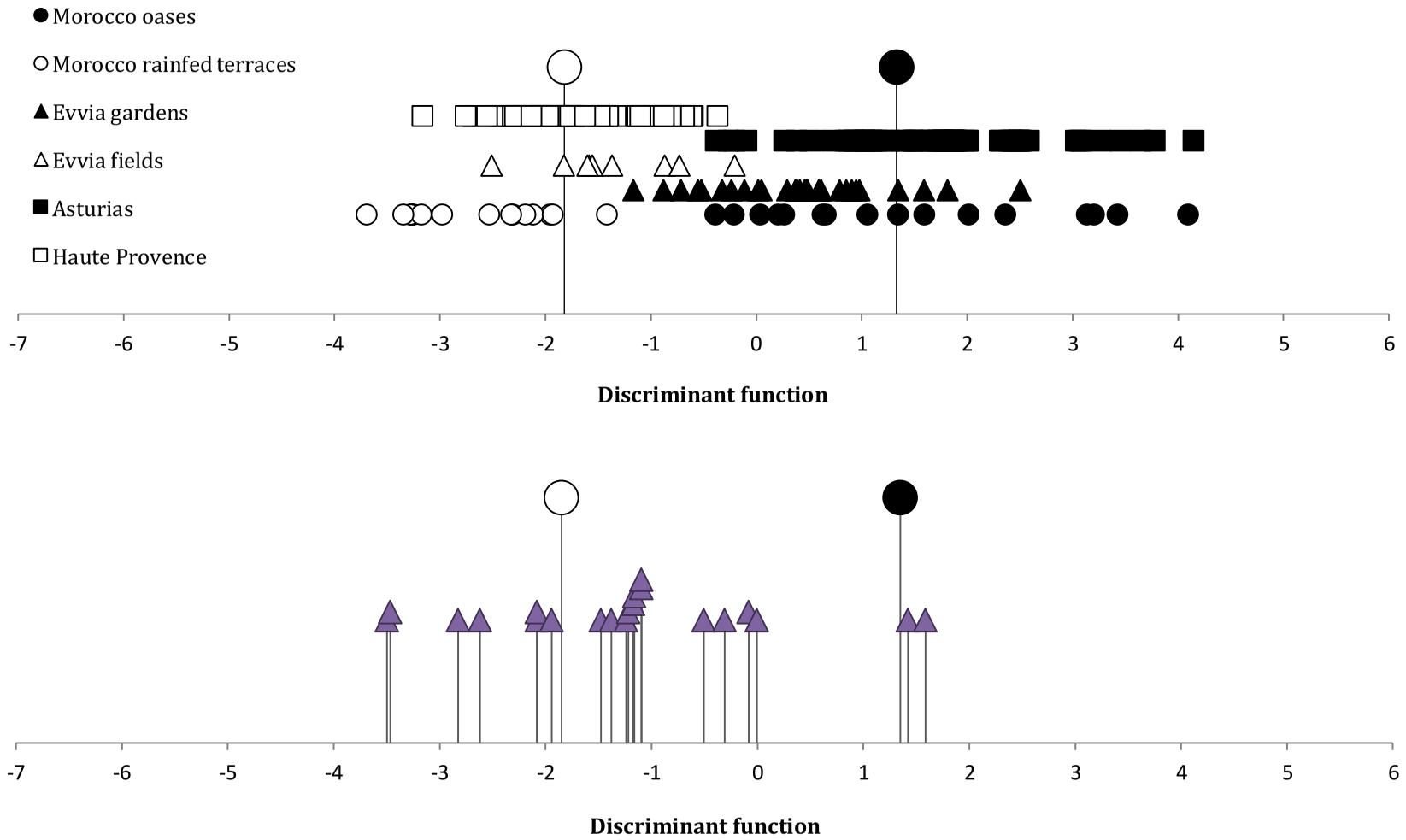


Figure 9.48 – The relationship of the Dja'de samples (bottom - purple) to the established discriminant function and modern regimes (top). This discriminant analysis is based on 21 samples and 18 taxa. The two lines represent the group centroids for low-input (white) and high-input (black) regimes.

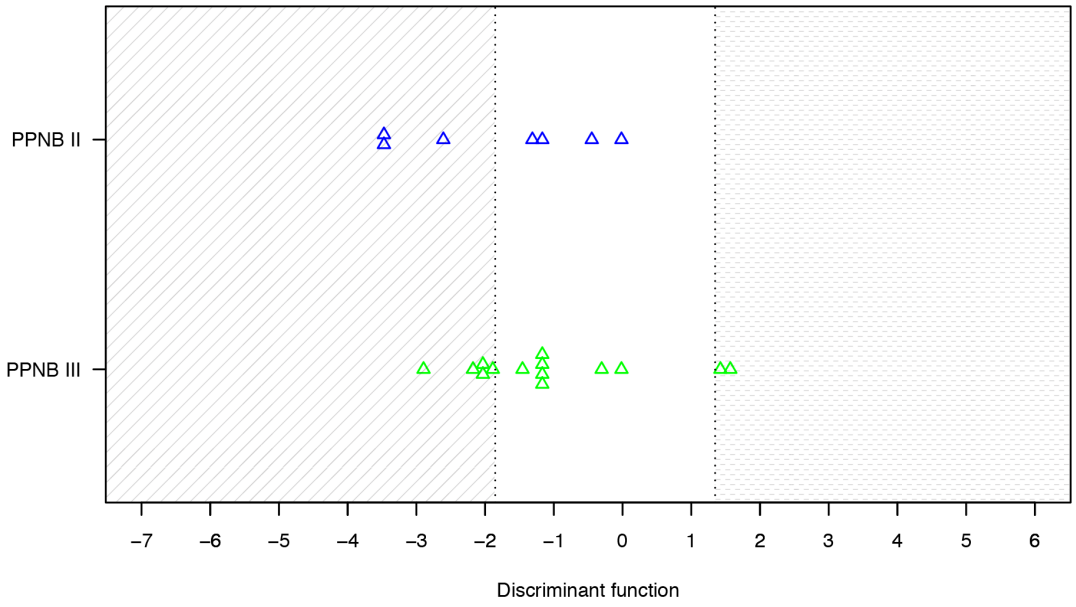


Figure 9.49 – The relationship of the Dja'de samples to the established discriminant function, coded by site phase. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

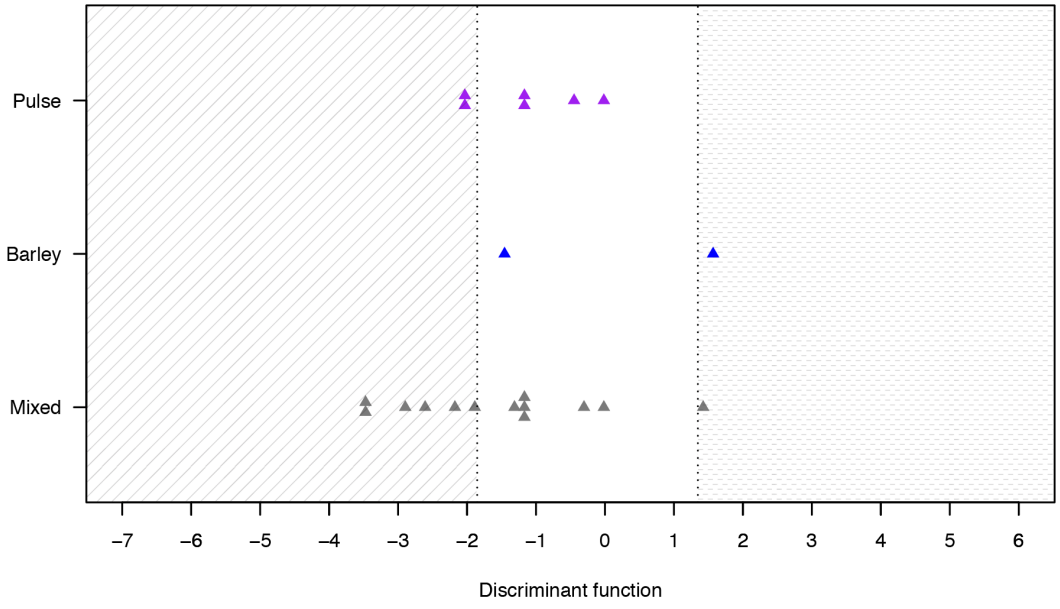


Figure 9.50 – The relationship of the Dja'de samples to the established discriminant function, coded by crop type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

9.5.3 Tell Aswad

Once all non-arable sources of wild taxa were excluded, only ten of the 16 samples from Tell Aswad contained the minimum number of weeds to be included within the discriminant analysis. However, an additional sample (AW04/30) that contained only eight weed seeds was also incorporated, bringing the total to 11 samples; its discriminant score was consistent with 'AW04/30 BIS', which was taken from the same stratigraphic unit. Table 9.32 shows the list of 15 isolated weed species/taxa used within the analysis, which reflected the taxon exclusions from the fifth version of the crop-processing discriminant analysis (above, 9.4.1.3). Figure 9.51 presents the discriminant scores for each sample and compares them with the modern field study data. Table 9.33 summarises the classification of the archaeobotanical samples by the discriminant function.

The small selection of samples from Tell Aswad aggregate towards the low end of the intensity spectrum, with three deviating samples reflecting slightly higher levels of agronomic input. The assemblage was mostly classified as 'low-input', with 82% of samples falling within this category, of which 89% were classified with high probability. Like the other two Syrian sites, there is a cluster of samples lining up towards the centre of the Evvia fields distribution, but in the Aswad case samples are shifted slightly further down the intensity spectrum, representing low to moderate levels of soil fertility and disturbance. The discriminant scores for the most extensive samples in the assemblage are equivalent to the poorest conditions observed from the Evvia fields and in Haute Provence. At the other end of this more restricted intensity scale, three samples are equivalent to the lower end of the 'garden' style cultivation, which relate to moderately enriched and fertile soils.

The sample size at Tell Aswad was too restricted to determine patterns related to site phase (Figure 9.52) or crop type (Figure 9.53), with the poor preservation of cereal grains (i.e. wheat indeterminate, cereal indeterminate) in some samples constraining this further. However, close attention was given to the grain-rich barley sample (AW06/39) identified

above (9.4.1.3), which was taken from an occupation layer. The purity of this sample provides an especially reliable indicator for barley growing conditions at the site (Figure 9.53). This sample lay towards the low-input end of the spectrum, beyond the low input group centroid; this is equivalent to the rain-fed terraces from Morocco and Haute Provence.

Of further interest at this site was the significant impact of non-arable wild contaminants on the ecological signatures. Figure 9.54 compares the discriminant scores for the wild/weed assemblage before and after non-arable contaminants were removed from the analysis. When compared with the modified assemblage, the initial distribution is considerably more shifted towards the low-input end of the discriminant scale, with all samples reflecting the same low intensity scores observed in the Moroccan rain-fed terraces. The original wild/weed dataset included a number of pervasive species that were inconsistent with the ubiquities of the other weeds and were also commonly associated with animal dung deposits at other sites (Bogaard *et al.* 2013a; Filipović 2014) (above, 9.4.1.3; Table 9.24). Of these excluded taxa, the sedges *Bolboschoenus glaucus* and *Scirpus* cf. *lacustris* have very low SLA scores, which was the principal attribute driving the combined discriminant analysis (above, 6.2). This demonstrates the importance of excluding non-arable sources from the weed dataset, as even on a presence/absence basis, a small number of taxa have the potential to skew the ecological analyses.

Table 9.32 – The 15 taxa used to investigate the intensity of cultivation at Tell Aswad.

Species/ taxa present in assemblage
Adonis cf. *aestivalis*
Adonis aestivalis/ annua type
Androsace maxima
Atriplex rosea type
Bromus danthoniae
Eremopyrum bonaepartis type
Galium tricornutum type
Hordeum bulbosum
Hordeum murinum
Hordeum murinum/bulbosum
Lolium perenne/rigidum type
Polygonum aviculare type
Silene cf. *gallica*
Thymelaea passerina type
Vaccaria pyramidata

Table 9.33 – The classification of archaeobotanical samples (n=11) by high and low input regimes, showing samples in relation to site phase, classified with high probability (≥0.90) and low probability (<0.90).

Archaeobotanical samples	**High input**		**Low input**		**Average DF**
Site phase	*With high probability*	*With low probability*	*With high probability*	*With low probability*	
Early			1		-2.19
Middle		1	2	1	-0.99
Late		1	5		-1.46
TOTAL	0	2	8	1	

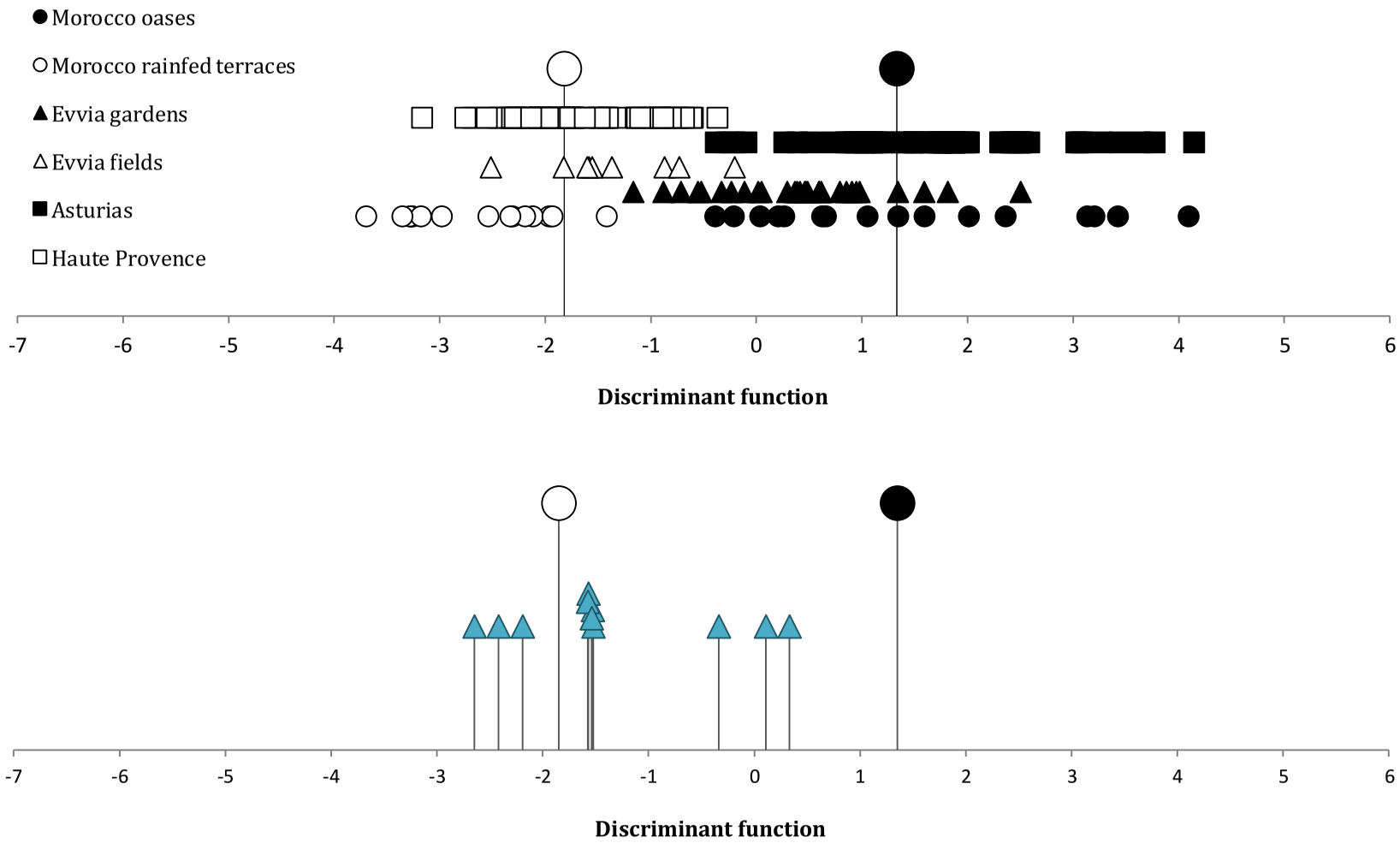


Figure 9.51 – The relationship of the Tell Aswad samples (bottom - blue) to the established discriminant function and modern regimes (top). This discriminant analysis is based on 11 samples and 15 taxa. The two lines represent the group centroids for low-input (white) and high-input (black) regimes.

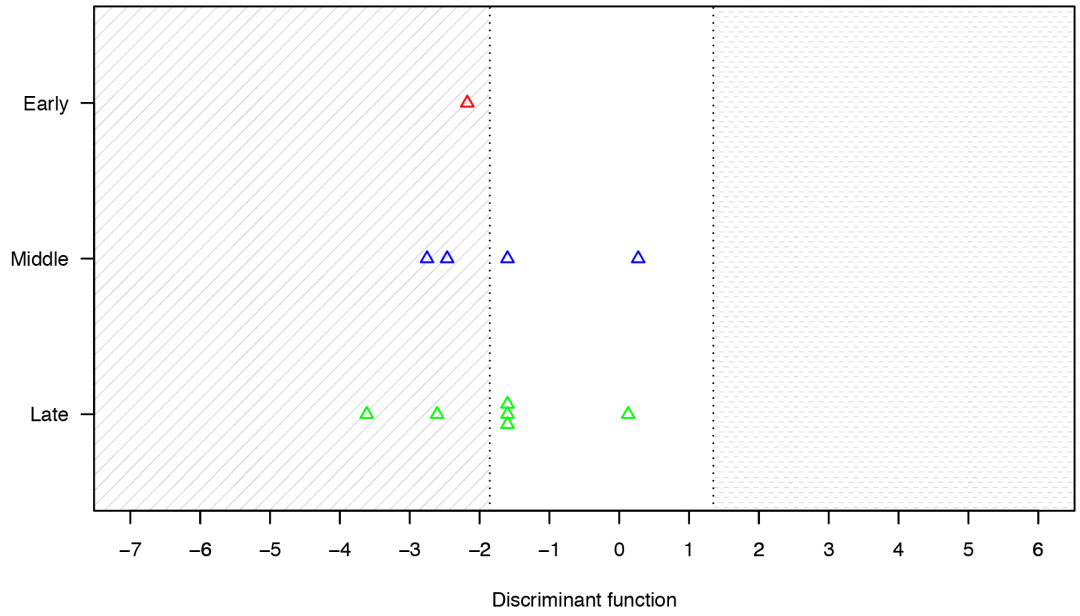


Figure 9.52 – The relationship of the Tell Aswad samples to the established discriminant function, coded by site phase. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

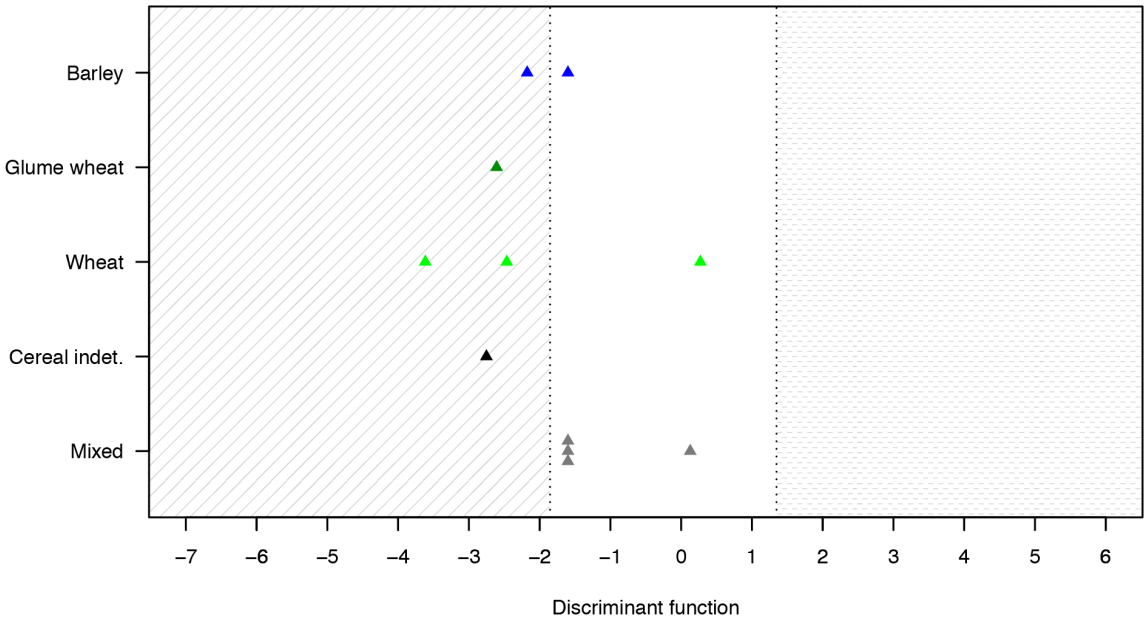


Figure 9.53 – The relationship of the Tell Aswad samples to the established discriminant function, coded by crop type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

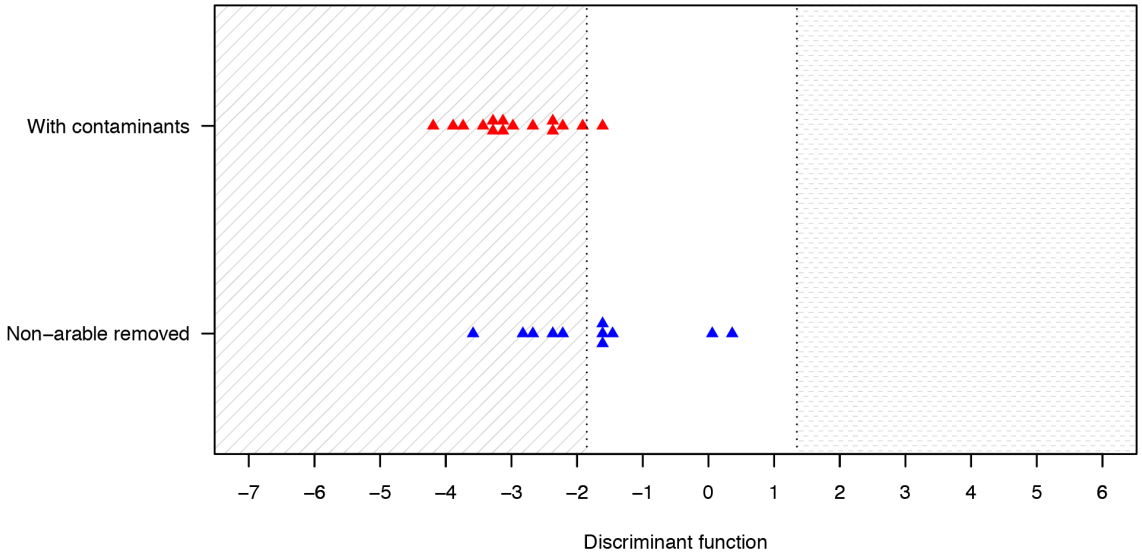


Figure 9.54 – The impact of removing non-weed contaminants upon the intensity signatures. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types. When potential dung-derived species are included, the group of samples is significantly more shifted towards the input end of the spectrum.

9.5.4 Çatalhöyük

Over 80% (27/33) of the storage samples contained ten or more identified weed seeds once all non-arable wild taxa were removed. The weed data was merged from the three 'new type' spikelet samples (u.16480) (above 9.4.2.2) to meet this threshold, which separately contained insufficient weed material; this brought the total to 28 stores analysed using discriminant analysis. Table 9.34 shows the list of 19 isolated weed species/taxa whose functional attributes were drawn upon within the analysis; this selection was based on the fourth version of the crop-processing discriminant analysis, which removed collected and dung-derived taxa (9.4.1.4). The distribution of the storage deposits can be viewed in relation to the modern field studies in Figure 9.55. Table 9.35, Table 9.36, and Table 9.37 show the classification of the samples by the discriminant function in relation to site level, stored crop type, and building number.

When the distribution of Çatalhöyük stores are compared with the modern farming regime data (Figure 9.55), the samples are highly variable, extending from oasis style levels of inputs at the high intensity end of the spectrum, to low inputs observed in the extensive field systems from Morocco and Haute Provence. However, the highest discriminant score from the archaeobotanical samples is represented by a single outlier, which will be investigated below. The classification of the samples (Table 9.35) is almost equally split between the two groups, with 54% (15/28) identified as 'high-input', though only 60% were classified with high probability. This can be explained by the main distribution of samples occupying the centre of the modern intensity scale between the two group centroids; this represents the overlap between the poorest soil conditions observed from the high intensity 'garden' style plots and the most fertile conditions analysed from the extensive field systems. When considering the stacking of samples (those containing the same/very similar discriminant values), there is notable clustering midway between the two group centroids, which reflects the centre of the main Evvia garden distribution, as well as the poorest conditions observed from the Moroccan oases and Asturias garden plots.

When the samples were analysed by site level (Table 9.35; Figure 9.56), the discriminant scores were closely clustered together for three of the four defined levels, with the two later levels clearly distinct from the earlier distributions. The exception, level North G, was highly variable in its discriminant scores and represented the full Çatalhöyük distribution, but this phase also had the largest sample size, number of buildings, and crop types analysed (Table 9.1). With each of the levels excavated from different areas of the site, it is difficult to disentangle local variants in cultivation intensity from temporal trends (above, Table 9.2). Nevertheless, there appears to be a tendency towards higher-input regimes over time.

Patterns observed by site level are elucidated further when explored by building number (Table 9.36; Figure 9.57). Excluding Building 52, each of the buildings were highly consistent in their intensity scores. The burning events that preserved the *in situ* stores likely captured the specific farming practices undertaken by single domestic units. The variety of inputs observed within Building 52 is particularly interesting, as it was the only building to contain distinct clusters within formal storage features and may reflect separate harvesting events; this interpretation is further supported when specific crop types are considered from the building, with only limited clustering by crop type (Figure 9.58). Comparison between contemporary structures among the North and South areas indicate both similarities and differences in crop husbandry. In the North area, Building 1 and Building 52 overlap in their discriminant scores, whereas the adjacent Building 77 indicates distinctly lower farming inputs. In the South area, the neighbouring buildings, Building 79 and Building 80, have relatively similar scores, but the small dataset confines interpretations of possible cooperation between these domestic units.

Examination of the intensity signatures in relation to stored crop type revealed further patterns in the data (Table 9.37; Figure 9.59). Though with some variation, the barley stores formed a cohesive group towards the centre of the group centroids, with many samples possessing similar discriminant functions. On the other hand, the pea samples covered a slightly broader range of intensity scores, with minimal overlapping between

samples; two separate groups could be discerned, which was suggested by the weed data in the correspondence analysis (above, 9.3). However, when the mixing of other crop types was explored (Figure 9.60), the four pea stores classified as mixed had higher discriminant function scores than those that met the 70% threshold. The purer pea samples had distinctly low intensity scores when compared with other crop types, equivalent to the modern Evvia fields. The highest intensity in the selection could be discerned for the free-threshing wheat stores, but these two samples were still highly distinct from one another, with one sample appearing as an outlier in the context of the full assemblage. This sample (Fl.6049) was unmixed in crop content (Figure 9.60) and processing stage (partially sieved cleaned product) and contained over 60 weeds, so its weed assemblage should be an especially reliable indicator of free-threshing wheat growing conditions (Bogaard 2004: 60). This sample may perhaps be a glimpse of high-input regimes that were not fully captured by the selected assemblage. The remaining glume wheat and lentil stores reflected the centre of the intensity scale, whereas the single mixed barley/pea deposit had a distinctly low intensity signature comparable to the purer pea samples.

The relationship between storage type (cf. above, 9.1.2) and farming intensity was also explored (Figure 9.61) to assess potential biases linked to context type. Four of the five groups greatly overlapped in their distributions, suggesting little impact upon the discriminant scores in relation to storage type. The distinct fifth group, 'prepared food', represented several samples taken from a single deposit in Building 77. With a separate glume wheat sample from Building 77 relatively similar in its discriminant score (Figure 9.58), this discrepancy could therefore be attributed to building rather than storage type.

Table 9.34 – The 19 taxa used to investigate the intensity of cultivation at Çatalhöyük. When taxa were not identified to species, average functional attribute values were calculated based on other identified specimens.

Species/ taxa present in assemblage	Merged species
Adonis cf. *microcarpa*	
cf. *Androsace maxima*	
Bromus danthoniae	
Bromus hordeaceus	
Conringia orientalis	
Convolvulus arvensis type	
Eremopyrum bonaepartis type	
Galium spurium/*odoratum* type	
Galium tricornutum type	
Hordeum murinum	
Phragmites australis	
Polygonum sp.	*P. aviculare, P. convolvulus*
Polygonum aviculare	
Polygonum convolvulus	
Rumex conglomeratus	
Taeniatherum caput-medusae	
Thymelaea passerina type	
Triticum boeticum	
Vaccaria pyramidata	

Table 9.35 – The classification of archaeobotanical samples (n=28) by high and low input regimes, showing samples in relation to site phase, classified with high probability (≥0.90) and low probability (<0.90).

Archaeobotanical samples	High input		Low input		Average DF
Site phase	*With high probability*	*With low probability*	*With high probability*	*With low probability*	
North G	3	4	6	3	-0.32
South O		1	2	1	-0.77
South Q-T	2	2			0.35
TPC (Late Neolithic)	1	2		1	-0.01
TOTAL	6	10	8	4	

Table 9.36 – The classification of archaeobotanical samples (n=28) by high and low input regimes, showing samples in relation to building number, classified with high probability (≥0.90) and low probability (<0.90).

Archaeobotanical samples	High input		Low input		Average DF
Building no.	*With high probability*	*With low probability*	*With high probability*	*With low probability*	
B. 79			1	1	-0.98
B. 80		1	1		-0.57
B. 1		2	2	1	-0.49
B. 52	3	2	1	1	0.56
B. 77			3	1	-1.67
B. 63	2	2			0.35
B. 122	1	2		1	-0.01
TOTAL	6	9	8	5	

Table 9.37 – The classification of archaeobotanical samples (n=19) by high and low input regimes, showing samples in relation to crop type, classified with high probability (≥0.90) and low probability (<0.90).

Archaeobotanical samples	High input		Low input		Average DF
Crop type	*With high probability*	*With low probability*	*With high probability*	*With low probability*	
Barley	3	5	2	2	-0.08
Pea	1	2	4		-0.74
Glume wheat		2	1	2	-0.45
Free-threshing wheat	2				2.17
Lentil				1	-0.52
Barley/Pea			1		-2.42
TOTAL	6	9	8	5	

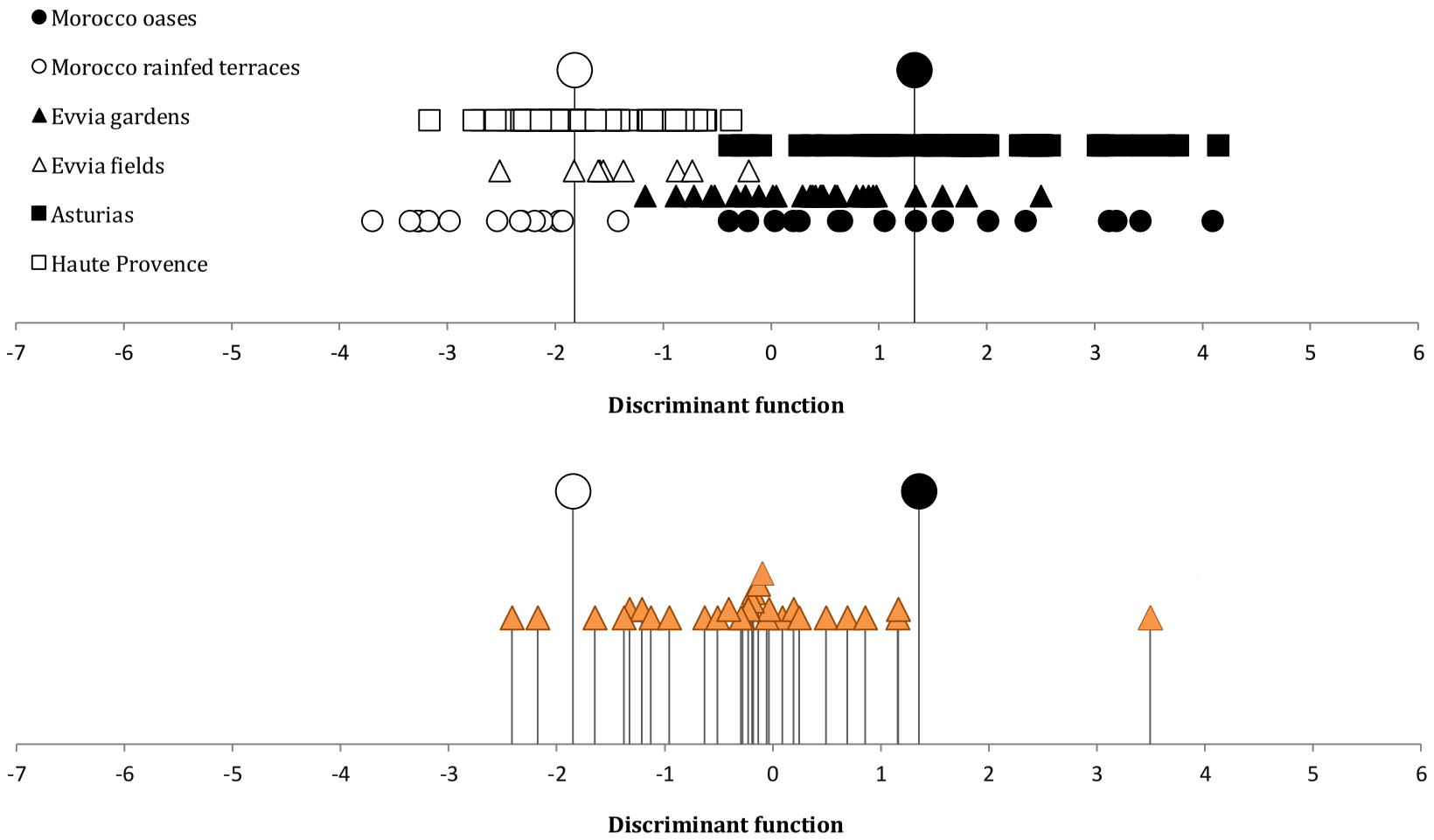


Figure 9.55 – The relationship of the Çatalhöyük storage samples (bottom - orange) to the established discriminant function and modern regimes (top). This discriminant analysis is based on 28 samples and 19 taxa. The two lines represent the group centroids for low-input (white) and high-input (black) regimes.

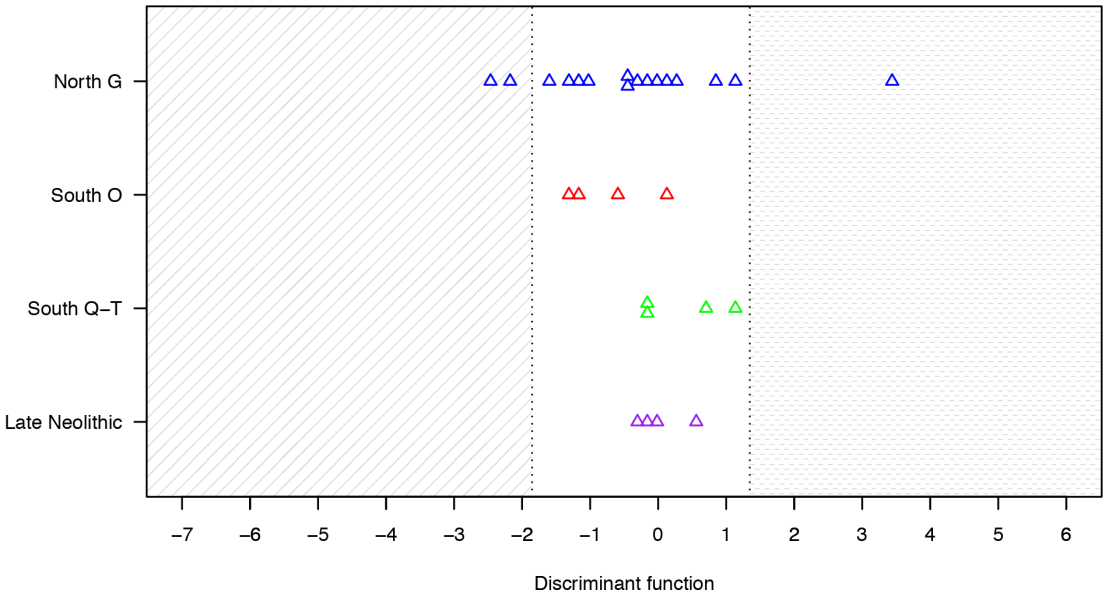


Figure 9.56 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by site phase. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

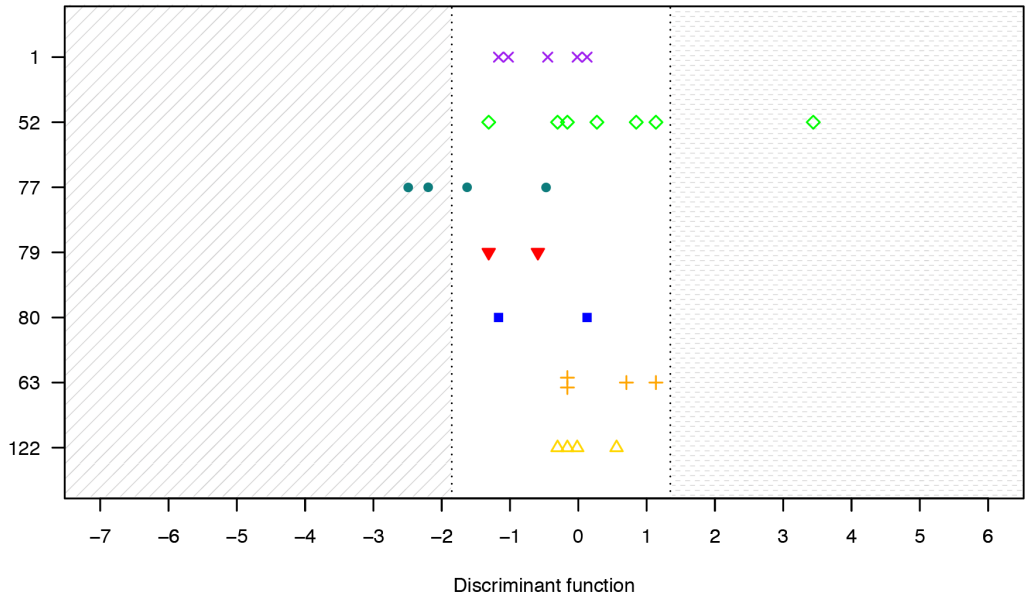


Figure 9.57 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by building number. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

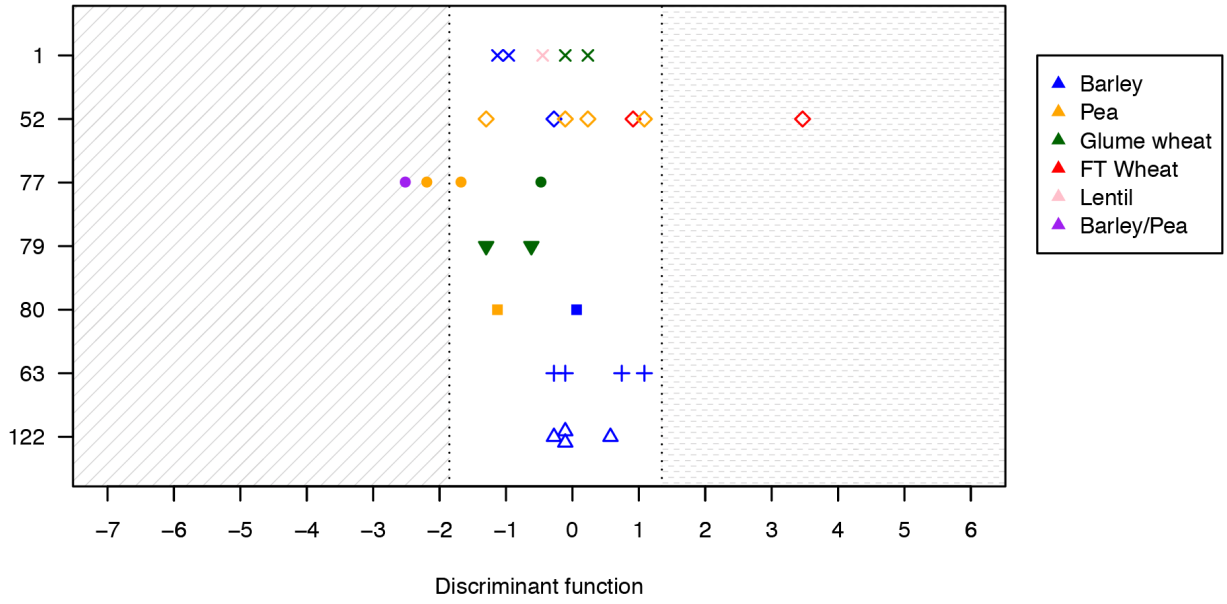


Figure 9.58 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by building number and crop type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

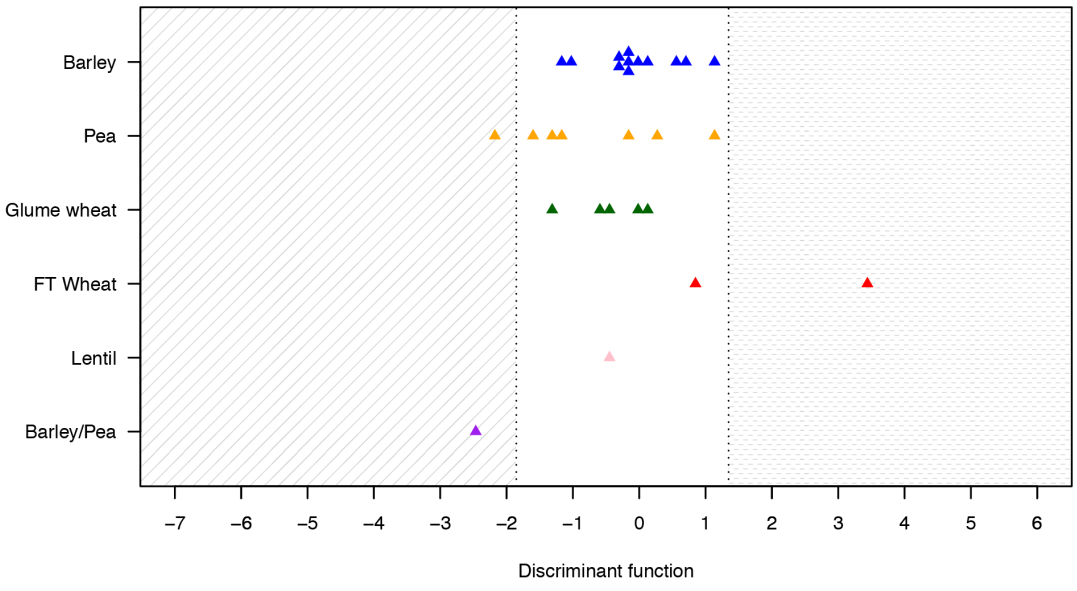


Figure 9.59 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by dominant stored crop type (see Table 9.5). The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

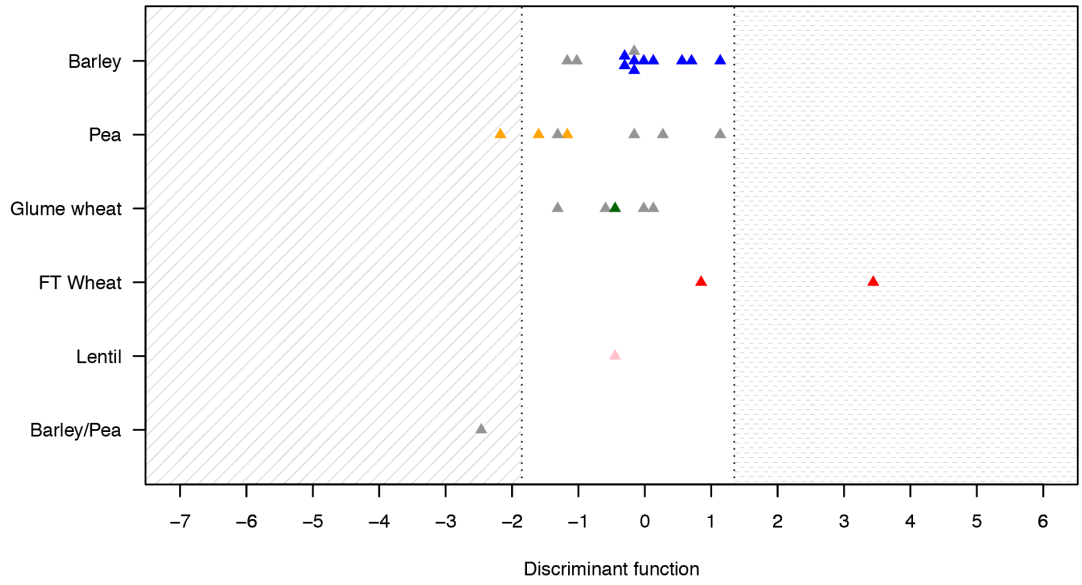


Figure 9.60 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by dominant stored crop type with samples of mixed crop type (<70%) classification distinguished in grey. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

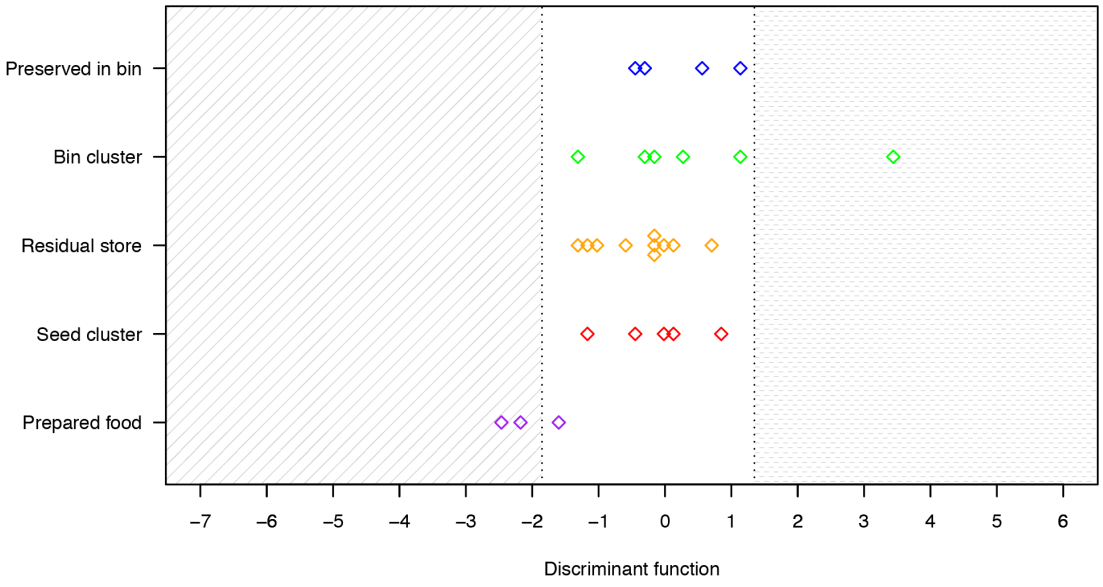


Figure 9.61 – The relationship of the Çatalhöyük samples to the established discriminant function, coded by storage type. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

Chapter 10

Discussion

Comparative assessment of cultivation intensity and its implications for understanding early farming regimes

While the four early farming sites in this project were strategically selected to investigate different stages of early farming in western Asia, from pre-domestication cultivation to established farming 'megasites', each of these sites was located within a distinct environmental setting, which possessed unique challenges for agricultural production in terms of resource availability, natural soil fertility and levels of aridity (above, Chapter 3). The cultivation intensity scale developed from contrasting modern agrosystems (above, Chapter 6), offers a useful comparative framework for assessing relative levels of labour input within and between sites in (semi-)arid regions.

10.1 Jerf el-Ahmar

10.1.1 Variability of cultivation intensity

The selected samples from Jerf el-Ahmar exhibit a wide range of arable intensity scores (above, Figure 9.45), varying from 'garden' style levels of productivity at the high-input of the scale, to less productive conditions indicative of dry rain-fed farming. With an array of ecological zones in close proximity to the small mound (i.e. steppe, riverine forest, hills; above, 3.1.1.2), this variation may partially reflect diversity in the environments selected by

early farmers, which offered different growing conditions (e.g. free-draining vs. water retentive soils) for the cultivation of cereals and pulses. However, similar wide ranges in discriminant scores could also be observed within single agrosystems (e.g. high intensity Moroccan oases) in the modern field studies, reflecting variable levels of manuring, tillage, weeding and watering (Bogaard *et al.* 2016b). The central position of the Jerf el-Ahmar samples across the discriminant function (above, Figure 9.45), which reflects both high- and low-intensity regimes, suggests that both the strategic selection of land *and* additional labour inputs likely played a role within cultivation management strategies.

While the range of intensity scores was relatively wide at Jerf el-Ahmar, most samples grouped towards the low-input end of the scale, closely resembling the distribution of modern fields in Evvia, central Greece (cf. Jones *et al.* 1999) with their medium to low management intensity and rain-fed conditions. Under a climate that was more humid during the early Holocene, rain-fed farming methods would have been possible at Jerf el-Ahmar, but water would have been a major limitation for plant growth (Noy-Meir 1973; Keatinge *et al.* 1985). Mean annual rainfall was estimated as 325mm for the Pre-Pottery Neolithic by multiplying the site's current precipitation levels (250mm) by 130%; this approximation is based on a recent synthesis of palaeoenvironmental data (i.e. stable isotopes from speleothems and lake sediments, pollen analysis, macrofossil data) for the early Holocene period (Roberts *et al.* 2018). With poorer soil conditions observable within the modern studies from Haute Provence (above, Figure 9.45), with its much higher rainfall levels (700-900mm) (Bogaard *et al.* 2016a), the greater discriminant scores at Jerf el-Ahmar are consistent with higher labour inputs, such as mechanical disturbance and anthropogenic enrichment of soils (e.g. middening). This is further supported when considering the specific management strategies for the Evvia fields. While characterised as low-intensity, these larger fields were still tilled, weeded, and in some cases fertilised, but at distinctly lower levels than the Evvia gardens (Jones *et al.* 1999).

The small number of samples distributed at the high-input end of the scale suggest productivity levels resembling those of 'garden' style plots, which in the modern studies

included intensive manuring, tillage, watering and weeding practices. With a lack of evidence for animal herding and dung-derived wild taxa at Jerf el-Ahmar (cf. above, 9.4.1.1.), it is unlikely that these high discriminant scores are linked to manuring practices. However, similar levels of soil enrichment could have been achieved through the spreading of kitchen waste/midden material (Bogaard 2012; Araus *et al.* 2014). Closely related to higher fertility levels are greater levels of disturbance, as enriched growing conditions would have required further hand-weeding practices to prevent the crop from being outcompeted (Radosevich *et al.* 1997). The intensity of labour necessary to maintain these high-input regimes indicate that these plots were most likely located close to the settlement (Halstead & Jones 1989; Jones 2005; Bogaard & Isaakidou 2010).

10.1.2 Cultivation intensity by crop type

Patterning within the Jerf el-Ahmar dataset was related to crop type, with the two wheat/rye (*Triticum/Secale*) samples noticeably higher in their inputs compared with the main distribution of barley (*Hordeum spontaneum*) (above, Figure 9.47). The natural habitats for wild rye and wild einkorn (*Triticum boeoticum*) lie between 100-200km north of Jerf el-Ahmar, restricted to cooler areas with acidic soils (Willcox 2007; Willcox *et al.* 2008). Wild barley, however, is highly drought-tolerant and adapted to poor calcareous soils, with wild stands continuing to grow near the site (Willcox 2005; 2007). Even with wetter conditions during the early Holocene, the poor chalk soils surrounding Jerf el-Ahmar are largely unsuitable for wild stands of wheat and rye, so deviation beyond their natural distribution zones was likely due to anthropogenic mechanisms, such as their transportation along exchange networks (Willcox 2005). Cereals can tolerate greater ranges of climatic and edaphic conditions under cultivation conditions, where competition from other plants are managed (i.e. tillage, hand-weeding) (Willcox 2005). Therefore, the higher intensity signatures indicated for wheat/rye may reflect the strategic selection of favourable microhabitats accompanied by higher inputs of labour to maintain crop growth in these conditions. Furthermore, greater restrictions upon natural stands of wheat/rye

may have resulted in these cereals having a greater cultural significance in this early farming community, thus was preferentially treated with greater labour inputs (cf. Halstead 2014: 213; Wallace *et al.* 2013).

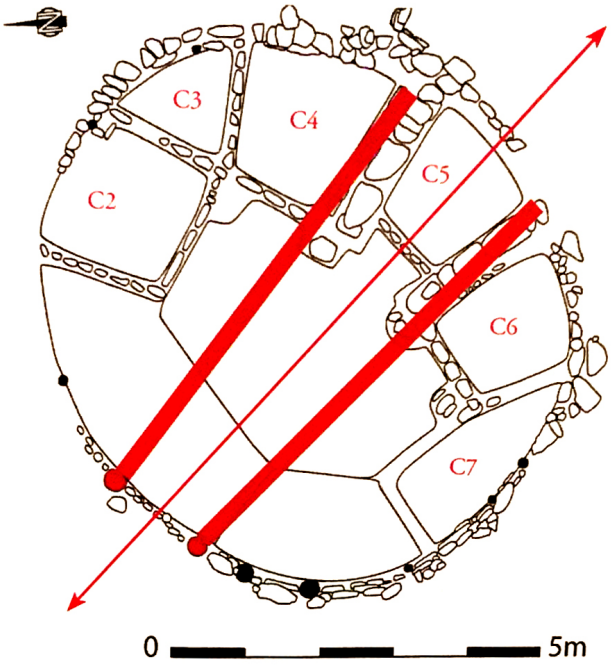


Figure 10.1 – Plan of large 'communal' building EA30 at Jerf el-Ahmar, indicating spatial alignment in relation to the structures roof supports (Stordeur 2015: Fig. 30).

One of the barley-dominated samples was highly distinct from the remaining barley distribution, with intensity levels that exceeded those of the wheat/rye samples (above, Figure 9.47). This sample (JF631) was taken from building collapse layers in one of the small cells (room 5), from the large circular building EA30. While the central alignment of cell 5 within this communal structure may appear significant (Figure 10.1), the archaeobotanical remains from these proposed storerooms were apparently not charred *in situ* (Willcox & Stordeur 2012: 107; Stordeur 2015: 209), and crop-processing analyses indicate a mixture of stages (above, 9.4). Thus, it is unlikely that this sample represents the residues of a 'special' grain store. Nevertheless, the high discriminant score from this sample suggests that barley was occasionally cultivated at greater intensities at Jerf el-Ahmar despite its tolerance to poor soil conditions and local availability.

A recent study by Araus *et al.* (2014) further complements the weed analysis from this study, through its investigation of agronomic conditions using stable carbon and nitrogen isotope values of grain. Crop $\Delta^{13}C$ values (converted from $\delta^{13}C$ values[1]) reflect the water status of a crop during its growth period, while crop $\delta^{15}N$ values reflect the $\delta^{15}N$ value of the soil in which they were grown; soil $\delta^{15}N$ values are influenced by a variety of factors, which may include soil enrichment practices (i.e. manuring) and aridity (Araus *et al.* 2014; Styring *et al.* 2017). The study by Araus *et al*. analysed cereal grains from 11 archaeological sites from the Upper Mesopotamian region, including Jerf el-Ahmar and Dja'de. While only single grains were analysed per sample, which does not smooth out variability generally detectable even within single cereal ears (cf. Bogaard *et al.* 2007; Fraser *et al.* 2011; Nitsch *et al.* 2015), the broader trends from this study offer useful complementary insights into water availability, as well as potential reflections of soil fertility.

To infer relative levels of water availability from the $\Delta^{13}C$ values produced by Araus *et al.* (2014), the results were examined in relation to a set of watering bands (i.e. well-watered, moderately watered, poorly watered) established from previous modern field-based experiments (Wallace *et al.* 2013). Furthermore, these studies indicated that barley tends to have higher $\Delta^{13}C$ values than other crops (wheat, lentil) when grown in comparable water conditions (Wallace *et al.* 2013). Therefore, an offset of 1‰ was used to adjust the set of watering bands for barley at higher $\Delta^{13}C$ values. When the Jerf el-Ahmar samples were examined in relation to these thresholds, barley appeared to have been grown in distinctly drier conditions than wheat/rye (Figure 10.2). Most of the barley samples fell below the threshold for moderate watering levels, indicative of sub-optimal watering levels. By contrast, the smaller number of wheat/rye samples reflected higher water availability, which mostly reflected moderately to well-watered conditions.

These inferences correspond with the patterns observed for barley and wheat/rye in the functional ecological analysis, further supporting the notion that these crops were cultivated using different management strategies. Wheat/rye, with its greater susceptibility

[1] This conversion takes into account changes in atmospheric CO_2 since antiquity (cf. Ferrio *et al.* 2005; Wallace *et al*. 2015), which enables archaeological and modern studies to be directly compared.

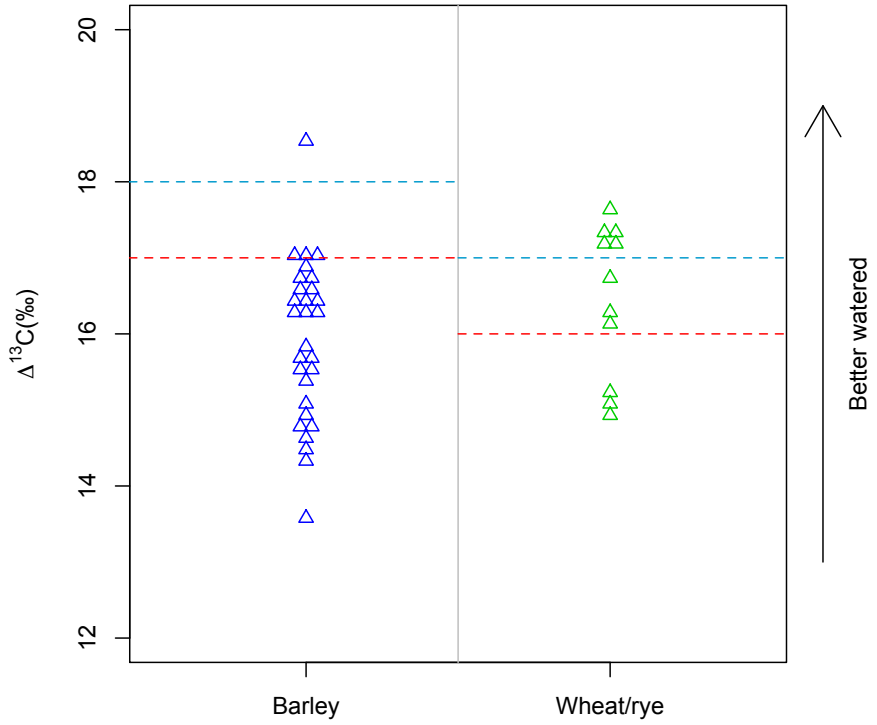


Figure 10.2 – Δ¹³C values for barley and wheat/rye at Jerf el-Ahmar from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of watering threshold for poorly watered (red) and well-watered (blue) values (after Wallace *et al.* 2013).

to drier conditions, may have been strategically grown on soils with better moisture retention, such as breaks in slope and shallow wadi bottoms (Hillman 2000). While the use of flood recession soils cannot be categorically ruled out, this scenario appears unlikely due to the risk to immature crops from spring flooding cycles (Hillman 2000). In this semi-arid region, crops were most likely autumn-sown to utilise winter rainfall during the growing season, as well as to avoid the hot, dry summer (Willcox 1996; Hillman 2000).

Modern field studies (Figure 10.3) suggest that soil enrichment practices (i.e. manuring, middening) can significantly increase soil nitrogen levels and therefore the δ15N of cereals (Bogaard *et al*. 2007). A set of thresholds were determined by Bogaard *et al.* (2013b) using modern field data, indicating equivalent nitrogen levels for low, medium and high manuring rates. Research indicates that environmental factors such as aridity can also increase $\delta^{15}N$ values (cf. Handley *et al.* 1999; Aranibar *et al.* 2004; Austin *et al.* 2004; Styring *et al.* 2016). Therefore, to allow more accurate identifications of soil enrichment practices in semi-arid

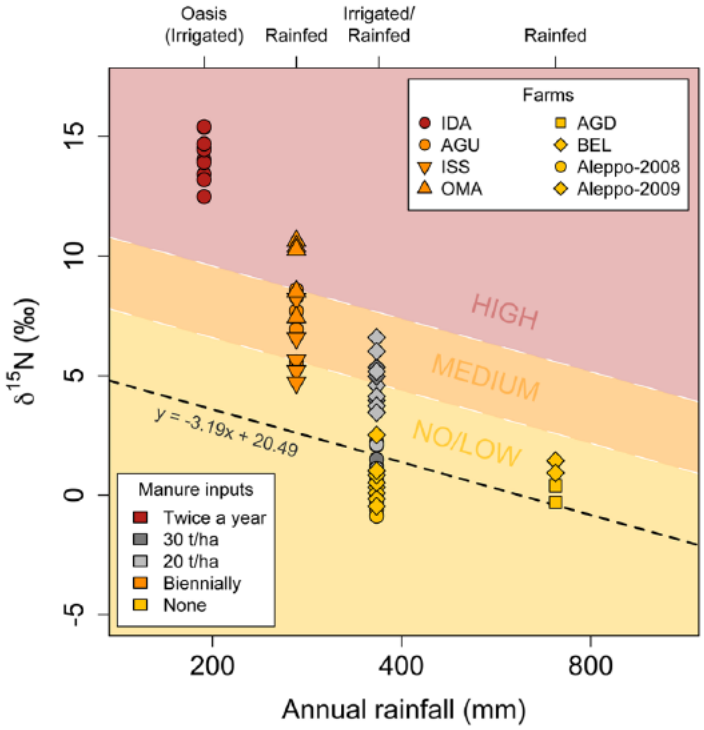


Figure 10.3 – Plot of modern barley and bread wheat $\delta^{15}N$ values analysed from different known farming regimes against a natural log scale of rainfall. The manuring bands have been adjusted for the regression between unmanaged plant $\delta^{15}N$ values and rainfall (Styring *et al. 2016)*.

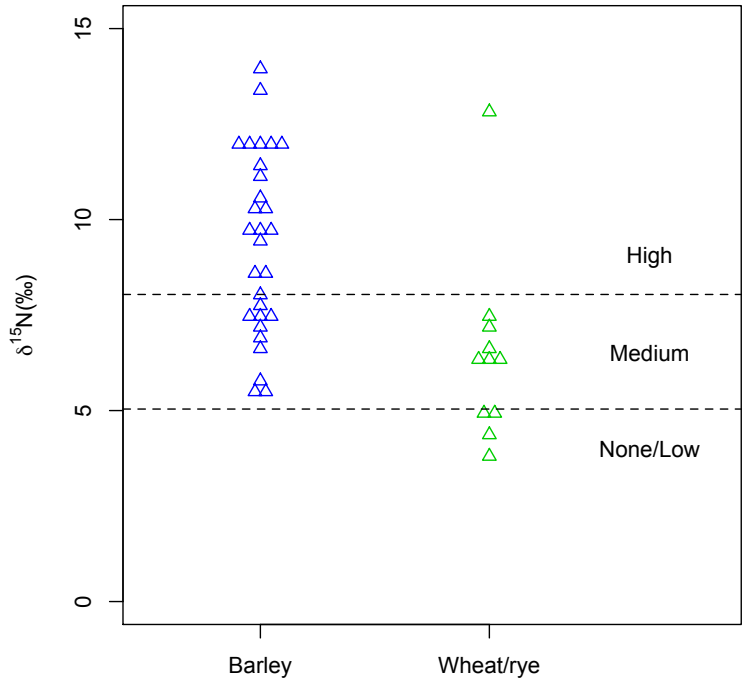


Figure 10.4 – $\delta^{15}N$ values for barley and wheat/rye at Jerf el-Ahmar from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of thresholds adjusted for rainfall to indicate possible levels of manuring (after Styring *et al.* 2016).

regions the effect of aridity must be disentangled from crop $\delta^{15}N$ values. A recent study by Styring *et al.* (2016) used the relationship between modern plant δ15N values and rainfall in the eastern Mediterranean (cf. Hartman & Danin 2010) to adjust expected manuring levels from a series of modern field studies[2]. Following Styring *et al.* (2016), an aridity offset was calculated for Jerf el-Ahmar[3], which was added to the Bogaard *et al.* (2013b) manuring thresholds to infer potential soil enrichment (Figure 10.4).

When compared with modern field data from known regimes (Figure 10.3), the barley samples from Jerf el-Ahmar appeared unusually high in their δ15N values, equivalent to intensively manured and irrigated plots from Moroccan oases (Bogaard *et al*. 2016b; Styring *et al*. 2016). This contrasts significantly with the poorly watered signature indicated by the barley samples' low $\Delta^{13}C$ values (Figure 10.2), as well as the low-inputs determined by the weed ecology (above, Figure 9.47). The wheat/rye samples were more consistent between the three analyses (Figure 9.47, 10.2 & 10.4), with most samples falling within the central band, indicative of moderate levels of soil enrichment. However, a single wheat/rye sample replicated the unusually high $\delta^{15}N$ values observed in the barley samples; its $\Delta^{13}C$ value was also very low (15.1‰) indicating sub-optimal watering conditions. Therefore, it appears that aridity, or other environmental factors (e.g. temporary waterlogging; cf. Styring *et al.* 2016), influenced $\delta^{15}N$ values at Jerf el-Ahmar, over and above the aridity effect accounted for by a rainfall-based offset. Nevertheless, in the absence of water stress, the relationship between higher δ15N values and soil enrichment appear plausible; several of the wheat/rye samples with elevated δ15N values correlated with well-watered conditions, suggesting moderate levels of soil enrichment. This further supports the notion indicated by the weed ecology that wheat/rye was cultivated with relatively high levels of labour input.

[2] An offset for aridity was determined using the regression equation ($\delta^{15}N=-3.19[\log(\text{mean annual rainfall})]+20.49$) (cf. Hartman & Danin 2010), which accounts for the difference between leaves and grain (~1.4‰) (Styring *et al.* 2016).
[3] 2.04‰ based on an average annual rainfall of 325mm.

10.1.3 Summary

This combined 'weed plus isotope' approach (cf. Bogaard *et al.* 2016b) at Jerf el-Ahmar demonstrates a range of different cultivation intensities at the site, varying from low-intensity rain-fed systems to highly productive conditions suggestive of intensive management. This variation likely represents both the strategic selection of soils, as well as variable levels of labour input. Comparison of weed discriminant scores and $\Delta^{13}C$ values indicate that wheat/rye was preferentially treated compared with barley in regard to labour inputs and water availability. The restricted natural distributions of this crop, which were linked to its greater susceptibility to drier conditions, may have given this cereal added cultural value.

10.2 Dja'de

10.2.1 Variability of cultivation intensity

The selected samples analysed from Dja'de indicated an even broader range of cultivation intensities, varying from relatively high-inputs recognised from intensive regimes, to very low-inputs, equivalent to the poorest soil conditions observed in the modern field studies (above, Figure 9.48). Situated only 30km north of Jerf el-Ahmar, the ecological zones surrounding Dja'de were similarly varied (i.e. steppe, riverine forest, hills, marsh; above, 3.1.2.2), offering a range of different environments for these early farmers to exploit (Roitel 1997; Coqueugniot 1998). With both low- and high-intensity management indicated by the assemblage, it is probable that the breadth of discriminant scores relates to both variable scales of agricultural inputs (i.e. mechanical disturbance, soil enrichment) *and* the selection of different environment types.

Despite this variability across the overall assemblage, most samples grouped towards the low-input end of the intensity scale. As at Jerf el-Ahmar, the majority of samples most closely reflected discriminant values observed within the Evvia fields (cf. Jones *et al.* 1999), a regime characterised by medium to low cultivation intensities with rain-fed conditions. The area surrounding Dja'de would have been suitable for rain-fed cultivation, receiving an estimated 390mm per year during the site's EPPNB occupation[4]. However, water availability would have been a major limiting factor in this semi-arid region, affecting crop growth and yield (Noy-Meir 1973; Keatinge *et al.* 1985). The cluster of Dja'de samples (above, Figure 9.48) that align with the centre of the Evvia field distribution also overlap with the lowest extent observed from the Evvia garden distribution. This suggests that most cultivation plots at Dja'de were, at least to some extent, routinely managed by mechanical disturbance and/or weeding practices, though at low to moderate levels.

[4] Current rainfall levels are 300mm per annum; see above for estimation method, (10.1.2).

A small number of samples from Dja'de were classified as high-input and indicated higher levels of soil productivity comparable to 'garden' style regimes. These cultivation plots were likely more intensively tilled and/or weeded, as well as managed with other soil enrichment strategies. With Dja'de presenting some of earliest evidence for animal domestication (Helmer *et al.* 2005), it is conceivable that animal dung may have been collected for manuring purposes, although there is no evidence for dung-derived taxa within the selected archaeobotanical assemblage (above, 9.4.1.2). Other possibilities for replenishing soil nutrients at this early farming site include the application of midden material (Bogaard 2012; Araus *et al*. 2014), or the use of crop rotation regimes with pulses (Bogaard *et al.* 1999). Pulses (*Lens* and *Pisum/Vicia/Lathyrus* type) were abundant at Dja'de (Willcox *et al.* 2008) and were the most common crop type within the selected samples (above, 9.2.2.1). With water availability a major limitation in this semi-arid region, it is also likely that the highest intensity scores represent the strategic selection of water-retentive soils.

At the other end of the scale, the Dja'de assemblage presents low discriminant scores indicative of relatively low productivity, similar to those observed in the rain-fed terraces from southern Morocco. These modern plots were characterised by shallow stony soils, which were inconsistently replenished with manure and without the regular use of crop rotation regimes (Bogaard *et al.* 2016b). Therefore, the low-input signatures from Dja'de likely reflect less carefully managed cultivation plots situated in areas with relatively poor soils. It is difficult to suggest possible locations from current geomorphology owing to the extent of environmental degradation from millennia of overgrazing, deforestation and erosion (Miller 1997). Nevertheless, the middle Euphrates region is characterised by its distinction between the fertile river valley with its silty soils, and the drier steppe plateau, consisting of shallow chalky and gypsum soils that are largely unfavourable for cultivation (Geyer 1985: 296; Geyer & Besançon 2002). The very low discriminant scores observed within the Dja'de material may suggest cultivation in this drier and less fertile steppe with relatively low additional labour inputs. This is further supported when examining the weed floras of the lowest values; these commonly included *Taeniatherum caput-medusae* and

Adonis aestivalis/annua, which occur in steppic environments (Davis 1965; Guest & Townsend 1966)

Furthermore, the contrasting levels of intensity management observable at Dja'de, as at Jerf el-Ahmar, may relate to the relative distance of plots from the settlement (cf. Jones 2005). In small-scale farming communities, intensive management strategies (i.e. manuring, tillage, weeding and watering) are restricted by the availability of labour and resources, thus must be strategically applied (Halstead & Jones 1989). Modern studies suggest that intensive 'garden' style plots are typically located close to the site to facilitate maintenance tasks (Jones 2005; Bogaard & Isaakidou 2010). The transportation of resources (i.e. manure/kitchen waste, water) to distant fields would have presented various challenges, both in terms of time and labour supply (Halstead 2014). Therefore, the samples with very low levels of intensity are consistent with cultivation on the steppic hinterland, accessible within a short distance (<1km) from the site (Coqueugniot 1998). These low-input plots may have managed existing wild cereal stands from these areas, which were tended infrequently alongside the exploitation of other resources, such as gazelle or raw materials for stone tools (Coqueugniot 1998; Willcox 2007).

10.2.2 Cultivation intensity by site phase

The clearest trend within the ecological analysis at Dja'de was by site phase; there was a noticeable shift towards higher inputs between the middle (Dj II) and late (Dj III) phases (above, 3.1.2.1). These two phases represent significant changes in spatial organisation, which continue developments from the preceding PPNA/PPNB transitional phase (Dj I) and offer possible explanations for increases in cultivation intensity (Coqueugniot 2014). In the earliest phase, the presence of a large (7.5m diameter) 'communal' building with internal decoration, accompanied by smaller ephemeral 'tent-like' structures, suggest continuity with a hunter-gatherer past where resources were shared among the community (Coqueugniot 2014). The middle phase signals the beginning of major social changes with the disappearance of these larger 'community houses' (Coqueugniot 2006). Buildings are

characterised by rectangular structures that consisted of several large rooms, which perhaps accommodated multiple or extended families (Coqueugniot 2014). However, there is evidence for large-scale community meals or 'feasts', where rapid depositions of butchery waste are detected (Gourichon 2004; Coqueugniot 2014); such strategies may have been used to mitigate scalar stresses from early village life (Twiss 2008).

In the most recent PPN phase this village had a very different organisation: buildings were typically small, rectangular and unicellular, which were separated by large open spaces (Coqueugniot 2014). 'Grill-plan' buildings are particularly characteristic of this phase, which feature low parallel walls that acted as supports for external elevated platforms; it is possible that these were used to dry harvested plants for storage, as they enabled air to pass freely underneath (Coqueugniot 1998). These changes in spatial organisation perhaps represent a shift away from communal subsistence strategies towards nuclear household modes of production, which can be observed at other western Asian sites during the PPNB (Banning 1998; 2003; Flannery 2002).

The intensive management of smaller cultivation plots would have offered a more efficient strategy for smaller household units, where labour supply was restricted (Bogaard 2005). Furthermore, reductions in sharing would have presented greater incentives to invest in the land, as the household would reap all of the benefits (cf. Flannery 1972; Sahlins 1972; Hayden 1995). Such temporal patterns in cultivation intensity were also hinted across the phases at Jerf el-Ahmar, but this could only be determined by the highest discriminant scores (above, 9.5.1). Greater investments in cultivation intensity in the later phases may also suggest the increased longevity of these cultivation plots over time; the production and maintenance of fertile soils require higher inputs over successive years, often with delayed returns (Jones 2005). Excavators at Dja'de propose that the site's inhabitants were not fully sedentary, with various clues (e.g. deposition sequences) pointing to seasonal rhythms (Coqueugniot 2006; 2014). Therefore, increases in cultivation intensity in the latest PPN phase may signal a departure from this lifestyle, with increasing permanence of settlement. The publication of detailed specialist reports is needed to investigate this notion further.

Stable isotope data from cereals at Dja'de further support observations from the weed ecological analysis, including the inference that agricultural inputs increased over time. When examining $\Delta^{13}C$ values for wheat/rye in the Araus *et al.* (2014) study (see above, 10.1.2) there is a notable shift towards greater water availability at the end of Dj III (Figure 10.5). However, there were no wheat/rye dominant samples within the current weed analysis to directly compare cultivation intensity scores. The pattern is less clear for $\Delta^{13}C$ values in barley, but higher watering levels were still discernible in Dj III (Figure 10.6). These higher $\Delta^{13}C$ values in the latest PPN phase may relate to increasing management of available water resources, either through additional watering practices, or the concentration of cultivation plots in soils with better water availability. Comparison of $\Delta^{13}C$ values for these two cereals (Figure 10.5 &Figure 10.6) also indicated distinctions in their water status, with wheat/rye consistently grown with higher water availability; however, the values for barley are less extreme than at Jerf el-Ahmar (above, 10.1.2), perhaps relating to the slightly higher rainfall levels at Dja'de.

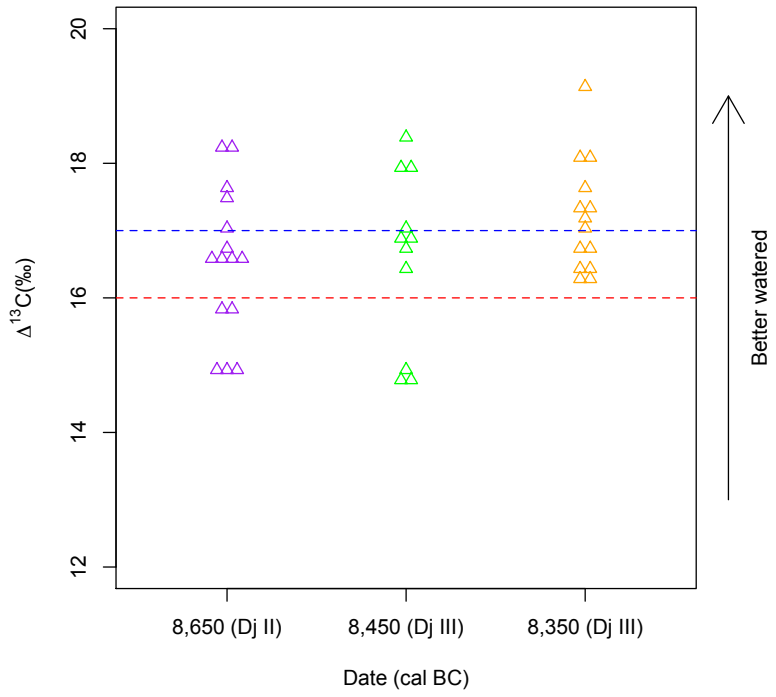


Figure 10.5 – $\Delta^{13}C$ values for wheat/rye at Dja'de by phase from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of watering threshold for poorly watered (red) and well-watered (blue) values (after Wallace *et al.* 2013).

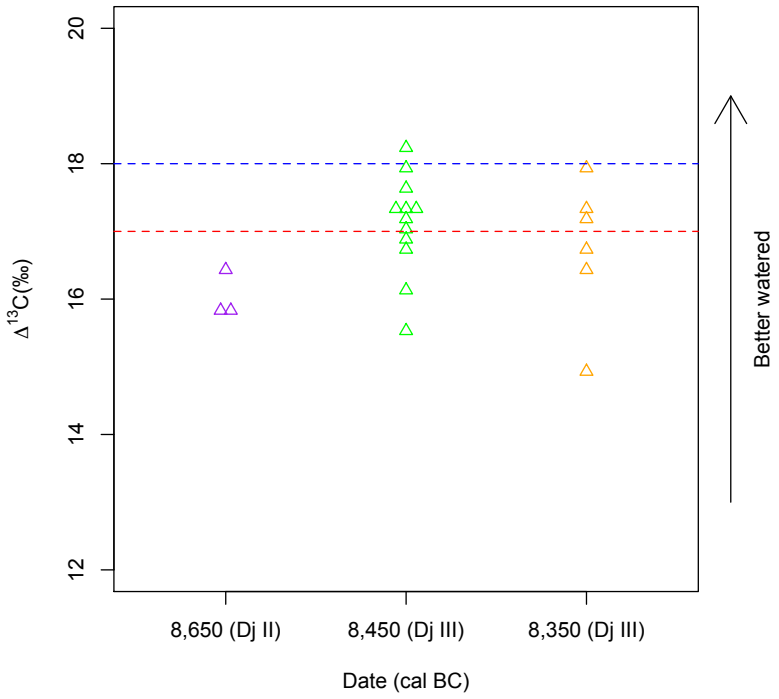


Figure 10.6 – Δ¹³C values for barley at Dja'de by phase from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of watering threshold for poorly watered (red) and well-watered (blue) values (after Wallace *et al.* 2013).

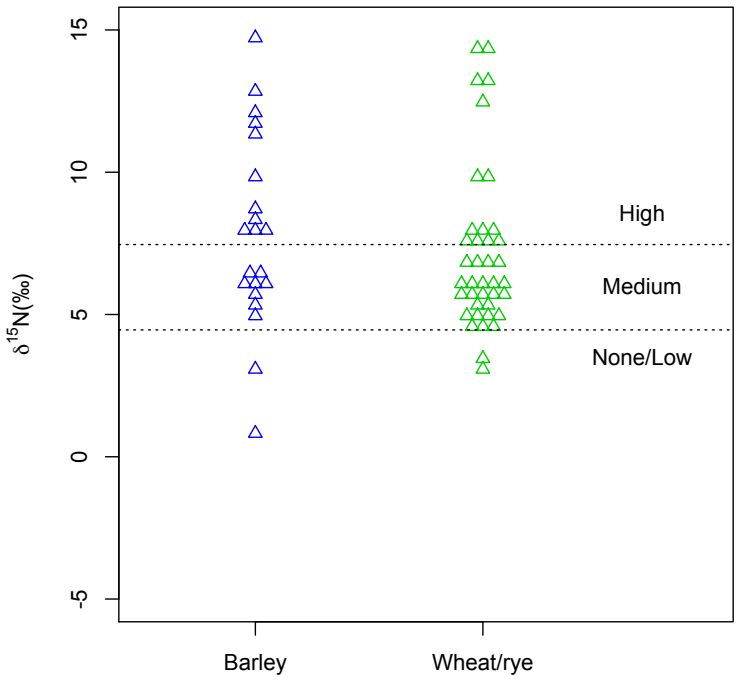


Figure 10.7 – δ¹⁵N values for barley and wheat/rye at Dja'de from a recent stable isotope study by (Araus *et al.* 2014). The dashed lines relate to a series of thresholds adjusted for rainfall to indicate possible levels of manuring (after Styring *et al.* 2016).

Similar to Jerf el-Ahmar, the $\delta^{15}N$ values for barley and wheat/rye are abnormally high at Dja'de when compared with modern field studies, equivalent to intensively manured oases (Figure 10.3 & 10.7) (Styring *et al.* 2016). While the cereals from Dja'de were less affected by aridity due to their greater water availability (particularly for barley), the replication of these distinctly high values suggest that other factors may have altered the nitrogen content of soils in this region, such as aridity combined with seasonal wetting and drying (cf. Handley *et al.* 1999; Aranibar *et al.* 2004; Austin *et al.* 2004). Further research is required to characterise the expected stable isotope values for growing conditions such as temporary waterlogging, and increased salinity, which may relate to denitrification processes (Van Gestel *et al.* 1991; Styring *et al.* 2016).

10.2.3 Summary

The weed ecological analysis at Dja'de demonstrated that cultivation intensity was highly variable at the site. This ranged from some of the poorest conditions observed in the modern field studies, to high-input levels identified from highly managed 'garden' style regimes. With both high and low intensity management represented, it is likely that this variation reflects both differences in the level of labour inputs *and* the strategic selection of land. When considering both the weed ecological data and $\Delta^{13}C$ values, there appears to have been a shift towards higher cultivation intensities in the latest PPN phase. This may relate to major changes in spatial organisation observable in the late phase, perhaps signalling a shift towards household levels of production. In addition to greater incentives to invest in the land, cultivation plots may have been located closer to the site to facilitate maintenance tasks with a diminished labour supply.

10.3 Tell Aswad

10.3.1 Variability of cultivation intensity

The small assemblage assessed from Tell Aswad presented a degree of variation within its intensity scores (above, Figure 9.48), but was restricted to lower to moderate levels of input. The highest discriminant values from the site were equivalent to the lowest extent observed from the three high-input modern regimes, while the lowest discriminant values reflected the limited inputs identified in low-input rain-fed field systems. With the smaller number of samples applicable for the weed ecological analysis, it was difficult to determine whether these values represented the full extent of regimes practiced at the site. Further species identification work is required to expand this dataset. Nevertheless, when compared with settlement data from the site and its environmental setting, these initial intensity scores offer useful insights into farming practices at Tell Aswad.

In today's climate, the Damascus basin is extremely dry, receiving an average annual rainfall of less than 200mm (van Zeist & Bakker-Heeres 1982). Using the calculation presented by Roberts *et al.* (2018; above, 10.1.1) precipitation levels were estimated to approximately 260mm per year for the early Holocene; this only slightly exceeds the lower limit for reliable dry farming methods (150mm) (Noy-Meir 1973). However, in antiquity, the site would have been established near the edge of two freshwater lakes, providing perennial water sources to supplement rainwater (van Zeist & Bakker-Heeres 1982). The majority of samples from Tell Aswad reflected low-input farming methods that most closely resembled the distribution observed from the Evvia fields (cf. Jones *et al.* 1999); this regime was characterised by rain-fed farming methods with medium to low levels of input (i.e. mechanical disturbance, weeding, occasional enrichment with fertiliser). The largest cluster of samples aligned with the centre of the Evvia field distribution, which equally reflects the most productive conditions observed from the Moroccan rain-fed terraces; this suggests that cultivation plots were at least partly maintained by tillage and/or weeding practices.

Without stable isotope data at this site, it is difficult to disentangle crop water availability from levels of soil nutrients as contributing factors to soil productivity. However, by observing the weed data it was clear that farming methods at Tell Aswad did not resemble highly watered (and manured) conditions, such as the plots from Moroccan oases, instead mostly indicating drier conditions (cf. Bogaard *et al.* 2016b). This inference contrasts with previous discussions of the archaeobotanical data (above, 3.1.3.3) where crops were suggested to have been grown in moist soil conditions, i.e. were irrigated (Stordeur *et al.* 2010). Such interpretations were largely based on the frequent occurrences of wet-loving taxa, such as *Scirpus* and *Bolboschoenus glaucus* (Stordeur *et al.* 2010); however, their presence does not necessarily relate to agronomic conditions (cf. Charles 2011). Consideration of the crop-processing stages within the selected samples indicated that these taxa were not of arable origin and likely derived from alternative sources (e.g. dung-derived, building materials) (above, 9.4.1.3). The current weed dataset excludes the use of intensive irrigation practices at Tell Aswad, though supplementary watering per se and/or strategic planting in relatively well watered soils cannot be ruled out. Furthermore, despite the availability of animal dung at Tell Aswad, which accompanied the site's intensive herding practices (Stordeur *et al.* 2010), the weed flora indicates that manuring practices were not typically used, with this resource perhaps favoured for its use as fuel. The trend towards relatively low-input signatures therefore suggests a focus upon the cultivation of drier soils further away from the site and the lake's edge.

The small number of samples classified as high-input (but with low probability) indicated marginally higher levels of soil productivity and disturbance, but aligned with the poorest conditions from the 'garden' style regimes. In these modern gardens, lower intensities could be correlated with farming methods such as broadcast sowing on larger allotment plots (30-60m^2)[5], manual hoeing, and the limited application of manure (Jones *et al.* 1999; Charles *et al.* 2002). Broadcast sowing methods often resulted in inefficient weeding practices as they were difficult to access without trampling (Jones *et al.* 1999). Thus, the higher intensity

[5] While large for 'garden' style plots, these were considerably smaller than the modern extensive 'fields', which ranged from 60-1,500m^2 (Jones *et al.* 1999).

scores identified from Tell Aswad may relate to similar styles of cultivation, with plots modest in size compared with modern fields, but with only moderate levels of labour inputs. With the region very dry for rain-fed agriculture, it is also possible that these higher discriminant scores represent the selection of soils with greater moisture retention, perhaps located at the margins of the lake's marshes closer to the site (Stordeur *et al.* 2010).

10.3.2 Patterning within the intensity scores

It is difficult to relate the discriminant scores from Tell Aswad to factors such as site phase, or crop type, owing to the limited dataset (above, Figure 9.52 & 9.53). Further samples are particularly required for the early PPNB phase to investigate possible shifts in cultivation intensity throughout the PPN occupation at the tell. From the current dataset, the middle and late phases appear very similar in both their average levels and range in intensity scores. When considering crop type, from those that contained more than one sample—barley (*Hordeum vulgare*) and wheat (*Triticum* sp.)—barley was the most uniform in its discriminant scores; the two samples were positioned towards the low-input end of the spectrum, which is consistent with its greater tolerance to poorer and drier soil conditions (Willcox 2007). This included a grain-rich barley sample (AW06/39), which was recognised as fine sieved product from the two crop-processing analyses (above, 9.4.1), thus provided an especially reliable indicator of crop husbandry. The discriminant scores for the glume wheat (*Triticum dicoccum*/*Triticum monococcum*) and indeterminate wheat samples were also very low (with one exception); this contrasted with the distinctly higher intensities observed for wheat/rye at Jerf el-Ahmar (above, 10.1.2).

10.3.3 Summary

While further samples are required to establish the full range and trends of cultivation intensity at Tell Aswad, this initial weed ecological analysis has presented initial insights into farming methods at the site. Contrary to initial interpretations (cf. Stordeur *et al.* 2010), the weed data suggest that crops tended to be grown in relatively dry soil conditions, with limited evidence for intensive cultivation management, such as intensive watering and manuring practices. However, the use of small-scale watering practices cannot be ruled out in this dry region that was very marginal for rain-fed farming. The clustering of samples towards the upper extent of the low-intensity regimes indicate that cultivation plots were partially managed by tillage and/or weeding practices. A small number of samples indicated higher labour inputs and may have been located closer to the site, where they received greater levels of maintenance and water availability.

10.4 Çatalhöyük

10.4.1 Variability of cultivation intensity

The *in situ* crop stores analysed from Çatalhöyük demonstrated a wide range of intensity signatures (above, Figure 9.55), varying from low-input conditions observed from rain-fed fields, to very high intensity levels that resemble well-watered, tilled and manured plots. Part of this variability may relate to the site's surrounding landscape, which was a mosaic of environments offering variable conditions for farming: these ranged from drier marl hummocks to better-watered zones near the edge of seasonal flooding (above, 3.2.2) (Charles *et al.* 2014; Ayala *et al.* 2017). Nevertheless, the wide range of discriminant scores determined from the Çatalhöyük assemblage, indicative of both low- and very high-intensity regimes, suggest that additional labour inputs accompanied the strategic selection of different natural soil conditions.

While the assemblage displayed considerable variability, the main distribution of samples clustered in an intermediate position between the two group centroids, relating to an area of overlap between low- and high-input farming methods. When referring to the modern regimes, this clustering most clearly resembles the lower extent of values observed in the Evvia gardens, central Greece (cf. Jones *et al.* 1999), though similar scores were also indicated from the poorest conditions in the Moroccan oases and Asturias garden plots in Spain. A single data point from the low-input Evvia fields overlaps in this section, representing the highest inputs identified from this regime. Management intensity in the Evvia gardens was characterised by small-scale plots (6-100m^2) located within 200m of the village, which were frequently hand-watered, tilled, manured and weeded (Jones *et al.* 1999). The lower intensity scores from this modern regime, which relate to the main cluster of samples at Çatalhöyük, correlate with larger allotment gardens (50-100m^2), which due to practical reasons (i.e. availability of labour supply and resources; cf. Jones 2005) were managed at lower intensities (Jones *et al.* 1999). Therefore, the main distribution of Çatalhöyük scores likely represent the levels of management intensity achievable in

medium-scale plots (compared with larger fields) with moderate to relatively high labour inputs (i.e. tillage, weeding, manuring, watering), and/or the targeting of soils with greater levels of moisture retention.

When considering the high-input end of the scale at Çatalhöyük, one sample (Fl. 6049) emerged as an outlier with distinctly high discriminant score (3.49). As discussed previously (9.5.4), this free-threshing wheat sample was of unmixed crop type and processing-stage, and contained over 60 weeds, thus can be regarded as an especially reliable indicator of growing conditions. This high discriminant score can be related to some of the highest inputs observed within the Moroccan oases and intensively managed gardens from Asturias, with greater values than observed in the Evvia gardens. In the Moroccan oases, these high intensities relate to the farming of intensively tilled, dung-enriched alluvial soils, which were irrigated fortnightly to the point of saturation, and heavily weeded to obtain animal fodder (Bogaard *et al*. 2016b). Similar strategies were undertaken in the Asturias gardens, with small plots (15-25m^2) located within short distances of the village (<500m) that were heavily manured, tilled and weeded[6] (Charles *et al.* 2002). Therefore, this free-threshing wheat sample likely represents a snapshot of more intensive regimes undertaken at the site, which included the selection of well-watered soils and/or the intensive use of hand-watering, as well as regular tillage, weeding and manuring practices. The social implications of this high discriminant score will be explored further below, in relation to its specific archaeological context, building and crop type.

While much of the Çatalhöyük assemblage was characterised by moderate to high-inputs, a smaller group of samples had lower discriminant scores indicative of less productive conditions detected in rain-fed field systems. Dry-farming could have been achieved in this region during the Neolithic, with an estimated annual rainfall between 350-550mm (Charles *et al.* 2014). However, increasing aridity throughout the site's occupation (cf. Roberts *et al*. 2008; 2016), would have gradually reduced the reliability of this low-input

[6] Irrigation was not required at Asturias due to the location of the village in an Atlantic climatic zone, which received an average rainfall of 1100-1200mm per year (Charles *et al.* 2002).

form of intensity management. The lowest inputs observed within the Çatalhöyük samples aligned with the most extensive values identified from the modern Evvia fields, as well as the centre of the Moroccan rain-fed terrace distribution. Variation in the Moroccan rain-fed terrace distribution related to field size, the frequency of weeding and manuring applications (though all infrequent), as well as the intensity of ploughing (Bogaard *et al*. 2016b). Thus, with discriminant scores more intensive than some of the modern field data, it is probable that these less productive Çatalhöyük plots were still managed to some extent (i.e. weeding, tillage), though at lower levels. Furthermore, these instances of low productivity may relate to cultivation on the drier, nutrient poor marls, and/or more distant areas from the site, such as the drier soils east of the tell (Ayala *et al.* 2017).

Recent studies have provided complementary investigations into agronomic conditions at Çatalhöyük using stable carbon and nitrogen isotope analysis (Wallace *et al.* 2015; Vaiglova 2016). In these studies, multiple grains/seeds were measured from each archaeological sample, providing more reliable averaging of the inherent variability detectable within single plant specimens (cf. above, 10.1.2) (Bogaard *et al.* 2007; Fraser *et al.* 2011; Nitsch *et al.* 2015). Between the two studies, a total of 135 samples was selected from primary burnt contexts, which targeted all major phases (above, Table 3.5) of the mound, and included several of the storage deposits analysed in this project. While direct comparability between stable isotope results and weed intensity scores on a sample-by-sample basis is limited (cf. Bogaard *et al.* 2016b: 16), the integrated approach of these two forms of analysis offer useful insights into site-wide trends. The $\Delta^{13}C$ values from Çatalhöyük indicated that the water status of crops was highly variable, with significant variation identifiable *within* species. The $\delta^{15}N$ values were similarly diverse, ranging from unmanaged levels to high values indicative of anthropogenic enrichment (Vaiglova 2016). These results correlate with the wide range of cultivation intensities indicated by the weed ecology, with water availability and nitrogen levels major aspects of soil productivity.

10.4.2 Cultivation intensity by site level

There was considerable patterning within the dataset, which alludes to specific farming practices and social organisation at the site. When the discriminant scores were examined by site level (above, Figure 9.56), there was an overall trend towards higher labour inputs over time, most clearly distinguishable within the two later levels, South Q-T and TPC. However, these distributions do not reflect a simple linear progression, instead appearing to relate to the site's shifting settlement extent over time. The earliest phase examined in this study, North G, was highly variable in intensity management and captured the full range of the site's weed intensity scores, though, it must be noted that this level also had the largest sample size due to its high frequency of burnt grain stores. North G relates to the middle phase of the site (Table 3.5), where the settlement reached its greatest extent, both in terms of population size (est. 3,500 to 8,000 people) and density (above, 3.2.1); this was determined by a range of factors, including clustered settlement layout, high fertility rates, and a peak in instances of osteoperiostitis, a condition more easily spread with increased crowding (Hillson *et al.* 2013; Hodder 2013; Hodder & Farid 2014).

To sustain this larger population, greater cultivated areas would have been required with increased efficiency (i.e. higher yields). Such stresses may have fostered intensive management strategies, which can be reflected by the highest weed intensity scores observed in North G, but would have been limited by the availability of suitable land located close to the settlement (Bogaard & Isaakidou 2010; Charles *et al.* 2014). The more extensive discriminant scores observed in this level may relate to the shortage of optimal cultivation plots, resulting in the cultivation of more distant areas from the settlement; the lower inputs may relate to the cultivation of drier soils (cf. Ayala *et al.* 2017), and/or areas that were less susceptible to intensive management, since they were further for people to travel. Therefore, the large variation of cultivation intensities in North G is consistent with a wide spectrum from intensively cultivated 'infield' plots to extensively cultivated 'outfield' areas (cf. Bogaard 2004: 145-6). Furthermore, such variability may have had significant social implications for the site: uneven distribution of prime cultivation plots would enable certain

households/groups to produce consistently higher yields, hence achieve greater surpluses (Bogaard 2011: 46). However, the remarkable evidence for an egalitarian social structure at the site (above, 3.2) (cf. Hodder 2014a; Kohler *et al.* 2017) indicate that other mechanisms were likely employed to regulate the distribution of land across the community (Bogaard & Isaakidou 2010; Charles *et al.* 2014).

The crop stores from level South O correlate with the end of the middle phase (Table 3.5); this stage introduces greater investments in sheep herding and domestic cattle at the site, with household units perhaps beginning to possess more control over their own resources (Hodder 2013). The smaller sample size from this level reflects moderate to relatively low intensities, similarly recognised in North G (above, Figure 9.56). There is a noticeable shift towards higher labour inputs in the two separate late levels, South Q-T and TPC, reflecting moderate to relatively high-inputs. With a declining population, the settlement became much more fragmented and dispersed during this later phase of the mound, with a greater frequency of open spaces between buildings (Hodder 2013; Hillson *et al.* 2013). These reduced population stresses would have offered greater opportunities to cultivate areas closer to the site, facilitating increasing labour inputs, as indicated by the weed flora (Jones 2005). Furthermore, the gradual increase in aridity throughout the site's occupation (cf. Roberts *et al*. 2008; 2016) may have decreased the reliability of dry-farming methods, resulting in the strategic selection of wetter areas, or the additional use of hand watering practices.

10.4.3 Cultivation intensity by building

In addition to these broader shifts across the mound's sequence, intensity scores also displayed patterning in relation to the building from which samples derive, with the stores appearing to reflect variable cultivation management among and within individual domestic units (above, Figure 9.57). With the exception of Building 52, all buildings were highly consistent in their own weed intensity scores. These distinct building signatures

varied in intensity between one another, suggesting that cultivation choices (i.e. manure use, tillage and weeding practices) were largely dictated at the household level. Nevertheless, there were also some areas of overlap that indicated possible instances of cooperation between households, either through the sharing of farming plots or their subsequent harvests (cf. Charles *et al*. 2014; Hodder 2014b; Bogaard 2017). While there was a tendency towards lower inputs in Building 77 compared with its adjacent neighbours (B.1 and B.52) (above, Figure 9.57), its pea stores were very similar to the most extensively managed pea stores from Building 52. Furthermore, the intensity scores in Building 1 and Building 52 showed considerable overlap, but related to different crop types. In the South Area, similarities between intensity scores in Building 79 and Building 80 were apparent, but further samples would be needed to explore the comparison between these abutting domestic units.

Building 52 (North G) (above, Figure 4.5) contained an unusually large range of stored crop types within its small store room (above, 4.3.1.1 & 9.1.3.2) (above, Figure 9.58) (cf. Bogaard *et al.* 2009; 2013a), and a wide spectrum of agricultural intensity within a single household. These stores ranged from the most intensive discriminant score identified from the selected assemblage, to relatively low levels of labour input. The building was also unique in containing multiple distinct seed clusters within built storage features (above, 9.1.2.2), likely separated by perishable containers, which may reflect separate harvesting events. One of these clusters related to the intensively cultivated free-threshing wheat store (Fl. 6049) discussed above (10.4.1). A second cluster of free-threshing wheat (Fl. 6026) analysed from this store room (above, Figure 9.58), identified as a distinct seed cluster on the room's floor (Bogaard *et al.* 2013a: 117), was associated with slightly lower labour inputs. While direct comparisons between weed intensity scores and stable isotope values do not necessarily present correlations (above, 10.4.1), it is interesting to note similarities between their results for these separated clusters of free-threshing wheat. The stable isotope analyses indicated there was a significant difference in water status between these stores, with the bin cluster having higher $\Delta^{13}C$ values (1‰), suggesting greater water

availability (Vaiglova 2016); this result matches the greater levels of productivity observed from the weed ecology.

To maintain these higher levels of productivity, equivalent to intensities seen in modern Moroccan oases (Bogaard *et al.* 2016b), the associated plot of land would have needed to have been easily accessible (i.e. close to the settlement) to facilitate soil enrichment practices, and to prevent the crop being outcompeted by weeds (Bogaard & Isaakidou 2010). The variability detected within this building's intensity signatures is consistent with the cultivation of disparate plots of land, located at varying distances from the site (cf. Jones 2005). Alternatively, some of these grain stores may have been acquired via processes of exchange with neighbouring households (such as B.77) that had access to different areas of land, acting as a risk-buffering strategy (Halstead 1990).

10.4.4 Cultivation intensity by crop type

Correlation of cultivation intensity with crop type was generally weaker than with the other factors (above, Figure 9.59); several crops appear to have been cultivated with similar ranges in intensity. The barley stores were the most prevalent in the assemblage and formed a cohesive group towards the centre of the intensity scale, though with notable variation, ranging between low- and high-input regimes. Similar ranges were reflected in the glume wheat and pea stores, but with their own subtle differences (above, 9.5.4). The most distinct crop type was free-threshing wheat, with its two associated samples indicating high to very high levels of labour input (above, 10.4.3).

When considering the stable isotope data, a similar story of high intra-species variability could be discerned across the assemblage, with many crop types grown in a similar range of water availability and soil fertility levels (Wallace *et al.* 2015: 6; Vaiglova 2016). The values for free-threshing wheat presented comparable values to other crops, suggesting that it was not preferentially treated at a broader site level (Wallace *et al.* 2015; Vaiglova 2016). However, a subset of $\Delta^{13}C$ values presented by Wallace *et al.* (2015) indicated that

barley tended to be poorly watered and grown in distinctly drier conditions than other crops at the site (Figure 10.8). Similar results were replicated in Vaiglova's (2016) wider study, with barley possessing comparable $\Delta^{13}C$ values to other crops, therefore suggesting that its moisture availability differed[7].

This contrasts with the results of the weed intensity scores (Figure 9.59), which suggest that barley was regularly grown in conditions of moderate to high levels of productivity, which to some extent reflects water status. Furthermore, the most extensive barley signature from the weed analysis was equivalent to the overlap between the modern Evvia fields and gardens (cf. Jones *et al.* 1999), suggesting conditions that were still relatively favourable for cultivation. The discrepancy between the two analyses could perhaps be explained by the greater influence of other factors within the productivity scale (i.e. nutrients, disturbance) in this region, where water availability was not as limiting. This inference is supported when

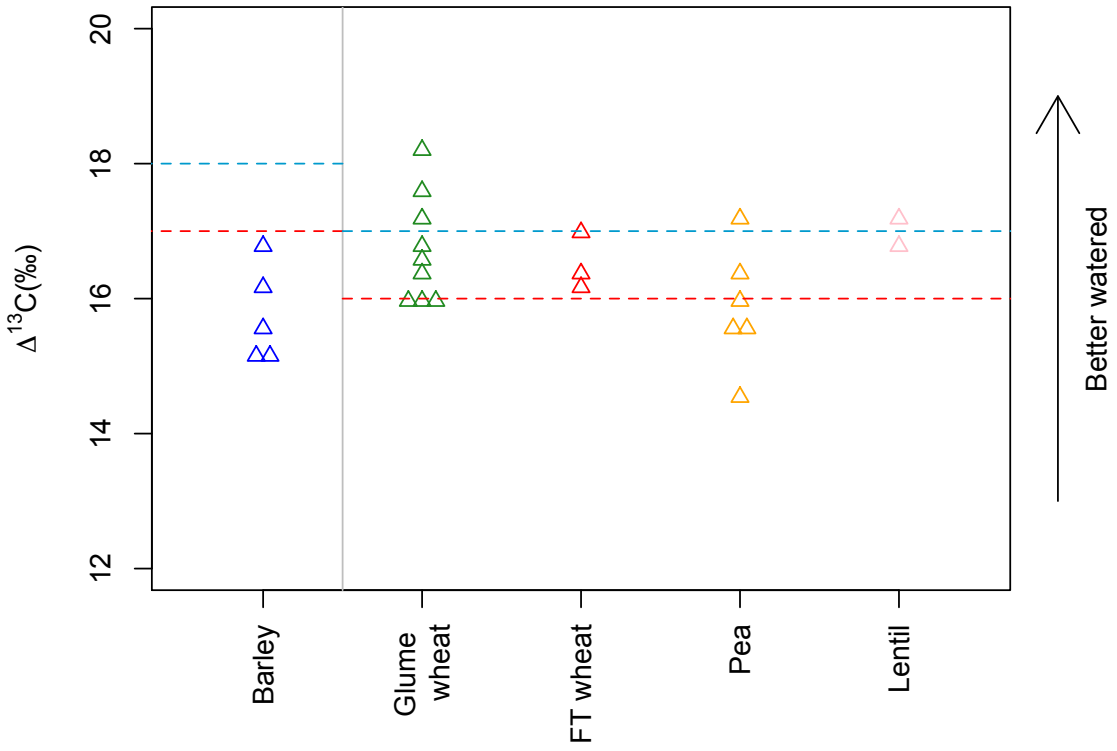


Figure 10.8 – Subset of $\Delta^{13}C$ values for different crop types at Çatalhöyük, suggesting barley was grown in drier conditions than other crop types (Wallace *et al.* 2015).

[7] Barley has been demonstrated to have higher $\Delta^{13}C$ values under the same conditions (cf. Wallace *et al.* 2013), so different values would be expected for barley and wheat grown with the same water availability.

comparing the $\Delta^{13}C$ values of barley at Çatalhöyük with drier barley signatures identified at Jerf el-Ahmar (Figure 10.2); $\Delta^{13}C$ values at Jerf el-Ahmar were much lower (as low as 13.6‰). Therefore, it may have been the case that barley was intentionally grown in drier areas at Çatalhöyük to utilise its greater drought-tolerance, but that soil conditions were still relatively productive compared with more arid areas in the Middle Euphrates, which were further enhanced by regular maintenance (i.e. tillage, weeding, manuring).

10.4.5 Summary

The complementary insights from weed intensity signatures and crop stable isotope analysis indicate that farming at Çatalhöyük featured an extensive range of agronomic conditions, with agricultural methods most likely dictated by individual households as opposed to being centrally controlled. Rather than separate treatments of different crop types, variation in the weed and isotope data most likely reflects plot location within the surrounding landscape, with closer areas facilitating the use of intensive farming methods. The broadest range of cultivation intensities could be detected from level North G in the middle phase of the mound, when the settlement reached its greatest extent. With the most desirable plots (i.e. those close to the site) constrained in number, the presence of extensive cultivation signatures may relate to the cultivation of more distant areas, more difficult to maintain, which were needed to sustain the site's increased population. Such variation could be detected within the stores of single households, suggesting that some domestic units had access to various areas of land, or alternatively shared the harvests from other households with disparate plots. As the settlement became more disparate in the late phase, there were greater opportunities to use intensive cultivation method close to the site, reflected by greater inputs in the weed signatures.

10.5 Comparison of cultivation intensity between sites

Comparison of the discriminant scores across all four early farming sites (Table 10.1; Figure 10.8) reveals notable distinctions in cultivation intensity, particularly between the three Syrian sites and the later established farming site at Çatalhöyük. While each of the sites possessed a wide range of intensity signatures, the husbandry practices at Çatalhöyük are noticeably shifted towards the high intensity end of the spectrum, particularly when considering site averages (Table 10.1). The distributions observed from Jerf el-Ahmar and Dja'de are extremely similar, with identical discriminant scores when averaged across the sites; this result is not surprising considering the close proximity and time frame between these two sites. The smaller assemblage examined from Tell Aswad presents a more restricted distribution, reflecting growing conditions that are marginally more extensive on average, but still highly comparable to the distribution from the two Euphrates sites, despite their considerable geographic distance.

Table 10.1 – Average discriminant functions with ±SD for each of the study sites in relation to the established cultivation intensity scale (Bogaard *et al.* 2016b).

Site	No. samples	Average discriminant function	±SD
Jerf el-Ahmar	19	-1.3	1.3
Dja'de	21	-1.3	1.3
Tell Aswad	11	-1.4	1.0
Çatalhöyük	28	-0.2	1.2

These four early farming settlements varied widely in their extent. The two pre-domestication sites, Jerf el-Ahmar and Dja'de, were village-like (<1.5 hectares) in scale (Stordeur 2015; Coqueugniot 1998), in contrast to the large 13.5 hectare 'megasite' at Çatalhöyük (Hodder 2006), with the six hectare mound at Tell Aswad midway between these extremes (Stordeur *et al.* 2010). However, rather than reflecting contrasts in site scale (cf. Bogaard & Isaakidou 2010), the relative differences in cultivation intensity *between* these disparate early farming sites appear to relate to each site's environmental setting and their specific ecological affordances.

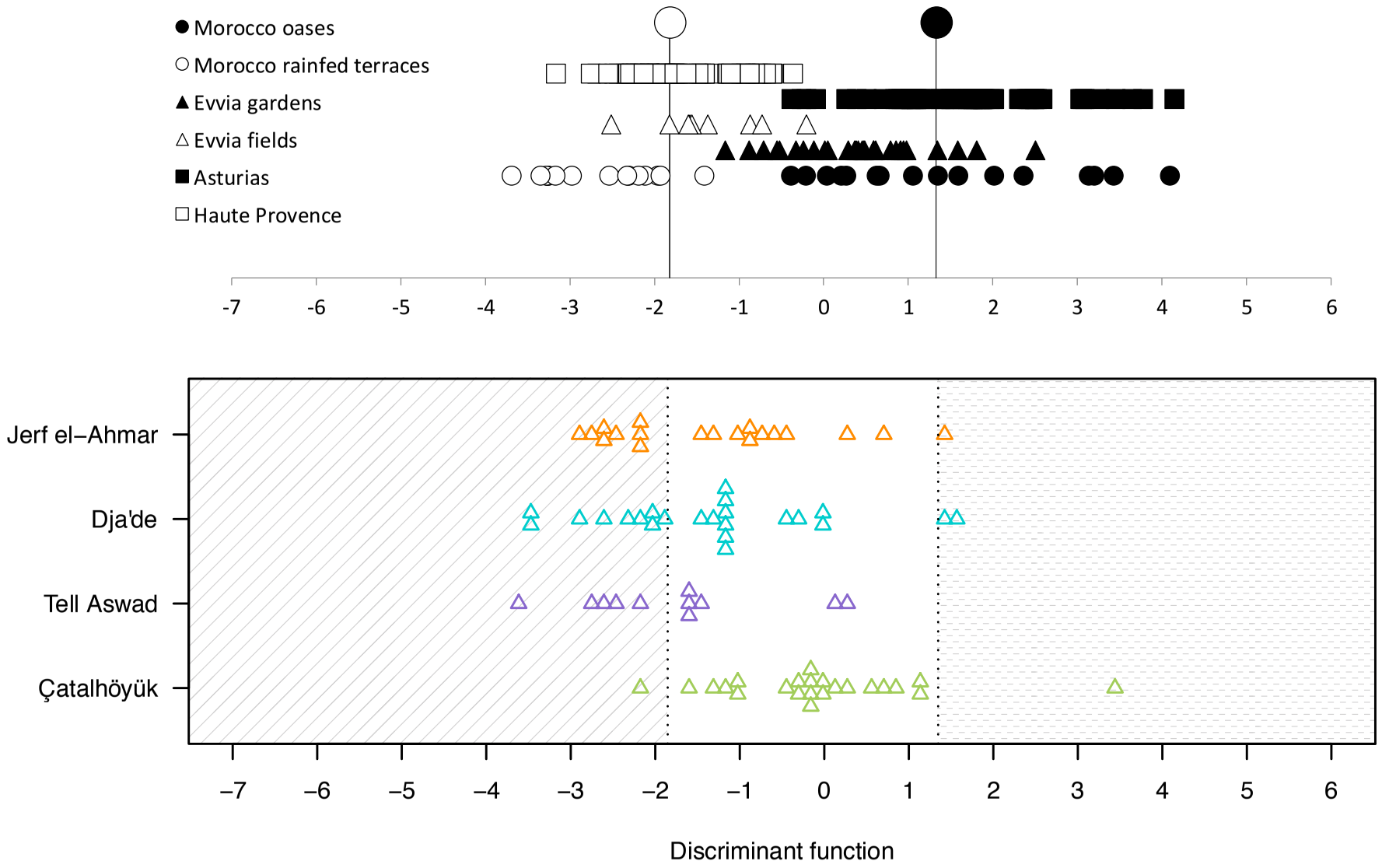


Figure 10.9 – The relationship of the four study sites to the established discriminant function and modern regimes. The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

These distinct climatic areas were variable in their available ecological niches and rainfall levels, which would have presented different opportunities for maintaining soil productivity. The higher rainfall levels at Çatalhöyük would have allowed more scope to use soil enrichment practices without 'burning' the crops, which can occur when water is scarce (cf. Halstead 2014: 212), hence facilitating higher levels of cultivation intensity. Furthermore, in areas of greater aridity, water availability would have been the main limiting factor for plant growth and thus soil productivity. To achieve truly high discriminant scores in the driest regions would require very labour-intensive regimes, such as those observed in the Moroccan oases (Bogaard *et al.* 2016b), which include intensive irrigation and manuring practices. To fully understand social change in farming practice, it is therefore more effective to compare and contrast the relative differences in husbandry *within* these sites than directly *between* them.

10.5.1 Variability in crop growing conditions

Crop growing conditions were characterised by high variability at each of the four early farming sites, consistently ranging between both low- and high-input regimes, though at different extents. In addition to the wide range of ecological niches that surrounded each site, which offered diverse soil conditions for cultivation, the contrasts in cultivation intensity also indicate variable levels of intensive management strategies, such as tillage, hand-weeding, anthropogenic soil enrichment (i.e. manuring, middening), as well as the strategic selection of wetter soils and/or hand-watering. Higher intensities appeared to have been used more selectively in the three Syrian sites, where increased levels of aridity would have constrained intensive methods. These more limited instances likely reflect strategic plantings of certain crops in wetter soils (e.g. wadi bottoms) (Hillman 2000), which would have consequently required greater maintenance (i.e. weeding, tillage) to prevent quick-growing weeds from outcompeting the crop (Radosevich *et al.* 1997).

The use of a combined 'weed plus isotope' approach (cf. Bogaard *et al.* 2016b) enabled distinctions between the treatment of wheat/rye and barley to be detected in the two pre-domestication sites, though particularly at Jerf el-Ahmar (above, 10.1.2). At a site level, barley was related to drier conditions than wheat/rye, which was likely an intentional strategy to utilise barley's greater drought-tolerance. Furthermore, in the context of these early cultivation sites, the availability of wheat/rye was more restricted, with natural wild stands located at greater distances from the site than wild barley (Willcox 2007; Willcox *et al.* 2008), thus it is possible that its higher labour inputs relate to it being ascribed a 'special' status. Similar strategic plantings likely occurred at Çatalhöyük, with barley utilised as a drier niche crop, though inferences for more productive soil conditions suggest associated plots were still regularly managed. With a smaller dataset at Tell Aswad and the absence of stable isotope studies, it is difficult to relate the site's occasional instances of higher inputs to specific crop types, nevertheless, the two samples of barley were towards the low-input end of the spectrum, which is consistent with drier conditions.

Despite these trends indicating the use of strategic planting strategies for certain crop types, growing conditions were often still highly variable *within* species across the sites. At Jerf el-Ahmar, where some of the poorest conditions for barley were indicated, there was a distinct barley sample grown with notably high labour inputs (above, 10.1.2). While the sample's secondary context prevented it from being related spatially, the sample demonstrated that barley was sometimes cultivated at greater intensities (i.e. in moist conditions) despite its drought-tolerance and local availability. Similar divergences in growing conditions were also indicated in the two barley samples at Dja'de, further supported by the wide range of $\Delta^{13}C$ values (above, 10.2.2). While there were few trends within the selected assemblage at Tell Aswad, the dataset indicated variable intensities for wheat cultivation, from poorer rain-fed conditions to the highest intensity indicated at the site (above, Figure 9.53). Comparable contrasts were determined at Çatalhöyük, with pea stores particularly variable, with samples representing both ends of the site's wide intensity scale (above, Figure 9.59).

These high levels of variation are consistent with agricultural decision-making at the local level as opposed to centralised control. However, such direct associations could only be confirmed at Çatalhöyük due to its extensive *in situ* storage, which isolated individual harvesting events within defined households. The presence of 'communal' storage structures at Jerf el-Ahmar raise questions about whether farming strategies were collectively organised at this site (Willcox & Stordeur 2012), but such inferences are difficult to address in the absence of primary crop stores. Nevertheless, with one exception (above, 10.1.2), all samples from building EA30 had similar intensity scores (above, Figure 9.46), clustering towards the low input end of the spectrum. It is possible that these samples represent joint cultivation ventures on a communal plot, tended with consistent management strategies. Furthermore, the low-input rain-fed signature of these samples may relate to the management of natural distributions of wild barley located on the dry steppe (Willcox 2007). Despite the potential for collaboration at Jerf el-Ahmar, the remaining diversity of signatures at the site suggest that farming practices were far from uniform, instead utilising variable land types and farming practices.

10.5.2 Shifts in cultivation intensity over time

In this selection of early farming sites, there is a reoccurring trend towards greater levels of labour inputs in the later phases of the settlements (Figure 10.10). In the pre-domestication sites, this could most clearly be detected at Dja'de, where there is a clear shift[8] (above, Table 9.30; Figure 9.49) towards greater inputs in the latest phase, identified in both the weed and isotope analyses. These increases in intensity follow significant changes in settlement structure, with households appearing to become more autonomous (above, 10.2.2). There are subtle hints of increasing intensities throughout the phases at Jerf el-Ahmar, but this was only reflected by the highest intensity scores rather than their full distributions. Shifts away from communal subsistence strategies towards nuclear household modes of

[8] There is an average increase in discriminant function of 0.74.

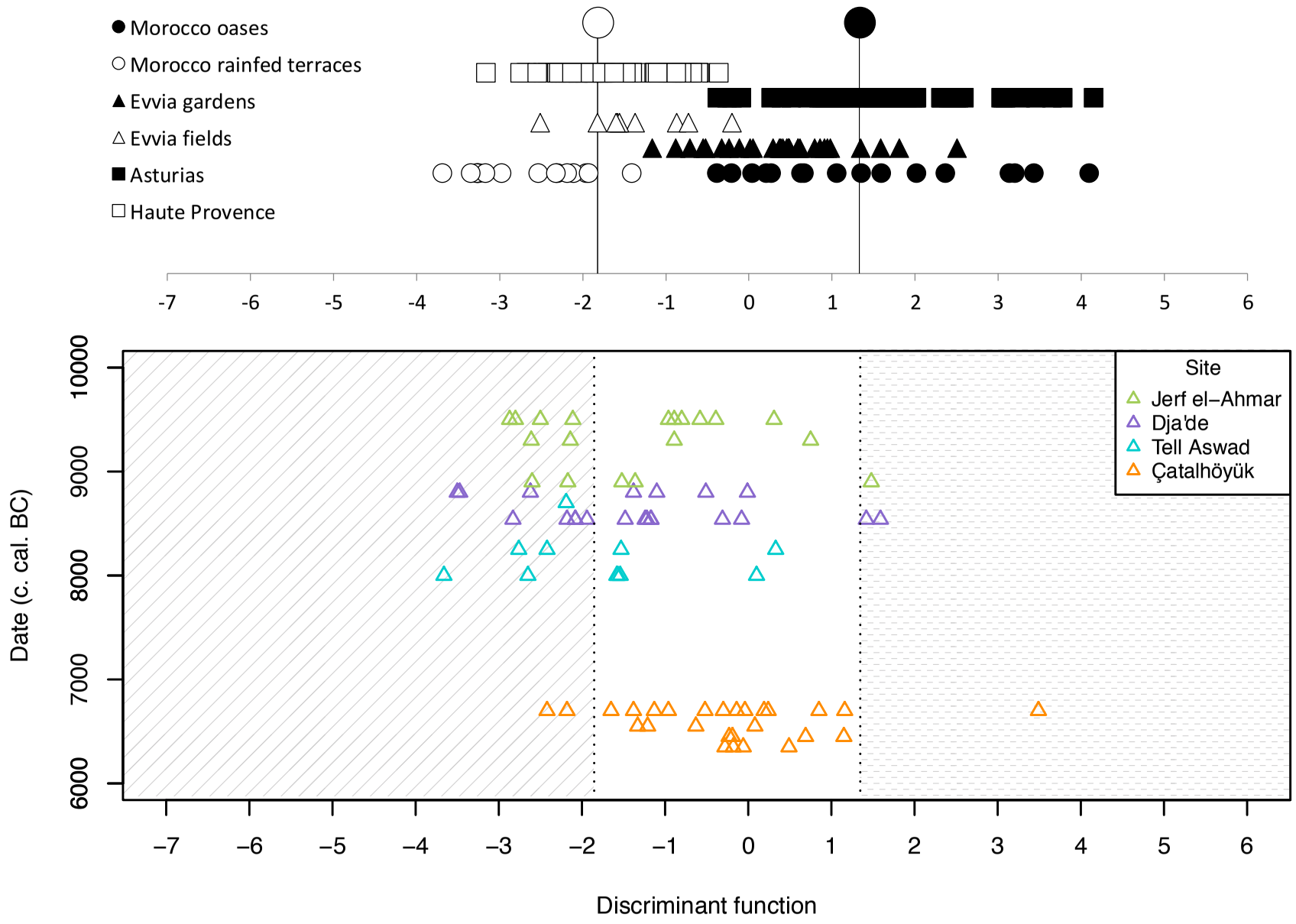


Figure 10.10 – The selected samples from the four study sites plotted by approximate date (based on site phases – see Appendix 1g). The two lines represent the two group centroids for high- (right) and low-input (left) regimes. The unshaded area indicates the area of overlap between the two regime types.

production have been consistently identified from the PPNB onwards within early farming sites in western Asia (Banning 1998; 2003; Flannery 2002). Such inferences are largely based on the spatial organisation of settlements, architectural design, the increasing privacy of food related activities, the emergence of individual household storage (above, Chapter 4), as well as the disappearance of larger 'communal' structures (Wright 2000; Kuijt & Goring-Morris 2002; Bogaard *et al.* 2009). The shifts in cultivation intensities within the PPNB levels at Dja'de appear to correlate with these broader changes in social organisation, with intensive cultivation methods more compatible with smaller households (cf. Bogaard 2005).

In the middle to late levels at Çatalhöyük, where household production was established, changes in labour inputs over time were less linear, following shifts in settlement extent throughout the site's occupation (above, 10.4.2). The widest range of discriminant scores were detected during the site's peak population in the middle phase, consistent with a broad spectrum from intensively cultivated 'infield' plots to extensively cultivated 'outfield' fields. A smaller range of relatively high inputs are indicated as the settlement became more dispersed in the late phase, likely relating to the reduced competition to cultivate in prime areas close to the settlement. There is currently insufficient weed data to identify temporal trends at Tell Aswad (above, Figure 9.52); further samples are required to characterise cultivation intensities for the early phase of the site.

When these collective results are set into a broader temporal context within the region, these early farming practices reflect relatively high levels of cultivation intensity compared with agricultural regimes from later periods. A clear example to highlight these distinctions is the weed ecological study from the mid-late third-millennium BC (Early Bronze Age) occupation from Tell Brak, Syria (Figure 10.11; above, 6.2) (Charles & Bogaard 2001; Bogaard *et al.* 2016b). Rainfall levels are similar to the Syrian sites analysed in this study,

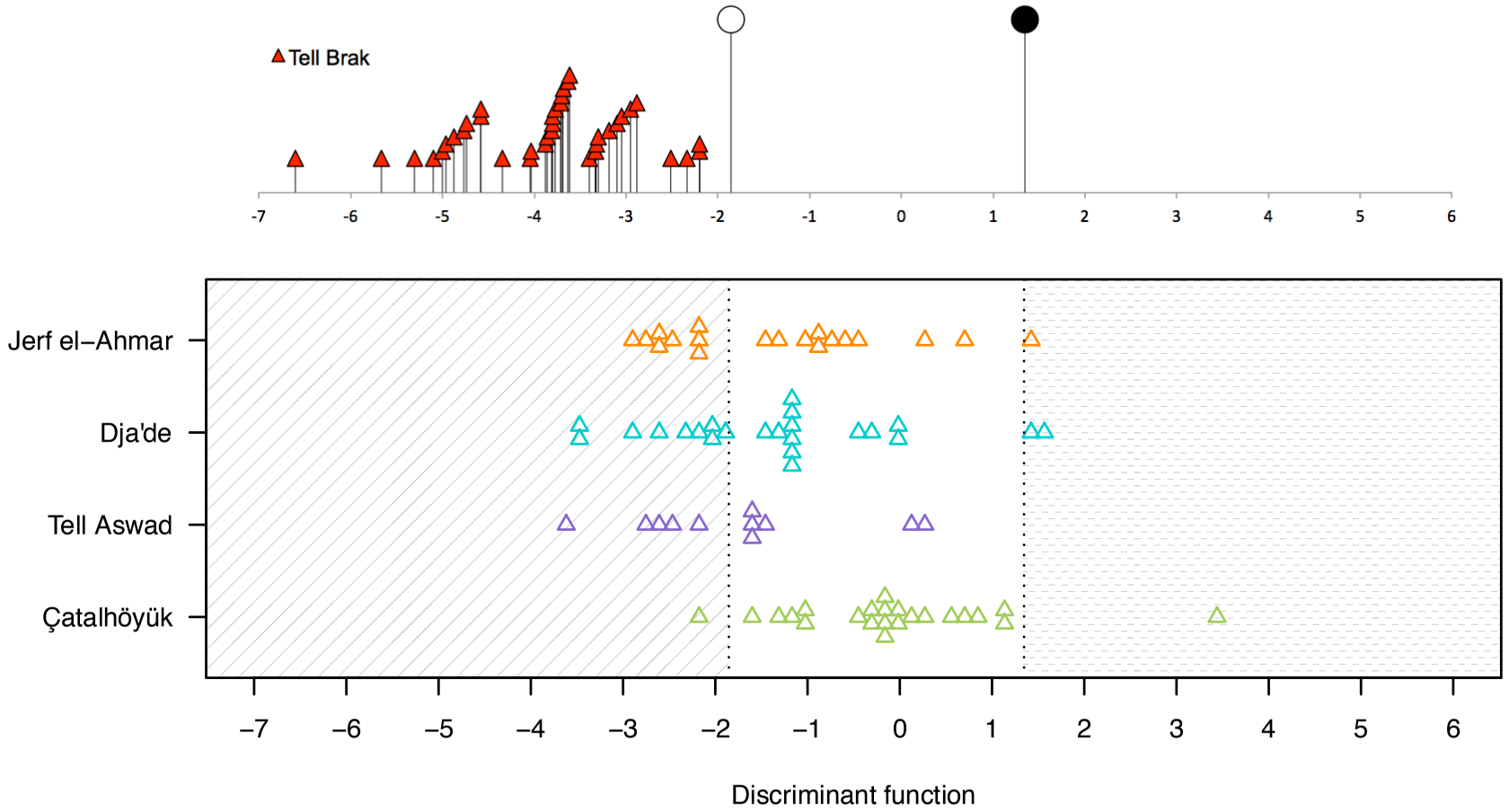


Figure 10.11 – The relationship of the four early farming study sites to samples from the Early Bronze Age occupation at Tell Brak, Syria along the same cultivation intensity scale. The two lines represent the group centroids for the modern low-input (white) and high-input (black) regimes. The unshaded area indicates the area of overlap between the two regime types.

estimated between c. 310-450mm per year (Bogaard *et al.* 2016b). The distribution of ecological signatures at this site is considerably lower down the intensity scale, relating to much poorer conditions than observed in the modern farming regimes. The weed intensity scores therefore appear to reflect rain-fed conditions with relatively limited labour inputs, with the wide range of low-input intensity scores reflecting variances in soil fertility.

This pattern towards the extensification of farming practices following the Neolithic period has been correlated with the establishment of urbanism in the region (cf. Styring *et al.* 2017). These larger urban populations would have demanded increased agricultural production, fostering the development of extensive farming methods. Greater scales of production would have been achievable through the significant expansion of cultivated land, using large-scale ard ploughing with specialised plough animals, which would have offset poorer yields from lower cultivation intensities (Halstead 1995). These expansions, perhaps into more marginal lands, coupled with erosion and more continuous cropping cycles, would have depleted soil conditions further (Araus *et al.* 2014: 4). Therefore, despite some of the low-input methods identified at the four selected early farming sites, when analysed in a broader context in western Asia these practices can be recognised as relatively small-scale and intensive in their nature.

10.5.3 Testing previous hypotheses for early farming methods in western Asia

While this study has only addressed levels of cultivation *intensity*, with further functional data still required to characterise field *seasonality* and *permanence* in semi-arid regions, this initial functional ecological analysis has presented several key insights into crop growing conditions in the selected early farming sites. One of the most well-defined models to specify the nature of early farming in western Asia was Sherratt's (1980) theory of floodplain cultivation, which referred to the frequent location of early farming sites near natural water sources (above, 1.1). This model has since been regarded as ecologically implausible, with

its problematic assumption that crops were spring-sown (Hillman & Davies 1999: 86; Isaakidou 2011). When considering the pre-domestication sites in the Middle Euphrates, autumn-sowing would have been more probable to utilise winter rainfall during the growing season, and avoid the increased aridity in the summer months (Willcox 1996; Hillman 2000). One of the biggest issues with Sherratt's model, which can be addressed with the weed intensity signatures, is the notion that early farming was 'practically self-cultivating' (Sherratt 1980: 318). This current study alternatively indicates that early farming strategies were characterised by variable, but relatively high-input methods when compared with later agricultural methods, which related to the climatic affordances of the local landscape, as well as plot distance from the settlement. Even the relatively low-input signatures, which were more abundant in the PPN sites, could be related to some level of cultivation management (i.e. tillage, infrequent manuring) when compared with the modern regimes.

The high frequency of wet-loving taxa within the archaeobotanical datasets of early farming sites, such as *Scirpus* and *Bolboschoenus glaucus,* has been regularly associated with the cultivation of areas of high groundwater, or to indicate the use of irrigation practices (Colledge 2001; Stordeur *et al.* 2010). While these interpretations directly consider the archaeobotanical evidence, they fail to consider possible alternative origins of such taxa within the assemblage (cf. Charles 2011). At Çatalhöyük, such taxa have been directly associated with animal dung deposits preserved by its use as a fuel (Bogaard *et al.* 2013a; Filipović 2014). Through the use of crop-processing analyses at Tell Aswad (9.4.1.3), a selection of taxa from marginal habitats including 'wet' indicators, were suggested to be from alternative sources (e.g. dung-derived, building materials) rather than arable weeds. This was indicated through incompatibilities in their physical characteristics (i.e. size, aerodynamics) with crop products and by-products. Furthermore, the inclusion of these alternative sources within the ecological analysis had substantial impacts upon intensity signatures (above, Figure 9.54). Contrary to initial interpretations, when non-weed sources were excluded, the cultivation intensities from Tell Aswad indicated relatively dry soil

conditions comparable to rain-fed systems. The investigation of a dung flora is perhaps something that should be considered at other sites possessing 'wet' weed signatures.

On the other hand, Colledge's (2001) inferences for increasing cultivation intensity through time were supported by the weed ecological data presented here, with greater indications for higher soil disturbance (among other factors) in later site phases (above, 10.5.2). However, these trends were more clearly identifiable *within* sites rather than *between* them, owing to the different opportunities prescribed by the climate and surrounding landscape. The idea put forward by Araus *et al.* (2014) that higher levels of soil productivity later shifted towards more extensive practices following the Neolithic could also be indicated (above, 10.5.2). Nevertheless, the suggestion that early farmers merely exploited areas of natural fertility cannot be supported, owing to the extensive variation of cultivation intensity signatures that suggest strategic planting strategies, as well as the variable use of intensive management strategies.

Chapter 11

Conclusions

Assessing the nature of early Neolithic farming in western Asia

This project aimed to develop a refined understanding of the specific nature and social implications of early plant cultivation in western Asia, as well as the potentially varied land management strategies involved. Through the application of a functional ecological approach to the interpretation of arable weed taxa at four key early farming sites, this study has provided new insights into the variability of Neolithic farming practices, as well as the specific opportunities presented by different ecological settings. This final chapter summaries the main findings from this research, as well as its wider archaeological implications in relation to broader chronological trends. The section will then conclude with a reflection on the processes involved in the successful isolation of arable weed flora and their refined identification.

11.1 Addressing the research questions

11.1.1 Characterising growing conditions in early plant cultivation

The weed ecology from the four selected sites demonstrated considerable variability in cultivation intensity *within* each of the sites, ranging from low-input rain-fed conditions, to highly managed productive plots, consistent with strategic planting strategies and

anthropogenic soil enrichment. Comparison between these four sites highlighted notable distinctions in average cultivation intensities, which appeared to reflect the specific affordances of local climate and surrounding landscapes. In the three Syrian sites where water availability was more limited due to lower rainfall, the use of intensive cultivation methods appeared to be used more selectively, often reserved for crops with greater susceptibility to arid conditions (i.e. wheat/rye). These instances of greater cultivation intensity likely reflected the strategic selection of moister soils within the landscape (e.g. wadi bottoms), as well as regular plot maintenance (i.e. weeding, tillage) to prevent weeds from outcompeting the crop in these more productive soil conditions. It is also possible that these higher input signatures relate to the use of additional intensive strategies, such as hand-watering and middening/manuring. Nevertheless, the three PPN sites were more generally characterised by modest labour inputs, comparable with intensities observed in present-day rain-fed field systems, though comparison with modern regimes suggest that these still likely involved some form of regular management (i.e. mechanical disturbance and/or weeding practices), albeit at moderate levels.

At Çatalhöyük, where rainfall levels were on average higher, there were greater opportunities for the application of soil enrichment practices, such as manuring, without the associated 'burning' of crops, which may occur in drier soil conditions (cf. Halstead 2014: 212). This is reflected by the clustering of samples towards the higher end of the cultivation intensity scale. Archaeobotanical crop $\Delta^{13}C$ values confirm that water availability was not as limiting as identified in the Syrian sites (Araus *et al*. 2014; Wallace *et al*. 2015; Vaiglova 2016), and the weed intensity scale here appears to more equally reflect water *and* nutrients levels. Despite higher intensities on average, there was still a wide range of labour inputs identified from Çatalhöyük, with greater variation detected during the settlement's phase of maximum size in the mid-Neolithic sequence. Close contextual examination of the crop stores combined with the weed ecological signatures indicated that farming practice was dictated at the household level, with levels of labour input likely relating to the distance of arable plots from the settlement (cf. Jones 2005).

11.1.2 Social implications of early farming methods

Several trends in cultivation intensity were identified across the selected sites, which revealed further insights into Neolithic social organisation, both at local and broader scales. There were notable trends towards increasing labour inputs per unit area as households appeared to become more autonomous. These shifts to some extent reflect practical aspects related to production at smaller scales, with intensive methods close to the settlement more compatible with balancing other household responsibilities (e.g. childcare) (Bogaard 2005), while enabling the production of large enough yields to sustain household units throughout the year. However, it is also likely that households invested increasingly more into the land when they began to directly receive the benefits. The samples analysed from the 'communal' storage building at Jerf el-Ahmar (although secondary contexts) perhaps support such a notion, with the majority of these potentially shared harvests reflective of the lower input end of the site's intensity spectrum. At Dja'de, shifts towards greater intensities were clearly identified in the latest phase, when dwellings became smaller and further separated by large open spaces (Coqueugniot 2014). When considering broader trends during the Neolithic in western Asia, there is wide-scale evidence for increasingly private household storage from the PPNB onwards (above, Chapter 4). Such architectural features were perhaps fostered by the production of small-scale crop surpluses, which resulted from increasingly intensive farming methods.

With farming practices (in most cases) highly consistent by household within the more extensive settlement at Çatalhöyük, it is possible that there were social mechanisms for distributing land tenure; the extensive evidence for low material wealth disparity and an egalitarian social structure at the site (cf. Hodder 2014a; Kohler *et al*. 2017) indicate this was likely organised at the local community level. Building 52 presented a particularly unusual case at the site, with its broad intensity spectrum that ranged from low-input rain-fed conditions to very high labour intensities comparable to Moroccan oases. This variability is consistent with the exploitation of a wide 'transect' of cultivation from relatively proximate to distant areas, indicating that this household had access to

disparate plots of land, or at least neighbours that were willing to share their harvests (cf. Charles *et al*. 2014; Hodder 2014b; Bogaard 2017). Regardless of the correct scenario, the large extent of variation within this household's crop growing conditions would have served as a successful risk-buffering strategy, particularly with the increased aridity throughout the site's occupation.

11.1.3 Lasting social and ecological consequences of early farming methods

While this functional ecological analysis identified a high degree of variability within early plant cultivation, when the results are assessed within a broader chronological time frame in western Asia, it is clear that early farming practices involved relatively intensive cultivation methods on small-scales. The weed ecological analysis from the EBA occupation at Tell Brak (Charles & Bogaard 2001; Bogaard *et al.* 2016b), combined with wider stable isotope studies of crops from the Neolithic to the Bronze Age (Araus *et al*. 2014; Styring *et al*. 2017), indicate that there was a gradual extensification of agricultural practices following the Neolithic, which culminated with the establishment of urban centres by the EBA. These shifts towards lower labour inputs reflect the increasing requirements for greater scales of production for these larger centres, achievable through significant expansion of cultivated land, using large-scale ard ploughing with specialised plough animals. These larger contrasts in cultivation intensity between early farming settlements and urban centres therefore reflect some of the fundamental differences in their social organisation, with household scales of production later becoming more susceptible to centralised control.

Furthermore, experimentation in cultivation methods within these early farming societies, further indicated by shifts in crop choice over time (cf. Bogaard *et al*. 2017), likely played an important role for establishing agricultural methods for long-term resilience in areas of increasing aridity. A key example indicated by the weed analysis was the recurrent

association of barley with drier, less productive conditions. This suggests that early farmers were aware of the different tolerances of different crop types, which was likely adapted as a strategy to most effectively manage the local landscape. Such practices would have been particularly important within the two later sites analysed, where larger settlement (and hence population) sizes would have demanded greater areas of land to be cultivated to feed the community. The detection of such distinctions from as early as the PPNA at Jerf el-Ahmar indicate that these strategic planting practices likely emerged from the initial management of wild cereal stands, when cultivars were first removed from their natural habitats.

11.2 Isolating and identifying relevant weed taxa

The targeting of *in situ* storage deposits at Çatalhöyük presented an effective way to analyse weed ecology, through their direct associations with individual behavioural events and the specific crops they were grown with. However, a review of the storage evidence from western Asia (above, Chapter 4) demonstrate the scarcity of such primary crop stores across early farming sites in the region. Furthermore, in addition to the generally more limited weed material recoverable from cleaned products, a degree of contamination from other sources was detectable within even the purest deposits examined (above, 9.1.5 & 9.3). Therefore, the use of statistical analyses to more accurately isolate arable weed taxa from archaeobotanical material (above, 9.3 & 9.4) is imperative for the application of a functional ecological approach, particularly in the absence of primary *in situ* plant concentrations. This was demonstrated when comparing ecological signatures before and after identified contaminants were removed (Figure 9.54).

The identification of isolated weed material to the species level presents further challenges for a functional ecological approach. The consultation of seed atlases and limited reference collections is rarely sufficient to confirm species level identification for regions with diverse floras (above, Chapter 7 & 8), with the potential for different species

of the same genus to vary considerably in their ecological signature (above, 6.3). The construction *and* dissemination of detailed species level keys presents an important step for refined archaeobotanical identification (above, Chapter 8); through the continual addition of further accessions, such keys can provide useful resources of comparative material, while also emphasising the wide extent of morphological variability within species. Nevertheless, the examination of ecological variability within genera presents a way to approach species identification more strategically (above, 6.3).

11.3 Future directions and final remarks

A principal limitation within this study, which restricted the final number of samples analysed, was the extent to which species level identifications were achievable. Through a critical review of species identification methods (above, Chapter 7) and the construction of species-level identification keys, it became apparent that a considerable amount of work is still required in this area. While time consuming, the development of further systematic identification keys for principal weed genera (e.g. *Bellevalia, Malva*), would enable additional samples to be examined, increasing the resolution of the full variation of cultivation intensity within the sites (particularly at Tell Aswad). The *Bromus* key, presented here (above, Chapter 8), presents a simple multi-access key format, easily adaptable for other grass genera. Though the use of SEM techniques proved limited for *Bromus*, it is likely this approach would be particularly useful for other genera (e.g. *Galium, Silene*), and is another avenue worth pursuing. Furthermore, even in the absence of refined identification methods, this thesis proposes a method for best practice when identifying specimens to species/types (see Identification Catalogue). With more systematic documentations of the number of species and accessions observed, it is more straightforward to assess the reliability of, or to refine, identifications in future studies.

Another area for future work includes the gathering of further modern datasets from (semi-)arid regions, to investigate other aspects of early farming practices in addition to

cultivation intensity. The recent fieldwork undertaken in Morocco was unable to gather sufficient data to characterise contrasts in plot permanence and seasonality. Further fieldwork is therefore required from (semi-)arid areas, to gather comparable datasets to those already available for temperate Europe (cf. Bogaard *et al*. 2001; Bogaard 2002b). A number of potential modern farming sites have already been identified in Morocco, including an area of flood recession fields dependent on unusually high winter rainfall (A. Bogaard, pers. comm.).

Bibliography

ADAMS, K.R. & S.S. MURRAY. 2004. *Identification Criteria for Plant Remains Recovered from Archaeological Sites in the Central Mesa Verde Region.* http://www.crowcanyon.org/plantID.

AGCABAY, M., A. BOGAARD, M. CHARLES, G. JONES & N. STONE. 2003. Macro botanical remains, in I. Hodder (ed.) *Çatalhöyük 2003 Archive Report. Online at http://www.catalhoyuk.com*.

ANDERBERG, A.L. 1994. *Atlas of seeds and small fruits of Northwest-European plant species with morphological descriptions. Part 4 Resedaceae-Umbelliferae.* Stockholm: Swedish Natural Science Research Council.

ANDERSON, E. 1952. *Plants, Man and Life*. Boston: Little, Brown and Co.

ANDERSON, S. & F. ERTUG-YARAS. 1998. Fuel Fodder and Faeces: An Ethnographic and Botanical Study of Dung Fuel Use in Central Anatolia. *Environmental Archaeology* 1: 99–109.

APLIN, D.M. & V.H. HEYWOOD. 2008. Do Seed Lists have a future? *Taxon* 57: 709–11.

ARANIBAR, J.N., L. OTTER, S.A. MACKO, C.J.W. FERAL, H.E. EPSTEIN, P.R. DOWTY, F. ECKARDT, H.H. SHUGART & ROBERT J. SWAP. 2004. Nitrogen cycling in the soil – plant system along a precipitation gradient in the Kalahari sands. *Global Change Biology* 10: 359–73.

ARAUS, J.L., J.P. FERRIO, J. VOLTAS, M. AGUILERA & R. BUXÓ. 2014. Agronomic conditions and crop evolution in ancient Near East agriculture. *Nature communications* 5: 3953.

ARCHÉORIENT 2012. *L'antenne de Jalès Collections.* http://www.archeorient.mom.fr/presentation/antenne-de-jales/collections.

ARNOLD, N., S. BAYDOUN, L. CHALAK & T. RAUS. 2015. A contribution to the flora and ethnobotanical knowledge of Mount Hermon, Lebanon. *Flora Mediterranea* 25: 13–55.

ARRANZ-OTAEGUI, A., S. COLLEDGE, J.J. IBAÑEZ & L. ZAPATA. 2016. Crop husbandry activities and wild plant gathering, use and consumption at the EPPNB Tell Qarassa North (south Syria). *Vegetation History and Archaeobotany* 25: 629–45.

ASOUTI, E. 2007. Beyond the Pre-Pottery Neolithic B interaction sphere. *Journal of World Prehistory* 20: 87–126.

— 2013. Woodland vegetation, firewood management and woodcrafts at Neolithic Çatalhöyük, in I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*: 129–61. London and Los Angeles: British Institute at Ankara.

ASOUTI, E., A. ERKAL, A. FAIRBAIRN, C. HASTORF, A. KENNEDY, J. NEAR & A.M. ROSEN. 1999. Archaeobotany and Related Plant Studies, in I. Hodder (ed.) *Çatalhöyük 1999 Archive Report. Online at http://www.catalhoyuk.com*.

AURENCHE, O., P. GALET, E. RÉGAGNON-CAROLINE & J. ÉVIN. 2001. Proto-Neolithic and Neolithic cultures in the Middle East - The birth of agriculture, livestock raising, and ceramics: a calibrated 13C chronology 12,500-5500 cal BC. *Radiocarbon* 43: 1191–1202.

AUSTIN, A.T., L. YAHDJIAN, J.M. STARK, J. BELNAP, A. PORPORATO, U. NORTON, D.A. RAVETTA & S.M. SCHAEFFER. 2004. Water pulses and biogeochemical cycles in arid and semiarid ecosystems. *Oecologia* 141: 221–35.

AYALA, G., J. WAINWRIGHT, J. WALKER, R. HODARA, J.M. LLOYD, M. LENG & C. DOHERTY. 2017.

Palaeoenvironmental reconstruction of the alluvial landscape of Neolithic Çatalhöyük, central southern Turkey: The implications for early agriculture and responses to environmental change *Journal of Archaeological. Science* 87: 30–43.
BAKER, H.G. 1965. Characteristics and modes of origin of weeds, in H. Baker & G. Stebbins (eds.) *The genetics of colonizing species*: 147–172. New York: Academic Press.
— 1974. The Evolution of Weeds. *Annual Review of Ecology and Systematics* 5: 1–24.
BANNING, E.B. 1998. The Neolithic Period: Triumphs of Architecture, Agriculture, and Art. *Near Eastern Archaeology* 61: 188–237.
— 2003. Housing Neolithic farmers. *Near Eastern Archaeology* 66: 1–21.
BANNING, E.B. & B.F. BYRD 1987. Houses and the changing residential unit: domestic architecture at PPNB 'Ain Ghazal, Jordan. *Proceedings of the Prehistoric Society* 53: 309–325.
BAR-YOSEF, O. 1994. The Lower Paleolithic of the near-East. *Journal of World Prehistory* 8: 211–65.
BAR-YOSEF, O., A. GOPHER, A.N. GORING-MORRIS & S.K. KOZLOWSKI. 2010. The Stratigraphy and Architecture of Gilgal I, in O. Bar-yosef, A.N. Goring-morris, & A. Gopher (eds.) *Gilgal - Early Neolithic Occupations in the Lower Jordan Valley: The Excavations of Tamar Noy*: 11–26. Oxford: Oxbow Books.
BARKER, G. 1985. *Prehistoric Farming in Europe*. Cambridge: Cambridge University Press.
BARKER, J.A. 2005. *Towards an Archaeobotanical Reference Bank: A Pilot Study for the Construction of an Identification Tool for Macroscopic Plant Remains from Archaeological Deposits*. Unpublished PhD thesis, Flinders University of South Australia, Department of Archaeology.
BARRETT, S.C.H. 1983. Crop Mimicry in Weeds. *Economic Botany* 37: 255–82.
BARTHLOTT, W., W. LAUER & A. PLACKE. 1996. Global Distribution of Species Diversity in Vascular Plants: Towards a World Map of Phytodiversity (Globale Verteilung der Artenvielfalt Höherer Pflanzen: Vorarbeiten zu einer Weltkarte der Phytodiversität). *Erdkunde* 50: 317–27.
BAYLISS, A., F. BROCK, S. FARID, I. HODDER, J. SOUTHON & R.E. TAYLOR. 2015. Getting to the Bottom of It All: A Bayesian Approach to Dating the Start of Çatalhöyük. *Journal of World Prehistory* 28: 1–26.
BEIJERINCK, W. 1976. *Zadenatlas der Nederlandsche flora.* Amsterdam: Backhuys & Meesters.
BEN-SHLOMO, D. & Y. GARFINKEL. 2009. Sha'ar Hagolan and New Insights on Near Eastern Proto-Historic Urban Concepts. *Oxford Journal of Archaeology* 28: 189–209.
BERGGREN, G. 1969. *Atlas of seeds and small fruits of Northwest-European plant species with morphological descriptions. Part 2, Cyperaceae*. Vol. 39. Stockholm: Swedish Natural Science Research Council.
— 1981. *Atlas of seeds. Part 3. Salicaceae-Cruciferae*. Stockholm: Swedish Museum of Natural History.
BESANCON, J. & B. GEYER. 2006. Contraintes écogeéographiques et modes d'occupation du sol, in B. Jaubert & R. Geyer (eds.) *Les marges arides du Croissant fertile. Peuplements, exploitation et contrôle des ressources en Syrie du Nord*: 11–53. Lyon: Maison de l'Orient et de la Méditerranée Jean Pouilloux.
BEWLEY, J.D., M. BLACK & P. HALMER. 2006. *The encyclopedia of seeds: science, technology and uses*. Wallingford: CABI.
BOARDMAN, S. & G. JONES. 1990. Experiments on the Effects of Charring on Cereal Plant Components. *Journal of Archaeological Science* 17: 1–11.
BOGAARD, A. 2002a. *The Permanence, Intensity and Seasonality of Early Crop Cultivation in Western-Central Europe*. Unpublished Ph.D. thesis, University of Sheffield.
— 2002b. Questioning the relevance of shifting cultivation to Neolithic farming in the loess belt of western-central Europe: evidence from the Hambach Forest experiment. *Vegetation History and Archaeobotany* 11: 155–68.
— 2004. *Neolithic Farming in Central Europe: An archaeobotanical study of crop husbandry practices*. London and New York: Routledge.
— 2005. 'Garden agriculture' and the nature of early farming in Europe and the Near

East. *World Archaeology* 37: 177–96.
— 2011. *Plant Use and Crop Husbandry in an Early Neolithic Village: Vaihingen an der Enz, Baden-Württemberg, Frankfurter Archäologische Schriften.* Bonn: Habelt-Verlag.
— 2012. Middening and manuring in Neolithic Europe: issues of plausibility, intensity, and archaeological method, in R.L. Jones (ed.) *Manure Matters: Historical, Archaeological and Ethnographic Perspectives*: 25–39. Farnham: Ashgate.
— 2016. Archaeobotany: The wheat and the chaff. *Nature Plants* 2: 16079.
— 2017. Neolithic 'cooperatives': assessing supra-household cooperation in crop production at Çatalhöyük and beyond, in M. Benz, H.-G.K. Gebel, & T. Watkins (eds.) *The Construction of Neolithic Corporate Identities (ICAANE Workshop Basel, June 9-10th, 2014)*: 119–133. Berlin: Ex oriente.
BOGAARD, A., M. CHARLES, M. ERGUN, G. JONES, K. NG., M. POLCYN. & N. STONE. 2005. Macro Botanical Remains, in I. Hodder (ed.) *Çatalhöyük 2005 Archive Report. Online at http://www.catalhoyuk.com.*
BOGAARD, A., M. CHARLES, D. FILIPOVIĆ, G. JONES. & N. STONE. 2004. Macro Botanical Remains, in I. Hodder (ed.) *Çatalhöyük 2004 Archive Report. Online at http://www.catalhoyuk.com.*
BOGAARD, A., M. CHARLES, A. LIVARDA, M. ERGUN, D. FILIPOVIĆ & G. JONES. 2013a. The Archaeobotany of Mid-later Occupation Levels at Neolithic Çatalhöyük, in I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*. London and Los Angeles: British Institute at Ankara.
BOGAARD, A., M. CHARLES, K. TWISS, A. FAIRBAIRN, N. YALMAN, D. FILIPOVIĆ, G.A. DEMIRERGI, F. ERTUĞ, N. RUSSELL & J. HENECKE. 2009. Private pantries and celebrated surplus: storing and sharing food at Neolithic Çatalhöyük, Central Anatolia. *Antiquity* 83: 649–68.
BOGAARD, A., M. CHARLES & K.C. TWISS. 2010. Food storage and sharing at Çatalhöyük: the botanical and faunal evidence, in M. Benz (ed.) *The Principle of Sharing. Segregation and Construction of Social Identities at the Transition from Foraging to Farming. Studies in Early Near Eastern Production, Subsistence, and Environment 14*: 313–30. Berlin: Ex oriente.
BOGAARD, A., D. FILIPOVIĆ, A. FAIRBAIRN, L. GREEN, E. STROUD, D. FULLER & M. CHARLES. 2017. Agricultural innovation and resilience in a long-lived early farming community: the 1,500-year sequence at Neolithic to early Chalcolithic Çatalhöyük, central Anatolia. *Anatolian Studies* 67: 1–28.
BOGAARD, A., R. FRASER, T.H.E. HEATON, M.P. WALLACE, P. VAIGLOVA, M. CHARLES, G. JONES, R.P. EVERSHED, A.K. STYRING, N.H. ANDERSEN, R.-M. ARBOGAST, L. BARTOSIEWICZ, A. GARDEISEN, M. KANSTRUP, U. MAIER, E. MARINOVA, L. NINOV, M. SCHÄFER & E. STEPHAN. 2013b. Crop manuring and intensive land management by Europe's first farmers. *Proceedings of the National Academy of Sciences of the United States of America* 110: 12589–94.
BOGAARD, A., T.H.E. HEATON, P. POULTON & I. MERBACH. 2007. The impact of manuring on nitrogen isotope ratios in cereals: archaeological implications for reconstruction of diet and crop management practices. *Journal of Archaeological Science* 34: 335–43.
BOGAARD, A., J. HODGSON, E. NITSCH, G. JONES, A.K. STYRING, C. DIFFEY, J. POUNCETT, C. HERBIG, M. CHARLES, F. ERTUĞ, O. TUGAY, D. FILIPOVIĆ & R. FRASER. 2016a. Combining functional weed ecology and crop stable isotope ratios to identify cultivation intensity: a comparison of cereal production regimes in Haute Provence, France and Asturias, Spain. *Vegetation History and Archaeobotany 25: 57–73*.
BOGAARD, A. & V. ISAAKIDOU. 2010. From Mega-Sites to Farmsteads: Community Size, Ideology and the Nature of Early Farming Landscapes in Western Asia and Europe, in D. Bolger & L.C. Maguire (eds.) *The Development of Pre-state Communities in the Ancient Near East: Studies in Honour of Edgar Peltenburg. Vol. 2*: 192–207. Oxford: Oxbow Books.
BOGAARD, A., G. JONES & M. CHARLES. 2005. The impact of crop processing on the reconstruction of crop sowing time and cultivation intensity from archaeobotanical weed evidence. *Vegetation History and Archaeobotany* 14: 505–

9.
BOGAARD, A., G. JONES, M. CHARLES & J.G. HODGSON. 2001. On the Archaeobotanical Inference of Crop Sowing Time using the FIBS Method. *Journal of Archaeological Science* 28: 1171–83.
BOGAARD, A., C. PALMER, G. JONES, M. CHARLES & J.G. HODGSON. 1999. A FIBS Approach to the Use of Weed Ecology for the Archaeobotanical Recognition of Crop Rotation Regimes. *Journal of Archaeological Science* 26: 1211–24.
BOGAARD, A., P. RYAN, N. YALMAN, E. ASOUTI, K.C. TWISS, C. MAZZUCATO & S. FARID. 2014. Assessing Outdoor Activities and Their Social Implications at Çatalhöyük, in I. Hodder (ed.) *Integrating Catalhoyuk: Vol. 10: Themes from the 2000-2008 Seasons*: 123–47. Los Angeles: Cotsen Institute of Archaeology Press.
BOGAARD, A., A.K. STYRING, M. ATER, Y. HMIMSA, L. GREEN, E. STROUD, J. WHITLAM, C. DIFFEY, E. NITSCH, M. CHARLES, G. JONES & J. HODGSON. 2016b. From Traditional Farming in Morocco to Early Urban Agroecology in Northern Mesopotamia: Combining Present-day Arable Weed Surveys and Crop Isotope Analysis to Reconstruct Past Agrosystems in (Semi-)arid Regions. *Environmental Archaeology.* doi:10.1080/14614103.2016.1261217.
BOJNANSKÝ, V. & A. FARGAŠOVÁ. 2007. *Atlas of Seeds and Fruits of Central and East-European Flora*. Dordrecht: Springer.
BOLLONGINO, R. & J.-D. VIGNE. 2008. Temperature monitoring in archaeological animal bone samples in the Near East arid area, before, during and after excavation. *Journal of Archaeological Science* 35: 873–81.
BOSERUP, E. 1965. *The Conditions of Agricultural Growth*. New York: Aldine.
BOWDERY, D., D.M. HART, C. LENTFER & L.A. WALLIS. 2001. A universal phytolith key, in J.D. Meunier & F. Colin (eds.) *Phytoliths: Applications in earth sciences and human history*: 267–78. Lisse: AA Balkema.
BROWN, D.A. 1984. Prospects and limits of a phytolith key for grasses in the central United States. *Journal of Archaeological Science* 11: 345–68.
BYRD, B.F. 2005a. *Early Village Life at Beidha, Jordan. Neolithic spatial organization and vernacular architecture: the excavations of Mrs. Diana Kirkbride-Helbaek.* Oxford: Oxford University Press.
— 2005b. Reassessing the Emergence of Village Life in the Near East. *Journal of Archaeological Research* 13: 231–90.
CAPPERS, R.T.J. 2007. *Fields of change: progress in African archaeobotany*. Vol. 5. Groningen: Barkhuis.
CAPPERS, R.T.J. & R.M. BEKKER. 2013. *A manual for the identification of plant seeds and fruits*. Vol. 23. Groningen: Barkhuis.
CAPPERS, R.T.J., R.M. BEKKER & J.E.A. JANS. 2012. *Digitale Zadenatlas van Nederland/Digital seed atlas of the Netherlands*. Vol. 4. Groningen: Barkhuis.
CAPPERS, R.T.J. & R. NEEF. 2012. *Handbook of Plant Palaeoecology*. Groningen: Barkhuis.
CAPPERS, R.T.J., R. NEEF & R.M. BEKKER. 2009. *Digital Atlas of Economic Plants: Acanthaceae-Hypoxidaceae. Vol. 2A*. Groningen: Barkhuis.
CASTILLO, C. & D.Q. FULLER. 2010. Still too fragmentary and dependent upon chance? Advances in the study of early Southeast Asian archaeobotany, in B. Bellina, E. Bacus, O. Pryce, & J. Weissman Christie (eds.) *Fifty years of archaeology in Southeast Asia: Essays in honour of Ian Glover*: 91–111. London: River Books.
CAUVIN, J. 2000. *The Birth of the Gods and the Origins of Agriculture*. Cambridge University Press.
CESSFORD, C. 2007. Building 5, in I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area Reports from the 1995-99 seasons*: 361–403. Cambridge: McDonald Institute for Archaeological Research/London: British Institute of Archaeology at Ankara.
CHARLES, M. 1998. Fodder From Dung: the Recognition and Interpretation of Dung-Derived Plant Material from Archaeological Sites. *Environmental Archaeology* 1: 111–22.
— 2011. Interpretation of *Scirpus* from early farming sites in western Asia and Europe: a cutting sedge of archaeobotanical research?, in A. Hadjikoumis, E. Robinson, & S. Viner (eds.) *The Dynamics of Neolithisation in Europe: Studies in*

honour of Andrew Sherratt: 113–30. Oxford: Oxbow Books.
CHARLES, M. & A. BOGAARD. 2001. Third-millennium BC Charred Plant Remains from Tell Brak. Vol. 2: Nagar in the third millennuium BC, in D. Oates, J. Oates, & H. McDonald (eds.) *Excavations at Tell Brak*: 301–26. London: British School of Archaeology in Iraq.
— 2007. Charred Plant Macro-Remains from Jeitun: Implications for Early Cultivation and Herding Practices in Western Central Asia, in D.R. Harris (ed.) *Origins of Agriculture in Western Central Asia*: 150–65. Philadelphia: University of Pennsylvania Press.
CHARLES, M., A. BOGAARD, G. JONES, J. HODGSON & P. HALSTEAD. 2002. Towards the archaeobotanical identification of intensive cereal cultivation: present-day ecological investigation in the mountains of Asturias, northwest Spain. *Vegetation History and Archaeobotany* 11: 133–42.
CHARLES, M., C. DOHERTY., E. ASOUTI., A. BOGAARD, E. HENTON., C.S. LARSEN., C.B. RUFF., P. RYAN., J.W. SADVARI. & K.C. TWISS. 2014. Landscape and Taskscape at Çatalhöyük : An Integrated Perspective, in I. Hodder (ed.) *Integrating Catalhoyuk: Vol. 10: Themes from the 2000-2008 Seasons*: 71–90. Los Angeles: Cotsen Institute of Archaeology Press.
CHARLES, M., D. FILIPOVIĆ & A. BOGAARD. 2010. Identification Criteria for Barley Rachis : Distinguishing Two- From Six-Row and Naked From Hulled Barley *Poster session presented at 15th Conference of the International Work Group for Palaeoethnobotany in Wilhelmshaven, Germany, 31 May - 5 June, 2010.* http://www.archaeobotany.org/posters.php.
CHARLES, M., E. FORSTER, M.P. WALLACE & G. JONES. 2015. 'Nor ever lightning char thy grain': establishing archaeologically relevant charring conditions and their effect on glume wheat grain morphology. *STAR: Science & Technology of Archaeological Research* 1: 1–6.
CHARLES, M. & P. HALSTEAD. 2001. Biological resource exploitation: problems of theory and method, in D.R. Brothwell & A. M. Pollard (eds.), *Handbook of archaeological sciences*: 365–78. Chicester: J Wiley.
CHARLES, M., C. HOPPÉ, G. JONES, A. BOGAARD & J.G. HODGSON. 2003. Using weed functional attributes for the identification of irrigation regimes in Jordan. *Journal of Archaeological Science* 30: 1429–41.
CHARLES, M., G. JONES & J.G. HODGSON. 1997. FIBS in Archaeobotany: Functional Interpretation of Weed Floras in Relation to Husbandry Practices. *Journal of Archaeological Science* 24: 1151–61.
CHEVALIER, A., E. MARINOVA & L. PEÑA-CHOCARRO. 2014. *Plants and People: Choices and Diversity Through Time*. Oxford: Oxbow Books.
CHILDE, V.G. 1957. *The Dawn of European Civilization*. London: Routledge.
CHRISTIDOU, R., E. COQUEUGNIOT & L. GOURICHON 2009. Neolithic Figurines Manufactured from Phalanges of Equids from Dja'de el Mughara, Syria. *Journal of Field Archaeology* 34: 319–35.
CLARK, J.G.D. 1952. *Prehistoric Europe: the economic basis*. Stanford: Stanford University Press.
CLEMENTS, D.R., A. DITOMMASO, N. JORDAN, B.D. BOOTH, J. CARDINA, D. DOOHAN, C.L. MOHLER, S.D. MURPHY & C.J. SWANTON. 2004. Adaptability of plants invading North American cropland. *Agriculture, Ecosystems and Environment* 104: 379–98.
COLLEDGE, S. 1998. Identifying Pre-domestication Cultivation Using Multivariate Analysis, in A.B. Damania, J. Valkoun, G. Willcox, & C.O. Qualset (eds.) *The Origins of Agriculture and Crop Domestication*: 121–31. Aleppo: ICARDA.
— 2001. *Plant exploitation on Epipalaeolithic and early Neolithic sites in the Levant*. Oxford: British Archaeological Reports, International Series 986.
COLLEDGE, S. & J. CONOLLY. 2010. Reassessing the evidence for the cultivation of wild crops during the Younger Dryas at Tell Abu Hureyra, Syria. *Environmental Archaeology* 15: 124–38.
CONTENSON, H. De. 1973. Chronologie absolue de Tell Aswad (Damascène, Syrie). *Bulletin de la Société préhistorique française* 70: 253–56.
— 1995. *Aswad et Ghoraifé: Sites Néolithiques en Damascène (Syrie) aux 1995*. Beirut:

Institut Français d'Archéologie du Proche-Orient.
CONTENSON, H. De., M. CAUVIN, W.V.A.N. ZEIST, A.H. JOHANNA & A. LEROI-GOURHAN. 1979. Tell Aswad (Damascene). *Paléorient* 5: 153–76.
COQUEUGNIOT, E. 1998. Dja'de el Mughara (moyen-euphrate), un village néolithique dans son environnement naturel à la veille de la domestication, in M. Fortin & O. Aurenche (eds.) *Espace naturel, espace habité en Syrie du Nord (10e-2e millénaires av. J.C.):* 109–114. Lyon: Maison de l'Orient méditerranéen.
— 2006. *Dja'de el Mughara (Syrie) Campagne de fouilles 2006: 26 aout – 6 Octobre.* Unpublished report.
— 2014. Dja'de (Syrie) et les representations symboliques au IXe millenaire cal. BC, in C. Manen, T. Perrin & J. Guilaine (eds.) *La transition néolithique en Méditerranée. The Neolithic transition in the Mediterranean*: 91-108. Arles et Toulouse: Errance/Archives d'Écologie Préhistorique.
DAVIS, P.H. 1965. *Flora of Turkey 1-10*. Edinburgh: Edinburgh University Press.
— 1968. Review: Flora Palaestina. by M. Zohary and N. Feinbrun-Dothan; Flora Palaestina. Vol. I. by Michael Zohary; Nouvelle Flore du Liban et de la Syrie. by Paul Mouterde. *The New Phytologist* 67: 447–49.
— 1986. *Flora of Turkey and the East Aegan Islands: Vol.9*. Edinburgh: Edinburgh University Press.
DEWET, J.M.J. 1968. The Origin of Weediness in Plants. *Proceedings of the Oklahoma Academy of Sciences 47*, 14–17.
DEMIR, T., R. WESTAWAY, D.R. BRIDGLAND & A. SEYREK. 2007. Terrace staircases of the River Euphrates in southeast Turkey, northern Syria and western Iraq: evidence for regional surface uplift. *Quaternary Science Reviews* 26: 2844–63.
DEMIRERGI, G.A., K.C. TWISS, A. BOGAARD, L. GREEN, P. RYAN & S. FARID. 2014. Of Bins , Basins and Banquets : Storing , Handling and Sharing at Neolithic Çatalhöyük, in I. Hodder (ed.) *Integrating Catalhoyuk: Vol. 10: Themes from the 2000-2008 Seasons*: 91–108. Los Angeles: Cotsen Institute of Archaeology Press.
DER, L. & J. ISSAVI. 2017. The Urban Quandary and the 'Mega-Site' from the Çatalhöyük Perspective. *Journal of World Prehistory* 30: 189–206.
DEWET, J.M.J. & J.R. HARLAN. 1975. Weeds and Domesticates : Evolution in the Man-Made Habitat. *Economic Botany* 29: 99–107.
DONNELLY, J.L., D.C. ADAMS & J. DEKKER. 1997. Weedy adaptation in Setaria spp.: VI. S. faberi seed hull shape as soil germination signal antenna. *arXiv preprint arXiv:1403.7064*.
DUISTERMAAT, K. & P.M.M.G. AKKERMANS. 1996. Of storage and nomads. The sealings from Late Neolithic, Sabi Abyad, Syria. *Paléorient* 22: 17–44.
EICHLER, H., J.A. JEANES & N.G. WALSH. 2007. Ranunculaceae, in A.J.G. Wilson (ed.) *Flora of Australia: Volume 2 Winteraceae to Platanaceae*. Canberra A.C.T.: Australian Biological Resources Study.
ELLENBERG, H. 1950. *Unkrautgemeinschaften als Zeiger für Klima und Boden*. Stuttgart: Eugen Ulmer-Verlag für Landwirtschaft, Gartenbau und Naturwissenschaften.
ELLENBERG, H., H.E. WEBER, R. DÜLL, V. WIRTH, W. WERNER & D. PAULISSEN. 1992. Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica 18: 1-248.
ERGUN, M. 2008. The archaeobotany of a burned house: Building 63, Istanbul Area, in I. Hodder (Ed.) *Çatalhöyük 2008 Archive Report. Online at http://www.catalhoyuk.com*.
ERTUĞ, F. 2000. An Ethnobotanical Study in Central Anatolia (Turkey). *Economic Botany* 54: 155–82.
FAHN, A., E. WERKER & P. BAAS. 1986. *Wood anatomy and identification of trees and shrubs from Israel and adjacent regions.* Jerusalem: Israel Academy of Sciences and Humanities.
FAIRBAIRN, A. 2014. Preliminary archaeobotanical investigations of Plant Production, consumption, and trade at bronze age KültePe-Kanesh, in L. Atici, G. Barjamovic, A. Fairbairn & F. Kulakoglu (eds.) *Current Research at Kultepe-Kanesh: An Interdisciplinary and Integrative Approach to Trade Networks, Internationalism, and Identity* 4: 177-193. Atlanta: Lockwood Press.
FAIRBAIRN, A., D. MARTINOLI, A. BUTLER & G.C. HILLMAN. 2007. Wild plant seed storage at

Neolithic Çatalhöyük East, Turkey. *Vegetation History and Archaeobotany* 16: 467–79.
FAIRBAIRN, A., J. NEAR & D. MARTINOLI. 2005. Macrobotanical investigations of the North, South and KOPAL areas at Çatalhöyük, I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995–99 seasons, Çatalhöyük Project Vol. 4*: 137–201. Cambridge: McDonald Institute Monographs.
FARID, S. 2007. Neolithic excavations in the south area, east mound, Çatalhöyük 1995–99, in I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area Reports from the 1995-99 seasons*: 41–342. Cambridge: McDonald Institute for Archaeological Research/London: British Institute of Archaeology at Ankara.
FARID, S. 2014a. Buildings 52/51, in I. Hodder (ed.) *Çatalhöyük Excavations: The 2000-2008 Seasons*: 359–98. London: British Institute of Archaeology at Ankara.
— 2014b. Timelines: Phasing Neolithic Çatalhöyük, in I. Hodder (ed.) *Çatalhöyük Excavations: The 2000-2008 Seasons*: 91–129. London: British Institute of Archaeology at Ankara.
FERRIO, J.P., J.L. ARAUS., R. BUXÓ., J. VOLTAS. & J. BORT. 2005. Water management practices and climate in ancient agriculture: Inferences from the stable isotope composition of archaeobotanical remains. *Vegetation History and Archaeobotany* 14: 510–17.
FILIPOVIĆ, D. 2012. An archaeobotanical investigation of plant use, crop husbandry and animal diet at early-mid Neolithic Çatalhöyük, Central Anatolia. Unpublished PhD thesis, University of Oxford, UK.
— 2014. *Early Farming in Central Anatolia: An archaeobotanical study of crop husbandry, animal diet and land use at Neolithic Çatalhöyük.* British Archaeological Reports International Series 2667. Oxford: Archaeopress.
FINLAYSON, B., S.J. MITHEN, M. NAJJAR, S. SMITH, D. MARIČEVIĆ, N. PANKHURST & L. YEOMANS. 2011. Architecture, sedentism, and social complexity at Pre-Pottery Neolithic A WF16, Southern Jordan. *Proceedings of the National Academy of Sciences of the United States of America* 108: 8183–88.
FIORENTINO, G., J.P. FERRIO, A. BOGAARD, J.L. ARAUS & S. RIEHL. 2014. Stable isotopes in archaeobotanical research. *Vegetation History and Archaeobotany 24*: 215–227.
FLANNERY, K. V. 1969. Origins and ecological effects of early domestication in Iran and the Near East, in P. Ucko & G. Dimbleby (eds.) *The Domestication and Exploitation of Plants and Animals*: 73-I00. London: Duckworth.
— 1972. The origins of the village as a settlement type in Mesopotamia and the Near East., in P. Ucko, R. Tringham & G. Dimbleby (eds.) *Man, Settlement and Urbanism.*: 23–53. New York: Academic Press.
FLANNERY, K. V. 2002. The Origins of the Village Revisited : From Nuclear to Extended Households. *American Antiquity* 67: 417–33.
FRASER, R.A., A. BOGAARD, T. HEATON, M. CHARLES, G. JONES, B.T. CHRISTENSEN, P. HALSTEAD, I. MERBACH, P.R. POULTON, D. SPARKES & A.K. STYRING. 2011. Manuring and stable nitrogen isotope ratios in cereals and pulses: towards a new archaeobotanical approach to the inference of land use and dietary practices. *Journal of Archaeological Science* 38: 2790–2804.
FRITZ, G. & M. NESBITT. 2014. Laboratory analysis and identification of plant macroremains, in *Method and Theory in Paleoethnobotany*: 115–46. Boulder: University of Colorado Press.
FRODIN, D. 2004. *Guide to Standard Floras of the World*. Second. Cambridge: Cambridge University Press.
FULLER, D.Q. 2002. *Fifty Years of Archaeobotanical Studies in India: Laying a Solid Foundation Indian Archaeology in Retrospect, Volume III. Archaeology and Interactive Disciplines*. New Delhi: Indian Council for Historical Research.
GARFINKEL, Y., O. MARDER, H. KHALAILY, I. MILEVSKI, A. RONEN, M. DAVIS, M. LAMDAN & N. GEZTOV. 2012. Field Observations, in Y. Garfinkel, D. Dag, I. Milevski & A. Ronen (eds.) *The Pre-Pottery Neolithic B Village of Yiftahel. The 1980s and 1990s Excavations*: 13–73. Berlin: Ex oriente.
GEYER, B. 1985. Géomorphologie et occupation du sol de la moyenne vallée de l'Euphrate dans la région de Mari. *MARI* 4: 27–39.
GEYER, B. & J. BESANÇON. 2002. Environmental and land-use evolution in the Syrian

Euphrates valley during the Neolithic and Chalcolithic periods, in M. Al-Maqdissi, M.A. Karim, A. Al-Azm, & M.D. Al-Khoury (eds.) *Deir ez-Zor, Syria. The Syrian Jezira, Cultural Heritage and Interrelations. Proceedings of the International conference held in Deir ez-Zor April 22nd-25th, 1996*: 61–68.
GHAZANFAR, S.A. & J.R. EDMONDSON. 2013. *Flora of Iraq, Volume 5 Part 2: Lythraceae to Campanulaceae*. London: Royal Botanic Gardens, Kew.
— 2016. *Flora of Iraq: Vol. 9, I. Elatinaceae to Sphenocleaceae*. Richmond: Royal Botanic Gardens, Kew.
GHAZANFAR, S.A. & T. MCDANIEL. 2016. Floras of the Middle East: a Quantitative Analysis and Biogeography of the Flora of Iraq. *Edinburgh Journal of Botany* 73: 1–24.
GORING-MORRIS, A.N. & A. BELFER-COHEN. 2008. A roof over one's head: Developments in Near Eastern residential architecture across the Epipalaeolithic–Neolithic transition, in J.P. Bocquet-Appel & O. Bar-Yosef (eds.) *The Neolithic demographic transition and its consequences*: 239–86. New York: Springer.
GORING-MORRIS, N., E. HOVERS & A. BELFER-COHEN. 2009. The Dynamics of Pleistocene and Early Holocene Settlement Patterns and Human Adaptations in the Levant: An Overview, in D.E. Lieberman & J.J. Shea (eds.) *Transitions in Prehistory: Essays in Honor of Ofer Bar-Yosef* : 185–252. Oxford: Oxbow Books.
GOURICHON, L. 2002. Bird remains from Jerf el Ahmar, a PPNA site in Northern Syria, with special reference to the griffon vulture (*Gyps fulvus*), in H. Buitenhuis, M. Mashkour, A.M. Choyke & A.H. Al-Shiyab (eds) *Archaeozoology of the Near East V:* 138-152. Groningen: ARC Publicatie 62.
— 2004. *Faune et saisonnalité: L'organisation temporelle des activités de subsistance dans l'Epipaléolithique et le Néolithique précéramique du Levant nord (Syrie)*. Unpublished PhD thesis, Université Lumière - Lyon II, France.
GRIME, J.P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *The American Naturalist* 111: 1169–94.
— 1979. *Plant strategies, vegetation processes, and ecosystem properties*. New York: John Wiley & Sons.
GROENMAN-VAN WAATERINGE, W. 1980. The origin of crop weed communities composed of summer annuals. *Vegetatio* 41: 57–59.
GUEST, E. & C.C. TOWNSEND. 1966. *Flora of Iraq*. Baghdad: Ministry of Agriculture of the Republic of Iraq.
GUSTAFSSON, S. 2000. Carbonized Cereal Grains and Weed Seeds in Prehistoric Houses—an Experimental Perspective. *Journal of Archaeological Science* 27: 65–70.
HAGEDORN, G., G. RAMBOLD & S. MARTELLOS. 2010. Types of identification keys, in P.L. Nimis & R. Vignes Lebbe (eds.) *Tools for Identifying Biodiversity: Progress and Problems*: 59–64. Trieste: Edizioni Universitàdi Trieste.
HAIDAR, A. 2004. Évolution de l'environnement au Levant nord de l'Épipaléolithique au présent à travers l'étude des microfaunes fossiles et actuelles. Unpublished PhD thesis, Paris 10, France.
HAJNALOVÁ, M. & D. DRESLEROVÁ. 2010. Ethnobotany of einkorn and emmer in Romania and Slovakia: towards interpretation of archaeological evidence. *Památky archeologické* 51: 169–202.
HALSTEAD, P. 1989. Like rising damp? An ecological approach to the spread of farming in south east and central Europe, in A. Milles, D. Williams, & N. Gardner (eds.) *The Beginnings of Agriculture*: 23–53. Oxford: British Archaeological Reports, International Series 496.
— 1990. Waste Not, Want Not: Traditional Responses to Crop Failure in Greece. *Rural History* 1: 147–64.
— 1995. Plough and power: the economic and social significance of cultivation with the ox-drawn ard in the Mediterranean. *Bulletin on Sumerian Agriculture* 8: 11–22.
— 2014. *Two Oxen Ahead: Pre-Mechanized Farming in the Mediterranean*. Chichester: John Wiley & Sons, Ltd.
HALSTEAD, P. & G. JONES. 1989. Agrarian Ecology in the Greek Islands: Time stress , scale

and risk. *The Journal of Hellenic Studies* 109: 41–55.
HANDLEY, L.L., A.T. AUSTIN, G.R. STEWART, D. ROBINSON, C.M. SCRIMGEOUR, J.A. RAVEN & S. SCHMIDT. 1999. The 15N natural abundance (δ15N) of ecosystem samples reflects measures of water availability. *Functional Plant Biology* 26. CSIRO: 185–99.
HARLAN, J.R. 1982. Relationships between weeds and crops, in W. Holzner & M. Numata (eds.) *Biology and ecology of weeds*: 91–96. Boston/ London: Dr W. Junk Publishers.
— 1992. *Crops and man.* Urbana: American Society of Agronomy.
HARLAN, J.R. & J.M.J. DEWET. 1965. Some Thoughts about Weeds. *Economic Botany* 30: 226–62.
HARPER, J.L., P.H. LOVELL & K.G. MOORE. 1970. The Shapes and Sizes of Seeds. *Annual Review of Ecology and Systematics* 1: 327–56.
HARRIS, D.R. 1969. Agricultural systems, ecosystems and the origins of agriculture, in G. W. Dimbleby (ed.) *The Domestication and Exploitation of Plants and Animals*: 3–15. London: Gerald Duckworth & Co.
HARRIS, D.R. 2002. Development of the agro-pastoral economy in the Fertile Crescent during the Pre-Pottery Neolithic period, in In R.T.J. Cappers and S. Bottema (eds.) *The Dawn of Farming in the Near East, Studies in Early Near Eastern Production, Subsistence, and Environment*: 67–84. Berlin: Ex oriente.
HARTMAN, G. & A. DANIN. 2010. Isotopic values of plants in relation to water availability in the Eastern Mediterranean region. *Oecologia* 162: 837–52.
HARTMANN-SHENKMAN, A., M.E. KISLEV, E. GALILI, Y. MELAMED & E. WEISS. 2014. Invading a new niche: obligatory weeds at Neolithic Atlit-Yam. *Vegetation History and Archaeobotany* 24: 9-18.
HASTORF, C. 2005. Macrobotanical investigation: field methods and laboratory analysis procedures, in I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995–99 seasons, Çatalhöyük Project Vol. 4*: 129–35. Cambridge: McDonald Institute Monographs.
HASTORF, C., K. KILLACKEY & M. AĞCABAY. 2000. Archaeobotany/ Arkeobotani, in I. Hodder (ed.) *Çatalhöyük 2000 Archive Report. Online at http://www.catalhoyuk.com*.
HASTORF, C. & J. NEAR. 1997. Archaeobotanical archive report, in I. Hodder (ed.) *Çatalhöyük 1997 Archive Report. Online at http://www.catalhoyuk.com.*
HATHER, J.G. 2000. *The identification of the northern European woods: A guide for archaeologists and conservators*. London: Archetype.
HAVINGA, R., A. KOOL, F. ACHILLE, J. BAVCON, C. BERG, C. BONOMI, M. BURKART, D. DE MEYERE, J. HART, M. HAVSTRÖM, P. KEßLER, B. KNICKMANN, N. KÖSTER, R. MARTINEZ, H. OSTGAARD, B. RAVNJAK, A.C. SCHEEN, P. SMITH, P. SMITH, S.A. SOCHER & V. VANGE. 2016. The Index Seminum: Seeds of change for seed exchange .*Taxon* 65: 333–36.
HAWKES, J.G. 1970. The Origins of Agriculture. *Economic Botany* 24: 131–33.
HAYDEN, B. 1990. Nimrods, piscators, pluckers, and planters: The emergence of food production. *Journal of Anthropological Archaeology* 9: 31–69.
— 1995. Pathways to power, in T.D. Price & G.M. Feinman (eds.) *Foundations of social inequality*: 15–86. Boston: Springer.
HEISS, A.G. 2009. Anatomy of European and North American woods—an interactive identification key. Version 2009–05–14. http://www.holzanatomie.at.
HELBAEK, H. 1964. First Impressions of the Çatal Hüyük Plant Husbandry. *Anatolian Studies* 14: 121–23.
HELMER, D. & L. GOURICHON. 2008. Premières données sur les modalités de subsistance à Tell Aswad (Syrie, PPNB moyen et récent, Néolithique céramique ancien) - Fouilles 2001-2005, in E. Vila (ed.) *Archaeozoology of the near East VIII : proceedings of the eighth International symposium on the archaeozoology of Southwestern Asia and adjacent areas : Aswa VIII, Lyon, June 28-July 1, 2006*, 119–51. Lyon: Maison de l'Orient méditerranéen.
— 2017. The fauna of Tell Aswad (Damascus, Syria), early Neolithic levels. Comparison with northern and southern Levant sites, in M. Mashkour & M. Beech (eds.) *Archaeozoology of the Near East*: 23–40. Oxford: Oxbow Books.
HELMER, D., L. GOURICHON, H. MONCHOT, J. PETERS & M.S. SEGUI. 2005. Identifying early

domestic cattle from Pre-Pottery Neolithic sites on the Middle Euphrates using sexual dimorphism, in J.-D. Vigne, J. Peters, & D. Helmer (eds.) *The First Steps of Animal Domestication*: 86–95. Oxford: Oxbow Books.
HELMER, D., V. ROITEL, M.S. SEGUI & G. WILLCOX. 1998. Interprétations environnementales des données archéozoologiques et archéobotaniques en Syrie du Nord de 16000 BP à 7000 BP, et les débuts de la domestication des plantes et des animaux, in *Espace naturel, Espace habité en Syrie du Nord (10e-2e millénaires av. J.-C.)*: 9–33. Lyon: Maison de l'Orient Méditerranéen.
HILL, T.A. 1977. *The Biology of Weeds: Studies in Biology no. 79.* London: Edward Arnold Ltd.
HILLMAN, G.C. 1991. Phytosociology and ancient weed floras: taking account of taphonomy and changes in cultivation methods., in D.R. Harris & K.D. Thomas (eds.) *Modelling Ecological Change*: 27–40. London: Institute of Archaeology, University College London.
— 2000. The plant food economy of Abu Hureyra 1 and 2. Abu Hureyra 1: The Epipalaeolithic, in *Village on the Euphrates: From Foraging to Farming at Abu Hureyra*: 327–398. Oxford: Oxbow Books.
HILLMAN, G.C. & M.S. DAVIES. 1999. Domestication rate in wild wheats and barley under primitive cultivation: preliminary results and archaeological implications of field measurements of selection coefficient, in P.C. Anderson (ed.) *Prehistory of Agriculture: New Experimental and Ethnographic Approaches*: 70–102. California: Cotsen Institute of Archaeology Press.
HILLMAN, G.C., R. HEDGES, A. MOORE, S. COLLEDGE & P. PETTITT. 2001. New evidence of Lateglacial cereal cultivation at Abu Hureyra on the Euphrates. *The Holocene* 11: 383–93.
HILLMAN, G.C., A.J. LEGGE & P.A. ROWLEY-CONWY. 1997. On the Charred Seeds from Epipalaeolithic Abu Hureyra: Food or Fuel? *Current Anthropology* 38: 651–59.
HILLSON, S., C.S. LARSEN, B. BOZ, M.A. PILLOUD, J.W. SADVARI, S.C. AGARWAL, B. GLENCROSS, P. BEAUCHESNE, J.A. PEARSON, C.B. RUFF, E.M. GAROFALO, L.D. HAGER & S.D. HADDOW. 2013. The Human Remains I: Interpreting Community Structure, Health and Diet in Neolithic Çatalhöyük, in I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*, Çatalhöyük: 339–96. London and Los Angeles: British Institute at Ankara.
HODDER, I. 2006. *The leopard's tale: revealing the mysteries of Çatalhöyük*. New York: Thames & Hudson.
— 2010. Çatalhöyük 2010 archive report *Online at http://www.catalhoyuk.com.*
— 2013. Dwelling at Çatalhöyük, in I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*: 1–29. London and Los Angeles: British Institute at Ankara.
— 2014a. *Çatalhöyük Excavations: The 2000-2008 Seasons*. London: British Institute of Archaeology at Ankara.
— 2014b. Çatalhöyük: The leopard changes its spots. A summary of recent work. *Anatolian Studies* 64: 1–22.
— 2014c. Mosaics and networks: the social geography of Çatalhöyük, in I. Hodder (ed.) *Integrating Çatalhöyük: themes from the 2000-2008 seasons*: 149–168. Los Angeles: Cotsen Institute of Archaeology Press.
— 2016. More on history houses at Çatalhöyük: A response to Carleton *et al. Journal of Archaeological Science* 67: 1–6.
HODDER, I. & C. CESSFORD. 2004. Daily Practice and Social Memory at Çatalhöyük. *American Antiquity* 69: 17–40.
HODDER, I., C. CESSFORD & S. FARID. 2007. Introduction to Methods and Approach, in I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area Reports from the 1995-99 seasons*: 3–24. Cambridge: McDonald Institute for Archaeological Research/London: British Institute of Archaeology at Ankara.
HODDER, I. & S. FARID. 2014. Questions, History of Work and Summary of Results, in I. Hodder (ed.) *Çatalhöyük Excavations: The 2000-2008 Seasons*: 1–34. London: British Institute of Archaeology at Ankara.
HODDER, I. & P. PELS. 2010. History houses: A new interpretation of architectural

elaboration at Çatalhöyük, in I. Hodder (ed.) *Religion in the emergence of civilization; Çatalhöyük as a case study*: 163–86. Cambridge: Cambridge University Press.
HODGSON, J.G. 1991. The use of ecological theory and autoecological datasets in studies of endangered plant and animal species and communities. *Pirineos* 138: 3–28.
HODGSON, J.G. & J.P. GRIME. 1990. The role of dispersal mechanism, regenerative strategies and seedbanks in the vegetation dynamics of the British landscape, in R.G.H. Bunce & D.C. Howard (eds.) *Species Dispersal in Agricultural Habitats*: 65–81. London: Belhaven.
HODGSON, J.G., P.J. WILSON, R. HUNT, J.P. GRIME, K. THOMPSON, J.G. HODGSON, P.J. WILSON, R. HUNT, J.P. GRIME & K. THOMPSON. 1999. Allocating C-S-R Plant Functional Types : A Soft Approach to a Hard Problem. *Oikos* 85: 282–94.
HODSON, M.J. & J.A. BRYANT. 2012. *Functional Biology of Plants*. Oxford: Wiley-Blackwell.
HOLZNER, W. 1978. Weed Species and Weed Communities. *Vegetatio* 38: 13–20.
— 1982. Concepts, categories and characteristics of weeds, in W. Holzner & M. Numata (eds.) *Biology and ecology of weeds*. Boston/ London: Dr W. Junk Publishers.
HOUSE, M. 2014. Building 77, in I. Hodder (ed.) *Çatalhöyük Excavations: The 2000-2008 Seasons*: 485–503. London: British Institute of Archaeology at Ankara.
HUBBARD, R.N.L.B. 1992. Dichotomous keys for the identification of the major Old World crops. *Review of Palaeobotany and Palynology* 73: 105–15.
HÜTTEROTH, W.-D. & V. HÖHFELD. 2002. *Türkei*. Darmstadt: Wissenschaftliche Buchgesellschaft.
IBM CORP. 2016. IBM SPSS Statistics for Macintosh, Version 24.0. Armonk, NY: IBM Corp.
INDA, L.A., I. SANMARTÍN, S. BUERKI & P. CATALÁN. 2014. Mediterranean origin and Miocene-Holocene Old World diversification of meadow fescues and ryegrasses (*Festuca* subgenus *Schedonorus* and *Lolium*). *Journal of Biogeography* 41: 600–614.
INGOLD, T. 1983. The Significance of Storage in Hunting Societies. *Man* 18: 553–71.
ISAAKIDOU, V. 2011. Farming regimes in Neolithic Europe: gardening with cows and other models, in J. Zilhão, A. Hadjikoumis, E. Robinson & S. Viner (eds.) *The dynamics of neolithisation in Europe: studies in honour of Andrew Sherratt*, 90–112. Oxford: Oxbow Books.
JACOMET, S. 2006. Identification of cereal remains from archaeological sites *Unpublished manuscript*.
JACOMET, S., C. BROMBACHER & M. DICK. 1989. *Archäobotanik am Zürichsee: Ackerbau, Sammelwirtschaft und Umwelt von neolithischen und bronzezeitlichen Seeufersiedlungen im Raum Zürich: Ergebnisse von Untersuchungen pflanzlicher Makroreste der Jahre 1979-1988*. Zürich: Orell Füssli.
JASIENIUK, M., A.L. BRÛLÉ-BABEL & I.N. MORRISON. 1996. The Evolution and Genetics of Herbicide Resistance in Weeds. *Weed Science* 44: 176–93.
JENSEN, H.A. 1998. *Bibliography on seed morphology*. Rotterdam: A.A. Balkema.
JONES, G. 1984. Interpretation of archaeological plant remains: Ethnographic models from Greece, in T. van Zeist & W. Casparie (eds.) *Plants and Ancient Man: Studies in palaeoethnobotany*: 43–61. Rotterdam: A.A.Balkema.
— 1987. A Statistical Approach to the Archaeological Identification of Crop Processing. *Journal of Archaeological Science* 14: 311–23.
— 1990. The application of present-day cereal processing studies to charred archaeobotanical remains. *Circaea* 6: 91–96.
— 1991. Numerical analysis in archaeobotany, in W. van Zeist, K. Wasylikowa, & K.E. Behre (eds.) *Progress in Old World Palaeoethnobotany*: 63–80. Rotterdam: A.A. Balkema.
— 1992. Weed phytosociology and crop husbandry: identifying a contrast between ancient and modern practice. *Review of Palaeobotany and Palynology* 73: 133–43.
— 2002. Weed ecology as a method for the archaeobotanical recognition of crop husbandry practices. *Acta Palaeobotanica* 42: 185–93.
— 2005. Garden cultivation of staple crops and its implications for settlement location and continuity. *World Archaeology* 37: 164–76.

JONES, G., A. BOGAARD, M. CHARLES & J.G. HODGSON. 2000. Distinguishing the Effects of Agricultural Practices Relating to Fertility and Disturbance: a Functional Ecological Approach in Archaeobotany. *Journal of Archaeological Science* 27: 1073–84.
JONES, G., A. BOGAARD, P. HALSTEAD, M. CHARLES & H. SMITH. 1999. Identifying the Intensity of Crop Husbandry Practices on the Basis of Weed Floras. *British School at Athens* 94: 167–89.
JONES, G., M. CHARLES, A. BOGAARD & J. HODGSON. 2010. Crops and weeds: the role of weed functional ecology in the identification of crop husbandry methods. *Journal of Archaeological Science* 37: 70–77.
JONES, G., S. VALAMOTI & M. CHARLES. 2000. Early crop diversity: A 'new' glume wheat from northern Greece. *Vegetation History and Archaeobotany* 9: 133–46.
JONES, M.K. 1991. Sampling in palaeoethnobotany, in W. van Zeist, K. Wasylikowa, & K.-E. Behre (eds.) *Progress in Old World Palaeoethnobotany*: 53–62. Rotterdam: A.A. Balkema.
JSTOR GLOBAL PLANTS. 2017. JSTOR Global Plants. *https://plants.jstor.org (accessed on 22 Aug 2017)*.
KAPLAN, L., M.B. SMITH & L.A. SNEDDON. 1992. Cereal grain phytoliths of Southwest Asia and Europe, in G. Rapp G. & S.C. Mulholland (eds) *Phytolith systematics*: an introduction: 149–74. Boston: Springer.
KAPP, R.O. 1969. *How to Know Pollen and Spores*. Dubuque, Iowa: Brown Company Publishers.
KAPP, R.O., J.E. KING & O.K. DAVIS. 2000. *Ronald O. Kapp's pollen and spores*. College Station, TX: American Association of Stratigraphic Palynologists Foundation Publication.
KARAGÖZ, A. 1996. Agronomic practices and socioeconomic aspects of emmer and einkorn cultivation in Turkey, in S. Padulosi, K. Hammer & J. Heller (eds.) *Hulled wheats: promoting the conservation and use of underutilized and neglected crops 4.*: 172–77. Rome: International Plant Genetic Resources Institute.
KEATINGE, J.D.H., M.D. DENNETT & J. RODGERS. 1985. The influence of precipitation regime on the management of three-course crop rotations in northern Syria. *Journal of Agricultural Science* 104: 281–87.
KENYON, K. 1981. *Excavations at Jericho. Vol. III: The Architecture and Stratigraphy of the Tell*. London: British School of Archaeology in Jerusalem.
KISLEV, M., Y. MELAMED, O. SIMCHONI & M. MARMORSTEIN. 1997. Computerized Key Of Grass Grains Of The Mediterranean Basin. *Lagascalia* 1–2: 289–94.
— 1999. Computerized keys for archaeological grains: first steps, in S. Pike & S. Gitin (eds.) *The Practical Impact of Science on Near Eastern and Aegean Archaeology*: 29–31. Athens: Archetype.
KISLEV, M., O. SIMCHONI, Y. MELAMED & M. MARMORSTEIN. 1995. Computerized keys for grass grains of Israel and its adjacent regions, in H. Kroll & K. Pasternak (eds.) *Res Arcaeobotanicae*: 69–79. Kiel: H. Kroll.
KISLEV, M.L., Y. GARFINKEL & D. ZOHARY. 2012. The Seeds, in Y. Garfinkel, D. Dag, I. Milevski, & A. Ronen (eds.) *The Pre-Pottery Neolithic B Village of Yiftahel. The 1980s and 1990s Excavations*: 283–86. Berlin: Ex oriente.
KOHLER, T.A., M.E. SMITH, A. BOGAARD, G.M. FEINMAN, C.E. PETERSON, A. BETZENHAUSER, M. PAILES, E.C. STONE, A. MARIE PRENTISS, T.J. DENNEHY, L.J. ELLYSON, L.M. NICHOLAS, R.K. FAULSEIT, A.K. STYRING, J. WHITLAM, M. FOCHESATO, T.A. FOOR & S. BOWLES. 2017. Greater post-Neolithic wealth disparities in Eurasia than in North America and Mesoamerica. *Nature* 551: 619–22.
KÖRBER-GROHNE, U. 1964. Bestimmungsschlüssel für subfossile Juncus-samen und Gramineen-früchte, in W. Haarnagel (ed.) *Probleme der Küstenforschung im südlichen Nordseegebiet* 7: 1-47. Hildesheim: Lax.
— 1991. Bestimmungsschlüssel für subfossile Juncus-samen und Gramineen-früchte (Identification key for subfossil Gramineae fruits), in W. Haarnagel (ed.) *Probleme der Küstenforschung im südlichen Nordseegebiet* 18: 169–234. Hildesheim: Lax.
KUIJT, I. 2008. Demography and Storage Systems During the Southern Levantine Neolithic Demographic Transition, n J.P. Bocquet-Appel & O. Bar-Yosef (eds.) *The*

Neolithic demographic transition and its consequences: 287–313. New York: Springer.
KUIJT, I. & B. FINLAYSON. 2009. Evidence for food storage and predomestication granaries 11,000 years ago in the Jordan Valley. *Proceedings of the National Academy of Sciences of the United States of America* 106: 10966–70.
KUIJT, I. & N. GORING-MORRIS. 2002. Foraging , Farming , and Social Complexity in the Pre-Pottery Neolithic of the Southern Levant: A Review and Synthesis. *Journal of World Prehistory* 16: 361–440.
LADIZINSKY, G. 1998. *Plant Evolution under Domestication*. Stoodleigh: Springer Science.
LANGE, E. 1979. Verkohlte Pflanzenreste aus den slawischen Siedlungsplätzen Brandenburg und Zirzow (Kr. Neubrandenburg), in U. Körber-Grohne (ed.) *Festschrift Maria Hopf* 65: 191–207. Rheinland-Verlag: Habelt in Komm.
LAWRENCE, A. & W. HAWTHORNE. 2013. *Plant identification: creating user-friendly field guides for biodiversity management*. London: Earthscan.
LUZURIAGA, A.L., A. ESCUDERO & F. PÉREZ-GARCÍA. 2006. Environmental maternal effects on seed morphology and germination in Sinapis arvensis (Cruciferae). *Weed Research* 46: 163–74.
MADELLA, M., C. LANCELOTTI & M. SAVARD. 2014. *Ancient Plants and People: Contemporary Trends in Archaeobotany*. Tuscon: University of Arizona Press.
MAIER, U., R. VOGT & M. AHRENS. 2001. *Siedlungsarchäologie im Alpenvorland VI: Botanische und pedologische Untersuchungen zur Ufersiedlung Hornstaad-Hörnle IA*. Stuttgart: Theiss.
MARCINIAK, A. 2015. A new perspective on the Anatolian Late Neolithic: The TPC Area excavations ad Çatalhöyük East, in S. R. Steadman & G. McMahon (eds.) *The Archaeology of Anatolia: Recent Discoveries (2011-2014) Volume I*: 6–25. Cambridge: Cambridge Scholars Publishing.
MARCINIAK, A., E. ASOUTI, C. DOHERTY & E. HENTON. 2015. The nature of household in the upper levels at Çatalhöyük: smaller, more dispersed, and more independent acquisition, production and consumption unit, in I. Hodder & A. Marciniak (eds.) *Assembling Çatalhöyük: Vol. 1*: 151–65. Leeds: Maney Publishing.
MARCINIAK, A. & L. CZERNIAK. 2007. Social transformations in the Late Neolithic and the Early Chalcolithic periods in central Anatolia. *Anatolian Studies* 57: 115–30.
MARTIN, A.C. 1946. The Comparative Internal Morphology of Seeds. *American Midland Naturalist* 36: 513–660.
MCCLELLAN, T.L. & M. MOTTRAM. 1994. Jerf el Ahmar 1993. Final report. *Annales Archéologiques Arabes Syriennes* 38: 1–12.
MELLAART, J. 1963. Excavations at Çatal Hüyük, 1962: Second Preliminary Report. *Anatolian Studies* 13: 43–103.
— 1967. *Çatal Hüyük: a Neolithic town in Anatolia*. London: Thames and Hudson.
MESSAGER, E., A. BADOU, F. FRÖHLICH, B. DENIAUX, D. LORDKIPANIDZE & P. VOINCHET. 2010. Fruit and seed biomineralization and its effect on preservation. *Archaeological and Anthropological Sciences* 2: 25–34.
MILLER, N.F. 1996. Seed Eaters of the Ancient Near East : Human or Herbivore? *Current Anthropology* 37: 521–28.
— 1997. The Macrobotanical evidence for vegetation in the Near East, c. 18000/16000 B.C to 4000 B.C. *Paléorient* 23: 197–207.
— 2001. Down the Garden Path: How Plant and Animal Husbandry Came Together in the Ancient Near East. *Near Eastern Archaeology* 64: 4–7.
— 2010. Archaeobotany Questionnaire Preliminary Result. *UPM Ethnobotanical Laboratory Report* 49: 1–30.
— 2011. Archaeobotanical methodology: results of an archaeobotany questionnaire. *SAA Archaeological Record* 11: 8–10.
MILLER, N.F. & T.L. SMART. 1984. Intentional Burning of Dung as Fuel: A Mechanism for the Incorporation of Charred Seeds into the Archaeological Record. *Journal of Ethnobiology* 4: 15–28.
MINNIS, P.E. 1987. Identification of wood from archaeological sites in the American Southwest. I. Keys for gymnosperms. *Journal of Archaeological Science* 14: 121–31.

MOHLER, C.L. 2001. Weed evolution and community structure, in M. Liebman, C.L. Mohler, & C.P. Staver (eds.) *Ecological management of agricultural weeds*: 444–93. Cambridge: Cambridge University Press.
MOORE, P.D., J.A. WEBB & M.E. COLLISON. 1991. *Pollen analysis.* Oxford: Blackwell scientific publications.
MOUTERDE, P. 1966. *Nouvelle flore du Liban et de la Syrie*, Vol. 1. Beirut: Éditions de l'Imprimerie Catholique.
— 1986. *Nouvelle flore du Liban et de la Syrie,* Vol. 2. Beiruit: Dar El-Maqhreq Editeurs.
MULHOLLAND, S.C. & G. RAPP JR. 1992. Phytolith systematics: an introduction, in G. Rapp Jr. & S C. Mulholland (eds.) *Phytolith systematics*: 1–13. Boston: Springer.
NAKAMURA, K., K.F. CHUNG, C.J. HUANG, Y. KONO, G. KOKUBUGATA & C.I. PENG. 2012. Extreme habitats that emerged in the Pleistocene triggered divergence of weedy Youngia (Asteraceae) in Taiwan. *Molecular Phylogenetics and Evolution* 63: 486–99.
NEEF, R., R.T.J. CAPPERS, R.M. BEKKER & L. BOULOS. 2012. *Digital atlas of economic plants in archaeology*. Vol. 17. Groningen: Barkhuis.
NESBITT, M. 1991. Seed reference collections and archaeobotany. *Circaea 8*: 21-40.
— 2006. *Identification Guide for Near Eastern Grass Seeds*. London: Institute of Archaeology, University College London.
NESBITT, M., S. COLLEDGE & M.A. MURRAY. 2003. Organisation and Management of Seed Reference Collections. *Environmental Archaeology* 8: 77–84.
NESBITT, M. & J. GRIEG. 1990. A bibliography for the archaeobotanical identification of seeds from Europe and the Near East. *Circaea* 7: 11–30.
NITSCH, E.K., M. CHARLES & A. BOGAARD. 2015. Calculating a statistically robust δ13 C and δ15 N offset for charred cereal and pulse seeds. *Science and Technology of Archaeological Research* 1: 1–14.
NOY-MEIR, I. 1973. Desert Ecosystems: environment and producers. *Annual Review of Ecology and Systematics* 4: 25–51.
NOY, T. 1989. Gilgal I : A Pre-Pottery Neolithic site, Israel. The 1985-1987 seasons. *Paléorient* 15: 11–18.
NOY, T. & S.K. KOZLOWSKI. 2010. A Basket of Flint Arifacts from Gilgal I: Locus 11 and Locus 37/42, in O. Bar-yosef, A.N. Goring-morris, & A. Gopher (eds.) *Gilgal - Early Neolithic Occupations in the Lower Jordan Valley: The Excavations of Tamar Noy*: 83–100. Oxford: Oxbow Books.
ORANGE, M., T. CARTER & F.-X. LE BOURDONNEC. 2013. Sourcing obsidian from Tell Aswad and Qdeir 1 (Syria) by SEM-EDS and EDXRF: Methodological implications. *Comptes Rendus Palevol* 12: 173–80.
ÖZBAŞARAN, M., G. DURU, A. BOGAARD, B. BOZ, M. CHARLES, M. ERGUN, H. GÜLTEKIN, N. KAYACAN, N. RUSSELL, D.T. ÖZBUDAK, K.C. TWISS & N. YALMAN. 2014. Istanbul (IST) Area of the East Mound, in I. Hodder (ed.) *Çatalhöyük Excavations: The 2000-2008 Seasons*: 621–58. London: British Institute of Archaeology at Ankara.
PEARSALL, D.M. 2015. *Paleoethnobotany: a handbook of procedures* (3rd edition). New York: Routledge.
PEARSALL, D.M. 2016. The Phytoliths in the Flora of Ecuador project: Perspectives on phytolith classification, identification, and establishing regional phytolith databases. *Journal of Archaeological Science* 68: 89–97.
PENNINGTON, H.L. & S.A. WEBER. 2004. Paleoethnobotany: modern research connecting ancient plants and ancient peoples. *Critical Reviews in Plant Sciences* 23: 13–20.
PETIT, S., A. BOURSAULT, M. GUILLOUX, N. MUNIER-JOLAIN & X. REBOUD. 2011. Weeds in agricultural landscapes. A review *Agronomy for Sustainable Development* 31: 309–17.
PICHON, F. 2017. Exploitation of the cereals during the Pre-pottery Neolithic of Dja'de-el-Mughara: Preliminary results of the functional study of the glossy blades. *Quaternary International* 427: 138–51.
PIPERNO, D.R. & D.M. PEARSALL. 1998. The Silica Bodies of Tropical American Grasses: Morphology, Taxonomy, and Implications for Grass Systematics and Fossil Phytolith Identification. *Smithsonian Contributions to Botany*: 1–40.
PORTILLO, M., S. KADOWAKI, Y. NISHIAKI & R.M. ALBERT. 2014. Early Neolithic household behavior at Tell Seker al-Aheimar (Upper Khabur, Syria): a comparison to

ethnoarchaeological study of phytoliths and dung spherulites. *Journal of Archaeological Science* 42: 107–18.
PUSTOVOYTOV, K.E., S. RIEHL & S. MITTMANN. 2004. Radiocarbon age of carbonate in fruits of Lithospermum from the early Bronze Age settlement of Hirbet ez-Zeraqōn (Jordan). *Vegetation History and Archaeobotany* 13: 207–12.
RADOSEVICH, S.R., J.S. HOLT & C. GHERSA. 1997. *Weed ecology: implications for management*. New York: John Wiley & Sons.
REICHERT, E.T. 1913. *The differentiation and specificity of starches in relation to genera, species, etc., (in Two Parts)*. Washington DC: Carnegie institution of Washington.
RICHARDSON, M. 1994. The botanic garden seed list–a curse to plant conservation. *Bot. Gardens Conservation News* 2: 21–22.
RIEHL, S. 2010. Plant Production in a Changing Environment: The Archaeobotanical Remains from Tell Mozan, in K. Deckers, M. Doll, P. Pfalzner & S. Riehl (eds.) *Development of the Environment, Subsistence and Settlement of the City of Urkes and Its Region*: 13–158. Wiesbaden: Harrassowitz.
RIEHL, S., M. ZEIDI & N.J. CONARD. 2013. Emergence of agriculture in the foothills of the Zagros Mountains of Iran. *Science* 341: 65–67.
RIVERA, D., C. INOCENCIO, C. OBON, E. CARRENO, A. REALES & F. ALCARAZ. 2002. Archaeobotany of capers (Capparis) (Capparaceae). *Vegetation History and Archaeobotany* 11: 295–313.
ROBERTS, N., S.L. ALLCOCK, F. ARNAUD, J.R. DEAN, W.J. EASTWOOD, M.D. JONES, M.J. LENG, S.E. METCALFE, E. MALET, J. WOODBRIDGE & H. YIĞITBAŞIOĞLU. 2016. A tale of two lakes: a multi-proxy comparison of Lateglacial and Holocene environmental change in Cappadocia, Turkey. *Journal of Quaternary Science* 31: 348–62.
ROBERTS, N., P. BOYER & J. MERRICK. 2007. The KOPAL on-site and off-site excavations and sampling. South, North and KOPAL Area reports from the 1995-99 seasons., in I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area Reports from the 1995-99 seasons*: 553–573. Cambridge: McDonald Institute for Archaeological Research/London: British Institute of Archaeology at Ankara.
ROBERTS, N., M.D. JONES, A. BENKADDOUR, W.J. EASTWOOD, M.L. FILIPPI, M.R. FROGLEY, H.F. LAMB, M.J. LENG, J.M. REED, M. STEIN, L. STEVENS, B. VALERO-GARCÉS & G. ZANCHETTA. 2008. Stable isotope records of Late Quaternary climate and hydrology from Mediterranean lakes: the ISOMED synthesis. *Quaternary Science Reviews* 27: 2426–41.
ROBERTS, N. & A. ROSEN. 2009. Diversity and Complexity in Early Farming Communities of Southwest Asia: New Insights into the Economic and Environmental Basis of Neolithic Çatalhöyük. *Current Anthropology* 50: 393–402.
ROBERTS, N., J. WOODBRIDGE, A. BEVAN, A. PALMISANO, S. SHENNAN & E. ASOUTI. 2018. Human responses and non-responses to climatic variations during the last Glacial-Interglacial transition in the eastern Mediterranean. *Quaternary Science Reviews 184:* 47-67.
ROITEL, V. 1997. Végétation et action de l'homme du Natoufien au Néolithique acéramique dans le Haut-Euphrate syrien. Unpublished PhD thesis, Montpellier II, France.
ROLLEFSON, G.O. & A.H. SIMMONS. 1986. The Neolithic Village of 'Ain Gh̊azāl, Jordan: Preliminary Report on the 1984 Season. *Bulletin of the American Schools of Oriental Research* 24: 145–64.
ROS, J., A. EVIN, L. BOUBY & M. RUAS. 2014. Geometric morphometric analysis of grain shape and the identification of two-rowed barley (*Hordeum vulgare* subsp. *distichum* L.) in southern France. *Journal of Archaeological Science* 41: 568–75.
RÖSCH, M. 1998. The history of crops and crop weeds in south-western Germany from the Neolithic period to modern times, as shown by archaeobotanical evidence. *Vegetation History and Archaeobotany* 7: 109–25.
ROWLEY-CONWY, P. 1981. Slash and burn in the temperate European Neolithic., in R. Mercer (ed.) *Farming Practice in British Prehistory*: 85–96. Edinburgh: Edinburgh University Press.
RUSSELL, N., K.C. TWISS, D.C. ORTON & G.A. DEMIRERGI. 2013. More on the Çatalhöyük Mammal Remains, in I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük:*

Reports from the 2000-2008 Seasons: 213–53. London and Los Angeles: British Institute at Ankara.
RYAN, P. 2011. Plants as material culture in the Near Eastern Neolithic: Perspectives from the silica skeleton artifactual remains at Çatalhöyük. *Journal of Anthropological Archaeology* 30.: 292–305.
RYAN, P. 2013. Plant Exploitation from Household and Landscape Perspectives: the Phytolith Evidence, in I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*. London and Los Angeles: British Institute at Ankara.
SAHLINS, M. 1972. *Stone Age Economics*. New York: Aldine de Gruyter.
SAUER, C.O. 1952. *Seeds, Spades, Hearths, and Herds. The Domestication of Animals and Foodstuffs.* Cambridge: The MIT Press.
SAVARD, M., M. NESBITT & R. GALE. 2003. Archaeobotanical evidence for early Neolithic diet and subsistence at M'lefaat (Iraq). *Paléorient* 29: 93–106.
SHERRATT, A. 1980. Water, soil and seasonality in Early Cereal Cultivation. *World Archaeology* 11: 313–30.
— 1981. Plough and pastoralism: aspects of the secondary products revolution, in I. Hodder, G. Isaac, & N. Hammond (eds.) *Pattern of the Past*: 261–305. Cambridge: Cambridge University Press.
SNIR, A., D. NADEL, I. GROMAN-YAROSLAVSKI, Y. MELAMED, M. STERNBERG, O. BAR-YOSEF & E. WEISS. 2015. The origin of cultivation and proto-weeds, long before neolithic farming. *PLoS ONE* 10: 1–12.
STEBBINS, G.L. 1981. Chromosomes and evolution in the genus *Bromus* (Gramineae) *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* 102: 359–79.
STORDEUR, D. 2014. Jerf El Ahmar Entre 9500 et 8700 Cal. BC. Un Village des Débuts de l'Agriculture. Une Société Complexe, in C. Manen, T. Perrin, & J. Guilaine (eds.) *La transition néolithique en Méditerranée. The Neolithic transition in the Mediterranean*: 27–45. Arles et Toulouse: Errance/Archives d'Écologie Préhistorique.
— 2015. *Le village de Jerf el Ahmar (Syrie, 9500-8700 av. J.-C): L'architecture, miroir d'une société néolithique complexe*. Paris: CNRS Éditions.
STORDEUR, D., M. BRENET, G. DER APRAHAMIAN & J.-C. ROUX. 2000. Les bâtiments communautaires de Jerf el Ahmar et Mureybet Horizon PPNA (Syrie). *Paléorient* 26: 29–44.
STORDEUR, D., D. HELMER, B. JAMOUS, R. KHAWAM, M. MOLIST & G. WILLCOX. 2010. Le PPNB de Syrie du Sud à travers les découvertes récentes à Tell Aswad, in M. Al-Maqdissi, F. Braemer, & J.-M. Dentzer (eds.) *La Syrie du sud du Néolithique à l'Antiquité tardive, Hauran V*: 41–69. Beiruit: Institut Français du Proche-Orient.
STORDEUR, D., B. JAMMOUS, D. HELMER & G. WILLCOX. 1996. Jerf el Ahmar, a New Mureybetian site (PPNA Period) on the Middle Euphrates. *Neo-lithics* 2/96: 1–2.
STORDEUR, D. & B. JAMOUS. 2009. La Damascène et la Révolution Néolithique. *Les Annales Archéologiques Arabes Syriennes* 51–52: 7–16.
STORDEUR, D., R. KHAWAM, B. JAMMOUS & É. MORERO. 2006. L'aire funéraire de Tell Aswad (PPNB). *Syria* 83: 39–62.
STORDEUR, D. & G. WILLCOX. 2009. Indices de culture et d'utilisation des céréales à Jerf el Ahmar, in *De Méditerranée et d'ailleurs… Mélanges offerts à Jean Guilaine*: 693-710. Toulouse: Archives d'Écologie Préhistorique.
STROUD, E. 2016. *An archaeobotanical investigation into the Chalcolithic economy and social organisation of central Anatolia*. Unpublished PhD thesis, University of Oxford.
STYRING, A.K., M. ATER, Y. HMIMSA, R.. FRASER, H. MILLER, R. NEEF, J.A. PEARSON & A. BOGAARD. 2016. Disentangling the effect of farming practice from aridity on crop stable isotope values: A present-day model from Morocco and its application to early farming sites in the eastern Mediterranean. *The Anthropocene Review* 3: 1–21.
STYRING, A.K., M. CHARLES, F. FANTONE, M.M. HALD, A. MCMAHON, R.H. MEADOW, G.K. NICHOLLS, A.K. PATEL, M.C. PITRE, A. SMITH, A. SOŁTYSIAK, G. STEIN, J.A. WEBER, H. WEISS

& A. BOGAARD. 2017. Isotope evidence for agricultural extensification reveals how the world's first cities were fed. *Nature Plants* 3: 1–11.
TER BRAAK, C.F.J. & P. SMILAUER. 2002. *CANOCO for Windows version 4.5.* Wageningen: Centre for Biometry.
TERRAL, J.F., E. TABARD, L. BOUBY, S. IVORRA, T. PASTOR, I. FIGUEIRAL, S. PICQ, J.B. CHEVANCE, C. JUNG, L. FABRE, C. TARDY, M. COMPAN, R. BACILIERI, T. LACOMBE & P. THIS. 2010. Evolution and history of grapevine (*Vitis vinifera*) under domestication: new morphometric perspectives to understand seed domestication syndrome and reveal origins of ancient European cultivars. *Annals of botany* 105: 443–55.
TESTART, A. 1982. The Significance of Food Storage among Hunter-Gatherers: Residence Patterns, Population Densities, and Social Inequalities. *Current Anthropology* 23: 523–37.
THE PLANT LIST. 2013. *Version 1.1. Published on the Internet;* http://www.theplantlist.org/ (accessed 07.06.17).
THOMPSON, K., S.R. BAND & J.G. HODGSON. 1993. Seed size and shape predict persistence in soil. *Functional Ecology* 7: 236–41.
TOMINAGA, T. & Y. YAMASUE. 2004. Crop-associated weeds, in Inderjit (ed.) *Weed Biology and Management*: 47–63. Dordrecht: Kluwer Academic Publishers.
TOWNSEND, C.C., E. GUEST & A. AL-RAWI. 1968. *Flora of Iraq: Vol. 9*. Baghdad: Ministry of Agriculture.
TWISS, K.C. 2008. Transformations in an early agricultural society: Feasting in the southern Levantine Pre-Pottery Neolithic. *Journal of Anthropological Archaeology* 27: 418–42.
TWISS, P.C., E. SUESS & R.M. SMITH. 1969. Morphological classification of grass phytoliths. *Soil Science Society of America Journal* 33: 109–15.
UNIVERSITY OF SHEFFIELD. 2016. Origins of Agriculture. https://www.shef.ac.uk/archaeology/research/origins-ofagriculture/origins-database.
VAIGLOVA, P. 2016. *Neolithic agricultural management in the Eastern Mediterranean: new insight from a multi-isotope approach*. Unpublished PhD thesis, University of Oxford, UK.
VALLA, F.R. 1991. Les Natoufiens de Mallaha et l'espace., in O. Bar-Yosef & F.R. Valla (eds.) *The Natufian Culture in the Levant*: 111–22. Ann Arbor: International Monographs in Prehistory.
VAN DER VEEN, M. 2007. Formation processes of desiccated and carbonized plant remains - the identification of routine practice. *Journal of Archaeological Science* 34: 968–90.
VAN DER VEEN, M. & N. FIELLER. 1982. Sampling Seeds. *Journal of Archaeological Science* 9: 287–98.
VAN GESTEL, M., J.N. LADD & M. AMATO. 1991. Carbon and nitrogen mineralization from two soils of contrasting texture and microaggregate stability: Influence of sequential fumigation, drying and storage. *Soil Biology and Biochemistry* 23: 313–22.
VAN KLEUNEN, M., W. DAWSON & N. MAUREL. 2015. Characteristics of successful alien plants. *Molecular Ecology* 24: 1954–68.
VAN ZEIST, W. 1970. Prehistoric and early historic food plants in the Netherlands. *Palaeohistoria* 14: 41–173.
— 2001. Third to first millennium BC plant cultivation on the Khabur, North-Eastern Syria. *Palaeohistoria* 41: 111–25.
VAN ZEIST, W. & J.A.H. BAKKER-HEERES. 1982. Archaeobotanical studies in the Levant 1. Neolithic sites in the Damascus basin: Aswad, Ghoraifé, Ramad. *Palaeohistoria* 24: 165–256.
VIGUEIRA, C.C., K.M. OLSEN & A.L. CAICEDO. 2013. The red queen in the corn: agricultural weeds as models of rapid adaptive evolution. *Heredity* 110: 303–11.
VIOLLE, C., H. CASTRO, J. RICHARTE & M.L. NAVAS. 2009. Intraspecific seed trait variations and competition: Passive or adaptive response? *Functional Ecology* 23: 612–20.
WALLACE, M.P. & M. CHARLES. 2013. What goes in does not always come out: The impact of the ruminant digestive system of sheep on plant material, and its importance

for the interpretation of dung-derived archaeobotanical assemblages. *Environmental Archaeology* 18: 18–30.
WALLACE, M.P., G. JONES, M. CHARLES, R. FRASER, P. HALSTEAD, T.H.E. HEATON & A. BOGAARD. 2013. Stable carbon isotope analysis as a direct means of inferring crop water status and water management practices. *World Archaeology* 45: 388–409.
WALLACE, M.P., G. JONES, M. CHARLES, R. FRASER, T.H.E. HEATON. & A. BOGAARD. 2015. Stable carbon isotope evidence for Neolithic and Bronze Age crop water management in the eastern Mediterranean and southwest Asia. *PLOS ONE* 10: e0127085.
WARINNER, C., J.D.A. GUEDES & D. GOODE. 2011. Paleobot.org: Establishing open-access online reference collections for archaeobotanical research. *Vegetation History and Archaeobotany* 20: 241–44.
WEISS, E., M.E. KISLEV. & A. HARTMANN. 2006. Autonomous Cultivation Before Domestication. *Science* 312: 1608–10.
WERKER, E. 1997. *Seed Anatomy. Encyclopedia of plant anatomy*. Berlin: Gebrüder Borntraeger.
WESTHOFF, V. & E. VAN DER MAAREL. 1973. The Braun-Blanquet approach, in R.H. Whittaker (ed.) *Handbook of Vegetation Science, 5: Ordination and Classification of Communities*: 617–726. The Hague: Junk.
WETTERSTROM, W. 2003. Ninevite 5 period agriculture at Tell Leilan: preliminary results, in E. Rova & H. Weiss (eds.) *The origins of North Mesopotamian civilization: Ninevite 5 chronology, economy, society*, IX: 387–400. Turnhout, Belgium: Brepols.
WHITE, C.E. 2013. The Emergence and Intensification of Cultivation Practices at the Pre-Pottery Neolithic Site of El-Hemmeh, Jordan: An Archaeobotanical Study. Unpublished PhD thesis, Boston University.
WHITLAM, J.T. 2015. *Plant Use and Neolithic Societies of the Eastern Fertile Crescent c. 10,000 – 5500 BC*. Unpublished Ph.D. thesis, University of Reading.
WHITTLE, A. 1996. *Europe in the Neolithic*. Cambridge: Cambridge University Press.
WILLCOX, G. 1996. Evidence for plant exploitation and vegetation history from three Early Neolithic pre-pottery sites on the Euphrates (Syria). *Vegetation History and Archaeobotany* 5: 143–52.
— 2002. Charred plant remains from a 10th millennium B.P. kitchen at Jerf el Ahmar (Syria). *Vegetation History and Archaeobotany* 11: 55–60.
— 2005. The distribution, natural habitats and availability of wild cereals in relation to their domestication in the Near East: multiple events, multiple centres. *Vegetation History and Archaeobotany* 14: 534–41.
— 2007. The adoption of farming and the beginnings of the Neolithic in the Euphrates valley: cereal exploitation between the 12th and 8th millennia cal BC, in S. Colledge & J Conolly (eds.) *The origins and spread of domestic plants in Southwest Asia and Europe*: 21–36. Walnut Creek, CA: Left Coast Press.
— 2012a. The Beginnings of Cereal Cultivation and Domestication in Southwest Asia, in D.T. Potts (ed.) *A Companion to the Archaeology of the Ancient Near East*: 163–80. Oxford: Blackwell Publishing Ltd.
— 2012b. Searching for the origins of arable weeds in the Near East. *Vegetation History and Archaeobotany* 21: 163–67.
— 2016. Early farming and the origins of agriculture: Near Eastern archaeobotany. http://g.willcox.pagesperso-orange.fr/index.htm.
WILLCOX, G. & S. FORNITE. 1999. Impressions of wild cereal chaff in pise from the 10th millennium uncal B.P. at Jerf el Ahmar and Mureybet: northern Syria. *Vegetation History and Archaeobotany* 8: 21–24.
WILLCOX, G., S. FORNITE & L. HERVEUX. 2008. Early Holocene cultivation before domestication in northern Syria. *Vegetation History and Archaeobotany* 17: 313–25.
WILLCOX, G. & V. ROITEL. 1998. Rapport archéobotanique préliminaire de trois sites précéramiques du Moyen-Euphrate (Syrie). *Cahiers de l'Euphrate* 8: 65–84.
WILLCOX, G. & D. STORDEUR. 2012. Large-scale cereal processing before domestication during the tenth millennium cal BC in northern Syria. *Antiquity* 86: 99–114.
WOLLSTONECROFT, M., P.R. ELLIS, G.C. HILLMAN & D.Q. FULLER. 2008. Advances in plant

food processing in the Near Eastern Epipalaeolithic and implications for improved edibility and nutrient bioaccessibility: an experimental assessment of *Bolboschoenus maritimus* (L.) Palla (sea club-rush). *Vegetation History and Archaeobotany* 17: 19-27.
WOLLSTONECROFT, M. & A. ERKAL. 1999. Summary of plant-processing experiments, in I. Hodder (ed.) *Çatalhöyük 1999 Archive Report, www.catalhoyuk.com/archive_reports/1999/index.html*.
WOLLSTONECROFT, M., Z. HROUDOVA, G.C. HILLMAN & D.Q. FULLER. 2011. *Bolboschoenus glaucus* (Lam.) S. G. Smith, a new species in the flora of the ancient Near East. *Vegetation History and Archaeobotany* 20: 459–70.
WOOD, J.R.I., B.R.M. WILLIAMS, T.C. MITCHELL, M.A. CARINE, D.J. HARRIS & R.W. SCOTLAND. 2015. A foundation monograph of *Convolvulus* L . (Convolvulaceae). *PhytoKeys* 51: 1–282.
WOODBURN, J. 1982. Egalitarian Societies. *Man* 17: 431–51.
WRIGHT, K.I. 1993. Early Holocene Ground Stone Assemblages in the Levant. *Levant* 25: 93–111.
— 2000. The Social Origins of Cooking and Dining in Early Villages of Western Asia. *Proceedings of the Prehistoric Society* 66: 89–121.
— 2014. Domestication and inequality? Households, corporate groups and food processing tools at Neolithic Çatalhöyük. *Journal of Anthropological Archaeology* 33: 1–33
YAMASUE, Y. 2001. Strategy of *Echinochloa oryzicola* Vasing. for survival in flooded rice. *Weed Biology and Management* 1: 28–36.
YANG, X. & L. PERRY. 2013. Identification of ancient starch grains from the tribe Triticeae in the North China Plain. *Journal of Archaeological Science* 40: 3170–77.
YANG, X., J. ZHANG, L. PERRY, Z. MA, Z. WAN, M. LI, X. DIAO & H. LU. 2012. From the modern to the archaeological: Starch grains from millets and their wild relatives in China. *Journal of Archaeological Science* 39: 247–54.
YARTAH, T. 2005. Les bâtiments communautaires de Tell 'Abr 3 (PPNA, Syrie). *Neo-Lithics: The Newsletter of Southwest Asian Neolithic Research* 1/05: 3–9.
YEOMANS, L. 2014. Building 64, in I. Hodder (ed.) *Çatalhöyük Excavations: The 2000-2008 Seasons*: 475–80. London: British Institute of Archaeology at Ankara.
YOUNG, J.A. & R.A. EVANS. 1976. Responses of Weed Populations to Human Manipulations of the Natural Environment. *Weed Science* 24: 186–90.
ZOHARY, M. 1973. *Geobotanical foundations of the Middle East*. Stuttgart: G. Fischer.
ZOHARY, M. & N. FEINBURN-DOTHAN. 1966. *Flora Palaestina*. Vol. 1. Jerusalem: Israel Academy of Sciences and Humanities.

Appendix 1

Raw data for analyses

Appendix 1a – Bin feature measurements for *in situ* built storage examples (based on Green *et al.* in Demirergi *et al.* 2014).

Feature no.	Recorded feature type	Building no.	Location - basic	Relative location	Towards corner of room?	Core material	Outer lining/colour	Shape	Grouping	Preserved depth (m)	Covered?	Internal floor area (m2)
use for pca			side = 1; main = 2	C = 1; wall = 2	away from corner = 1, corner = 2	clay = 1; wood = 2, cut = 3, plaster = 4	core = 1, clay = 2, plaster = 3, plaster/white = 4, painted plaster = 5	elliptical = 1; irregular/truncated = 2, rectilinear = 3	1=single, 2=double, 3=triple, 4=quadruple	use	0 = don't know; 1 = covered	
variable type			nominal	nominal		nominal	nominal	nominal			nominal	
214	bin	1	1	2	1	2	3	3	1	0.25	0	0.24
215	bin	1	2	2	1	1	3	3	2	0.4	0	0.84
2002	bin	52	1	2	2	1	3	3	4	0.28	0	0.37
2003	bin	52	1	2	2	1	3	3	4	0.35	0	0.8
2004	bin	52	1	2	2	1	3	3	4	0.38	0	0.44
2005	bin	52	1	2	2	1	3	3	4	0.5	0	0.25
2085	bin	56	1	2	2	1	4	1	1	0.16	0	0.36
2500	bin	65	1	2	2	1	4	3	2	0.35	0	0.26
2502	bin	65	1	2	2	1	4	3	3	0.22	0	0.29
2503	bin	65	1	2	2	1	4	3	3	0.2	0	0.35
2903	bin	64	1	2	2	3	4	3	1	0.2	0	0.23
3092 NE	bin	77	1	2	2	1	4	3	3	0.85	0	0.99
3092 NW	bin	77	1	2	2	1	4	3	3	0.85	0	0.98
3092 sml front	bin	77	1	2	2	1	4	1	3	0.85	0	0.07
3	bin	EVI 17	?	?	?	1	?	?	1	?	?	?
1967	pit/bin	63	1	2	1	1	4	1	1	?	0	?
2330	bin	63	1	2	2	1	1	3	1	?	0	?
3435	bin	80	1	2	1	1	1	1	1	0.1	0	0.07
5031	bin	79	2	2	1	1	1	3	1	0.12	0	0.21
7182	bin	122	1	2	2	1	1	3	1	0.6	0	0.36
7198	bin	122	1	1	2	1	1	3	1	0.42	0	0.1

*Features highlighted in red have been added since Green *et al.* in Demirergi *et al.* 2014 study, some information is incomplete.

Appendix 1b – Final selection of crop stores for analysis at Çatalhöyük, indicating original context descriptions by excavators and the initials of the associated archaeobotanist. LG= Laura Green (author), AB= Amy Bogaard, DF= Dragana Filipović, ME= Müge Ergun.

Flot no.	Unit no.	Feature no.	Building no.	Context type	Source
171/329	1314	215	1	Bin fill	DF
144	1344	215	1	Lentil bin	DF
135	1349	27	1	Basin fill	DF
516	1442	34	1	Basin fill	DF
535	1442	34	1	Basin fill	DF
6026	10309	-	52	Seeds pocket	AB
6019	11900	2002	52	Bin fill	AB/LG
6052	11903	2002	52	Bin fill	AB/LG
6049	11908	2002	52	Bin fill	AB
6059	11908	2002	52	Bin fill	AB/LG
6050	11911	2004	52	Peas concentration	AB/LG
6051	11911	2004	52	Peas concentration	AB
6056	11911	2004	52	Peas concentration	AB
6070	11911	2004	52	Peas concentration	AB/LG
6638	11866	1967	63	Bin	ME
6594/6641	12417	1984	63	Bin	ME
7906	13919	2330	63	Wooden container?	ME
8048/8049/ 8205	13962	1967	63	Outer N wall of the bin	ME
8413	16480	-	77	Spread of burnt grain	AB
8415	16480	-	77	Spread of burnt grain	AB
8416	16480	-	77	Spread of burnt grain	AB
8486	16498	-	77	Burnt seeds/organics	AB
8505	16498	-	77	Burnt seeds and organics	AB
8614	17519	-	77	Burnt pea concentration	AB/LG
9176	18596	5031	79	Charred seeds	LG
9159	18598	5031	79	Charred seeds	LG
9256	18945	-	80	Grain cluster	LG
9255	18949	-	80	Cluster of seeds	LG
9271	18952	-	80	Cluster of seeds NE Corner	LG
11922	22709	7198	122	Bottom of bin	AB
10922	30785	-	122	Barley cluster	LG
10921	30859	7182	122	Bin fill	LG
10961	30871	7198	122	Bin fill	LG

Appendix 1c – This table gathers information from a range of sources to determine the probable status for each wild taxon identified from the four selected sites. A total of 85 wild genera were assessed, relating to four possible modes of deposition: weed, collected, dung-derived, and ruderal.

Latin names	Family	Weed	Collected	Dung	Ruderal	Status	Comments	Reference
Aizoon hispanicus	Aizoaceae				x	ruderal?	Deserts sometimes on saline ground'	*Flora Palaestina*;
Alisma	Alismataceae			x		dung	Identified dung taxon - associated with wet places	Filipović 2012: 189; *Flora of Turkey*;
Atriplex	Amaranthaceae	x	x			collected?	Large numbers recovered from Dja'de - suggested as a possible fuel by Willcox et al. 2008	Willcox *et al.* 2008: 317;
Bellevalia	Asparagaceae	x				weed	Common arable weed, too delicate to survive in dung?	*Flora of Turkey;*
Ornithogalum	Asparagaceae	x				weed	Common arable weed, no dung reference	*Flora of Turkey;*
Centaurea	Asteraceae	x				weed	Common arable weed, too large for dung	Filipović 2012: 189; *Flora of Turkey*;
Arnebia decumbens	Boraginaceae				*x*	ruderal?	Not known as a weed. Rarely carbonised - unsure of origin	van Zeist and Bakker-Heeres 1982: 212; Willcox *et al.* 2008: 315;
Heliotropium	Boraginaceae	x		x		dung/weed	Identified with dung deposits. Identified as weed by Willcox	Filipović 2012: 189; *Flora of Turkey*;
Lithospermum	Boraginaceae				x	ruderal?	Uncharred - unsure of origin	Filipović 2012: 270; *Flora of Turkey*;
Capparis	Capparaceae	?	x			collected	Known to be edible and collected	Stroud 2016: 208; *Flora of Turkey;*
Valerianella	Caprifoliaceae	x				weed	Common arable weed.	Filipović 2012: 189; *Flora of Turkey*;
Gypsophila	Caryophyllaceae	x				weed	Common arable weed, though small types could potentially survive in dung	Whitlam 2015;
Silene	Caryophyllaceae	x		?		weed	Common arable weed, though small types could potentially survive in dung	Whitlam 2015;
Vaccaria pyramidata	Caryophyllaceae	x				weed	Common arable weed, too large for dung, no collected use	Filipović 2012: 189; *Flora of Turkey*;
Chenopodium	Chenopodiaceae	x		x		dung/weed	Identified dung taxon - though also found as a weed	Filipović 2012: 189; Anderson and Ertug-Yaras 1998; *Flora of Turkey*;
Salsola type	Chenopodiaceae			x	x	dung	Identified dung taxon - saline ruderal species	Filipović 2012: 189; *Flora of Turkey*;
Suaeda	Chenopodiaceae	x		x		dung	Identified dung taxon - associated with wet places, occasionally found as a weed	Filipović 2012: 189; Wallace and Charles 2013; *Flora of Turkey*;
Helianthemum	Cistaceae		x			collected	Large concentrations recovered from storage contexts at Catal. Not likely as a weed.	Bogaard *et al.* 2013; *Flora of Turkey;*
Artemisia annua type	Compositae	x		x		dung	Identified dung taxon - though occasionally found as a weed	Filipović 2012: 189; *Flora of Turkey*;
Convolvulus	Convolvulaceae	x				weed	Common arable weed, too fragile for dung	*Flora of Turkey;*

Latin names	Family	Weed	Collected	Dung	Ruderal	Status	Comments	Reference
Alyssum/Lepidum	Cruciferae	x	x			collected?	Concentration of seeds in one sample - collected? Also known as a weed.	Willcox *et al.* 2008; 2012; *Flora of Turkey;*
Brassica	Cruciferae	x	x			wild/weed	Small numbers - likely a weed in contexts at Aswad	-
Conringia orientalis	Cruciferae	x				weed	Correspondence analysis indicates most likely represented as arable weed	Bogaard *et al.* 2013: 103;
Bolboschoenus glaucus	Cyperaceae	x	x	x	x	dung?	Complicated status - found embedded within dung but could easily invade cultivated fields. Also debated to be collected for food or for basket making etc. Abundant in wet habitats.	Filipović 2012: 159: 189; Wollstonecroft *et al.* 2008, 2011; Wallace and Charles 2013;
Carex	Cyperaceae	x		x		dung?	Identified dung taxon - though also found as a weed	Filipović 2012: 189; *Flora of Turkey* ;
Scirpus type	Cyperaceae	x	x	x	x	dung?	Complicated status - found embedded within dung but could easily invade cultivated fields. Also debated to be collected for food or for basket making etc. Abundant in wet habitats.	Filipović 2012: 159: 189; Wollstonecroft *et al.* 2008, 2011; Wallace and Charles 2013;
Scirpus/Eleocharis	Cyperaceae	x	x	x	x	dung	Complicated status - found embedded within dung but could easily invade cultivated fields. Also debated to be collected for food or for basket making etc. Abundant in wet habitats.	Filipović 2012: 159: 189; Wollstonecroft *et al.* 2008, 2011; Wallace and Charles 2013;
Cephalaria /Umbelliferae type	Dipsacaceae/Umbelliferae	x				weed	Common arable weed, too large for dung, crop mimic	*Flora of Turkey;*
Erodium	Geraniaceae	x				weed	Found in fallow fields, likely weed	Filipović 2012: 189; *Flora of Turkey;*
Geranium type	Geraniaceae	x				weed	Common arable weed	Filipović 2012: 189; *Flora of Turkey* ;
Aegilops	Gramineae	x	?			weed	Common arable weed, too large for dung. Found in small numbers so probably does not reflect collected.	Nesbitt 2006; *Flora of Turkey;*
Aeluropus	Gramineae	x		x		dung	Identified dung taxon - though also found as a weed	Filipović 2012: 189; *Flora of Turkey* ;
Agrostis sp. type	Gramineae			x		dung	Associated with other dung taxa. Often found in wet places.	See samples; *Flora of Turkey;*
Alopecurus	Gramineae	x		x		dung	Associated with other dung taxa. Often associated with wet places, but could also be a weed	Stroud 2016: 240; *Flora of Turkey* ;
Bromus	Gramineae	x				weed	Common arable weed, too large for dung	Filipović 2012: 189; Nesbitt 2006: 80; *Flora of Turkey* ;
Crypsis	Gramineae	x		x		dung	Identified dung taxon - though also associated with abandoned fields	Filipović 2012: 189; *Flora of Turkey* ;
Echinaria capitata	Gramineae	x		?		wild/weed	Found in fallow fields, likely weed, though could potentially survive in dung	Nesbitt 2006: 65; *Flora of Turkey;*

405

Latin names	Family	Weed	Collected	Dung	Ruderal	Status	Comments	Reference
Eragrostis	Gramineae	x		x		dung	Identified dung taxon - though occasionally found as a weed	Filipović 2012: 189; Miller 1984: 24; *Flora of Turkey* ;
Eremopyrum bonaepartis type	Gramineae	x				weed	Common arable weed, too large for dung	Filipović 2012: 189; Nesbitt 2006: 88; *Flora of Turkey* ;
Hordeum murinum/bulbosum	Gramineae	x	x			weed/collected	Large numbers recovered from Jerf - may have been collected for food	Willcox 1996: 148;
Lolium	Gramineae	x				weed	Common arable weed, too large for dung	Nesbitt 2006: 54; *Flora of Turkey;*
Phalaris	Gramineae	x				weed	Known as a weed. Too large for dung	*Flora of Turkey;*
Phragmites	Gramineae	x			x	weed	Wet taxa but could invade cultivated fields	Filipović 2012: 161;
Phragmites australis	Gramineae	x			x	weed	Wet taxa but could invade cultivated fields	Filipović 2012: 161;
Poa Bulbosa	Gramineae			?		dung?	Unlikely weed, possible dung taxa	Stroud 2016: 259; *Flora of Turkey;*
Sporobolus	Gramineae			x		dung	Identified dung taxon - found in dung pellets at Catal, associated with salt marshes	Filipović 2012: 189; Bogaard et al. 2013; Miller 1984: 24; *Flora of Turkey* ;
Stipa	Gramineae	x				weed	Common arable weed, too large for dung	Filipović 2012: 189; Nesbitt 2006: 50;
Stipagrostis type	Gramineae			x		dung	Associated with other dung taxa	Bogaard *et al.* 2013;
Taeniatherum caput-medusae	Gramineae	x	x			weed/collected	Common arable weed. Too large for dung. Collection also possible though check context.	Fairbairn *et al.* 2007; *Flora of Turkey;*
Triticum boeticum	Gramineae	x				weed	Identified as a weed in late Neolithic contexts	Bogaard *et al* . 2013;
Juncus	Juncaceae			x		dung	Identified dung taxon - associated with wet places	Filipović 2012: 189; Wallace and Charles 2013; *Flora of Turkey;*
Mentha	Labiatae	x	x	?		weed/collected	Possible collections at Catal, though small enough to survive in dung	Bogaard *et al* . 2013: 101;
Sideritis type	Labiatae	x				weed	Common arable weed	Filipović 2012: 189; Stroud 2016: 260; *Flora of Turkey* ;
Teucrium	Labiatae	x	x			weed/collected	Possible collections at Catal, though also possible as a weed.	Bogaard *et al.* 2013: 101; Filipović 2012: 189;
Ajuga/Teucrium	Lamiaceae	x	x			weed/collected	Possible collections at Catal, though also possible as a weed.	Bogaard *et al* . 2013: 101; Filipović 2012: 189;
Ziziphora	Lamiaceae	x	?	x		dung?	Identified dung taxon - though also found as a weed. Collections identified at Tell Qaramel	Filipović 2012: 189; Anderson and Ertug-Yaras 1998;
Astragalus	Leguminosae	x		x		dung?	Identified dung taxon - though also found as a weed	Miller 1984: 18; Filipović 2012: 118; *Flora of Turkey;*

Latin names	Family	Weed	Collected	Dung	Ruderal	Status	Comments	Reference
Cicer	Leguminosae	x				weed	Wild type possibly associated with fallow fields	*Flora of Turkey;*
Coronilla	Leguminosae	x		x		dung?	High likelihood of being dung-derived	Whitlam 2015: 352;
Lathyrus	Leguminosae	x				weed	Common arable weed, too large for dung	Filipović 2012: 189; *Flora of Turkey* ;
Medicago	Leguminosae	x		x		dung?	Identified dung taxon - though also found as a weed	Filipović 2012: 118; *Flora of Turkey* ;
Melilotus	Leguminosae	x		x		dung?	Identified dung taxon - though also found as a weed	Filipović 2012: 118; *Flora of Turkey* ;
Onobrychis	Leguminosae	x				weed	Common arable weed, no dung reference	*Flora of Turkey;*
Trifolium	Leguminosae	x		x		dung?	Identified dung taxon - though also found as a weed	Filipović 2012: 118; Charles 1998;
Trigonella astroites	Leguminosae	x		x		dung?	Identified dung taxon - though also found as a weed	Filipović 2012: 189; Flora of Turkey;
Vicia/Lathyrus	Leguminosae	x				weed	Common arable weed, too large for dung	*Flora of Turkey;*
Lemna	Lemnaceae			x		dung	Uncharred - associated with wet places	Filipović 2012: 271; *Flora of Turkey* ;
Linum	Linaceae	x	x			weed	Status of linum unclear - possibly a weed - present in fallow fields	Zeist and Bakker-Heeres 1982; *Flora of Turkey* ;
Abutilon type	Malvaceae	x	x			weed/collected	Concentration of seeds in one sample - collected? Also known as a weed.	Petit *et al.* 2011;
Lavatera type	Malvaceae	x				weed	Common arable weed, too large for dung	Filipović 2012: 189; *Flora of Turkey* ;
Malva	Malvaceae	x				weed	Common arable weed, too large for dung	Filipović 2012: 189; *Flora of Turkey* ;
Fumaria	Papaveraceae	x		?		weed	Common arable weed, though could potentially survive in dung	Whitlam 2015;
Glaucium	Papaveraceae	x		?		weed	Common arable weed, though could potentially survive in dung	Whitlam 2015: 143;
Polygonum	Polygonaceae	x		x		weed	Common arable weed but also found associated with dung at Catal	Filipović 2012: 189; Bogaard *et al.* 2013: 103; *Flora of Turkey* ;
Rumex	Polygonaceae	x				weed	Common arable weed	Filipović 2012: 189; *Flora of Turkey* ;
Androsace maxima	Primulaceae	x			x	weed	Considered as a ruderal by Willcox - though could also be a weed - found on cultivated or fallow fields	Willcox 2012: 164; *Flora of Turkey;*
Adonis	Ranunculaceae	x				weed	Common arable weed, too large for dung, no collected use	Filipović 2012: 189; *Flora of Turkey* ;

Latin names	Family	Weed	Collected	Dung	Ruderal	Status	Comments	Reference
Ranunculus type	Ranunculaceae	x				weed	Common arable weed	Filipović 2012: 189; *Flora of Turkey* ;
Asperula	Rubiaceae	x				weed	Common arable weed, though could potentially survive in dung	Whitlam 2015;
Galium (small type)	Rubiaceae	x		?		weed	Common arable weed, though could potentially survive in dung	Whitlam 2015: 373;
Galium tricornutum type	Rubiaceae	x				weed	Common arable weed, too large for dung	Filipović 2012: 189; *Flora of Turkey* ;
Verbascum	Scrophulariaceae	x		?		weed	Common arable weed, though could potentially survive in dung	Stroud 2016: 259; *Flora of Turkey;*
Hyoscyamus	Solanaceae	x			x	ruderal?	Considered as a ruderal by Willcox - though could also be a weed - found in cereal fields	Willcox 2012: 164; *Flora of Turkey;*
Thymelaea passerina	Thymelaeaceae	x				weed	Common arable weed, though could potentially survive in dung	Anderson and Ertug-Yaras 1998;
Tribulus terrestris	Zygophyllaceae	x			x	ruderal?	Considered as a ruderal by Willcox - though could also be a weed - found on fallow fields	Willcox 2012: 164; *Flora of Turkey;*

Appendix 1d – Codes and deposition type for simplified wild taxa data used in correspondence analysis at Çatalhöyük. Species with fewer than two counts are excluded.

Count	Species	Species code	Source (weed/dung/collected)
25	*Polygonum*	Polysp	weed
22	*Bolboschoenus glaucus*	Bolbgla	weed/dung
19	*Vaccaria pyramidata*	Vaccpyr	weed
17	*Convolvulus arvensis* type	Convarv	weed
13	*Bromus*	Bromsp	weed
13	*Taeniatherum caput-medusae*	Taencap	weed
12	*Galium*	Galisp	weed
11	*Phragmites australis*	Phragaus	weed
10	*Juncus*	Juncsp	dung
9	*Carex*	Caresp	weed/dung
8	*Helianthemum*	Heliasp	collected
7	*Hordeum murinum*	Hordmur	weed
6	*Aeluropus*	Aelusp	dung
4	*Cephalaria*	Cephsp	weed
4	*Conringia orientalis*	Conrori	weed
4	*Sideritis* type	Sidesp	weed
4	*Artemisia*	Arteann	dung
4	*Sporobolus*	Sporsp	dung
4	*Teucrium*	Teucsp	collected
3	*Atriplex*	Atrisp	weed
3	*Rumex conglomeratus*	Rumecon	weed
3	*Silene*	Silesp	weed
3	*Thymelaea passerina* type	Thympas	weed
3	*Chenopodium*	Chensp	dung
3	*Crypsis*	Crypsp	dung
3	*Salsola* type	Salssp	dung
2	*Adonis microcarpa*	Adonmic	weed
2	*Cicer*	Cicesp	weed
2	*Eremopyrum bonaepartis* type	Erembon	weed
2	*Malva*	Malvsp	weed
2	*Agrostis* type	Agrosp	dung
2	*Alisma*	Alissp	dung
2	*Eragrostis*	Eragsp	dung
2	*Mentha*	Mentsp	collected

Appendix 1e – Classification of wild/weed taxa into crop-processing physical types.

Taxa	*Family*	*Classification*	
Capparis	Capparaceae	Big-Headed-Heavy	bhh
Onobrychis	Leguminosae	Big-Headed-Heavy	bhh
Lavatera L. type	Malvaceae	Big-Headed-Heavy	bhh
Atriplex rosea type, fruit & *grain*	Amaranthaceae	Big-Free-Heavy	bfh
Atriplex, fruit & *grain*	Amaranthaceae	Big-Free-Heavy	bfh
Convolvulus	Convolvulaceae	Big-Free-Heavy	bfh
Convolvulus arvensis	Convolvulaceae	Big-Free-Heavy	bfh
Cephalaria	Dipsacaceae	Big-Free-Heavy	bfh
Cephalaria/Umbelliferae type	Dipsacaceae/ Umbelliferae	Big-Free-Heavy	bfh
Aegilops	Gramineae	Big-Free-Heavy	bfh
Aegilops/Triticum	Gramineae	Big-Free-Heavy	bfh
Bromus hordeaceus	Gramineae	Big-Free-Heavy	bfh
Eremopyrum bonaepartis type	Gramineae	Big-Free-Heavy	bfh
Taeniatherum caput-medusae	Gramineae	Big-Free-Heavy	bfh
Triticum boeticum	Gramineae	Big-Free-Heavy	bfh
Cicer	Leguminosae	Big-Free-Heavy	bfh
Lathyrus	Leguminosae	Big-Free-Heavy	bfh
Vicia/Lathyrus	Leguminosae	Big-Free-Heavy	bfh
Fumaria	Papaveraceae	Big-Free-Heavy	bfh
Glaucium	Papaveraceae	Big-Free-Heavy	bfh
Polygonum convolvulus	Polygonaceae	Big-Free-Heavy	bfh
Adonis	Ranunculaceae	Big-Free-Heavy	bfh
Adonis aestivalis/annua type	Ranunculaceae	Big-Free-Heavy	bfh
Adonis annua/aestivalis type	Ranunculaceae	Big-Free-Heavy	bfh
Adonis cf. aestivalis	Ranunculaceae	Big-Free-Heavy	bfh
Adonis cf. annua	Ranunculaceae	Big-Free-Heavy	bfh
Adonis cf. microcarpa	Ranunculaceae	Big-Free-Heavy	bfh
Ranunculus type	Ranunculaceae	Big-Free-Heavy	bfh
Galium	Rubiaceae	Big-Free-Heavy	bfh
Galium tricornutum type	Rubiaceae	Big-Free-Heavy	bfh
Tribulus terrestris	Zygophyllaceae	Big-Free-Heavy	bfh
Gypsophila	Caryophyllaceae	Small-Headed-Heavy	shh
Silene	Caryophyllaceae	Small-Headed-Heavy	shh
Silene cf. gallica	Caryophyllaceae	Small-Headed-Heavy	shh
Silene/Gypsophila	Caryophyllaceae	Small-Headed-Heavy	shh
Medicago	Leguminosae	Small-Headed-Heavy	shh
Medicago radiata	Leguminosae	Small-Headed-Heavy	shh
Abutilon type	Malvaceae	Small-Headed-Heavy	shh
Malva	Malvaceae	Small-Headed-Heavy	shh
Thymelaea passerina	Thymelaeaceae	Small-Headed-Heavy	shh
Alyssum/Lepidum	Cruciferae	Small-Headed-Light	shl
Erodium	Geraniaceae	Small-Headed-Light	shl
Hordeum	Gramineae	Small-Headed-Light	shl

Taxa	*Family*	*Classification*	
Hordeum murinum	Gramineae	Small-Headed-Light	shl
Hordeum murinum/bulbosum	Gramineae	Small-Headed-Light	shl
Lolium	Gramineae	Small-Headed-Light	shl
Lolium perenne/rigidum type	Gramineae	Small-Headed-Light	shl
Aizoon	Aizoaceae	Small-Free-Heavy	sfh
Aizoon hianicus	Aizoaceae	Small-Free-Heavy	sfh
Bellevalia	Asparagaceae	Small-Free-Heavy	sfh
Ornithogalum	Asparagaceae	Small-Free-Heavy	sfh
Centaurea	Asteraceae	Small-Free-Heavy	sfh
Arnebia decumbens	Boraginaceae	Small-Free-Heavy	sfh
Heliotropium	Boraginaceae	Small-Free-Heavy	sfh
Valerianella	Caprifoliaceae	Small-Free-Heavy	sfh
Vaccaria pyramidata	Caryophyllaceae	Small-Free-Heavy	sfh
Atriplex	Chenopodiaceae	Small-Free-Heavy	sfh
Chenopodium	Chenopodiaceae	Small-Free-Heavy	sfh
Salsola type	Chenopodiaceae	Small-Free-Heavy	sfh
Suaeda	Chenopodiaceae	Small-Free-Heavy	sfh
Artemisia	Compositae	Small-Free-Heavy	sfh
Artemisia annua type	Compositae	Small-Free-Heavy	sfh
Brassica	Cruciferae	Small-Free-Heavy	sfh
Conringia orientalis	Cruciferae	Small-Free-Heavy	sfh
Conringia type	Cruciferae	Small-Free-Heavy	sfh
Cruciferae	Cruciferae	Small-Free-Heavy	sfh
Bolboschoenus glaucus	Cyperaceae	Small-Free-Heavy	sfh
Carex	Cyperaceae	Small-Free-Heavy	sfh
Scirpus cf. lacustris	Cyperaceae	Small-Free-Heavy	sfh
Scirpus type	Cyperaceae	Small-Free-Heavy	sfh
Scirpus/Eleocharis	Cyperaceae	Small-Free-Heavy	sfh
Geranium type	Geraniaceae	Small-Free-Heavy	sfh
Agrostis type	Gramineae	Small-Free-Heavy	sfh
Echinaria	Gramineae	Small-Free-Heavy	sfh
Eragrostis	Gramineae	Small-Free-Heavy	sfh
Phalaris	Gramineae	Small-Free-Heavy	sfh
Phragmites	Gramineae	Small-Free-Heavy	sfh
Phragmites australis	Gramineae	Small-Free-Heavy	sfh
Poa bulbosa	Gramineae	Small-Free-Heavy	sfh
Stipa	Gramineae	Small-Free-Heavy	sfh
Sideritis type	Labiatae	Small-Free-Heavy	sfh
Teucrium	Labiatae	Small-Free-Heavy	sfh
Ajuga/Teucrium	Lamiaceae	Small-Free-Heavy	sfh
Ziziphora	Lamiaceae	Small-Free-Heavy	sfh
Astragalus	Leguminosae	Small-Free-Heavy	sfh
cf. Trifolium	Leguminosae	Small-Free-Heavy	sfh
Coronilla	Leguminosae	Small-Free-Heavy	sfh
Leguminosae, small-seeded	Leguminosae	Small-Free-Heavy	sfh
Melilotus	Leguminosae	Small-Free-Heavy	sfh

Taxa	*Family*	*Classification*	
Trigonella	Leguminosae	Small-Free-Heavy	sfh
Trigonella astroites	Leguminosae	Small-Free-Heavy	sfh
Plantago	Plantaginaceae	Small-Free-Heavy	sfh
Polygonum	Polygonaceae	Small-Free-Heavy	sfh
Polygonum aviculare	Polygonaceae	Small-Free-Heavy	sfh
Polygonum/Rumex	Polygonaceae	Small-Free-Heavy	sfh
Rumex conglomeratus	Polygonaceae	Small-Free-Heavy	sfh
Rumex crispus type	Polygonaceae	Small-Free-Heavy	sfh
Androsace maxima	Primulaceae	Small-Free-Heavy	sfh
Asperula	Rubiaceae	Small-Free-Heavy	sfh
Asperula, small type	Rubiaceae	Small-Free-Heavy	sfh
Galium spurium/odoratum type	Rubiaceae	Small-Free-Heavy	sfh
Galium, small type	Rubiaceae	Small-Free-Heavy	sfh
Galium, tiny type	Rubiaceae	Small-Free-Heavy	sfh
Hyoscyamus	Solanaceae	Small-Free-Heavy	sfh
Alisma	Alismataceae	Small-Free-Light	sfl
Helianthemum	Cistaceae	Small-Free-Light	sfl
Aeluropus	Gramineae	Small-Free-Light	sfl
Bromus	Gramineae	Small-Free-Light	sfl
Bromus danthoniae	Gramineae	Small-Free-Light	sfl
Bromus japonicus	Gramineae	Small-Free-Light	sfl
Bromus sterilis	Gramineae	Small-Free-Light	sfl
Bromus tectorum/sterilis type	Gramineae	Small-Free-Light	sfl
cf. Alopecurus	Gramineae	Small-Free-Light	sfl
Crypsis	Gramineae	Small-Free-Light	sfl
Sporobolus	Gramineae	Small-Free-Light	sfl
Stipagrostis type	Gramineae	Small-Free-Light	sfl
Juncus	Juncaceae	Small-Free-Light	sfl
Mentha	Labiatae	Small-Free-Light	sfl
Linum	Linaceae	Small-Free-Light	sfl
Verbascum	Scrophulariaceae	Small-Free-Light	sfl

Appendix 1f – Raw data table for the 33 crop stores from Çatalhöyük.

				1	2	3	4	5	6	7	8	9	10	11
	Area			South	South	South	South	South	TPC	TPC	TPC	TPC	North	North
	Unit number			18596	18598	18945	18949	18952	30785	30859	30871	22709	1314	1344
	Sample number			2	2				3	11	4	3		
	Flot number			**9176**	**9159**	**9256**	**9255**	**9271**	**10922**	**10921**	**10961**	**11922**	**171.329**	**144**
	Hodder Level			South.O	South.O	South.O	South.O	South.O	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	North.G	North.G
	Building			79	79	80	80	80	122	122	122	122	1	1
	Internal Space			134	134	135	135	135	493	493	493	493	71	71
	Feature			-	5031	3435	-	-	7182	7182	7198	7198	215	215
	Fraction of total sample			1	1	0.5	1	0.5	0.5	0.25	0.0625	0.25	1	0.5
	[Adjusted] soil volume (l)			12	2	2	2	7	2.5	1.25	0.5	3.75	50	21
	Density items/litre			223.2	1087.5	1075.7	214.7	107.2	8241.8	25704.6	10878.8	440.3	10.9	2093.5
	Density items/litre (exc. Desc.)			213.9	1015.5	1055.7	214.7	107.2	8225.8	25704.6	10566.8	406.2	10.9	2093.5
	Multiplication factor			1	1	2	1	2	2	4	16	4	1	2
	Total crop			837.4	770	2021.8	336	616.9	20455.6	32032.5	5248	1355.5	463	43781
	Total wild (excl. desc)			1725	1261	89	91	123	101	95	27	165.1	74	179
COUNT		**Latin names**	**Family**											
	Non-seed/fruit/chaff material													
6	>2 mm dung (ml)													
1	>2 mm cf. dung (ml)													
4	>2 mm tuber (ml)					0.5								
2	>2 mm fish bone charred mass (ml)													
2	>2 mm burnt cereal mass (ml)			1				4.5						
1	>2 mm fruit/bread											0.5		
1	<2 mm tuber (ml)													
4	<2 mm stalk indet.			1					8	2				
1	cf. Monocot root													
8	Mouse pellets			1			2	2.5						
	Cereals													
26	Naked barley grain	*Hordeum vulgare var. nudum*	Gramineae	4		1357.5	2	6	10944	19200.5	3912	300	1	
3	cf. Naked barley grain	*Hordeum vulgare var. nudum*	Gramineae		1									
4	Naked barley grain, fused	*Hordeum vulgare var. nudum*	Gramineae			3						28.75		
8	Naked barley grain, straight	*Hordeum vulgare var. nudum*	Gramineae			501			7968	12769	1304			
2	Naked barley grain, twisted	*Hordeum vulgare var. nudum*	Gramineae											
4	cf. Naked barley grain, twisted	*Hordeum vulgare var. nudum*	Gramineae			8			96	32				
1	Naked barley grain indet., with spikelet attached	*Hordeum vulgare var. nudum*	Gramineae											
2	Hulled barley grain	*Hordeum vulgare*	Gramineae											
3	cf. Hulled barley grain	*Hordeum vulgare*	Gramineae									8		
18	Barley grain indeterminate	*Hordeum*	Gramineae	4								112	11	1
3	cf. Barley grain indeterminate	*Hordeum*	Gramineae											
4	Wizened barley grain/ wild barley	*Hordeum*	Gramineae			24		2	4		8			
5	Naked 6-row barley rachis	*Hordeum vulgare convar. vulgare var. nudum*	Gramineae			6								
14	Naked 2-row barley rachis	*Hordeum vulgare convar. distichon var. nudum*	Gramineae			24			8	6	1	1	4	8
1	Naked 2-row barley, basal rachis	*Hordeum vulgare convar. distichon var. nudum*	Gramineae						4					
2	Naked barley rachis indeterminate	*Hordeum vulgare convar. vulgare var. nudum*	Gramineae			8						112		
12	Barley rachis indeterminate	*Hordeum*	Gramineae			4				6			9	
14	Free-threshing wheat grain	*Triticum aestivum/durum*	Gramineae	14	14		15						5	1
1	Free-threshing wheat grain, fused	*Triticum aestivum/durum*	Gramineae											
7	cf. Free-threshing wheat grain	*Triticum aestivum/durum*	Gramineae	11	28								7	
11	Bread wheat rachis	*Triticum aestivum*	Gramineae	23		16	27					2		
4	Free-threshing wheat indet. rachis	*Triticum aestivum/durum*	Gramineae	22		2	6							
7	Free-threshing wheat indet., basal rachis	*Triticum aestivum/durum*	Gramineae										1	
7	Einkorn grain, one-seeded type	*Triticum monococcum*	Gramineae	2				2					3	
2	cf. Einkorn grain, one-seeded type	*Triticum monococcum*	Gramineae						4					
3	Einkorn grain, one-seeded possible wild type	*Triticum boeticum/monococcum*	Gramineae											1
5	Einkorn grain, two-seeded type	*Triticum monococcum*	Gramineae									2		

				1	2	3	4	5	6	7	8	9	10	11
	Area			South	South	South	South	South	TPC	TPC	TPC	TPC	North	North
	Unit number			18596	18598	18945	18949	18952	30785	30859	30871	22709	1314	1344
	Sample number			2	2				3	11	4	3		
	Flot number			**9176**	**9159**	**9256**	**9255**	**9271**	**10922**	**10921**	**10961**	**11922**	**171.329**	**144**
	Hodder Level			South.O	South.O	South.O	South.O	South.O	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	North.G	North.G
	Building			79	79	80	80	80	122	122	122	122	1	1
	Internal Space			134	134	135	135	135	493	493	493	493	71	71
	Feature			-	5031	3435	-	-	7182	7182	7198	7198	215	215
	Fraction of total sample			1	1	0.5	1	0.5	0.5	0.25	0.0625	0.25	1	0.5
	[Adjusted] soil volume (l)			12	2	2	2	7	2.5	1.25	0.5	3.75	50	21
	Density items/litre			223.2	1087.5	1075.7	214.7	107.2	8241.8	25704.6	10878.8	440.3	10.9	2093.5
	Density items/litre (exc. Desc.)			213.9	1015.5	1055.7	214.7	107.2	8225.8	25704.6	10566.8	406.2	10.9	2093.5
	Multiplication factor			1	1	2	1	2	2	4	16	4	1	2
	Total crop			837.4	770	2021.8	336	616.9	20455.6	32032.5	5248	1355.5	463	43781
	Total wild (excl. desc)			1725	1261	89	91	123	101	95	27	165.1	74	179
COUNT		**Latin names**	**Family**											
6	Einkorn/emmer grain	*Triticum monococcum/dicoccum*	Gramineae	2									21	1
8	Emmer grain	*Triticum dicoccum*	Gramineae	18	106		16	16						
4	cf. Emmer grain	*Triticum dicoccum*	Gramineae	72	111		8							
2	Emmer/ "New type" glume wheat grain	*Triticum dicoccum/sp.*	Gramineae						32		8			
6	"New Type" glume wheat grain	*Triticum sp.*	Gramineae						220			4		
2	cf. "New type" glume wheat grain	*Triticum sp.*	Gramineae						116			2		
1	"New Type" glume wheat grain, in spikelet pairs	*Triticum sp.*	Gramineae											
9	Glume wheat grain indeterminate, two seeded	*Triticum monococcum/dicoccum/sp.*	Gramineae	64	83	2	33		56			36		
9	Glume wheat grain indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae									4		
5	Einkorn glume bases	*Triticum monococcum*	Gramineae									56		
2	cf. Einkorn glume bases	*Triticum monococcum*	Gramineae											
10	Einkorn/emmer glume bases	*Triticum monococcum /dicoccum*	Gramineae											
16	Emmer glume bases	*Triticum dicoccum*	Gramineae	22		8	24					72.25	8	3
4	cf. Emmer glume bases	*Triticum dicoccum*	Gramineae	2			4							
15	Emmer/ "New Type" glume bases	*Triticum sp./dicoccum*	Gramineae	12		4	2	44		2		22.25	1	13
4	Emmer/ "New Type" glume bases, basal	*Triticum sp./dicoccum*	Gramineae				2						1	1
2	Emmer/ "New Type" glume bases, terminal	*Triticum sp./dicoccum*	Gramineae					4			2			
17	"New Type" glume bases	*Triticum sp.*	Gramineae						248			66	5	1
4	cf. "New Type" glume bases	*Triticum sp.*	Gramineae						20		3			
1	"New Type" glume bases, terminal spikelet	*Triticum sp.*	Gramineae						24					
1	"New Type" glume bases, phytolith	*Triticum sp.*	Gramineae						20					
21	Glume wheat chaff indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae	71		10	77	18	680	8	9	492	41	23
1	cf. Glume wheat chaff indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae											
15	Terminal glume bases	*Triticum dicoccum/sp.*	Gramineae									24	2	2
25	Wheat indeterminate grain	*Triticum*	Gramineae	465	425		120	6	4	1		4	29	3
1	cf. Wheat indeterminate grain	*Triticum*	Gramineae											
15	Cereal indeterminate grain		Gramineae	20				8				4	246	
1	cf. Cereal indeterminate grain		Gramineae											
3	Large grass indeterminate grain		Gramineae	4	2			2						
2	Cereal type culm node		Gramineae								1			
2	Small grass culm		Gramineae											
6	Cereal/grass culm/rachis 'join'/node		Gramineae	3		4			4	8				
3	Culm bases indeterminate		Gramineae											
2	Culm indeterminate		Gramineae											
	Pulses													
5	Bitter vetch	*Vicia ervilia*	Leguminosae									1		
1	cf. Bitter vetch	*Vicia ervilia*	Leguminosae											
2	Chickpea	*Cicer arietinum*	Leguminosae											
12	Lentil	*Lens culinaris*	Leguminosae									1	66	43696

				1	2	3	4	5	6	7	8	9	10	11
	Area			South	South	South	South	South	TPC	TPC	TPC	TPC	North	North
	Unit number			18596	18598	18945	18949	18952	30785	30859	30871	22709	1314	1344
	Sample number			2	2				3	11	4	3		
	Flot number			**9176**	**9159**	**9256**	**9255**	**9271**	**10922**	**10921**	**10961**	**11922**	**171.329**	**144**
	Hodder Level			South.O	South.O	South.O	South.O	South.O	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	North.G	North.G
	Building			79	79	80	80	80	122	122	122	122	1	1
	Internal Space			134	134	135	135	135	493	493	493	493	71	71
	Feature			-	5031	3435	-	-	7182	7182	7198	7198	215	215
	Fraction of total sample			1	1	0.5	1	0.5	0.5	0.25	0.0625	0.25	1	0.5
	[Adjusted] soil volume (l)			12	2	2	2	7	2.5	1.25	0.5	3.75	50	21
	Density items/litre			223.2	1087.5	1075.7	214.7	107.2	8241.8	25704.6	10878.8	440.3	10.9	2093.5
	Density items/litre (exc. Desc.)			213.9	1015.5	1055.7	214.7	107.2	8225.8	25704.6	10566.8	406.2	10.9	2093.5
	Multiplication factor			1	1	2	1	2	2	4	16	4	1	2
	Total crop			837.4	770	2021.8	336	616.9	20455.6	32032.5	5248	1355.5	463	43781
	Total wild (excl. desc)			1725	1261	89	91	123	101	95	27	165.1	74	179
COUNT		**Latin names**	**Family**											
1	Lentil stalks	*Leguminosae*	Leguminosae											27
15	Pea	*Pisum sativum*	Leguminosae			12.5		164.5				1.25		
3	cf. Pea	*Pisum sativum*	Leguminosae			19.5		262.5						
1	Pea testa with hilum	*Pisum sativum*	Leguminosae											
4	cf. Pea pod (frags)	*Pisum sativum*	Leguminosae	2.4		0.3		3.9	3.6					
8	Vicia/Lathyrus type	*Vicia/Lathyrus*	Leguminosae											
1	cf. Vicia/Lathyrus type	*Vicia/Lathyrus*	Leguminosae											
4	Large legume	*Leguminosae*	Leguminosae			4								
9	Pulse indeterminate	*Leguminosae*	Leguminosae			4		78					2	
	Fruit/nut taxa													
6	Pistachio nutshell	*Pistacia*	Anacardiaceae									2		
3	Pistacia-like nutshell	*Pistacia*	Anacardiaceae									0.1		
3	Terebinth	*Pistacia terebinthus*	Anacardiaceae										3	1
3	Acorn nutshell	*Quercus*	Fagaceae										5	
1	Acorn kernel	*Quercus*	Fagaceae											
3	Almond, whole	*Amygdalus*	Rosaceae											
1	Almond, kernel	*Amygdalus*	Rosaceae					1						
5	Almond nutshell	*Amygdalus*	Rosaceae											
5	Almond/plum	*Amygdalus/Prunus*	Rosaceae					1						
13	Hackberry	*Celtis*	Ulmaceae					0.5					1	2
7	Nutshell indeterminate			0.05			0.4	0.3			0.4		0.05	
10	Fruitstone/nutshell													
4	Fruit skin (frags)			1.2		0.1		0.4		1.2				
	Other wild taxa													
1		*Bellevalia*	Asparagaceae											
2		*Alisma*	Alismataceae											
1		Boraginaceae	Boraginaceae						1					
1		cf. Boraginaceae, silicified	Boraginaceae				1							
1		*cf. Heliotropium*	Boraginaceae											
1		*Lithospermum,* silicified	Boraginaceae											
3		*Silene*	Caryophyllaceae											17
3		*cf. Vaccaria*	Caryophyllaceae									3		
17		*Vaccaria pyramidata*	Caryophyllaceae					8	27	50			1	
2		*cf. Vaccaria pyramidata*	Caryophyllaceae								12			
2		Caryophyllaceae	Caryophyllaceae					8						
3		*Atriplex*	Chenopodiaceae					8						
3		*Chenopodium*	Chenopodiaceae											
3		*Salsola type*	Chenopodiaceae									68	1	

				1	2	3	4	5	6	7	8	9	10	11
	Area			South	South	South	South	South	TPC	TPC	TPC	TPC	North	North
	Unit number			18596	18598	18945	18949	18952	30785	30859	30871	22709	1314	1344
	Sample number			2	2				3	11	4	3		
	Flot number			**9176**	**9159**	**9256**	**9255**	**9271**	**10922**	**10921**	**10961**	**11922**	**171.329**	**144**
	Hodder Level			South.O	South.O	South.O	South.O	South.O	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	North.G	North.G
	Building			79	79	80	80	80	122	122	122	122	1	1
	Internal Space			134	134	135	135	135	493	493	493	493	71	71
	Feature			-	5031	3435	-	-	7182	7182	7198	7198	215	215
	Fraction of total sample			1	1	0.5	1	0.5	0.5	0.25	0.0625	0.25	1	0.5
	[Adjusted] soil volume (l)			12	2	2	2	7	2.5	1.25	0.5	3.75	50	21
	Density items/litre			223.2	1087.5	1075.7	214.7	107.2	8241.8	25704.6	10878.8	440.3	10.9	2093.5
	Density items/litre (exc. Desc.)			213.9	1015.5	1055.7	214.7	107.2	8225.8	25704.6	10566.8	406.2	10.9	2093.5
	Multiplication factor			1	1	2	1	2	2	4	16	4	1	2
	Total crop			837.4	770	2021.8	336	616.9	20455.6	32032.5	5248	1355.5	463	43781
	Total wild (excl. desc)			1725	1261	89	91	123	101	95	27	165.1	74	179
COUNT		**Latin names**	**Family**											
1		*Suaeda*	Chenopodiaceae											
8		Chenopodiaceae	Chenopodiaceae										9	1
1		cf. Chenopodiaceae	Chenopodiaceae		8									
3		Chenopodiaceae [cores]	Chenopodiaceae	8								8		
2		Chenopodiaceae/Caryophyllaceae											17	
8		*Helianthemum*	Cistaceae	1488	1075			8						
1		cf. Cistaceae	Cistaceae											
3		*Artemisia*	Compositae											
1		*Artemisia annua type*	Compositae											
1		*cf. Centaurea*	Compositae											
2		Compositae	Compositae											
1		Compositae, small	Compositae											
1		Compositae, small long linear type	Compositae											
1		Compositae, flat linear ridge type	Compositae											
1		Compositae, large long linear type	Compositae											
8		*Convolvulus*	Convolvulaceae									3		
6		*cf. Convolvulus*	Convolvulaceae			1			1	1				
1		*Convolvulus* type	Convolvulaceae											
7		*Convolvulus arvensis* type	Convolvulaceae						6	4			2	75
1		*Conringia orientalis*	Cruciferae											
3		*Conringia type*	Cruciferae	16	32			1						
5		Cruciferae	Cruciferae				72	1						
3		Cruciferae, large type	Cruciferae									2		
1		Cruciferae, medium type	Cruciferae											
2		Cruciferae, medium (linear pattern)	Cruciferae	12				1						
1		Cruciferae, medium (type 2 - patterned)	Cruciferae						1					
1		Cruciferae, small	Cruciferae											
23		Cruciferae, small (*Descurainia sophia* et al.)	Cruciferae	112	144	40			40		156	128		
1		Cruciferae, v. small round type	Cruciferae								8			
1		Cruciferae, round type	Cruciferae					8						
1		Crucifer, flanged type	Cruciferae											
2		Cruciferae pod	Cruciferae								1			
2		Cruciferae, pod - linear groove	Cruciferae	1										
22		*Bolboschoenus glaucus*	Cyperaceae	12		2	1	4	1			7	4	3
1		*Bolboschoenus glaucus, in dung*	Cyperaceae											
1		*Bolboschoenus glaucus, mineralised*	Cyperaceae											
9		*Carex*	Cyperaceae	8			1							
5		Cyperaceae	Cyperaceae											
1		*Scirpus/Eleocharis*	Cyperaceae											

				1	2	3	4	5	6	7	8	9	10	11
	Area			South	South	South	South	South	TPC	TPC	TPC	TPC	North	North
	Unit number			18596	18598	18945	18949	18952	30785	30859	30871	22709	1314	1344
	Sample number			2	2				3	11	4	3		
	Flot number			**9176**	**9159**	**9256**	**9255**	**9271**	**10922**	**10921**	**10961**	**11922**	**171.329**	**144**
	Hodder Level			South.O	South.O	South.O	South.O	South.O	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	North.G	North.G
	Building			79	79	80	80	80	122	122	122	122	1	1
	Internal Space			134	134	135	135	135	493	493	493	493	71	71
	Feature			-	5031	3435	-	-	7182	7182	7198	7198	215	215
	Fraction of total sample			1	1	0.5	1	0.5	0.5	0.25	0.0625	0.25	1	0.5
	[Adjusted] soil volume (l)			12	2	2	2	7	2.5	1.25	0.5	3.75	50	21
	Density items/litre			223.2	1087.5	1075.7	214.7	107.2	8241.8	25704.6	10878.8	440.3	10.9	2093.5
	Density items/litre (exc. Desc.)			213.9	1015.5	1055.7	214.7	107.2	8225.8	25704.6	10566.8	406.2	10.9	2093.5
	Multiplication factor			1	1	2	1	2	2	4	16	4	1	2
	Total crop			837.4	770	2021.8	336	616.9	20455.6	32032.5	5248	1355.5	463	43781
	Total wild (excl. desc)			1725	1261	89	91	123	101	95	27	165.1	74	179
COUNT		**Latin names**	**Family**											
2		*Cephalaria*	Dipsacaceae											
2		*Cephalaria*/Umbelliferae Type	Dipsacaceae/Umbelliferae				2							
1		cf. Dipsacaceae	Dipsacaceae					1						
1		*Geranium* type	Geraniaceae					1						
1		*Aegilops*	Gramineae					1						
1		*Aegilops/Triticum*	Gramineae											
6		*Aeluropus*	Gramineae											
1		*cf. Alopecurus*	Gramineae											
2		*Agrostis* sp type	Gramineae											
3		*Bromus*	Gramineae											2
9		*Bromus danthoniae*	Gramineae			1		1		1			2	
1		*Bromus hordeaceus*	Gramineae						1					
3		*Crypsis*	Gramineae					8						
2		*Eragrostis*	Gramineae		24									
2		*Eremopyrum bonaepartis* type	Gramineae					3						
3		Gramineae	Gramineae											
5		Gramineae, large indeterminate	Gramineae										2	
1		Gramineae, medium laterally flattened type	Gramineae											
2		Gramineae, rachis indeterminate	Gramineae		8									
3		Gramineae, small	Gramineae											
5		Gramineae, small round type	Gramineae	144		16					8			
6		Gramineae, small elongated type	Gramineae			48			8			24		
1		Gramineae, small pointed type	Gramineae											
1		Gramineae, small striped type (Check Poa?)	Gramineae			8								
2		Gramineae, small indeterminate	Gramineae											
3		*Hordeum*	Gramineae											
6	Weed barley	*Hordeum murinum*	Gramineae			1				1		2	1	
1	cf. Weed barley	*cf. Hordeum murinum*	Gramineae											
1		*cf. Phalaris*	Gramineae					8						
9	Reed culm nodes	*Phragmites*	Gramineae							8		0.1		
2		*Phragmites australis*	Gramineae											2
4		*Sporobolus*	Gramineae										16	
1		*Stipagrostis type*	Gramineae											
12	Taeniatherum grain	*Taeniatherum caput-medusae*	Gramineae	1				5	2	1	1	8		
4	cf. Taeniatherum grain	*Taeniatherum caput-medusae*	Gramineae			1				2	1	2		
2	Taeniatherum rachis	*Taeniatherum caput-medusae*	Gramineae											
1	Wild einkorn grain	*Triticum boeticum*	Gramineae									15		
10		*Juncus*	Juncaceae		8								8	
4		Labiatae	Labiatae											
2		Labiatae type - spked/bumpy, oblong	Labiatae											

				1	2	3	4	5	6	7	8	9	10	11
	Area			South	South	South	South	South	TPC	TPC	TPC	TPC	North	North
	Unit number			18596	18598	18945	18949	18952	30785	30859	30871	22709	1314	1344
	Sample number			2	2				3	11	4	3		
	Flot number			**9176**	**9159**	**9256**	**9255**	**9271**	**10922**	**10921**	**10961**	**11922**	**171.329**	**144**
	Hodder Level			South.O	South.O	South.O	South.O	South.O	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	TPC.Late Neo	North.G	North.G
	Building			79	79	80	80	80	122	122	122	122	1	1
	Internal Space			134	134	135	135	135	493	493	493	493	71	71
	Feature			-	5031	3435	-	-	7182	7182	7198	7198	215	215
	Fraction of total sample			1	1	0.5	1	0.5	0.5	0.25	0.0625	0.25	1	0.5
	[Adjusted] soil volume (l)			12	2	2	2	7	2.5	1.25	0.5	3.75	50	21
	Density items/litre			223.2	1087.5	1075.7	214.7	107.2	8241.8	25704.6	10878.8	440.3	10.9	2093.5
	Density items/litre (exc. Desc.)			213.9	1015.5	1055.7	214.7	107.2	8225.8	25704.6	10566.8	406.2	10.9	2093.5
	Multiplication factor			1	1	2	1	2	2	4	16	4	1	2
	Total crop			837.4	770	2021.8	336	616.9	20455.6	32032.5	5248	1355.5	463	43781
	Total wild (excl. desc)			1725	1261	89	91	123	101	95	27	165.1	74	179
COUNT		**Latin names**	**Family**											
2		*Mentha*	Labiatae					8						
4		*Sideritis type*	Labiatae											53
4		*Teucrium*	Labiatae											
2		*Cicer*	Leguminosae	3										
12		Leguminosae, small-seeded	Leguminosae	16		1	1	1	8				2	1
3		*Lemna* , silicified	Lemnaceae			8	8		8					
1		*cf. Linum*	Linaceae											
2		Malvaceae	Malvaceae										2	
3		Malvaceae, large type	Malvaceae				1	2						
2		*Malva*	Malvaceae										1	
1		*Lavatera* type	Malvaceae										1	
1		*Fumaria*	Papaveraceae											
1		Papaveraceae	Papaveraceae		56									
2		Polygonaceae	Polygonaceae											
1		cf. Polygonaceae	Polygonaceae											
11		*Polygonum*	Polygonaceae	8					1					
4		*cf. Polygonum*	Polygonaceae					8						
14		*Polygonum aviculare*	Polygonaceae		1		1	1	3	9			2	24
3		*Polygonum cf. aviculare*	Polygonaceae									1		
6		*Polygonum convolvulus*	Polygonaceae						11	9	4	2		
4		*cf. Polygonum convulvulus*	Polygonaceae						2			11		
1		*cf. Rumex*	Polygonaceae											
2		*Rumex conglomeratus*	Polygonaceae											
1		*cf. Androsace maxima*	Primulaceae											
2		*Adonis cf. microcarpa*	Ranunculaceae					4						
1		*Ranunculus type*	Ranunculaceae											
1		*Asperula* small type	Rubiaceae									8		
7		*Galium tricornutum* type	Rubiaceae						9				2	1
2		*Galium spurium/odoratum* type	Rubiaceae									1		
1		*Galium sp.* (tiny type)	Rubiaceae						8					
3		*cf. Galium*	Rubiaceae			1	1							
3		*Thymelaea passerina*	Thymelaeaceae										1	
3		Umbelliferae	Umbelliferae											
1		cf. Umbelliferae	Umbelliferae											
2		cf. Umbelliferae/Dipsacaceae	Umbelliferae/Dipsacaceae											
12	Unidentified wild seed		Unknown	8		1	1	24	3	9				
13	Potentially identifiable seed		Unknown		49		1							
1	Capsule/Pod/Bud		Unknown											

				12	13	14	15	16	17	18	19	20	21	22
	Area			North	North	North	IST	IST	IST	IST	4040	4040	4040	4040
	Unit number			1349	1442	1442	11866	12417	13919	13962	10309	11900	11903	11908
	Sample number						4		1		1	5	4	1
	Flot number			**135**	**516**	**535**	**6638**	**6594, 6641**	**7906**	**8048,8049,8205**	**6026**	**6019**	**6052**	**6049**
	Hodder Level			North.G	North.G	North.G	South.Q-T	South.Q-T	South.Q-T	South.Q-T	North.G	North.G	North.G	North.G
	Building			1	1	1	63	63	63	63	52	52	52	52
	Internal Space			188	187	187	283	283	283	283	93	93	93	93
	Feature			27	34	34	1967	1984	2330	1967	-	2002	2002	2002
	Fraction of total sample			1	0.5	0.25	1	1	1	1	0.125	1	0.25	0.25
	[Adjusted] soil volume (l)			8.5	28	37	4	58	8	9	0.075	17	5.75	0.8375
	Density items/litre			35.3	24.2	24.6	447.3	10.4	1174.8	1492.6	38828.0	3311.0	4602.2	1360.6
	Density items/litre (exc. Desc.)			35.3	24.2	24.6	446.8	10.2	1174.8	1492.6	5494.7	369.7	254.4	1341.5
	Multiplication factor			1	2	4	1	1	1	1	8	1	4	4
	Total crop			204	591	805	1656	465.5	7964	13010	400	6194	1417.75	1064
	Total wild (excl. desc)			96	86	101	129	114.5	1414	418	12	83	20	16.5
COUNT		**Latin names**	**Family**											
	Non-seed/fruit/chaff material													
6	>2 mm dung (ml)						0.1		1	0.1				
1	>2 mm cf. dung (ml)								0.1					
4	>2 mm tuber (ml)								0.1					
2	>2 mm fish bone charred mass (ml)													
2	>2 mm burnt cereal mass (ml)													
1	>2 mm fruit/bread													
1	<2 mm tuber (ml)													
4	<2 mm stalk indet.													
1	cf. Monocot root								2					
8	Mouse pellets								0.1					
	Cereals													
26	Naked barley grain	*Hordeum vulgare var. nudum*	Gramineae	2	19	4	1431	276	3778	8827	8	5960	1184	
3	cf. Naked barley grain	*Hordeum vulgare var. nudum*	Gramineae				75	27						
4	Naked barley grain, fused	*Hordeum vulgare var. nudum*	Gramineae							77			201.25	
8	Naked barley grain, straight	*Hordeum vulgare var. nudum*	Gramineae		6									
2	Naked barley grain, twisted	*Hordeum vulgare var. nudum*	Gramineae					10	70					
4	cf. Naked barley grain, twisted	*Hordeum vulgare var. nudum*	Gramineae				11							
1	Naked barley grain indet., with spikelet attached	*Hordeum vulgare var. nudum*	Gramineae									1		
2	Hulled barley grain	*Hordeum vulgare*	Gramineae				1	3						
3	cf. Hulled barley grain	*Hordeum vulgare*	Gramineae				13	7						
18	Barley grain indeterminate	*Hordeum*	Gramineae	4	179	98	50	51.5	78	75		2		
3	cf. Barley grain indeterminate	*Hordeum*	Gramineae				2		1905	2231				
4	Wizened barley grain/ wild barley	*Hordeum*	Gramineae											
5	Naked 6-row barley rachis	*Hordeum vulgare convar. vulgare var. nudum*	Gramineae											
14	Naked 2-row barley rachis	*Hordeum vulgare convar. distichon var. nudum*	Gramineae			1						1		
1	Naked 2-row barley, basal rachis	*Hordeum vulgare convar. distichon var. nudum*	Gramineae											
2	Naked barley rachis indeterminate	*Hordeum vulgare convar. vulgare var. nudum*	Gramineae											
12	Barley rachis indeterminate	*Hordeum*	Gramineae	2	1	2								
14	Free-threshing wheat grain	*Triticum aestivum/durum*	Gramineae	4				4	72		214	2	24	572
1	Free-threshing wheat grain, fused	*Triticum aestivum/durum*	Gramineae											3
7	cf. Free-threshing wheat grain	*Triticum aestivum/durum*	Gramineae	10	17	1			118					
11	Bread wheat rachis	*Triticum aestivum*	Gramineae									8		
4	Free-threshing wheat indet. rachis	*Triticum aestivum/durum*	Gramineae									3		
7	Free-threshing wheat indet., basal rachis	*Triticum aestivum/durum*	Gramineae		1									0.5
7	Einkorn grain, one-seeded type	*Triticum monococcum*	Gramineae		1				1					
2	cf. Einkorn grain, one-seeded type	*Triticum monococcum*	Gramineae	2										
3	Einkorn grain, one-seeded possible wild type	*Triticum boeticum/monococcum*	Gramineae		1									
5	Einkorn grain, two-seeded type	*Triticum monococcum*	Gramineae		1									

				12	13	14	15	16	17	18	19	20	21	22
	Area			North	North	North	IST	IST	IST	IST	4040	4040	4040	4040
	Unit number			1349	1442	1442	11866	12417	13919	13962	10309	11900	11903	11908
	Sample number						4		1		1	5	4	1
	Flot number			**135**	**516**	**535**	**6638**	**6594, 6641**	**7906**	**8048,8049,8205**	**6026**	**6019**	**6052**	**6049**
	Hodder Level			North.G	North.G	North.G	South.Q-T	South.Q-T	South.Q-T	South.Q-T	North.G	North.G	North.G	North.G
	Building			1	1	1	63	63	63	63	52	52	52	52
	Internal Space			188	187	187	283	283	283	283	93	93	93	93
	Feature			27	34	34	1967	1984	2330	1967	-	2002	2002	2002
	Fraction of total sample			1	0.5	0.25	1	1	1	1	0.125	1	0.25	0.25
	[Adjusted] soil volume (l)			8.5	28	37	4	58	8	9	0.075	17	5.75	0.8375
	Density items/litre			35.3	24.2	24.6	447.3	10.4	1174.8	1492.6	38828.0	3311.0	4602.2	1360.6
	Density items/litre (exc. Desc.)			35.3	24.2	24.6	446.8	10.2	1174.8	1492.6	5494.7	369.7	254.4	1341.5
	Multiplication factor			1	2	4	1	1	1	1	8	1	4	4
	Total crop			204	591	805	1656	465.5	7964	13010	400	6194	1417.75	1064
	Total wild (excl. desc)			96	86	101	129	114.5	1414	418	12	83	20	16.5
COUNT		**Latin names**	**Family**											
6	Einkorn/emmer grain	*Triticum monococcum/dicoccum*	Gramineae	18	11	9								
8	Emmer grain	*Triticum dicoccum*	Gramineae			1								
4	cf. Emmer grain	*Triticum dicoccum*	Gramineae		3									
2	Emmer/ "New type" glume wheat grain	*Triticum dicoccum/sp.*	Gramineae											
6	"New Type" glume wheat grain	*Triticum sp.*	Gramineae									1		
2	cf. "New type" glume wheat grain	*Triticum sp.*	Gramineae											
1	"New Type" glume wheat grain, in spikelet pairs	*Triticum sp.*	Gramineae											
9	Glume wheat grain indeterminate, two seeded	*Triticum monococcum/dicoccum/sp.*	Gramineae					4	4	32				
9	Glume wheat grain indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae											
5	Einkorn glume bases	*Triticum monococcum*	Gramineae					2						
2	cf. Einkorn glume bases	*Triticum monococcum*	Gramineae					1						
10	Einkorn/emmer glume bases	*Triticum monococcum /dicoccum*	Gramineae								2			
16	Emmer glume bases	*Triticum dicoccum*	Gramineae	16	34	51						6		
4	cf. Emmer glume bases	*Triticum dicoccum*	Gramineae									2		
15	Emmer/ "New Type" glume bases	*Triticum sp./dicoccum*	Gramineae	26	91	115		1	16			35		
4	Emmer/ "New Type" glume bases, basal	*Triticum sp./dicoccum*	Gramineae			2								
2	Emmer/ "New Type" glume bases, terminal	*Triticum sp./dicoccum*	Gramineae											
17	"New Type" glume bases	*Triticum sp.*	Gramineae	4	27	13			20			7		
4	cf. "New Type" glume bases	*Triticum sp.*	Gramineae					1				1		
1	"New Type" glume bases, terminal spikelet	*Triticum sp.*	Gramineae											
1	"New Type" glume bases, phytolith	*Triticum sp.*	Gramineae											
21	Glume wheat chaff indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae	44	99	422	2	27	104	81		154	8	
1	cf. Glume wheat chaff indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae				2							
15	Terminal glume bases	*Triticum dicoccum/sp.*	Gramineae	4	20	8								
25	Wheat indeterminate grain	*Triticum*	Gramineae	12	22	9	48	14	161		149	3		488
1	cf. Wheat indeterminate grain	*Triticum*	Gramineae							32				
15	Cereal indeterminate grain		Gramineae	50	44	63	17	15.5	1629	1555	25			
1	cf. Cereal indeterminate grain		Gramineae							80				
3	Large grass indeterminate grain		Gramineae											
2	Cereal type culm node		Gramineae											
2	Small grass culm		Gramineae											
6	Cereal/grass culm/rachis 'join'/node		Gramineae									3		
3	Culm bases indeterminate		Gramineae											
2	Culm indeterminate		Gramineae											
	Pulses													
5	Bitter vetch	*Vicia ervilia*	Leguminosae					1		1				
1	cf. Bitter vetch	*Vicia ervilia*	Leguminosae		1									
2	Chickpea	*Cicer arietinum*	Leguminosae											
12	Lentil	*Lens culinaris*	Leguminosae	6	3	2					2	3	0.5	

				12	13	14	15	16	17	18	19	20	21	22
	Area			North	North	North	IST	IST	IST	IST	4040	4040	4040	4040
	Unit number			1349	1442	1442	11866	12417	13919	13962	10309	11900	11903	11908
	Sample number						4		1		1	5	4	1
	Flot number			**135**	**516**	**535**	**6638**	**6594, 6641**	**7906**	**8048,8049,8205**	**6026**	**6019**	**6052**	**6049**
	Hodder Level			North.G	North.G	North.G	South.Q-T	South.Q-T	South.Q-T	South.Q-T	North.G	North.G	North.G	North.G
	Building			1	1	1	63	63	63	63	52	52	52	52
	Internal Space			188	187	187	283	283	283	283	93	93	93	93
	Feature			27	34	34	1967	1984	2330	1967	-	2002	2002	2002
	Fraction of total sample			1	0.5	0.25	1	1	1	1	0.125	1	0.25	0.25
	[Adjusted] soil volume (l)			8.5	28	37	4	58	8	9	0.075	17	5.75	0.8375
	Density items/litre			35.3	24.2	24.6	447.3	10.4	1174.8	1492.6	38828.0	3311.0	4602.2	1360.6
	Density items/litre (exc. Desc.)			35.3	24.2	24.6	446.8	10.2	1174.8	1492.6	5494.7	369.7	254.4	1341.5
	Multiplication factor			1	2	4	1	1	1	1	8	1	4	4
	Total crop			204	591	805	1656	465.5	7964	13010	400	6194	1417.75	1064
	Total wild (excl. desc)			96	86	101	129	114.5	1414	418	12	83	20	16.5
COUNT		**Latin names**	**Family**											
1	Lentil stalks	*Leguminosae*	Leguminosae											
15	Pea	*Pisum sativum*	Leguminosae		5	1		5						0.5
3	cf. Pea	*Pisum sativum*	Leguminosae							4				
1	Pea testa with hilum	*Pisum sativum*	Leguminosae											
4	cf. Pea pod (frags)	*Pisum sativum*	Leguminosae											
8	Vicia/Lathyrus type	*Vicia/Lathyrus*	Leguminosae				1	2.5	4	9				
1	cf. Vicia/Lathyrus type	*Vicia/Lathyrus*	Leguminosae					1						
4	Large legume	*Leguminosae*	Leguminosae						4	5				
9	Pulse indeterminate	*Leguminosae*	Leguminosae		5	3	3	12		1		2		
	Fruit/nut taxa													
6	Pistachio nutshell	*Pistacia*	Anacardiaceae							0.1				
3	Pistacia-like nutshell	*Pistacia*	Anacardiaceae										0.4	
3	Terebinth	*Pistacia terebinthus*	Anacardiaceae			3								
3	Acorn nutshell	*Quercus*	Fagaceae			1			1.6					
1	Acorn kernel	*Quercus*	Fagaceae											
3	Almond, whole	*Amygdalus*	Rosaceae										19.5	37.5
1	Almond, kernel	*Amygdalus*	Rosaceae											
5	Almond nutshell	*Amygdalus*	Rosaceae									4	5	5
5	Almond/plum	*Amygdalus/Prunus*	Rosaceae							3		2.4		
13	Hackberry	*Celtis*	Ulmaceae				2	12	14	2		1		
7	Nutshell indeterminate											0.8		
10	Fruitstone/nutshell						0.2	0.3	1.7	0.25	0.1			0.5
4	Fruit skin (frags)													
	Other wild taxa													
1		*Bellevalia*	Asparagaceae											
2		*Alisma*	Alismataceae											
1		Boraginaceae	Boraginaceae											
1		cf. Boraginaceae, silicified	Boraginaceae											
1		*cf. Heliotropium*	Boraginaceae											
1		*Lithospermum,* silicified	Boraginaceae										0.5	
3		*Silene*	Caryophyllaceae	1										
3		*cf. Vaccaria*	Caryophyllaceae				6	1						
17		*Vaccaria pyramidata*	Caryophyllaceae	12			8	3	139	179	2	1		
2		*cf. Vaccaria pyramidata*	Caryophyllaceae						38					
2		Caryophyllaceae	Caryophyllaceae											
3		*Atriplex*	Chenopodiaceae									8		
3		*Chenopodium*	Chenopodiaceae				10	12	48					
3		*Salsola type*	Chenopodiaceae											

				12	13	14	15	16	17	18	19	20	21	22
	Area			North	North	North	IST	IST	IST	IST	4040	4040	4040	4040
	Unit number			1349	1442	1442	11866	12417	13919	13962	10309	11900	11903	11908
	Sample number						4		1		1	5	4	1
	Flot number			**135**	**516**	**535**	**6638**	**6594, 6641**	**7906**	**8048,8049,8205**	**6026**	**6019**	**6052**	**6049**
	Hodder Level			North.G	North.G	North.G	South.Q-T	South.Q-T	South.Q-T	South.Q-T	North.G	North.G	North.G	North.G
	Building			1	1	1	63	63	63	63	52	52	52	52
	Internal Space			188	187	187	283	283	283	283	93	93	93	93
	Feature			27	34	34	1967	1984	2330	1967	-	2002	2002	2002
	Fraction of total sample			1	0.5	0.25	1	1	1	1	0.125	1	0.25	0.25
	[Adjusted] soil volume (l)			8.5	28	37	4	58	8	9	0.075	17	5.75	0.8375
	Density items/litre			35.3	24.2	24.6	447.3	10.4	1174.8	1492.6	38828.0	3311.0	4602.2	1360.6
	Density items/litre (exc. Desc.)			35.3	24.2	24.6	446.8	10.2	1174.8	1492.6	5494.7	369.7	254.4	1341.5
	Multiplication factor			1	2	4	1	1	1	1	8	1	4	4
	Total crop			204	591	805	1656	465.5	7964	13010	400	6194	1417.75	1064
	Total wild (excl. desc)			96	86	101	129	114.5	1414	418	12	83	20	16.5
COUNT		**Latin names**	**Family**											
1		*Suaeda*	Chenopodiaceae				2							
8		Chenopodiaceae	Chenopodiaceae	1	12			4	32					
1		cf. Chenopodiaceae	Chenopodiaceae											
3		Chenopodiaceae [cores]	Chenopodiaceae											
2		Chenopodiaceae/Caryophyllaceae				10								
8		*Helianthemum*	Cistaceae	8		8					5			
1		cf. Cistaceae	Cistaceae											
3		*Artemisia*	Compositae											
1		*Artemisia annua type*	Compositae						32					
1		*cf. Centaurea*	Compositae											
2		Compositae	Compositae											
1		Compositae, small	Compositae	1										
1		Compositae, small long linear type	Compositae											
1		Compositae, flat linear ridge type	Compositae											
1		Compositae, large long linear type	Compositae											
8		*Convolvulus*	Convolvulaceae					0.5	2	2	3	1		
6		*cf. Convolvulus*	Convolvulaceae						2					
1		*Convolvulus* type	Convolvulaceae							32				
7		*Convolvulus arvensis* type	Convolvulaceae	27	3	2								
1		*Conringia orientalis*	Cruciferae											
3		*Conringia type*	Cruciferae											
5		Cruciferae	Cruciferae									4		
3		Cruciferae, large type	Cruciferae					2						
1		Cruciferae, medium type	Cruciferae											
2		Cruciferae, medium (linear pattern)	Cruciferae											
1		Cruciferae, medium (type 2 - patterned)	Cruciferae											
1		Cruciferae, small	Cruciferae									4		
23		Cruciferae, small (*Descurainia sophia* et al.)	Cruciferae				2	8			2500	50002	25000	16
1		Cruciferae, v. small round type	Cruciferae											
1		Cruciferae, round type	Cruciferae											
1		Crucifer, flanged type	Cruciferae									8		
2		Cruciferae pod	Cruciferae											
2		Cruciferae, pod - linear groove	Cruciferae											
22		*Bolboschoenus glaucus*	Cyperaceae	7	17	26		5	9	32		18	2	
1		*Bolboschoenus glaucus, in dung*	Cyperaceae											
1		*Bolboschoenus glaucus, mineralised*	Cyperaceae										0.5	
9		*Carex*	Cyperaceae		11	9	2	4	8					
5		Cyperaceae	Cyperaceae	10			8	9	36					
1		*Scirpus/Eleocharis*	Cyperaceae											

				12	13	14	15	16	17	18	19	20	21	22
	Area			North	North	North	IST	IST	IST	IST	4040	4040	4040	4040
	Unit number			1349	1442	1442	11866	12417	13919	13962	10309	11900	11903	11908
	Sample number						4		1		1	5	4	1
	Flot number			**135**	**516**	**535**	**6638**	**6594, 6641**	**7906**	**8048,8049,8205**	**6026**	**6019**	**6052**	**6049**
	Hodder Level			North.G	North.G	North.G	South.Q-T	South.Q-T	South.Q-T	South.Q-T	North.G	North.G	North.G	North.G
	Building			1	1	1	63	63	63	63	52	52	52	52
	Internal Space			188	187	187	283	283	283	283	93	93	93	93
	Feature			27	34	34	1967	1984	2330	1967	-	2002	2002	2002
	Fraction of total sample			1	0.5	0.25	1	1	1	1	0.125	1	0.25	0.25
	[Adjusted] soil volume (l)			8.5	28	37	4	58	8	9	0.075	17	5.75	0.8375
	Density items/litre			35.3	24.2	24.6	447.3	10.4	1174.8	1492.6	38828.0	3311.0	4602.2	1360.6
	Density items/litre (exc. Desc.)			35.3	24.2	24.6	446.8	10.2	1174.8	1492.6	5494.7	369.7	254.4	1341.5
	Multiplication factor			1	2	4	1	1	1	1	8	1	4	4
	Total crop			204	591	805	1656	465.5	7964	13010	400	6194	1417.75	1064
	Total wild (excl. desc)			96	86	101	129	114.5	1414	418	12	83	20	16.5
COUNT		**Latin names**	**Family**											
2		*Cephalaria*	Dipsacaceae					1						
2		*Cephalaria*/Umbelliferae Type	Dipsacaceae/Umbelliferae						2					
1		cf. Dipsacaceae	Dipsacaceae											
1		*Geranium* type	Geraniaceae											
1		*Aegilops*	Gramineae											
1		*Aegilops/Triticum*	Gramineae						4					
6		*Aeluropus*	Gramineae	8		8	2	4						
1		*cf. Alopecurus*	Gramineae					2						
2		*Agrostis* sp type	Gramineae				2	8						
3		*Bromus*	Gramineae											
9		*Bromus danthoniae*	Gramineae	1	1				32			1		
1		*Bromus hordeaceus*	Gramineae											
3		*Crypsis*	Gramineae											
2		*Eragrostis*	Gramineae											
2		*Eremopyrum bonaepartis* type	Gramineae		2									
3		Gramineae	Gramineae					1	28					
5		Gramineae, large indeterminate	Gramineae	1	10	2	14							
1		Gramineae, medium laterally flattened type	Gramineae						8					
2		Gramineae, rachis indeterminate	Gramineae											
3		Gramineae, small	Gramineae				4	16	112					
5		Gramineae, small round type	Gramineae											
6		Gramineae, small elongated type	Gramineae						80			8		
1		Gramineae, small pointed type	Gramineae											
1		Gramineae, small striped type (Check Poa?)	Gramineae											
2		Gramineae, small indeterminate	Gramineae				8							
3		*Hordeum*	Gramineae						6	1				0.5
6	Weed barley	*Hordeum murinum*	Gramineae						30	35				
1	cf. Weed barley	*cf. Hordeum murinum*	Gramineae						2					
1		*cf. Phalaris*	Gramineae											
9	Reed culm nodes	*Phragmites*	Gramineae						32	32				
2		*Phragmites australis*	Gramineae			7								
4		*Sporobolus*	Gramineae	9					80					
1		*Stipagrostis type*	Gramineae											
12	Taeniatherum grain	*Taeniatherum caput-medusae*	Gramineae		3	2		8				1		
4	cf. Taeniatherum grain	*Taeniatherum caput-medusae*	Gramineae											
2	Taeniatherum rachis	*Taeniatherum caput-medusae*	Gramineae											
1	Wild einkorn grain	*Triticum boeticum*	Gramineae											
10		*Juncus*	Juncaceae			8		10	64					
4		Labiatae	Labiatae											
2		Labiatae type - spked/bumpy, oblong	Labiatae										0.5	

				12	13	14	15	16	17	18	19	20	21	22
	Area			North	North	North	IST	IST	IST	IST	4040	4040	4040	4040
	Unit number			1349	1442	1442	11866	12417	13919	13962	10309	11900	11903	11908
	Sample number						4		1		1	5	4	1
	Flot number			**135**	**516**	**535**	**6638**	**6594, 6641**	**7906**	**8048,8049,8205**	**6026**	**6019**	**6052**	**6049**
	Hodder Level			North.G	North.G	North.G	South.Q-T	South.Q-T	South.Q-T	South.Q-T	North.G	North.G	North.G	North.G
	Building			1	1	1	63	63	63	63	52	52	52	52
	Internal Space			188	187	187	283	283	283	283	93	93	93	93
	Feature			27	34	34	1967	1984	2330	1967	-	2002	2002	2002
	Fraction of total sample			1	0.5	0.25	1	1	1	1	0.125	1	0.25	0.25
	[Adjusted] soil volume (l)			8.5	28	37	4	58	8	9	0.075	17	5.75	0.8375
	Density items/litre			35.3	24.2	24.6	447.3	10.4	1174.8	1492.6	38828.0	3311.0	4602.2	1360.6
	Density items/litre (exc. Desc.)			35.3	24.2	24.6	446.8	10.2	1174.8	1492.6	5494.7	369.7	254.4	1341.5
	Multiplication factor			1	2	4	1	1	1	1	8	1	4	4
	Total crop			204	591	805	1656	465.5	7964	13010	400	6194	1417.75	1064
	Total wild (excl. desc)			96	86	101	129	114.5	1414	418	12	83	20	16.5
COUNT		**Latin names**	**Family**											
2		*Mentha*	Labiatae											
4		*Sideritis type*	Labiatae	2										
4		*Teucrium*	Labiatae											
2		*Cicer*	Leguminosae								1			
12		Leguminosae, small-seeded	Leguminosae	1	2	1	2					9		
3		*Lemna* , silicified	Lemnaceae											
1		*cf. Linum*	Linaceae											
2		Malvaceae	Malvaceae		1									
3		Malvaceae, large type	Malvaceae											
2		*Malva*	Malvaceae											
1		*Lavatera* type	Malvaceae											
1		*Fumaria*	Papaveraceae											
1		Papaveraceae	Papaveraceae											
2		Polygonaceae	Polygonaceae	1					1					
1		cf. Polygonaceae	Polygonaceae						2					
11		*Polygonum*	Polygonaceae					20	43					16
4		*cf. Polygonum*	Polygonaceae						2				0.5	
14		*Polygonum aviculare*	Polygonaceae	4	11	9			2			1		
3		*Polygonum cf. aviculare*	Polygonaceae				30		8					
6		*Polygonum convolvulus*	Polygonaceae					3				1		
4		*cf. Polygonum convulvulus*	Polygonaceae									8		
1		*cf. Rumex*	Polygonaceae									1		
2		*Rumex conglomeratus*	Polygonaceae		1				18					
1		*cf. Androsace maxima*	Primulaceae											
2		*Adonis cf. microcarpa*	Ranunculaceae											
1		*Ranunculus type*	Ranunculaceae											
1		*Asperula* small type	Rubiaceae											
7		*Galium tricornutum* type	Rubiaceae	2	12	9			2					
2		*Galium spurium/odoratum* type	Rubiaceae											
1		*Galium sp.* (tiny type)	Rubiaceae											
3		*cf. Galium*	Rubiaceae											
3		*Thymelaea passerina*	Thymelaeaceae					1	32					
3		Umbelliferae	Umbelliferae											
1		cf. Umbelliferae	Umbelliferae											
2		cf. Umbelliferae/Dipsacaceae	Umbelliferae/Dipsacaceae											
12	Unidentified wild seed		Unknown				4		235	72		9		
13	Potentially identifiable seed		Unknown				27		239	33	1		16	
1	Capsule/Pod/Bud		Unknown						4					

				23	24	25	26	27	28	29	30	31	32	33
	Area			4040	4040	4040	4040	4040	4040	4040	4040	4040	4040	4040
	Unit number			11908	11911	11911	11911	11911	16480	16480	16480	16498	16498	17519
	Sample number			2	1	2	4	3	2	4	5	2	5	2
	Flot number			**6059**	**6050**	**6051**	**6056**	**6070**	**8415**	**8413**	**8416**	**8486**	**8505**	**8614**
	Hodder Level			North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G
	Building			52	52	52	52	52	77	77	77	77	77	77
	Internal Space			93	93	93	93	93	337	337	337	336	336	336
	Feature			2002	2004	2004	2004	2004	-	-	-	-	-	-
	Fraction of total sample			1	0.5	1	1	0.5	1	0.25	1	0.125	1	0.25
	[Adjusted] soil volume (l)			6	3	1.5	0.5	0.5	4	5.5	1	10.625	0.35	1.5
	Density items/litre			1020.8	10859.7	86596.1	161740.5	27565.4	564.0	486.0	1539.0	314.9	2245.7	624.9
	Density items/litre (exc. Desc.)			354.2	2923.7	1262.8	1740.5	4781.4	562.0	484.5	1523.0	293.8	2234.3	395.6
	Multiplication factor			1	2	1	1	2	1	4	1	8	1	4
	Total crop			2046	4611.2	1207	462	1091.7	2233	2660.5	1381	2986.125	414	541.75
	Total wild (excl. desc)			53	4062.4	252	75.15	1019	13	3.5	142	110.4	17.5	50.6
COUNT		**Latin names**	**Family**											
	Non-seed/fruit/chaff material													
6	>2 mm dung (ml)							0.2					0.5	0.8
1	>2 mm cf. dung (ml)													
4	>2 mm tuber (ml)					1								0.2
2	>2 mm fish bone charred mass (ml)											25	350	
2	>2 mm burnt cereal mass (ml)													
1	>2 mm fruit/bread													
1	<2 mm tuber (ml)				0.1									
4	<2 mm stalk indet.				16									
1	cf. Monocot root													
8	Mouse pellets				46	428	331	278						
	Cereals													
26	Naked barley grain	*Hordeum vulgare var. nudum*	Gramineae	96	20	5	1					281	28	133
3	cf. Naked barley grain	*Hordeum vulgare var. nudum*	Gramineae											
4	Naked barley grain, fused	*Hordeum vulgare var. nudum*	Gramineae											
8	Naked barley grain, straight	*Hordeum vulgare var. nudum*	Gramineae				1					1		2
2	Naked barley grain, twisted	*Hordeum vulgare var. nudum*	Gramineae											
4	cf. Naked barley grain, twisted	*Hordeum vulgare var. nudum*	Gramineae											
1	Naked barley grain indet., with spikelet attached	*Hordeum vulgare var. nudum*	Gramineae											
2	Hulled barley grain	*Hordeum vulgare*	Gramineae											
3	cf. Hulled barley grain	*Hordeum vulgare*	Gramineae											
18	Barley grain indeterminate	*Hordeum*	Gramineae		4	6	7	4				10		31.5
3	cf. Barley grain indeterminate	*Hordeum*	Gramineae											
4	Wizened barley grain/ wild barley	*Hordeum*	Gramineae											
5	Naked 6-row barley rachis	*Hordeum vulgare convar. vulgare var. nudum*	Gramineae		8	8		4						2
14	Naked 2-row barley rachis	*Hordeum vulgare convar. distichon var. nudum*	Gramineae		24	14		10				2		2
1	Naked 2-row barley, basal rachis	*Hordeum vulgare convar. distichon var. nudum*	Gramineae											
2	Naked barley rachis indeterminate	*Hordeum vulgare convar. vulgare var. nudum*	Gramineae											
12	Barley rachis indeterminate	*Hordeum*	Gramineae		96	1	22	24				2		12
14	Free-threshing wheat grain	*Triticum aestivum/durum*	Gramineae	1950								4		
1	Free-threshing wheat grain, fused	*Triticum aestivum/durum*	Gramineae											
7	cf. Free-threshing wheat grain	*Triticum aestivum/durum*	Gramineae											
11	Bread wheat rachis	*Triticum aestivum*	Gramineae		52	24	7	38				32		4
4	Free-threshing wheat indet. rachis	*Triticum aestivum/durum*	Gramineae											
7	Free-threshing wheat indet., basal rachis	*Triticum aestivum/durum*	Gramineae		8	2	3					4		
7	Einkorn grain, one-seeded type	*Triticum monococcum*	Gramineae		2					4				
2	cf. Einkorn grain, one-seeded type	*Triticum monococcum*	Gramineae											
3	Einkorn grain, one-seeded possible wild type	*Triticum boeticum/monococcum*	Gramineae					2						
5	Einkorn grain, two-seeded type	*Triticum monococcum*	Gramineae			1	2	2						

				23	24	25	26	27	28	29	30	31	32	33
	Area			4040	4040	4040	4040	4040	4040	4040	4040	4040	4040	4040
	Unit number			11908	11911	11911	11911	11911	16480	16480	16480	16498	16498	17519
	Sample number			2	1	2	4	3	2	4	5	2	5	2
	Flot number			**6059**	**6050**	**6051**	**6056**	**6070**	**8415**	**8413**	**8416**	**8486**	**8505**	**8614**
	Hodder Level			North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G
	Building			52	52	52	52	52	77	77	77	77	77	77
	Internal Space			93	93	93	93	93	337	337	337	336	336	336
	Feature			2002	2004	2004	2004	2004	-	-	-	-	-	-
	Fraction of total sample			1	0.5	1	1	0.5	1	0.25	1	0.125	1	0.25
	[Adjusted] soil volume (l)			6	3	1.5	0.5	0.5	4	5.5	1	10.625	0.35	1.5
	Density items/litre			1020.8	10859.7	86596.1	161740.5	27565.4	564.0	486.0	1539.0	314.9	2245.7	624.9
	Density items/litre (exc. Desc.)			354.2	2923.7	1262.8	1740.5	4781.4	562.0	484.5	1523.0	293.8	2234.3	395.6
	Multiplication factor			1	2	1	1	2	1	4	1	8	1	4
	Total crop			2046	4611.2	1207	462	1091.7	2233	2660.5	1381	2986.125	414	541.75
	Total wild (excl. desc)			53	4062.4	252	75.15	1019	13	3.5	142	110.4	17.5	50.6
COUNT		**Latin names**	**Family**											
6	Einkorn/emmer grain	*Triticum monococcum/dicoccum*	Gramineae											
8	Emmer grain	*Triticum dicoccum*	Gramineae		2	1			1					
4	cf. Emmer grain	*Triticum dicoccum*	Gramineae											
2	Emmer/ "New type" glume wheat grain	*Triticum dicoccum/sp.*	Gramineae											
6	"New Type" glume wheat grain	*Triticum sp.*	Gramineae						24	232	17			
2	cf. "New type" glume wheat grain	*Triticum sp.*	Gramineae											
1	"New Type" glume wheat grain, in spikelet pairs	*Triticum sp.*	Gramineae							13.5				
9	Glume wheat grain indeterminate, two seeded	*Triticum monococcum/dicoccum/sp.*	Gramineae											
9	Glume wheat grain indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae		12	7	6	14	1058	1351	271	6		
5	Einkorn glume bases	*Triticum monococcum*	Gramineae					2					4	2
2	cf. Einkorn glume bases	*Triticum monococcum*	Gramineae		8									
10	Einkorn/emmer glume bases	*Triticum monococcum /dicoccum*	Gramineae		478	790	236	258		324	22	128	12	136
16	Emmer glume bases	*Triticum dicoccum*	Gramineae		222	175	10	62				6		20
4	cf. Emmer glume bases	*Triticum dicoccum*	Gramineae		16									
15	Emmer/ "New Type" glume bases	*Triticum sp./dicoccum*	Gramineae		8									
4	Emmer/ "New Type" glume bases, basal	*Triticum sp./dicoccum*	Gramineae											
2	Emmer/ "New Type" glume bases, terminal	*Triticum sp./dicoccum*	Gramineae											
17	"New Type" glume bases	*Triticum sp.*	Gramineae		28		6	20	1108	712	1031	8		8
4	cf. "New Type" glume bases	*Triticum sp.*	Gramineae											
1	"New Type" glume bases, terminal spikelet	*Triticum sp.*	Gramineae											
1	"New Type" glume bases, phytolith	*Triticum sp.*	Gramineae											
21	Glume wheat chaff indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae		1048			216						
1	cf. Glume wheat chaff indeterminate	*Triticum monococcum/dicoccum/sp.*	Gramineae											
15	Terminal glume bases	*Triticum dicoccum/sp.*	Gramineae		32	4	18	4	36	8	18	8		14
25	Wheat indeterminate grain	*Triticum*	Gramineae		2	9		4	2	16	22	4		
1	cf. Wheat indeterminate grain	*Triticum*	Gramineae											
15	Cereal indeterminate grain		Gramineae		8		3							6
1	cf. Cereal indeterminate grain		Gramineae											
3	Large grass indeterminate grain		Gramineae											
2	Cereal type culm node		Gramineae					2						
2	Small grass culm		Gramineae		0.4			0.2						
6	Cereal/grass culm/rachis 'join'/node		Gramineae					2						
3	Culm bases indeterminate		Gramineae		8	1						2		
2	Culm indeterminate		Gramineae		0.8			0.5						
	Pulses													
5	Bitter vetch	*Vicia ervilia*	Leguminosae		4							1		
1	cf. Bitter vetch	*Vicia ervilia*	Leguminosae											
2	Chickpea	*Cicer arietinum*	Leguminosae		2	1								
12	Lentil	*Lens culinaris*	Leguminosae		12		1	6						

				23	24	25	26	27	28	29	30	31	32	33
	Area			4040	4040	4040	4040	4040	4040	4040	4040	4040	4040	4040
	Unit number			11908	11911	11911	11911	11911	16480	16480	16480	16498	16498	17519
	Sample number			2	1	2	4	3	2	4	5	2	5	2
	Flot number			**6059**	**6050**	**6051**	**6056**	**6070**	**8415**	**8413**	**8416**	**8486**	**8505**	**8614**
	Hodder Level			North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G
	Building			52	52	52	52	52	77	77	77	77	77	77
	Internal Space			93	93	93	93	93	337	337	337	336	336	336
	Feature			2002	2004	2004	2004	2004	-	-	-	-	-	-
	Fraction of total sample			1	0.5	1	1	0.5	1	0.25	1	0.125	1	0.25
	[Adjusted] soil volume (l)			6	3	1.5	0.5	0.5	4	5.5	1	10.625	0.35	1.5
	Density items/litre			1020.8	10859.7	86596.1	161740.5	27565.4	564.0	486.0	1539.0	314.9	2245.7	624.9
	Density items/litre (exc. Desc.)			354.2	2923.7	1262.8	1740.5	4781.4	562.0	484.5	1523.0	293.8	2234.3	395.6
	Multiplication factor			1	2	1	1	2	1	4	1	8	1	4
	Total crop			2046	4611.2	1207	462	1091.7	2233	2660.5	1381	2986.125	414	541.75
	Total wild (excl. desc)			53	4062.4	252	75.15	1019	13	3.5	142	110.4	17.5	50.6
COUNT		**Latin names**	**Family**											
1	Lentil stalks	*Leguminosae*	Leguminosae											
15	Pea	*Pisum sativum*	Leguminosae		2506	158	138	400	4			2486.875	370	163.75
3	cf. Pea	*Pisum sativum*	Leguminosae											
1	Pea testa with hilum	*Pisum sativum*	Leguminosae					10						
4	cf. Pea pod (frags)	*Pisum sativum*	Leguminosae											
8	Vicia/Lathyrus type	*Vicia/Lathyrus*	Leguminosae				1	1				0.25		5.5
1	cf. Vicia/Lathyrus type	*Vicia/Lathyrus*	Leguminosae											
4	Large legume	*Leguminosae*	Leguminosae					6						
9	Pulse indeterminate	*Leguminosae*	Leguminosae											
	Fruit/nut taxa													
6	Pistachio nutshell	*Pistacia*	Anacardiaceae		6	1.1	1	1.8						
3	Pistacia-like nutshell	*Pistacia*	Anacardiaceae		3.6									
3	Terebinth	*Pistacia terebinthus*	Anacardiaceae											
3	Acorn nutshell	*Quercus*	Fagaceae											
1	Acorn kernel	*Quercus*	Fagaceae									0.00625		
3	Almond, whole	*Amygdalus*	Rosaceae	18										
1	Almond, kernel	*Amygdalus*	Rosaceae											
5	Almond nutshell	*Amygdalus*	Rosaceae	6	0.3									
5	Almond/plum	*Amygdalus/Prunus*	Rosaceae						0.05					0.03
13	Hackberry	*Celtis*	Ulmaceae	2	8	2			2	1				
7	Nutshell indeterminate				0.4									
10	Fruitstone/nutshell				16	3.05	1.1					0.4		
4	Fruit skin (frags)													
	Other wild taxa													
1		*Bellevalia*	Asparagaceae		1									
2		*Alisma*	Alismataceae		8			8						
1		Boraginaceae	Boraginaceae											
1		cf. Boraginaceae, silicified	Boraginaceae											
1		*cf. Heliotropium*	Boraginaceae		8									
1		*Lithospermum,* silicified	Boraginaceae											
3		*Silene*	Caryophyllaceae		8									
3		*cf. Vaccaria*	Caryophyllaceae											
17		*Vaccaria pyramidata*	Caryophyllaceae		8	5	6	5	3	1.25				
2		*cf. Vaccaria pyramidata*	Caryophyllaceae											
2		Caryophyllaceae	Caryophyllaceae									16		
3		*Atriplex*	Chenopodiaceae		8									
3		*Chenopodium*	Chenopodiaceae											
3		*Salsola type*	Chenopodiaceae								4			

				23	24	25	26	27	28	29	30	31	32	33
	Area			4040	4040	4040	4040	4040	4040	4040	4040	4040	4040	4040
	Unit number			11908	11911	11911	11911	11911	16480	16480	16480	16498	16498	17519
	Sample number			2	1	2	4	3	2	4	5	2	5	2
	Flot number			**6059**	**6050**	**6051**	**6056**	**6070**	**8415**	**8413**	**8416**	**8486**	**8505**	**8614**
	Hodder Level			North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G
	Building			52	52	52	52	52	77	77	77	77	77	77
	Internal Space			93	93	93	93	93	337	337	337	336	336	336
	Feature			2002	2004	2004	2004	2004	-	-	-	-	-	-
	Fraction of total sample			1	0.5	1	1	0.5	1	0.25	1	0.125	1	0.25
	[Adjusted] soil volume (l)			6	3	1.5	0.5	0.5	4	5.5	1	10.625	0.35	1.5
	Density items/litre			1020.8	10859.7	86596.1	161740.5	27565.4	564.0	486.0	1539.0	314.9	2245.7	624.9
	Density items/litre (exc. Desc.)			354.2	2923.7	1262.8	1740.5	4781.4	562.0	484.5	1523.0	293.8	2234.3	395.6
	Multiplication factor			1	2	1	1	2	1	4	1	8	1	4
	Total crop			2046	4611.2	1207	462	1091.7	2233	2660.5	1381	2986.125	414	541.75
	Total wild (excl. desc)			53	4062.4	252	75.15	1019	13	3.5	142	110.4	17.5	50.6
COUNT		**Latin names**	**Family**											
1		*Suaeda*	Chenopodiaceae											
8		Chenopodiaceae	Chenopodiaceae			8					4			
1		cf. Chenopodiaceae	Chenopodiaceae											
3		Chenopodiaceae [cores]	Chenopodiaceae		17									
2		Chenopodiaceae/Caryophyllaceae												
8		*Helianthemum*	Cistaceae			8		24						
1		cf. Cistaceae	Cistaceae		8									
3		*Artemisia*	Compositae		24								4	8
1		*Artemisia annua type*	Compositae											
1		*cf. Centaurea*	Compositae		8									
2		Compositae	Compositae		8			1						
1		Compositae, small	Compositae											
1		Compositae, small long linear type	Compositae		16									
1		Compositae, flat linear ridge type	Compositae					8						
1		Compositae, large long linear type	Compositae		8									
8		*Convolvulus*	Convolvulaceae		12	1								
6		*cf. Convolvulus*	Convolvulaceae	1	9									
1		*Convolvulus* type	Convolvulaceae											
7		*Convolvulus arvensis* type	Convolvulaceae											
1		*Conringia orientalis*	Cruciferae											8
3		*Conringia type*	Cruciferae											
5		Cruciferae	Cruciferae	8				5						
3		Cruciferae, large type	Cruciferae			1								
1		Cruciferae, medium type	Cruciferae		3									
2		Cruciferae, medium (linear pattern)	Cruciferae											
1		Cruciferae, medium (type 2 - patterned)	Cruciferae											
1		Cruciferae, small	Cruciferae											
23		Cruciferae, small (*Descurainia sophia* et al.)	Cruciferae	4000	23808	128000	80000	11392	8	8	16	224	4	344
1		Cruciferae, v. small round type	Cruciferae											
1		Cruciferae, round type	Cruciferae											
1		Crucifer, flanged type	Cruciferae											
2		Cruciferae pod	Cruciferae								1			
2		Cruciferae, pod - linear groove	Cruciferae		5									
22		*Bolboschoenus glaucus*	Cyperaceae	15	9				2	0.5		8		1
1		*Bolboschoenus glaucus, in dung*	Cyperaceae											8
1		*Bolboschoenus glaucus, mineralised*	Cyperaceae											
9		*Carex*	Cyperaceae	1				8						
5		Cyperaceae	Cyperaceae	16										
1		*Scirpus/Eleocharis*	Cyperaceae		1									

				23	24	25	26	27	28	29	30	31	32	33
	Area			4040	4040	4040	4040	4040	4040	4040	4040	4040	4040	4040
	Unit number			11908	11911	11911	11911	11911	16480	16480	16480	16498	16498	17519
	Sample number			2	1	2	4	3	2	4	5	2	5	2
	Flot number			**6059**	**6050**	**6051**	**6056**	**6070**	**8415**	**8413**	**8416**	**8486**	**8505**	**8614**
	Hodder Level			North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G
	Building			52	52	52	52	52	77	77	77	77	77	77
	Internal Space			93	93	93	93	93	337	337	337	336	336	336
	Feature			2002	2004	2004	2004	2004	-	-	-	-	-	-
	Fraction of total sample			1	0.5	1	1	0.5	1	0.25	1	0.125	1	0.25
	[Adjusted] soil volume (l)			6	3	1.5	0.5	0.5	4	5.5	1	10.625	0.35	1.5
	Density items/litre			1020.8	10859.7	86596.1	161740.5	27565.4	564.0	486.0	1539.0	314.9	2245.7	624.9
	Density items/litre (exc. Desc.)			354.2	2923.7	1262.8	1740.5	4781.4	562.0	484.5	1523.0	293.8	2234.3	395.6
	Multiplication factor			1	2	1	1	2	1	4	1	8	1	4
	Total crop			2046	4611.2	1207	462	1091.7	2233	2660.5	1381	2986.125	414	541.75
	Total wild (excl. desc)			53	4062.4	252	75.15	1019	13	3.5	142	110.4	17.5	50.6
COUNT		**Latin names**	**Family**											
2		*Cephalaria*	Dipsacaceae			1								
2		*Cephalaria*/Umbelliferae Type	Dipsacaceae/Umbelliferae											
1		cf. Dipsacaceae	Dipsacaceae											
1		*Geranium* type	Geraniaceae											
1		*Aegilops*	Gramineae											
1		*Aegilops/Triticum*	Gramineae											
6		*Aeluropus*	Gramineae		8							8		
1		*cf. Alopecurus*	Gramineae											
2		*Agrostis* sp type	Gramineae											
3		*Bromus*	Gramineae									8	4	
9		*Bromus danthoniae*	Gramineae		9									
1		*Bromus hordeaceus*	Gramineae											
3		*Crypsis*	Gramineae		8									24
2		*Eragrostis*	Gramineae		32									
2		*Eremopyrum bonaepartis* type	Gramineae											
3		Gramineae	Gramineae									8		
5		Gramineae, large indeterminate	Gramineae											
1		Gramineae, medium laterally flattened type	Gramineae											
2		Gramineae, rachis indeterminate	Gramineae		32									
3		Gramineae, small	Gramineae											
5		Gramineae, small round type	Gramineae		8			8						
6		Gramineae, small elongated type	Gramineae					8						
1		Gramineae, small pointed type	Gramineae						8					
1		Gramineae, small striped type (Check Poa?)	Gramineae											
2		Gramineae, small indeterminate	Gramineae	8										
3		*Hordeum*	Gramineae											
6	Weed barley	*Hordeum murinum*	Gramineae											
1	cf. Weed barley	*cf. Hordeum murinum*	Gramineae											
1		*cf. Phalaris*	Gramineae											
9	Reed culm nodes	*Phragmites*	Gramineae		0.4		1.15					8.4	9.5	0.1
2		*Phragmites australis*	Gramineae											
4		*Sporobolus*	Gramineae		8									
1		*Stipagrostis type*	Gramineae		96									
12	Taeniatherum grain	*Taeniatherum caput-medusae*	Gramineae					17				2		
4	cf. Taeniatherum grain	*Taeniatherum caput-medusae*	Gramineae											
2	Taeniatherum rachis	*Taeniatherum caput-medusae*	Gramineae					9				2		
1	Wild einkorn grain	*Triticum boeticum*	Gramineae											
10		*Juncus*	Juncaceae		3312	8		744			132	16		
4		Labiatae	Labiatae		16	48	12	33						
2		Labiatae type - spked/bumpy, oblong	Labiatae		40									

				23	24	25	26	27	28	29	30	31	32	33
	Area			4040	4040	4040	4040	4040	4040	4040	4040	4040	4040	4040
	Unit number			11908	11911	11911	11911	11911	16480	16480	16480	16498	16498	17519
	Sample number			2	1	2	4	3	2	4	5	2	5	2
	Flot number			**6059**	**6050**	**6051**	**6056**	**6070**	**8415**	**8413**	**8416**	**8486**	**8505**	**8614**
	Hodder Level			North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G	North.G
	Building			52	52	52	52	52	77	77	77	77	77	77
	Internal Space			93	93	93	93	93	337	337	337	336	336	336
	Feature			2002	2004	2004	2004	2004	-	-	-	-	-	-
	Fraction of total sample			1	0.5	1	1	0.5	1	0.25	1	0.125	1	0.25
	[Adjusted] soil volume (l)			6	3	1.5	0.5	0.5	4	5.5	1	10.625	0.35	1.5
	Density items/litre			1020.8	10859.7	86596.1	161740.5	27565.4	564.0	486.0	1539.0	314.9	2245.7	624.9
	Density items/litre (exc. Desc.)			354.2	2923.7	1262.8	1740.5	4781.4	562.0	484.5	1523.0	293.8	2234.3	395.6
	Multiplication factor			1	2	1	1	2	1	4	1	8	1	4
	Total crop			2046	4611.2	1207	462	1091.7	2233	2660.5	1381	2986.125	414	541.75
	Total wild (excl. desc)			53	4062.4	252	75.15	1019	13	3.5	142	110.4	17.5	50.6
COUNT		**Latin names**	**Family**											
2		*Mentha*	Labiatae		16									
4		*Sideritis type*	Labiatae		8	8								
4		*Teucrium*	Labiatae		137	132	36	67						
2		*Cicer*	Leguminosae											
12		Leguminosae, small-seeded	Leguminosae											
3		*Lemna* , silicified	Lemnaceae											
1		*cf. Linum*	Linaceae		8									
2		Malvaceae	Malvaceae											
3		Malvaceae, large type	Malvaceae							0.5				
2		*Malva*	Malvaceae	1										
1		*Lavatera* type	Malvaceae											
1		*Fumaria*	Papaveraceae					1						
1		Papaveraceae	Papaveraceae											
2		Polygonaceae	Polygonaceae											
1		cf. Polygonaceae	Polygonaceae											
11		*Polygonum*	Polygonaceae	1	1	8	2	1		0.5				
4		*cf. Polygonum*	Polygonaceae		8									
14		*Polygonum aviculare*	Polygonaceae		8					0.5				
3		*Polygonum cf. aviculare*	Polygonaceae											
6		*Polygonum convolvulus*	Polygonaceae											
4		*cf. Polygonum convulvulus*	Polygonaceae	1										
1		*cf. Rumex*	Polygonaceae											
2		*Rumex conglomeratus*	Polygonaceae											
1		*cf. Androsace maxima*	Primulaceae					8						
2		*Adonis cf. microcarpa*	Ranunculaceae								1			
1		*Ranunculus type*	Ranunculaceae							0.25				
1		*Asperula* small type	Rubiaceae											
7		*Galium tricornutum* type	Rubiaceae											
2		*Galium spurium/odoratum* type	Rubiaceae					1						
1		*Galium sp.* (tiny type)	Rubiaceae											
3		*cf. Galium*	Rubiaceae		8									
3		*Thymelaea passerina*	Thymelaeaceae											
3		Umbelliferae	Umbelliferae					9				2		0.5
1		cf. Umbelliferae	Umbelliferae		1									
2		cf. Umbelliferae/Dipsacaceae	Umbelliferae/Dipsacaceae		5			9						
12	Unidentified wild seed		Unknown	1	32									
13	Potentially identifiable seed		Unknown		93	24	18	45				32		1
1	Capsule/Pod/Bud		Unknown											

Appendix 1g – Approximate dates for each of the phases examined at the four study sites.

Site	Period	Site Phase	Approx. date (cal. BC)	Reference
Jerf el-Ahmar	PPNA	Early	9500	Stordeur 2015: 18.
	PPNA	Middle	9300	Stordeur 2015: 18.
	PPNA	Late	8900	Stordeur 2015: 18.
Dja'de	EPPNB	PPNB II	8800	Coqueugniot 2014.
	EPPNB	PPNB III	8540	Coqueugniot 2014.
Tell Aswad	PPNB	Early	8700	Stordeur *et al*. 2010.
	PPNB	Middle	8250	Stordeur *et al*. 2010.
	PPNB	Late	8000	Stordeur *et al*. 2010.
Çatalhöyük	PN	North G	6700	Çatalhöyük Research Project phasing, autumn 2017.
	PN	South O	6550	Çatalhöyük Research Project phasing, autumn 2017.
	PN	South Q-T	6450	Çatalhöyük Research Project phasing, autumn 2017.
	PN	Late Neolithic	6350	Çatalhöyük Research Project phasing, autumn 2017.

Appendix 2

Archaeobotanical identification

Appendix 2a – Full list of accession sources for each species recorded in the *Bromus* identification key.

Species Name	Accession Name	Accession type	No. of specimens
Bromus alopecuros	RMN 2263	Field collection	3
	USDA	Gene bank	3
	Kew - Greece	Botanic garden	2
Bromus arvensis	CAEN	Botanic garden	1
	Pisa	Botanic garden	3
	Romania 2008	Field collection	2
	USDA	Gene bank	2
Bromus benekenii	Joensuu, Finland	Botanic garden	4
	Kew	Botanic garden	2
	USDA - Russia	Gene bank	2
Bromus cappadocicus	RMN 4566	Field collection	3
	USDA - Iran	Gene bank	2
	USDA - Ukraine	Gene bank	3
Bromus commutatus	Kew	Botanic garden	3
	USDA	Gene bank	5
Bromus danthoniae	DJS 454	Field collection	2
	Gatersleben	Gene bank	2
	RMN 4367	Field collection	1
	USDA - Turkey	Gene bank	3
Bromus diandrus	Kew	Botanic garden	1
	Siena	Botanic garden	2
	USDA	Gene bank	5
Bromus erectus	Kew	Botanic garden	3
	USDA - Turkey	Gene bank	5
Bromus fasciculatus	RMN 4354	Field collection	4
	USDA	Gene bank	2
	USDA - Iraq	Gene bank	2
Bromus hordeaceus	Kew	Botanic garden	3
	Nantes Mairie	Botanic garden	2
	Tortosa 2004	Field collection	3

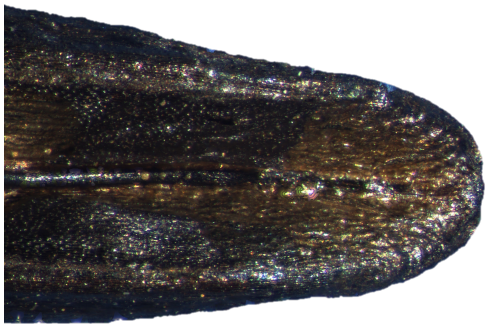
Species Name	Accession Name	Accession type	No. of specimens
Bromus intermedius	Kew	Botanic garden	2
	RMN 4553	Field collection	3
	USDA - Afghanistan	Gene bank	3
Bromus japonicus	Berlin Dahlem	Botanic garden	3
	RMN 4597	Field collection	2
	USDA - Turkey	Gene bank	3
Bromus lanceolatus	Kew	Botanic garden	3
	Turkey	Field collection	2
	USDA	Gene bank	3
Bromus madritensis	RMN 2262	Field collection	2
	Siena	Botanic garden	2
	USDA - Afghanistan	Gene bank	2
	USDA - Belgium	Gene bank	2
Bromus racemosus	Berlin Spathstro	Botanic garden	2
	Bonn	Botanic garden	3
	USDA - Turkey	Gene bank	3
Bromus ramosus	CAEN	Botanic garden	3
	Leipzig	Botanic garden	2
	USDA	Gene bank	3
Bromus rigidus	CAEN	Botanic garden	4
	Kew	Botanic garden	1
	RMN 4230	Field collection	3
Bromus riparius	Gatersleben	Gene bank	3
	USDA - Former Soviet Union	Gene bank	2
	USDA - Ukraine	Gene bank	3
Bromus rubens	Ghent	Botanic garden	2
	USDA	Gene bank	4
	USDA - Morocco	Gene bank	2
Bromus scoparius	DJS 392	Field collection	2
	Kew	Botanic garden	3
	RMN 3201	Field collection	1
	USDA - Turkey	Gene bank	2

Species Name	Accession Name	Accession type	No. of specimens
Bromus squarrosus	Kew	Botanic garden	3
	RMN 2490	Field collection	2
	USDA - Turkey	Gene bank	3
Bromus sterilis	Berb 9101	Field collection	3
	CAEN	Botanic garden	1
	Leipzig	Botanic garden	2
	RMN 2498a	Field collection	2
Bromus tectorum	Amsterdam	Botanic garden	2
	Berlin Dahlem	Botanic garden	1
	RMN 2952	Field collection	2
	RMN 4667	Field collection	3
Bromus tomentellus	Kew	Botanic garden	3
	RMN 4695	Field collection	3
	USDA - Iran	Gene bank	2

Appendix 2b – Illustrations to guide users of the computerised *Bromus* identification key with the measured seed characteristics. These images are incorporated within the user interface of the key in the Lucid Player function, enabling comparison with archaeobotanical material.

Apical end shape

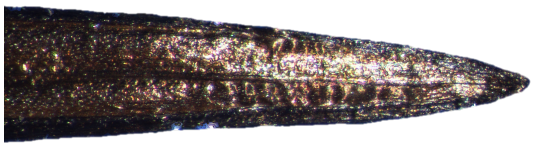
Blunt



Leaf point

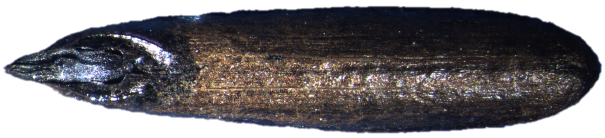


Narrowly pointed



Seed shape

Tapered towards embryo



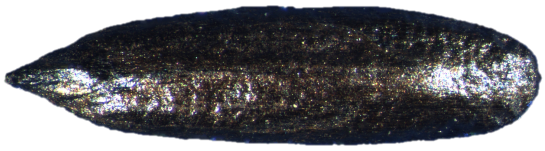
Tapered towards apex



Tapered ends



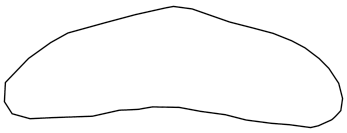
Breadth constant



Cross section shape

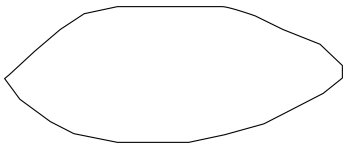
Flat semi-circle

Flat ventral side with rounded or flat roof, width greater than thickness.



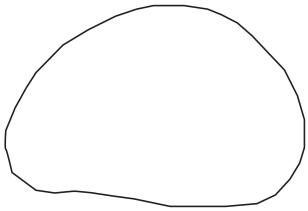
Lenticular

Lenticular shape, though thickness variable.



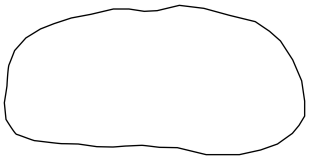
Semi-circle

Flat ventral side with rounded dorsal roof, or flattish roof with rounded edges.



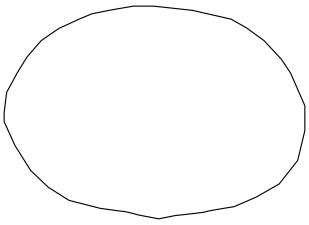
Rectangular

Flat ventral side and roof with relatively straight sides.



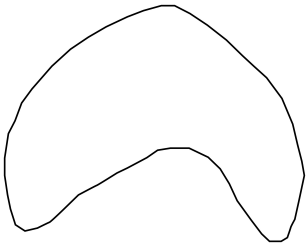
Round

Wide rounded shape, occasionally resembling a rounded diamond.



Arched

Flat or inverted ventral side with arched roof, or laterally compressed shape.



Appendix 2c – Final testing stage for *Bromus* identification key using 10 random modern experimentally charred *Bromus* specimens.

Specimen no.	Species name	Key outcome	Other notes	Correctly identified?
Brom_TEST_01	*Bromus japonicus*	B. japonicus		Y
Brom_TEST_02	*Bromus madritensis*	No result	Closest match: *B. rubens/ B. fasciculatus* (87%) *B. madritensis* (75%)	-
Brom_TEST_03	*Bromus fasciculatus*	No result	Closest match: B. fasciculatus (85%)	-
Brom_TEST_04	*Bromus intermedius*	B. scoparius, B. intermedius		Y
Brom_TEST_05	*Bromus erectus*	*B. danthoniae, B. japonicus*; Rare: *B. squarrosus, B. erectus, B. hordeaceus, B. cappadocicus*		Y >3
Brom_TEST_06	*Bromus sterilis*	*B. sterilis, B. tectorum*; Rare - *B. benekenii*		Y
Brom_TEST_07	*Bromus scoparius*	*B. alopecuros, B. intermedius*	Discarded based on seed shape	N
Brom_TEST_08	*Bromus danthoniae*	*B. alopecuros, B. danthoniae, B. intermedius*		Y
Brom_TEST_09	*Bromus arvensis*	No result	Closest match: *B. alopecuros, B. arvensis, B. danthoniae, B. hordeaceus, B. lanceolatus* (88%)	-
Brom_TEST_10	*Bromus arvensis*	*B. arvensis, B. danthoniae*; Rare: *B. squarrosus, B. hordeaceus, B. commutatus, B. japonicus*		Y >3

Appendix 2d – Raw data behind the *Bromus* identification key in Lucid 3.

Feature	Categories	*Bromus alopecuros*	*Bromus arvensis*	*Bromus benekenii*	*Bromus cappadocicus*	*Bromus commutatus*	*Bromus danthoniae*	*Bromus diandrus*	*Bromus erectus*	*Bromus fasciculatus*	*Bromus hordeaceus*	*Bromus intermedius*	*Bromus japonicus*	*Bromus lanceolatus*	*Bromus madritensis*	*Bromus racemosus*	*Bromus ramosus*	*Bromus rigidus*	*Bromus riparius*	*Bromus rubens*	*Bromus scoparius*	*Bromus squarrosus*	*Bromus sterilis*	*Bromus tectorum*	*Bromus tomentellus*
Filter by Archaeological site	Jerf el-Ahmar	1	0	0	0	0	1	1	0	1	0	0	1	1	1	0	0	1	0	1	1	1	1	1	0
	Dja'de	1	0	0	0	0	1	1	0	1	0	0	1	1	1	0	0	1	0	1	1	1	1	1	0
	Tell Aswad	0	0	0	0	0	1	1	0	0	0	0	1	1	1	0	0	1	0	1	1	1	1	1	0
	Çatalhöyük	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
General size category	Large (over 9mm)	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	1	1	1	1	0	0	1	0	1
	Medium (5-9mm)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Small (under 5mm)	0	1	0	0	1	1	0	0	0	1	1	1	0	0	1	0	0	0	0	1	1	0	0	0
Narrowness (L:B x 10 ratio)	Extremely narrow (above 80)	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
	Very narrow (70-80)	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	1	0	0	1	1	0
	Narrow (60-70)	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	1	0
	Medium (50-60)	1	0	1	1	0	0	1	1	0	0	1	0	0	0	0	1	1	1	0	1	0	1	1	1
	Medium (40-50)	1	1	1	1	0	1	0	1	0	1	1	1	1	0	1	0	1	1	0	1	1	0	0	1
	Broad (30-40)	0	1	0	0	1	1	0	0	0	1	1	1	0	0	1	0	0	0	0	0	1	0	0	0
	Very broad (under 30)	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Lateral compression (T:B x 100 ratio)	Laterally compressed (over 65)	0	1	1	0	0	0	1	1	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0

Feature	**Categories**	*Bromus alopecuros*	*Bromus arvensis*	*Bromus benekenii*	*Bromus cappadocicus*	*Bromus commutatus*	*Bromus danthoniae*	*Bromus diandrus*	*Bromus erectus*	*Bromus fasciculatus*	*Bromus hordeaceus*	*Bromus intermedius*	*Bromus japonicus*	*Bromus lanceolatus*	*Bromus madritensis*	*Bromus racemosus*	*Bromus ramosus*	*Bromus rigidus*	*Bromus riparius*	*Bromus rubens*	*Bromus scoparius*	*Bromus squarrosus*	*Bromus sterilis*	*Bromus tectorum*	*Bromus tomentellus*
	Slightly laterally compressed (55-65)	0	1	1	0	1	0	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	1	1	1
	Medium (45-55)	0	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	1	1	1
	Flattened shape (35-45)	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	0	1	0
	Flat (under 35)	1	1	0	0	1	1	0	1	0	1	1	0	1	0	0	0	0	0	0	1	1	0	0	0
Thickness (L:T x 10 ratio)	Very thin (over 190)	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Thin (170-190)	1	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	0	0	1	1	0	0	1	0
	Slightly thin (150-170)	1	0	0	0	0	1	1	0	1	0	1	0	0	1	0	0	0	0	1	1	0	0	1	0
	Medium (130-150)	1	0	1	1	0	1	1	1	1	0	1	0	1	1	0	1	1	0	1	1	0	0	1	0
	Medium (110-130)	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Medium (90-110)	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1
	Slightly thick (70-90)	0	1	1	0	1	0	1	1	0	1	0	1	1	0	1	1	1	0	0	0	1	0	0	0
	Thick (50-70)	0	1	1	0	1	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
	Very thick (under 50)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Scutellum percentage	Very large (>20%)	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0
	Large (15-20%)	1	1	0	1	1	1	0	1	0	1	1	1	0	0	1	0	0	1	0	1	1	1	0	0
	Medium (10-15%)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
	Medium (5-10%)	0	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1
	Small (under 5%)	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0

Feature	**Categories**	*Bromus alopecuros*	*Bromus arvensis*	*Bromus benekenii*	*Bromus cappadocicus*	*Bromus commutatus*	*Bromus danthoniae*	*Bromus diandrus*	*Bromus erectus*	*Bromus fasciculatus*	*Bromus hordeaceus*	*Bromus intermedius*	*Bromus japonicus*	*Bromus lanceolatus*	*Bromus madritensis*	*Bromus racemosus*	*Bromus ramosus*	*Bromus rigidus*	*Bromus riparius*	*Bromus rubens*	*Bromus scoparius*	*Bromus squarrosus*	*Bromus sterilis*	*Bromus tectorum*	*Bromus tomentellus*
Tapering (blunt apical end only)	Wide blunt apical end (>50)	0	1	0	1	0	1	1	0	0	1	0	0	0	0	0	1	0	1	1	0	0	1	1	1
	Medium (30-50)	1	1	1	1	1	1	1	1	0	1	0	1	1	0	1	1	0	1	1	0	1	1	1	1
	Narrow blunt apical end (<30)	1	0	1	1	1	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0	1	0	0	1
Seed shape	Breadth constant	1	2	1	1	1	1	2	2	0	2	1	1	1	0	1	1	0	2	0	0	0	2	2	1
	Tapered ends - both sides	1	2	2	0	2	0	1	1	0	2	2	0	1	2	0	2	1	1	1	1	0	1	1	1
	Tapered - towards embryo end	1	1	0	2	2	1	0	1	0	1	2	1	1	1	0	0	2	0	0	0	1	0	1	1
	Tapered - towards apical end	0	0	2	0	0	2	0	2	1	0	2	0	0	0	1	2	0	0	0	2	0	0	0	0
Apical end shape	Blunt	2	1	1	1	1	1	0	1	0	1	0	1	1	0	1	1	0	1	1	0	1	1	1	1
	Leaf point	1	1	0	1	2	1	2	0	0	1	1	2	0	2	2	1	1	1	2	1	1	1	1	2
	Narrowly pointed	2	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	1	0	1	2	0	0	0	0
Cross section shape	Arched	0	1	0	1	1	1	0	2	0	2	0	1	0	0	1	0	0	2	0	0	2	0	0	2
	Rectangular	2	0	1	0	1	0	1	1	1	0	0	0	1	1	0	1	1	1	1	0	0	1	1	1
	Round	0	0	1	0	0	1	1	0	1	0	0	0	0	1	2	1	2	0	1	2	0	0	0	2
	Lenticular	0	0	0	1	1	0	0	0	2	0	0	0	1	1	0	0	0	0	1	2	0	0	0	2
	Semi-circle	0	0	1	1	1	1	1	2	0	2	2	1	0	1	0	1	2	2	1	2	2	2	2	2
	Flat semi-circle	1	1	1	1	1	1	0	0	0	1	1	0	1	0	2	1	0	0	0	1	1	0	0	0

Appendix 2e – Final species level identifications achieved for *Bromus* specimens from the four archaeological case study sites.

Site name	Specimen no.	Sample no.	Selected sample?	Seed complete?	Puffed?	Type	Features available for analysis	Output of identification key	Possible candidates	Final ID
Jerf el-Ahmar	JF 11	285	N	Y	N	JF 1	7	*B. danthoniae,* RARE: *B. squarrosus*		*B. danthoniae*
Jerf el-Ahmar	JF 1	259	N	Y	Y	JF 1	5	*B. danthoniae*	*B. japonicus*	*B. danthoniae*
Jerf el-Ahmar	JF 20	610	Y	Y	N	JF 2	8	No result	*B. sterilis, B. tectorum*	*B. tectorum/sterilis type*
Jerf el-Ahmar	JF 63	631	Y	Y	N	JF 2	5	*B. tectorum*		*B. tectorum/sterilis type*
Jerf el-Ahmar	JF 6	447	N	Adj	N	JF 3	7	*B. rigidus, B. sterilis, B. tectorum*		*B. sterilis*
Dja'de	DJ 23	112	Y	Y	Y	DJ 1	6	No result	*B. danthoniae, B. japonicus*	*B. japonicus*
Dja'de	DJ 18	28	N	Y	Y	DJ 2	6	No result	*B. tectorum*	*B. tectorum/sterilis type*
Tell Aswad	AW 1	04/14	Y	Y	N	AW - 1	8	*B. danthoniae,* RARE: *B. squarrosus*		*B. danthoniae*
Tell Aswad	AW 5	02/98	Y	Y	N	AW - 1	8	*B. danthoniae*		*B. danthoniae*
Tell Aswad	AW 6	02/98	Y	Y	N	AW - 1	8	No result	*B. danthoniae, B. japonicus, B. squarrosus*	*B. danthoniae*
Tell Aswad	AW 4	02/98	Y	Y	Y	AW - 1	5	No result	*B. danthoniae, B. japonicus, B. squarrosus*	*B. danthoniae*
Tell Aswad	AW 7	02/98	Y	Y	Y	AW - 1	5	*B. danthoniae, B. japonicus*		*B. danthoniae*
Çatalhöyük	ÇH 1	104	N	Y	N	ÇH - 1	9	*B. danthoniae*		*B. danthoniae*
Çatalhöyük	ÇH 20	6019	Y	Adj	N	ÇH - 1	8	*B. danthoniae, B. intermedius*		*B. danthoniae*
Çatalhöyük	ÇH 25	10872	N	Y	N	ÇH - 1	8	*B. commutatus, B. danthoniae, B. japonicus, B. racemosus, RARE: B. hordeaceus, B. arvensis*		*B. danthoniae*
Çatalhöyük	ÇH 26	10872	N	Y	N	ÇH - 1	8	*B. danthoniae*		*B. danthoniae*
Çatalhöyük	ÇH 27	10872	N	Y	N	ÇH - 1	8	*B. arvensis, B. danthoniae, RARE: B. hordeaceus*		*B. danthoniae*
Çatalhöyük	ÇH 14	9271	Y	Adj	N	ÇH - 1	7	*B. arvensis, B. danthoniae, B. hordeaceus, B. lanceolatus, RARE: B. squarrosus*		*B. danthoniae*
Çatalhöyük	ÇH 18	9256	Y	Adj	N	ÇH - 1	7	*B. danthoniae*		*B. danthoniae*
Çatalhöyük	ÇH 2	10922	Y	Adj	N	ÇH - 2	7	*B. commutatus, B. hordeaceus*		*B. hordeaceus*
Çatalhöyük	ÇH 28	10872	N	Adj	N	ÇH - 3	7	*B. tectorum*		*B. tectorum*

Adj = specimen almost complete so length adjusted to represent full seed

Identification Catalogue

Identification catalogue: Potential refinements of other genera

Owing to the extensive amount of recorded seed accessions required to reliably separate species and the various lengthy procedures involved, it was only possible to create a systematic identification key for *Bromus* (see Chapter 8). Nevertheless, the refinement of further weed identifications was an essential step to meet the minimum threshold of identified weeds that were required for ecological analyses. As a way of addressing many of the critiques associated with common identification procedures (see Chapter 7), this identification catalogue examines the identification potential of selected weed genera, while proposing a method for best practice when identifying specimens to species/types in the absence of detailed identification keys or complete reference collections. A more detailed account is presented for the identification of *Adonis* specimens, while the remaining genera were approached strategically to achieve quick species 'type' identifications for ecological analysis.

(i) Adonis

Adonis was the first genus attempted to be systematically documented and measured for the creation of an identification key[1] (Figure 1). With only 10 species applicable to the four selected sites in western Asia, which was reduced further with geographic filtering (Table 1), it was believed that this genus would be straightforward to separate. Similar procedures were followed as for *Bromus*, with modern reference material experimentally charred, photographed and measured (above, Chapter 8). However, it soon became apparent that

[1] This explains why this genus is explored in greater detail than the other weed genera assessed.

unlike grass specimens, *Adonis* seeds were unsuitable for systematic recording methods. Different orientations of the same specimen affected basic measurements such as length and breadth, yet their asymmetric shape and protruding beak made this difficult to standardise (Figure 2). While measurements were regulated to be taken at right angles to the hilum edge, irregularities in form between specimens of the same species, as well as unclear attachment points, reduced the reliability of these dimensions. These irregular seed types that are difficult to measure with traditional measurements may benefit from shape analysis through geometric morphometric analyses. However, the limited reference material and ecological variability across the genus (above, 6.3) prevented this detailed form of analysis from being undertaken.

Table 1 – Compatibility of the altitude zone for each of the geographically relevant *Adonis* species to the four early farming sites (see Chapter 8). The number of accessions consulted for each species is also listed. Floras: FOT = *Flora of Turkey*, FOI = *Flora of Iraq*, NFLS = *Nouvelle Flore du Liban et de la Syrie*.

	Floras					***Altitude range***		
Species Name	**FOT**	**FOI**	**NFLS**	**No. of accessions consulted**	**Photo**	**Çatalhöyük**	**Jerf el-Ahmar/ Dja'de**	**Tell Aswad**
Adonis wolgensis	Y			0	-	N	-	-
Adonis cyllenea	Y			0	-	N	-	-
Adonis aleppica	Y	Y	Y	1	Y	Y	Y	Y
Adonis annua	Y	Y	Y	4	Y	Y	Y	Y
Adonis microcarpa	Y	Y	Y	2	Y	Y	Y	Y
Adonis dentata	Y	Y	Y	2	Y	N	Y	Y
Adonis aestivalis	Y	Y	Y	11	Y	Y	Y	Y
Adonis eriocalycina	Y	Y	Y	1	Y	Y	N	N
Adonis flammea	Y		Y	9	Y	Y	-	-
Adonis palaestina			Y	0	-	-	-	Y

These recording issues were further compounded by inconsistent reference material, with some accessions extensively different from others listed as the same species. It was difficult to ascertain if this was the result of misidentification by the botanic garden from which the accession was sourced, or whether this reflected genuine intra-species variability in seed morphology. Such discrepancies were particularly notable for *Adonis aestivalis*, which had the most available accessions; two distinct types were identified that were each replicated

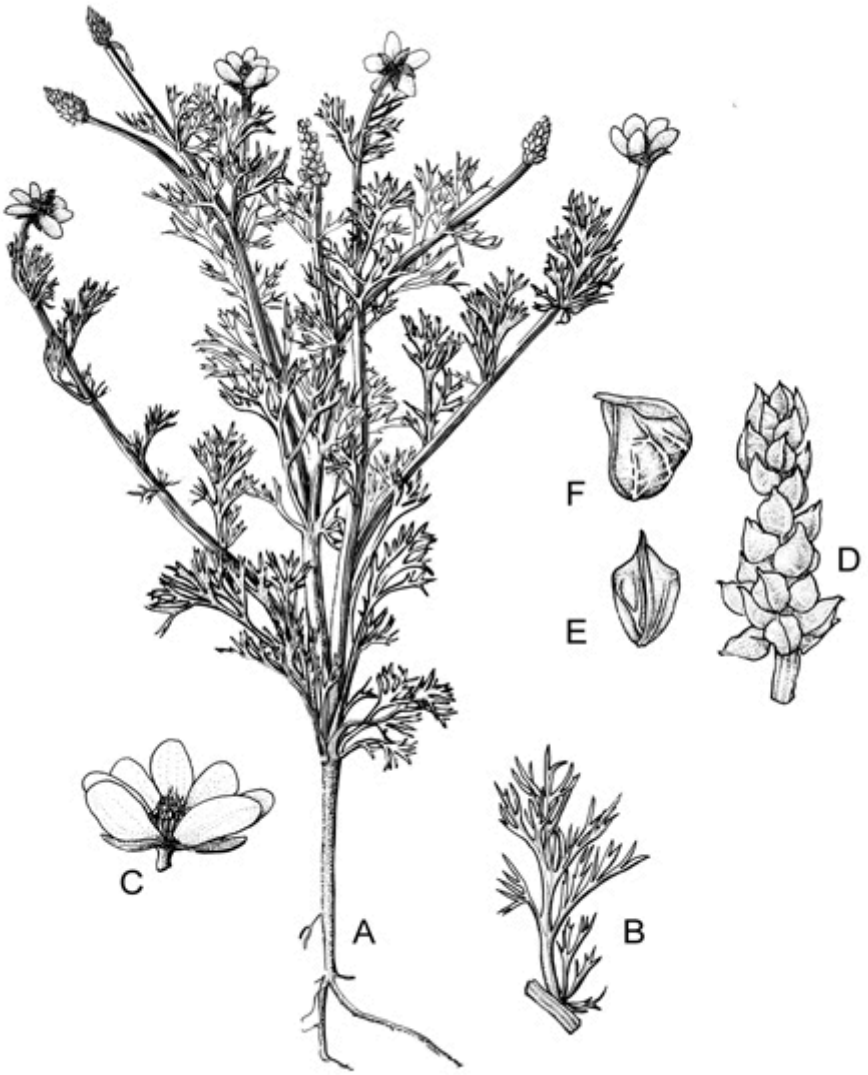


Figure 1 – Illustration of the plant parts for *Adonis microcarpa*. a. habit; b. leaf; c. flower; d. fruiting head; e. achene[2] (seed); f. achene (side view) (P.Kloot K7201, CANB). Scale bar: A = 24 mm; B = 12 mm; C = 8 mm; D = 6 mm; E, F = 3 mm. Drawn by D.Boyer. Adapted from (Eichler *et al.* 2007).

in multiple accessions from different sources (Figure 3). If accurate, it is possible that such intra-species variability may be linked to differing levels of seed maturity. This was indicated by a complete but immature fruiting head collected from the field; the green seeds looked closer to the first *Adonis aestivalis* type (Figure 3a) with its less robust features. Closer inspection of the dispersal unit for *Adonis* specimens (Figure 1) indicate additional factors that may contribute towards variation in seed form. The tight clustering of seeds within *Adonis* fruiting receptacles, as well as the relative positioning of the seed, reflect

[2] For simplicity, the term 'seed' will be used to refer to the various types of seed dispersules (i.e. achene, fruit, nutlet) indicated in this seed catalogue.

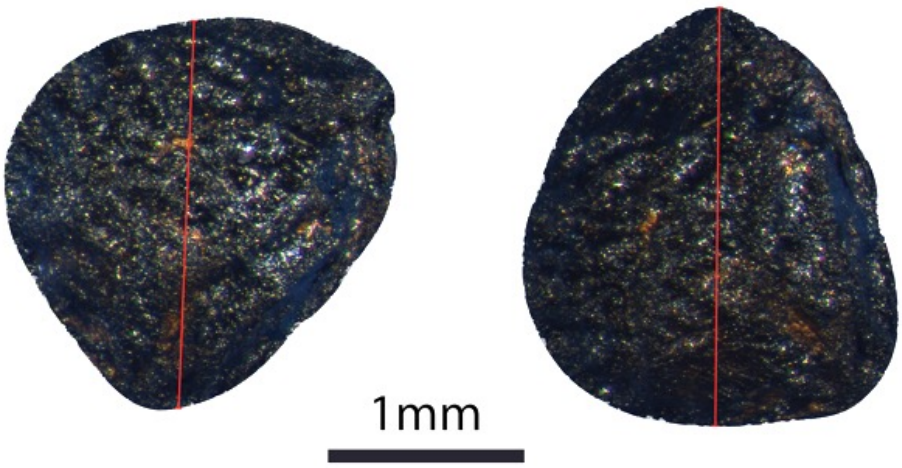


Figure 2 – In charred *Adonis* specimens, the attachment points are not always distinguishable, so it is difficult to consistently orient specimens for systematic recording. This image displays the same specimen with length recorded in two possible orientations, presenting alternative dimensions.

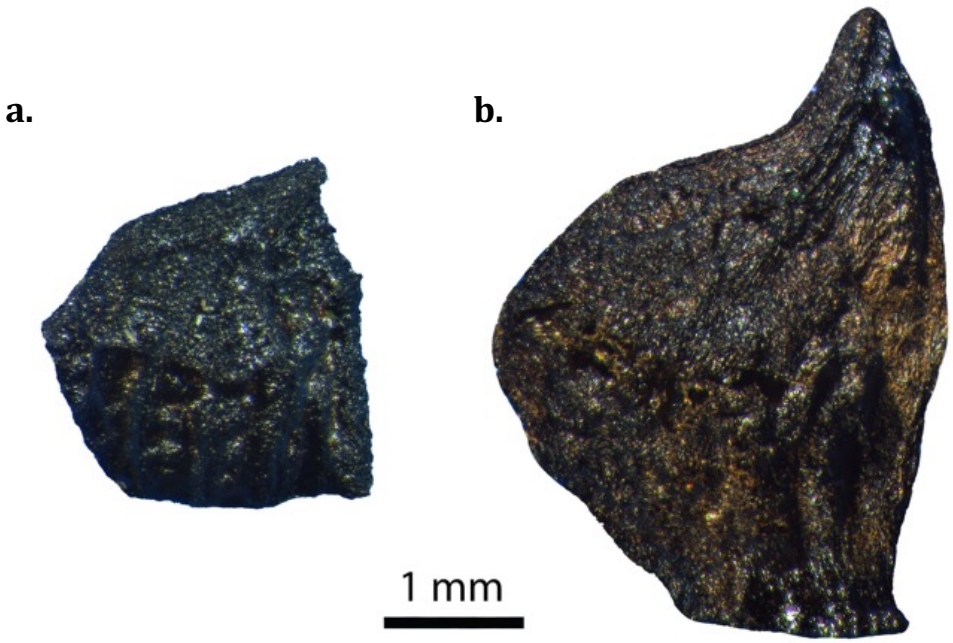


Figure 3 – These two modern specimens were both listed as *Adonis aestivalis* within the University of Oxford seed reference collection, yet were distinctly different in both size and shape characteristics. Type 1 (a.) was more consistent with several Seed Atlas illustrations, with type 2 (b.) possessing similarities to *Adonis flammea* in shape and dimensions, possibly indicating a misidentification.

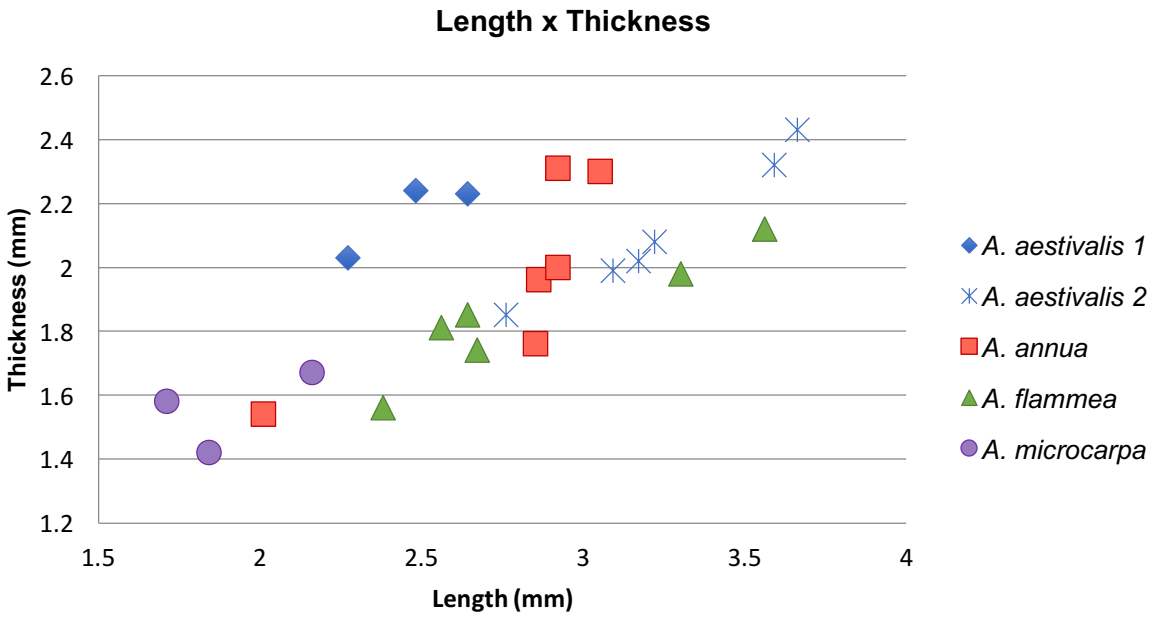


Figure 4 – The relationship between seed length and thickness in the experimentally charred modern *Adonis* species. The two types of *Adonis aestivalis* (1 & 2 as indicated in Fig. 3), were distinguished. Type 2 had very similar proportions to *Adonis flammea*, perhaps indicating a misidentification.

Table 2 – Main distinguishing characteristics observed for each of the modern *Adonis* species analysed (see Table 1). Descriptions for *Adonis aestivalis* were based on type 1 as this type was consistent with several Floras and seed atlases.

Species	Distinguishing characteristics
Adonis aestivalis (type 1)	Angular shape, rugose surface pattern, sharp beak and edges, transverse ridge, long thin hilum
Adonis aleppica	Weakly rugose surface pattern, long pronounced beak, long wide hilum
Adonis annua	Broadly semi-circle shape with straight edge at right angles to the hilum edge (occasionally ovate), reticulate surface pattern, short hilum
Adonis dentata	Small type, spiny surface pattern, short wide hilum
Adonis eriocalycina	Large type, weakly rugose surface pattern, long pronounced beak
Adonis flammea	Robust shape, shallow/grainy surface pattern, prominent short oval hilum
Adonis microcarpa	Small type, straight edge that rounds midway towards beak, rugose surface pattern, long thin hilum

subtle variations in seed size and shape associated with their variable compression by neighbouring seeds (Figure 1d). Yet such differences were observed across whole accessions rather than individual specimens. Furthermore, the second *Adonis aestivalis* type presents features remarkably similar to *Adonis flammea* (Table 2), so it is still possible that misidentifications were responsible for the conflicting material[3].

The preservation of the *Adonis* specimens appeared to be relatively constant for most features within both the archaeobotanical and the experimentally charred specimens. Though specimens were occasionally broken, their general surface texture and proportions appeared to be largely unaffected. There was however a small reduction in overall seed size that accompanied the charring process. Protruding features such as the tips of pointed beaks or transverse ridges were also regularly absent following charring, therefore the lack of such features should not be used to exclude species.

Table 1 lists the total number of modern accessions that were consulted for each *Adonis* species. Reference material could not be sourced for three species, but two of these were able to be filtered out once the altitudinal filters were applied. The third unchecked species, *Adonis palaestina*, featured within The *Nouvelle Flore du Liban et de la Syrie*[2] (Mouterde 1986), was mainly distributed across the southern part of Syria, so possibly has relevance for Tell Aswad[4] but not necessarily the other sites considered here.

Preliminary measurements for the principal candidates (Figure 4) revealed considerable overlap between seed dimensions, though a small type, *Adonis microcarpa*, was discernible from the limited dataset. The most useful characteristics for separation appeared to be subtle distinctions in shape that could be observed in the face view, though these aspects were less clear-cut than the characteristics observed for *Bromus* and were difficult to typify

[3] It is noted in the *Flora of Turkey* that plant specimens displaying intermediate characteristics between *Adonis aestivalis* and *Adonis flammea* were occasionally observed, which suggest there may be overlapping features between certain varieties.

[4] While no accessions or illustrations could be sourced for *Adonis palaestina*, scanned images of herbarium sheets with attached seeds were consulted using the JSTOR Global Plants (2017) database. Zoomed in views of the seeds suggest similarities to *Adonis aestivalis* (type 1) based on general shape, its long hilum and pointed/protruding features.

systematically. Table 2 details observed identification criteria collated from measured specimens, further consulted accessions, illustrations and Flora/Seed Atlas descriptions. These distinctions provided the basis for identification of the archaeobotanical material. Two of the most promising traits, which deserve further attention for future identification work, were the length and shape of the hilum and the type of surface patterning. However, both of these features were often difficult to analyse from recorded images, which proved problematic for the quickly documented Syrian material; while the use of 'Extended Depth of Focus' (EDF) within image acquisition software enables the whole of a specimen to be viewed in focus, it also flattens the image making it difficult to discern the depth of surface textures and hilum edges. Experiments with 3D image software such as 'Helicon Focus' (Kozub *et al.* 2000) made such analyses more accessible and is a possible avenue for further studies (Figure 5)[5].

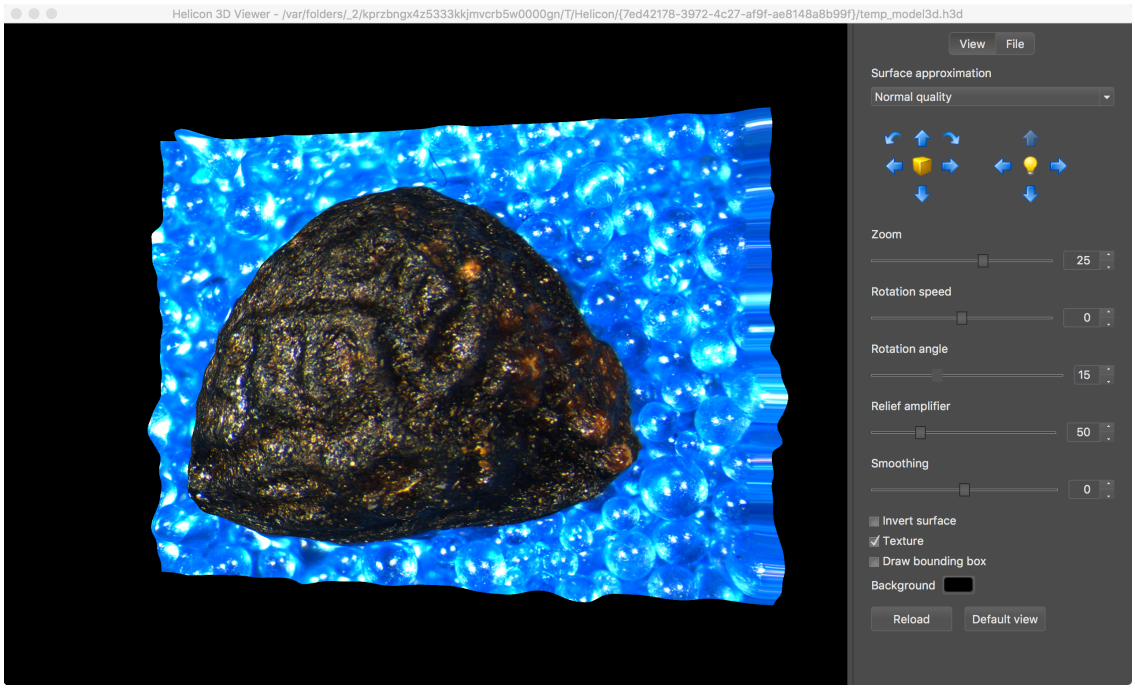


Figure 5 – Experiments with the 3D image software 'Helicon Focus (Kozub *et al.* 2000), which enables seed surface pattern to be examined at multiple angles.

[5] This software requires the original unstitched photographs (10-20 images) to form the 3D image, so would add a further step to the recording process.

Four *Adonis* species/types were identified from the selected archaeobotanical material, which include *Adonis* cf. *aestivalis* (Figure 6), *Adonis* cf. *annua* (Figure 7), *Adonis* cf. *microcarpa* (Figure 8) and a less distinct *Adonis aestivalis/Adonis annua* type (see Final ID Table). Each of the sites was represented by one main species, with further borderline or less well-preserved specimens identified as *Adonis aestivalis/Adonis annua* type. As with *Bromus*, the size of the seeds had limited influence upon the final identifications, with proportions, shape, and surface texture central to species distinctions.

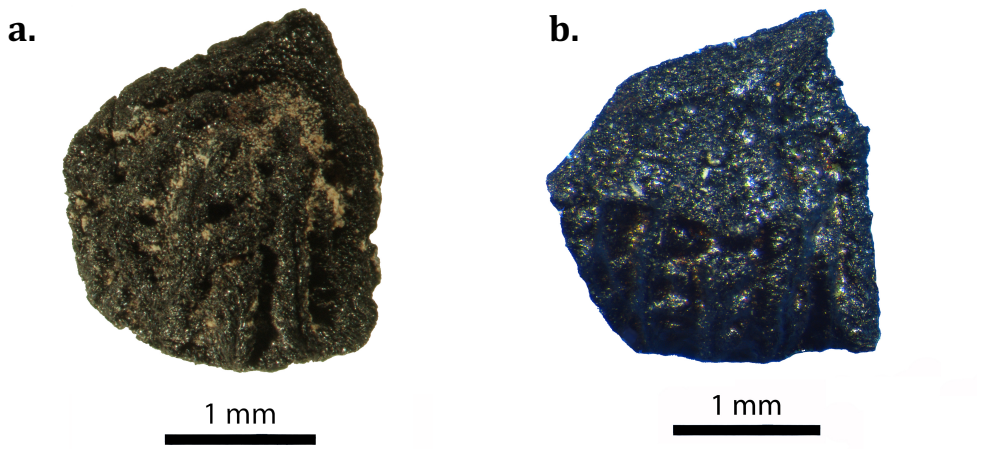


Figure 6 – (a.) Large angular *Adonis* type (Type specimen: Adon 01 - 0149) identified as *Adonis* cf. *aestivalis* from Tell Aswad. (b.) Modern experimentally charred *Adonis aestivalis* specimen that most closely resembled the archaeological material.

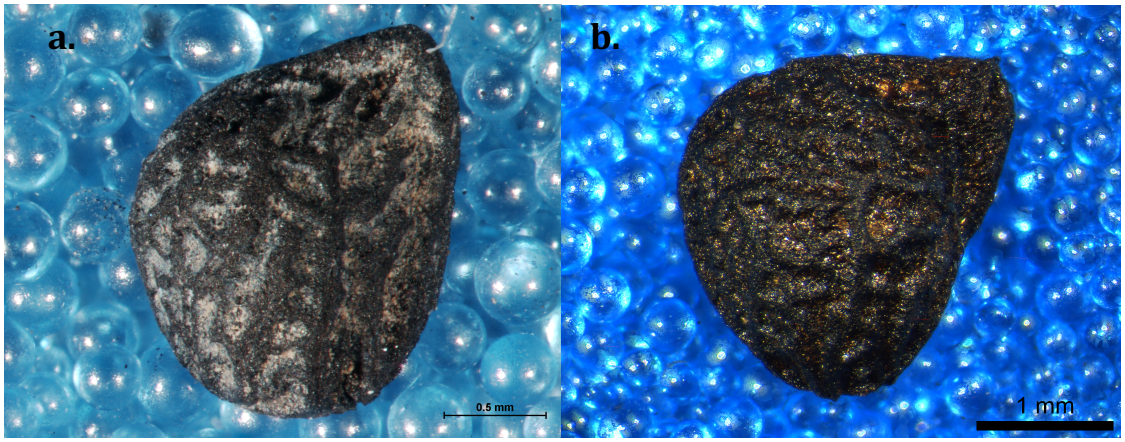


Figure 7 – (a.) Large semi-circular *Adonis* type (Type specimen: Adon_JF_544_26) identified as *Adonis* cf. *annua* from Dja'de. (b.) Modern experimentally charred *Adonis annua* specimen that most closely resembled the archaeological material.

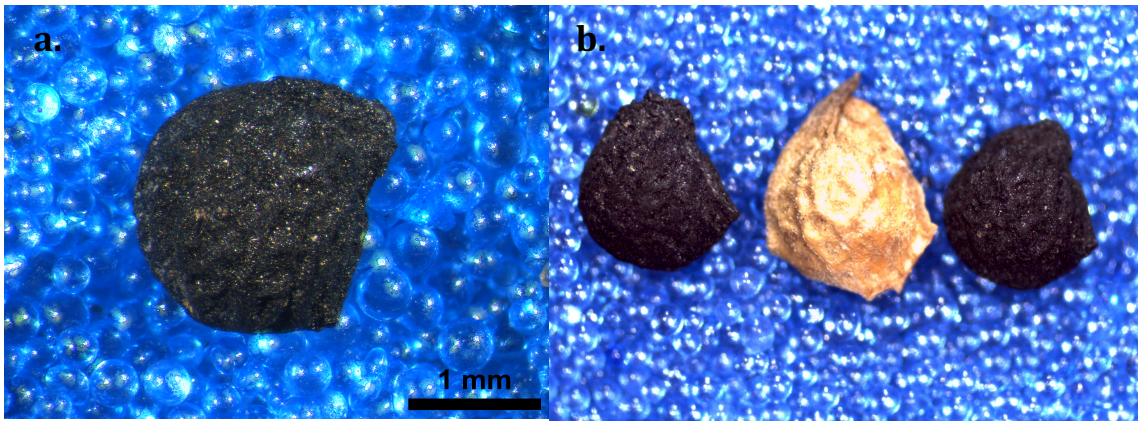


Figure 8 – (a.) Small *Adonis* type (Type specimen: Catal_Fl.9271_001) identified as *Adonis* cf. *microcarpa* from the Çatalhöyük stores. (b.) Comparison of the archaeological specimens with uncharred modern *Adonis microcarpa* (there was insufficient material to experimentally char this accession).

All of the observed archaeological specimens reflected the smaller end of the scale (<2.5mm) for seed length (Figure 4), but only the Çatalhöyük specimens fitted characteristics displayed by the modern small type *Adonis microcarpa*. When considering the ecological signatures of the specimens identified (Table 3; Figure 9) (above, 6.3), the three species reflect almost identical discriminant function scores towards the low input end of the overall scale. Compared to all *Adonis* specimens with available functional data, the identified species represent the centre and main core of the ecological distribution.

Table 3 – Ecological signatures (discriminant function) for each of the identified *Adonis* species/types in relation to the combined FIBS cultivation intensity model (Chapter 6).

Final ID	Discriminant function (DF)	DF based on averaged values
Adonis cf. *aestivalis*	-4.11	-
Adonis cf. *annua*	-5.12	-
Adonis cf. *microcarpa*	-4.81	-
Adonis aestivalis/ *Adonis annua* type	-	-4.62

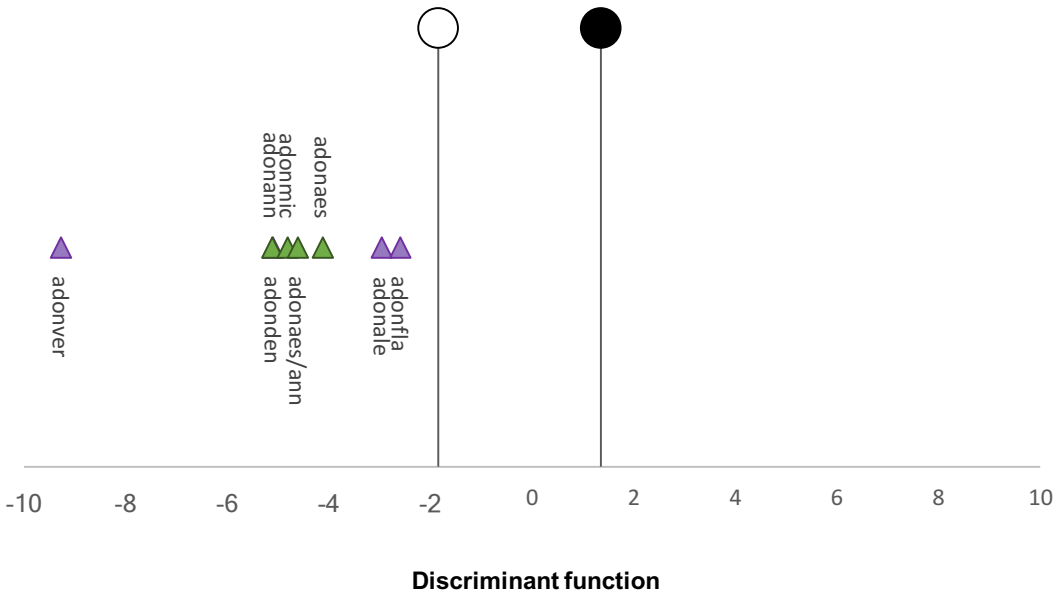


Figure 9 – Ecological signatures (discriminant function) for *Adonis* species in relation to the combined FIBS cultivation intensity model (see Chapter 6). The two lines represent the group centroids for low-input (white) and high-input (black) regimes. Species coded in green indicate those that were identifed within this study.

(ii) Large-seeded Gramineae: *Eremopyrum*, *Hordeum* and *Lolium*

Gramineae caryopses present some of the most straightforward genera to document systematically, with broad variances in shape easily expressed by length, breath and thickness ratios (above, Chapter 8). Therefore, a series of rudimentary analyses were undertaken for three large-seeded Graminae genera: *Eremopyrum*, *Hordeum* and *Lolium*. While *Lolium* did not feature within the original top-ten target weed genera (only identified at Tell Aswad), it had a very small list of relevant species, for which the majority (5/6) had accessions available for consultation. The recording methods followed those presented in the *Bromus* key, with a small number (two to three) of specimens photographed in multiple views and measured for each species. A slightly more detailed analysis was afforded for *Eremopyrum*, which had only four species candidates and was relevant to all four sites (Table 4); six specimens were experimentally charred and recorded per species. However, owing to time constraints and limited reference material, the same high quality[6] of accession sources could not be guaranteed for these more preliminary assessments. With distinguishing criteria based on only limited datasets, subsequent identifications were offered as 'types' rather than definitive species identifications for most cases.

Proportional ratios were calculated for each specimen, including length-to-breadth (L:B x 10), thickness-to-breadth (T:B x 100), length-to-thickness (L:T x 10) and scutellum percentage (above, 8.1.5). Following the *Bromus* key, these measurements were also adapted to represent the main seed 'body' without the protruding embryo tip. Both sets of measurements were considered for the final identifications, as the measured specimens were supplemented by existing measurement data presented in Nesbitt's 'Near Eastern Grass Seeds' (2006)[7]. Average values were computed for each measurement type, which were used to inform distinctions among the species. As with *Adonis*, the preliminary measurement data was considered in conjunction with consultation of further accessions,

[6] Some accessions in the reference collection were of unknown source, therefore had insufficient information regarding their method of acquisition.
[7] This data reflects the full extent of the seed with the embryo tip included.

illustrations and Flora/Seed Atlas descriptions to determine the final identifications. Comparable measurements were taken from each of the complete archaeobotanical specimens to directly compare with the reference specimens.

Eremopyrum

Analysis of the modern *Eremopyrum* material revealed a considerable amount of overlap among the recorded dimensions for the four species (Table 5), which was further complicated by conflicting reference material (Figure 7). Two accessions were analysed for each species, yet major inconsistencies in size and shape were observed between them, particularly for seed length, length:breadth and length:thickness ratios (c. 30-45% coefficient of variation) (Table 5; Figure 10). *Eremopyrum orientale,* however, presented an exception with its relatively stable dimensions (<15% coefficient of variation for all features). Explanations for these discrepancies were difficult to trace owing to the use of unknown accession sources[8]. Further accessions and images were checked against the recorded specimens to determine the normal distribution for each species.

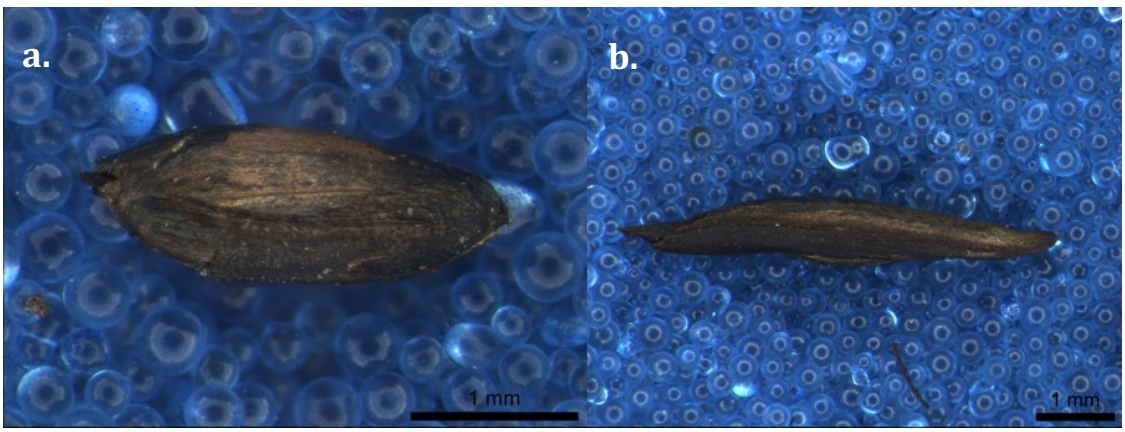


Figure 10 – Lateral views for two separate accessions of *Eremopyrum triticeum*. There were significant contrasts between their seed dimensions and shape, but seeds were relatively consistent within accessions. The first accession (a.) was of unknown source, so it is difficult to explain the differences. Further material would need to be acquired to create a detailed identification key similar to *Bromus.*

[8] This preliminary examination once more highlights the issues associated with using small reference collections for identification purposes; the investigation of one or two accessions is unlikely to yield a representative distribution of values for a species and therefore may be misleading.

Table 4 – Compatibility of the altitude zone for each of the geographically relevant *Eremopyrum* species to the four early farming sites. The number of accessions able to be consulted for each species is also listed. Floras: FOT = *Flora of Turkey*, FOI = *Flora of Iraq*, NFLS = *Nouvelle Flore du Liban et de la Syrie*.

	Floras					*Altitude range*		
Species Name	**FOT**	**FOI**	**NFLS**	**No. of accessions consulted**	**Photographed and recorded?**	**Çatalhöyük**	**Jerf el-Ahmar/ Dja'de**	**Tell Aswad**
Eremopyrum triticeum	Y			4	Y	Y	-	-
Eremopyrum bonaepartis	Y	Y	Y	4	Y	Y	Y	Y
Eremopyrum orientale	Y	Y		4	Y	Y	Y	N
Eremopyrum distans	Y	Y	Y	3	Y	Y	Y	Y

Table 5 – Average dimensions for *Eremopyrum* calculated from the small number of modern experimentally charred specimens measured in this study.

Species name	Collection notes	Accession type	No. of specimens	Average of Length (body)	Average of Scutellum %	Average of L:B x 10	Average of T:B x 100	Average of L:T x 10
Eremopyrum bonaepartis				3.77	26	38	96	40
	DJS 442	Field collection	3	2.99	25	33	98	34
	Z60051 (Sheffield)	Unknown	3	4.55	27	43	94	46
Eremopyrum distans				3.36	27	25	96	26
	DJS 395	Field collection	3	2.35	29	21	96	21
	-	Unknown	3	4.36	26	29	96	31
Eremopyrum orientale				4.10	29	33	102	33
	-	Unknown	3	4.21	28	31	91	34
	USDA	Gene bank	3	4.00	31	35	113	32
Eremopyrum triticeum				3.99	19	32	79	43
	-	Unknown	3	5.48	16	41	71	60
	USDA	Gene bank	3	2.49	22	23	86	27

Despite these major variations, two features remained relatively stable between the modern accessions; these included scutellum percentage (average coefficient of variation - 12.5%), and the thickness:breadth ratio (average coefficient of variation - 11%), which expresses lateral compression and cross-section shape. Subtle distinctions in these features among the four species observed assisted with the identification process.

Only one *Eremopyrum* type was identified from the archaeobotanical material across the four sites, which presented an unusually large dataset to relate to the modern material; comparison of the measurement data for 22 complete specimens presented highly consistent dimensions and shape ratios[9] (Table 6). The closest match for the archaeological type was *Eremopyrum bonaepartis*, which was comparable in dimensions for general size, dorsal shape (length:breadth ratio), thickness (thickness:breadth ratio) and scutellum percentage (Figure 11). Despite the inconsistent material for *Eremopyrum distans*, the cross-section was too laterally compressed (low thickness:breadth ratio) across all specimens observed and were also too broad in their dorsal shape (low length:breadth ratio). *Eremopyrum triticeum* could be excluded based on its low thickness:breadth ratio, which was noticeably flatter in cross-section shape compared to the other species. *Eremopyrum orientale* was very similar to *Eremopyrum bonaepartis* based on dimensions, but it was adapted to very low altitudes in the Flora of Iraq (<150m) which omitted it from consideration for Tell Aswad; as the same type was identified across all four sites,

Eremopyrum orientale was excluded. A separate genus also considered for this type was *Agropyron* (many now transferred to *Elymus*), which have near identical caryopses to *Eremopyrum* (Nesbitt 2006: 88). Yet most species listed in the Flora of Iraq were adapted to high altitudes above 1000m, with only one species (*Agropyron elongatiforme (Elymus repens*)) relevant to the target altitude range. However, due to the limited datasets and the clear overlaps observed, this identification was left as a *Eremopyrum bonaepartis* 'type'. The discriminant function for this species lies towards the centre of the farming input scale, though it was difficult to assess the full range of signatures for *Eremopyrum* as there was limited functional attribute data for this genus (Figure 12).

[9]There was a low coefficient of variation (all features <20%, average 13.8%) for all the features observed.

Table 6 – Average values, standard deviations (STDEV) and coefficient of variation (COEDFFIC VAR) for the dimensions measured for the 22 archaeological *Eremopyrum* specimens identified from the four early farming sites. The low coefficient of variation (<20%) for each measured trait indicate consistent seed shape proportions.

	Length (body)	Breadth	Thickness	Scutelleum (body)	Scutelleum %	L:B x 10	T:B x 100	L:T x 10
AVERAGE	2.92	0.87	0.83	0.74	25.66	33.95	95.88	35.35
STDEV	0.37	0.10	0.11	0.14	3.39	4.94	5.74	5.27
COEFFIC VAR	12.69	11.66	12.66	18.53	13.20	14.56	5.99	14.90

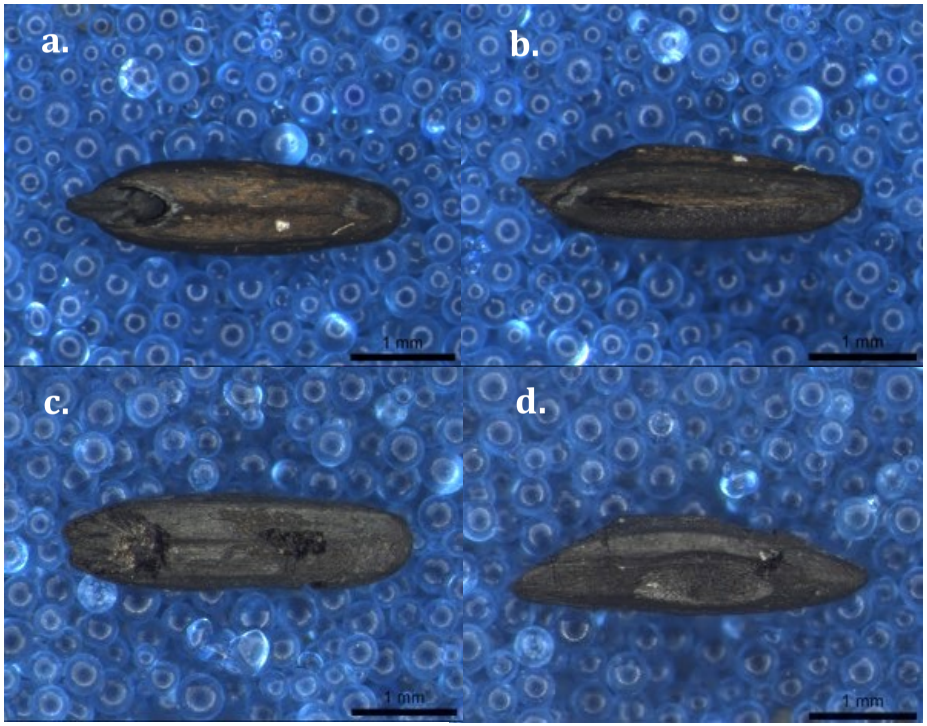


Figure 11 - Modern specimen of *Eremopyrum bonaepartis* (a. & b.) compared in dorsal and lateral views with the archaeological type specimen from Çatalhöyük (Erem_F9271_LG_05) (c. & d.).

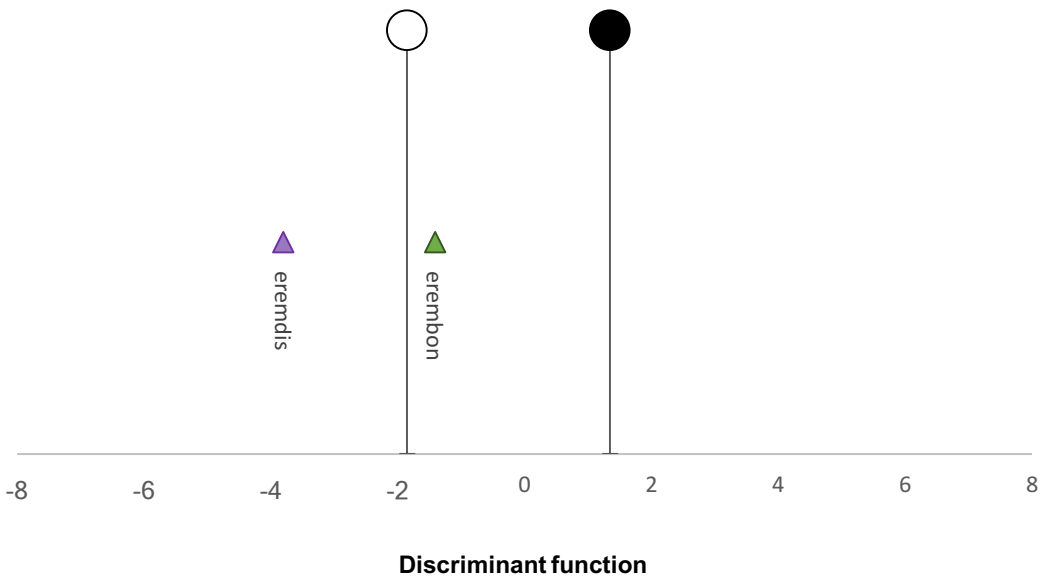


Figure 12 – Ecological signatures (discriminant function) for *Eremopyrum* species in relation to the combined FIBS cultivation intensity model (see Chapter 6). The two lines represent the group centroids for low-input (white) and high-input (black) regimes. The species coded in green was identifed within this study.

Hordeum

While twelve candidates were listed in the Floras for the genus *Hordeum*, only four species required consideration (Table 7); many have since been revised as subspecies of *Hordeum marinum* and *Hordeum murinum*, while others are cultivars. *Hordeum violaceum* was applicable to Çatalhöyük only and could be immediately excluded based on its high-altitude range (1600-3000m). While weedy *Hordeum* was identified from selected samples at all four of the archaeological sites, due to time constraints photographs and measurements were only systematically recorded from Çatalhöyük and Dja'de, with a single type observed between them (Figure 13).

A brief analysis of the remaining three candidates presented basic shape profiles for comparison with the archaeological material. The two species *Hordeum marinum* and *Hordeum murinum* were comparable in dorsal shape and cross-section shape, which best reflected the morphology of the archaeological observed type. *Hordeum bulbosum* was distinctly more elongated in dorsal shape and had a flatter cross-section shape, so was excluded. A second archaeological type with an elongated dorsal shape was initially identified from Dja'de, but direct comparison with modern reference material indicated that this extended embryo shape was more indicative of the preservation of the delicate embryo tip enclosed in outer pericarp (Figure 14)[10]. Consideration of this specimen's cross-section demonstrated further resemblance to the two shorter *Hordeum marinum*/*Hordeum murinum* species. *Hordeum murinum* was selected for the final identification of the archaeological type, which was chiefly determined by closer inspection of the two species'

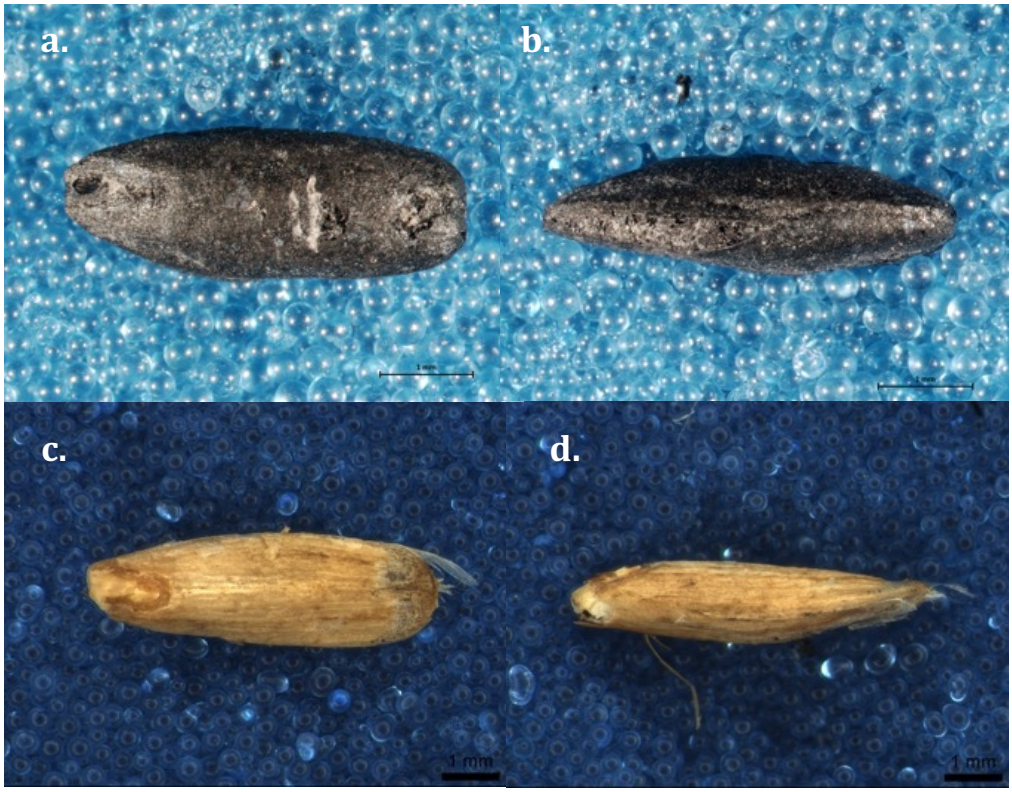


Figure 13 – (a. & b.) Type specimen for weedy *Hordeum* (Hord_mur_DJ_37_02) identified at Dja'de and Çatalhöyük. Comparison with fresh modern *Hordeum murinum* material (c. & d.).

[10] Further *Hordeum murinum/bulbosum* types were identified at the Syrian sites, but as only a select number of specimens could be examined and recorded they were left as indeterminate types.

Table 7 - Compatibility of the altitude zone for each of the geographically relevant *Hordeum* species to the four early farming sites. The number of accessions able to be consulted for each species is also listed. Floras: FOT = *Flora of Turkey*, FOI = *Flora of Iraq*, NFLS = *Nouvelle Flore du Liban et de la Syrie*.

	Floras					*Altitude range*		
Species Name	**FOT**	**FOI**	**NFLS**	**No. of accessions consulted**	**Photographed and recorded?**	**Çatalhöyük**	**Jerf el-Ahmar/ Dja'de**	**Tell Aswad**
Hordeum violaceum	Y			1	-	N	-	-
Hordeum marinum	Y	Y		1	Y	Y	Y	N
Hordeum murinum	Y		Y	3	Y	Y	Y	Y
Hordeum bulbosum	Y	Y	Y	3	Y	Y	N	N

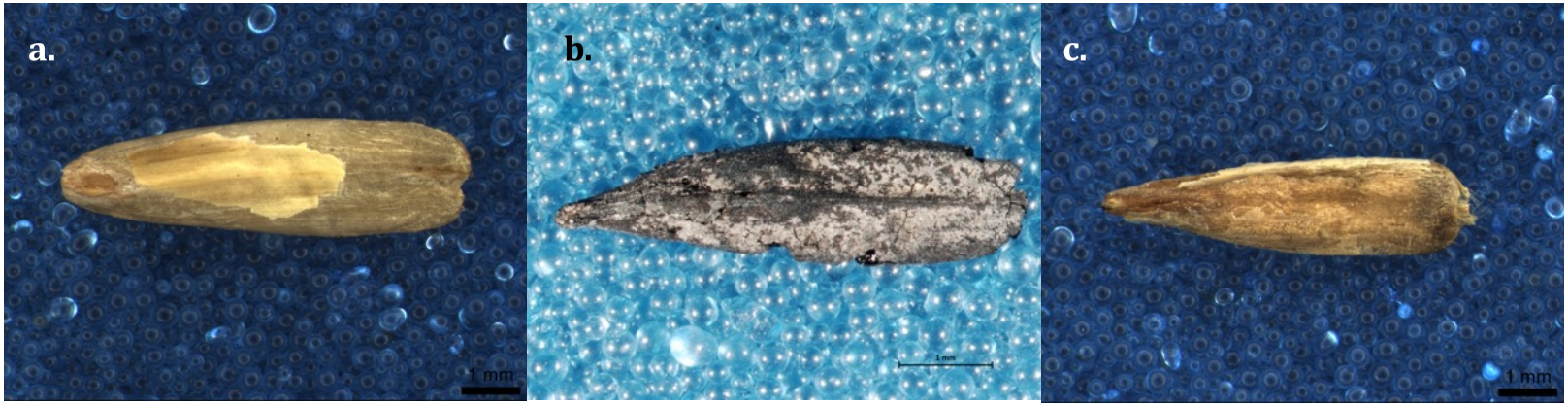


Figure 14 – An archaeological specimen from Dja'de (b.) was initially identified as *Hordeum bulbosum* (a.) due to its elongated dorsal shape and tapered embryo end. However, observation of modern reference material revealed that similar shapes occurred in other *Hordeum* species (eg. *Hordeum murinum* (c.)) when the delicate embryo tip was still enclosed in outer pericarp.

habitat preferences; while applicable within the geographical filters, the main distribution for *Hordeum marinum* was below 100m and primarily occurred in maritime sands and saltmarshes. The discriminant function for this species was at the very high-input end of the farming intensity scale, which was distinct from the other weedy *Hordeum* species observed (Figure 15).

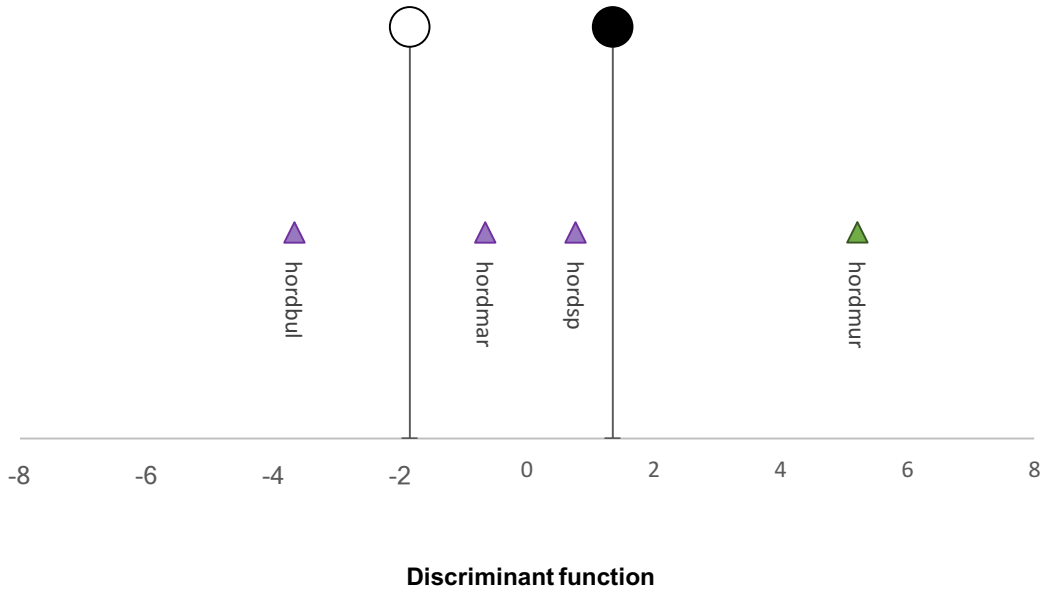


Figure 15 - Ecological signatures (discriminant function) for weedy *Hordeum* species in relation to the combined FIBS cultivation intensity model (see Chapter 6). The two lines represent the group centroids for low-input (white) and high-input (black) regimes. The species coded in green was identifed within this study.

Lolium

As *Lolium* only occurred in meaningful numbers within the selected samples at Tell Aswad, it was the only Syrian site where this genus was systematically documented. Therefore, only a basic analysis was undertaken to assist the identification of this genus, which aimed to assess the general variation in shape and to offer a type level identification. A single *Lolium* type was identified from the selected samples at Tell Aswad, though some specimens were noticeably puffed up and required slight adjustments to the dimensions (measured at unaffected sections) to relate to the uncharred modern material. *Lolium multiflorum* was excluded at the beginning of this analysis as it was not geographically relevant for Tell Aswad (Table 15).

This simple assessment (supplemented with existing measurements – see above) revealed highly overlapping measurements for the four remaining modern species observed. The two species *Lolium temulentum* and *Lolium persicum* could be distinguished as larger types[11], whose average lengths diverged from those observed in the archaeobotanical material. However, as with all grass genera, it is unclear how relevant seed size is for identification as this may have been influenced by crop processing activities over thousands of years (above, 8.1.7). Each of the proportional ratios greatly overlapped among the species, though divisions could be discerned when averages were considered. When evaluating the thickness:breadth ratio, the archaeological specimens most closely resembled *Lolium temulentum*, the thickest of the species observed, though these correlations may reflect puffed dimensions from charring. When the archaeological material was directly compared with *Lolium temulentum,* there were several divergent characteristics not easily expressed by traditional measurements; the archaeological type was consistently angular in dorsal shape (Figure 16a & b), whereas *Lolium temulentum* was distinctly rounded. Furthermore, the dorsal shape of the seed (length:breadth ratio) was on average much shorter than the Tell Aswad specimens and had a larger scutellum percentage, though the observation of this latter feature was based on limited data (two specimens). Therefore, *Lolium temulentum* was excluded from the list of potential candidates.

[11] Based on uncharred measurement data for 23 and 13 specimens respectively.

Table 8 - Compatibility of the altitude zone for each of the geographically relevant *Lolium* species to the four early farming sites. The number of accessions able to be consulted for each species is also listed. Floras: FOT = *Flora of Turkey*, FOI = *Flora of Iraq*, NFLS = *Nouvelle Flore du Liban et de la Syrie*.

	Floras				
Species Name	**FOI**	**NFLS**	**No. of accessions consulted**	**Photographed and recorded?**	**Tell Aswad altitude range?**
Lolium loliaceum	Y	Y	0	N	Y
Lolium multiflorum	Y	Y	2	Y	N
Lolium perenne	Y	Y	1	Y	Y
Lolium persicum	Y	Y	1	Y	Y
Lolium rigidum	Y	Y	3	Y	Y
Lolium temulentum	Y	Y	3	Y	Y

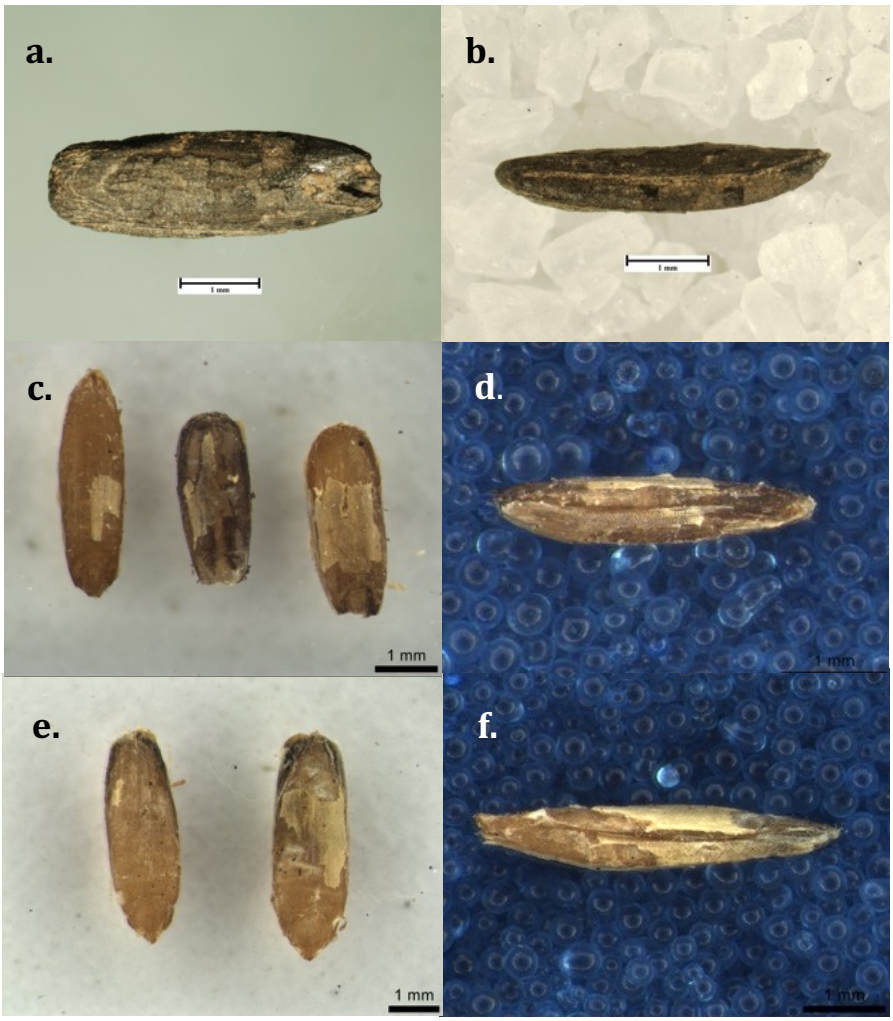


Figure 16 – (a. & b.) Type specimen for *Lolium* (Loli 1 - 363) identified at Tell Aswad. Comparison with fresh modern material of *Lolium perenne* (c. & d.) *and Lolium rigidum* (e. & f.).

Of the three remaining candidates, *Lolium persicum* had the thinnest cross-section observed and was the most distinct from the archaeobotanical specimens. *Lolium perenne/rigidum* type was selected as the final identification for the archaeological type as their dimensions and characteristics were most similar to the archaeological material (Figure 16c-f). These two species had almost identical dimension averages, so it was impossible to distinguish them further at the current level of analysis. Nevertheless, distinction beyond this species group was unnecessary for ecological purposes, as they also had near identical values for the discriminant function (*L. perenne,* -2.76, and *L. rigidum*, -2.78) (Figure 17).

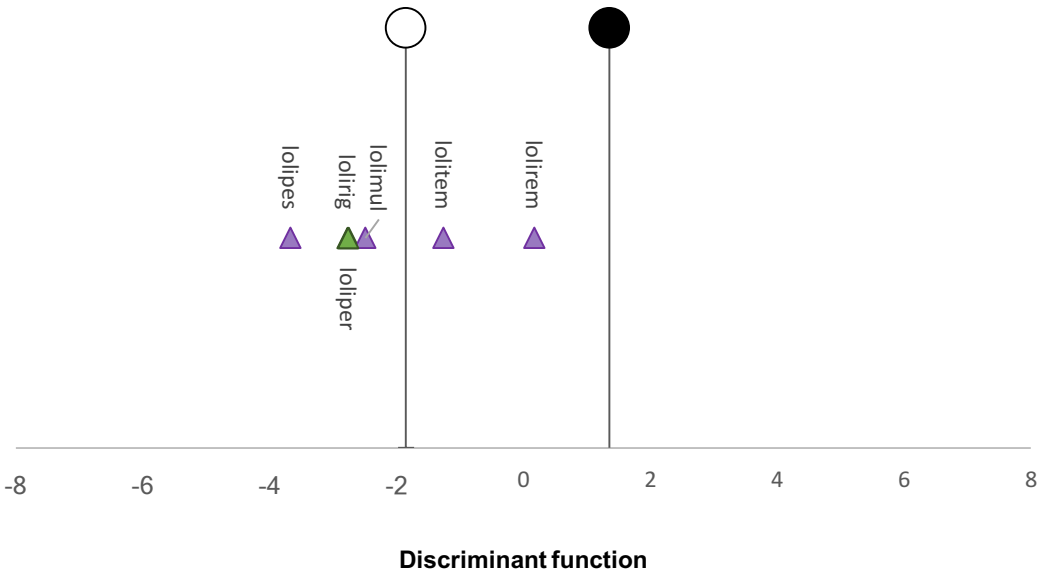


Figure 17 – Ecological signatures (discriminant function) for *Lolium* species in relation to the combined FIBS cultivation intensity model (see Chapter 6). The two lines represent the group centroids for low-input (white) and high-input (black) regimes. Species coded in green indicate those that were identifed within this study.

In summary, these brief systematic analyses support several observations regarding the identification potential of grass specimens that became apparent during the construction of the *Bromus* key. While grass caryopses present some of the easiest specimens to systematically document, they also possess considerable intra-species (and occasionally intra-population) variability, with recurrent overlapping dimensions and proportions among different species. These differences were most clearly discerned between accession sources, with seed morphology relatively stable within a single source. Such distinctions are likely to reflect variations in growing

conditions, i.e. native field populations for field collections versus garden conditions (with limited species competition) for botanic garden sources. Therefore, to achieve reliable species level identifications, the consultation of multiple accessions is essential to appreciate the full variability potential of candidate species.

(iii) Other genera: type identifications without systematic data

Many of the remaining priority weed genera had considerable numbers of candidate species that were unavailable within the University of Oxford reference collection and could not be obtained externally. While some candidates could be excluded according to the geographical filters, or observed at alternative reference collections, systematic recording of the limited species available was deemed unconstructive with so many unknown types and their unrecorded variations. Nevertheless, it was important to establish the most likely species types based on the accessions observed to provide further preliminary ecological data and to direct future identification attempts. The following section details the species and number of accessions that were consulted, as well as the criteria used to designate type level identifications.

Atriplex

While *Atriplex* has limited characteristics available for the identification of their seeds, numerous highly distinctive fruiting perianth segments (Figure 18a) were preserved at Dja'de, which were further observed (though in smaller quantities) at Tell Aswad. Only a third of the applicable species candidates were available for consultation, yet a comparable type was identified. *Atriplex rosea* had a similar veiny surface patterning with a matching general shape and irregular outer edge (Figure 18b). The perianth edges for the other species observed were noticeably smoother and greater defined. Flora illustrations of the fruiting perianths additionally indicated *Atriplex rosea* as likely candidate (Davis 1965; Ghazanfar & Edmondson 2016).

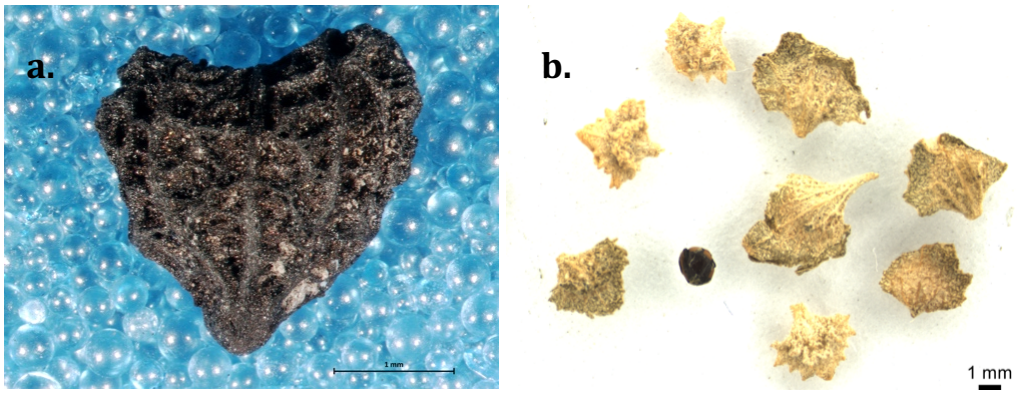


Figure 18 – (a.) *Atriplex* fruiting perianth specimen (Atri_DJ_68_09_01) identified at Dja'de. (b.) Comparison with fresh modern material of *Atriplex rosea* with similar veiny surface pattern.

Table 9 – Number of applicable *Atriplex* species by archaeological site and the number of species with modern reference material available for consultation. * = Cultivars removed.

	Number of species	
	Jerf el-Ahmar/ Dja'de	Tell Aswad
Total candidates	17	17
Excluded by altitude/other filters*	5	5
Remaining applicable candidates	12	12
Reference material available	4	4

Table 10 - Compatibility of the altitude zone for each of the geographically relevant *Atriplex* species that were able to be consulted. The number of accessions examined for each species is also listed. Floras: FOI = *Flora of Iraq*, NFLS = *Nouvelle Flore du Liban et de la Syrie*.

	Flora			*Altitude range*	
Species Name	**FOI**	**NFLS**	**No. of acc.**	**Jerf el-Ahmar/ Dja'de**	**Tell Aswad**
Atriplex halimus	Y	Y	1	Y	Y
Atriplex hastata		Y	2	Y	Y
Atriplex lasiantha	Y	Y	1	Y	Y
Atriplex rosea		Y	2	Y	Y

Convolvulus

Convolvulus only occurred as a single type at Çatalhöyük, though it was ubiquitous across the selected storage samples and was often well-preserved. Yet, less than half of the 21 relevant species were obtainable after extensive searches of botanical seed catalogues. Much of the modern reference specimens had distinctive surface patterning, but experimental charring revealed that this was easily stripped away following charring. Of the 10 species observed, the closest match was *Convolvulus arvensis*, which was comparable in size, shape and surface texture. The slight variants in shape observed across the archaeobotanical material are also consistent with modern *Convolvulus arvensis* specimens. While usually 4-seeded creating distinctive trigonous seeds, the fruiting capsules for this species are occasionally 1-seeded, which produce more ellipsoidal seeds (Figure 19); this characteristic has only been observed in a restricted number of species (Wood *et al.* 2015: 27, 56).

Table 11 - Number of applicable *Convolvulus* species by archaeological site and the number of species with modern reference material available for consultation.

	Number of species
	Çatalhöyük
Total candidates	32
Excluded by altitude	11
Remaining applicable candidates	21
Reference material available	10

Table 12 - Compatibility of the altitude zone for each of the geographically relevant *Convolvulus* species that were able to be consulted. The number of accessions examined for each species is also listed. Accessions were consulted at both the University of Oxford and from the reference collection held at the British Institute of Archaeology at Ankara (BIAA). Floras: FOT = *Flora of Turkey*.

	Flora	*No. of acc.*		*Altitude range*
Species Name	**FOT**	**Oxford**	**Ankara**	**Çatalhöyük**
Convolvulus arvensis	Y	3	3	Y
Convolvulus betonicifolius	Y	1	0	Y
Convolvulus cantabrica	Y	2	0	Y
Convolvulus compactus	Y	1	0	Y
Convolvulus dorycnium	Y	3	0	Y
Convolvulus galaticus	Y	0	1	Y
Convolvulus holosericeus	Y	1	0	Y
Convolvulus lineatus	Y	1	0	Y
Convolvulus reticulatus	Y	0	1	Y
Convolvulus stachydifolius	Y	0	1	Y



Figure 19 – Archaeological specimens of *Convolvulus* from Çatalhöyük, including an ellipsoidal example which can be observed in modern *Convolulus arvensis* specimens.

Galium

Galium presents one of the greatest challenges for species level identifications, owing to its substantial number of applicable species. This was most problematic for the Çatalhöyük material, where 66 candidates remained applicable after geographical filtering (Table 13). Nevertheless, the genus frequently occurred across the selected samples and was identified at all four sites. Five separate archaeological types were identified in total between the four sites, which included one large type (>2mm) and four smaller types. Only a tiny proportion of the applicable species were available for consultation (Table 14). Furthermore, the presence of the outer spiny surface texture in modern specimens made it difficult to compare surface patterning in any detail. To assist with the identification process, the dichotomous Rubiaceae key by Lange (1979) was consulted for guidance. While this key is specific to central Europe, it was developed using extensive measurement data for each species and included many of the target candidates (above, 7.1). The large globular *Galium* type was most similar to *Galium aparine* and *Galium tricornutum* (Figure 20a)*;* closer examination of the cell patterning on the dorsal side of the seed revealed a clustered isodiametric cell arrangement, which is indicative of *Galium tricornutum* specimens (Lange 1979: 204). Though patches of linear cells were also observed, these were restricted to the hilum edges, which are not considered in the Lange identification key.

The smaller types (<2mm) were distinguished by their shape, hilum type and extremes in size. One type observed at Jerf el-Ahmar and Dja'de also had clustered squared cells, however was more rectangular in general shape with a rectangular hilum (Figure 20c); *Galium spurium* was

Table 13 – Number of applicable *Galium* species by archaeological site and the number of species with modern reference material available for consultation.

	Number of species		
	Çatalhöyük	Jerf el-Ahmar/ Dja'de	Tell Aswad
Total candidates	101	23	23
Excluded by altitude	35	8	8
Remaining applicable candidates	66	15	15
Reference material available	10	3	3

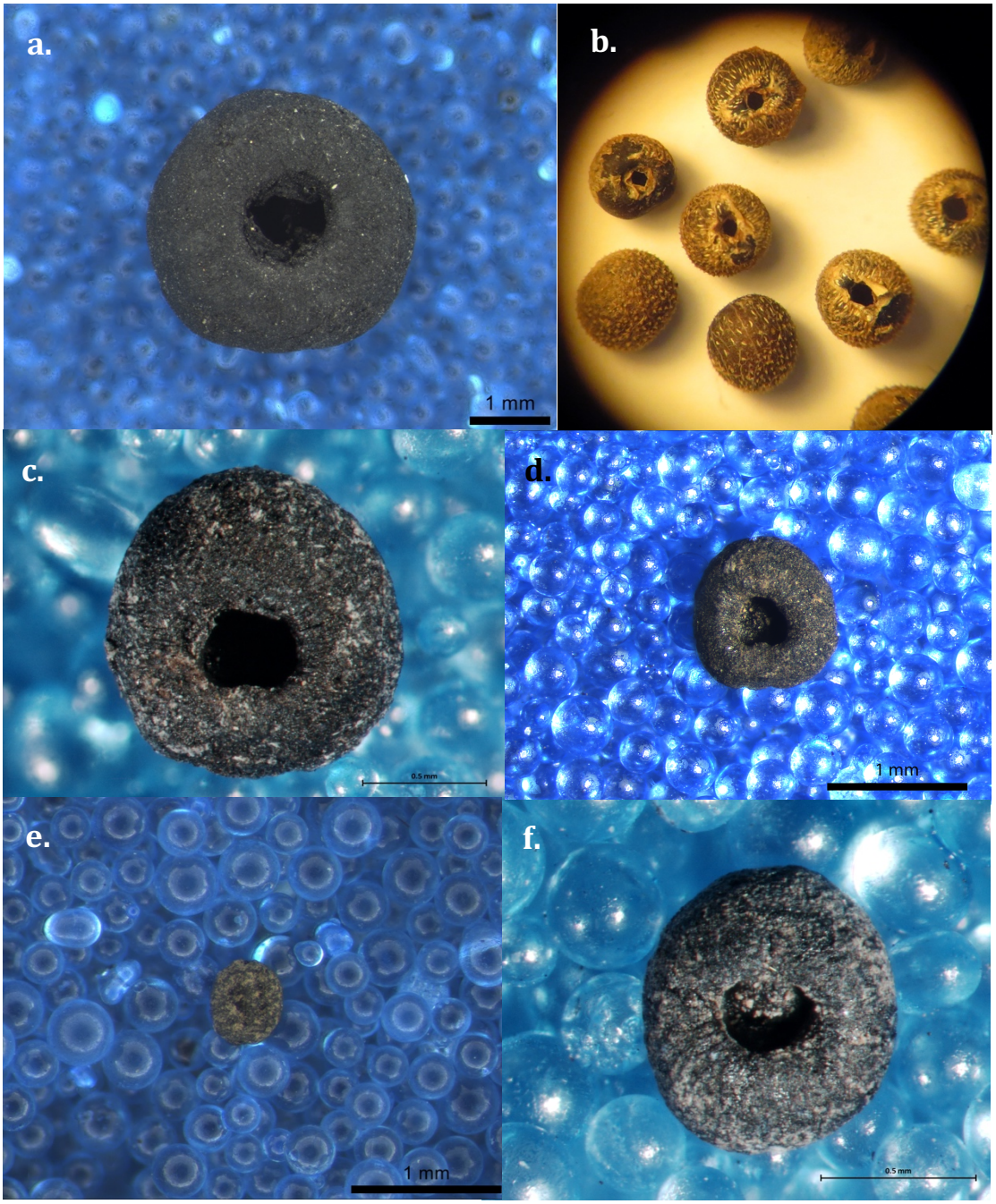


Figure 20 – Type specimens for the five *Galium* and *Asperula* types identified across the four sites. (a.) Large *G. tricornutum* type (Gali_F516_DF_06). (b.) Comparison with fresh modern material of *G. tricornutum*. (c.) Small *Galium* sp. type (Gali_DJ_68_11_01) - no species comparisons identified. (d.) *Galium spurium/odoratum* type from Çatalhöyük. (e.) Tiny *Galium* sp. type identified at Çatalhöyük – no species comparisons identified. (f.) *Asperula* sp. type identified from the three Syrian sites.

Table 14 – Compatibility of the altitude zone for each of the geographically relevant *Galium* species that were able to be consulted. The number of accessions examined for each species is also listed. Accessions were consulted at both the University of Oxford and from the reference collection held at the British Institute of Archaeology at Ankara (BIAA). Floras: FOT = *Flora of Turkey*, FOI = *Flora of Iraq*.

	Floras		*No. of acc.*		*Altitude range*		
Species Name	**FOT**	**FOI**	**Oxford**	**Ankara**	**Çatalhöyük**	**Jerf el-Ahmar/ Dja'de**	**Tell Aswad**
Galium album	Y		1	1	Y	-	-
Galium aparine	Y	Y	4	1	Y	Y	Y
Galium floribundum	Y		0	3	Y	-	-
Galium odoratum	Y		1	2	Y	-	-
Galium palustre	Y		5	0	Y	-	-
Galium parisiense	Y		1	0	Y	-	-
Galium rotundifolium	Y		1	0	Y	-	-
Galium spurium	Y	Y	4	0	Y	N	N
Galium tricornutum	Y	Y	2	2	Y	Y	Y
Galium verum	Y	Y	3	5	Y	Y	Y

identified as a likely candidate using the Rubiaceae key, but was not applicable to the specified altitude zones for the Syrian sites. A comparable type was identified at Çatalhöyük, though also had shallow furrows visible (Figure 20d); this combination of features best reflects *Galium odoratum,* though the hilum proportion in the archaeological type was smaller and more like *Galium spurium*. There was one type that occurred at all three of the Syrian sites, with a distinctive protrusion visible within the void of the hilum (Figure 20f). The Lange key identified this as a feature of *Asperula* rather than *Galium,* though only one applicable species was available within the reference collection (Table 15). A comparable species for the smallest type (~0.6mm) from Çatalhöyük could not be identified as its surface texture was indiscernible (Figure 20e).

Table 15 - Number of applicable *Asperula* species by archaeological site and the number of species with modern reference material available for consultation.

	Number of species	
	Jerf el-Ahmar/ Dja'de	Tell Aswad
Total candidates	12	12
Excluded by altitude	8	7
Remaining applicable candidates	4	5
Reference material available	0	1

Table 16 - Compatibility of the altitude zone for the geographically relevant *Asperula* species that were able to be consulted. The number of accessions examined for each species is also listed. Floras: FOI = *Flora of Iraq*.

	Floras	*No. of acc.*	*Altitude range*	
Species Name	**FOI**	**Oxford**	**Jerf el-Ahmar/ Dja'de**	**Tell Aswad**
Asperula arvensis	Y	2	N	Y

Polygonum

Polygonum was ubiquitous across the four sites for the selected samples, with two archaeological types identified. While much of the applicable reference material was available for this genus, the Çatalhöyük *Polygonum* types were already well established (A. Bogaard, pers. comm.), so were not selected for the construction of a comprehensive identification key. After further consultation of the reference material, *Polygonum aviculare* and *Polygonum convolvulus* were confirmed as the most likely candidates for the two Çatalhöyük types, each with their distinctive combination of shape and surface textures (Figure 21). *Polygonum convolvulus* is widest in the middle (Figure 21a-b), whereas *Polygonum aviculare* is widest towards the apex. Furthermore, *Polygonum convolvulus* is distinctly elliptic-rhombic in shape and has a characteristic stippled surface texture (Figure 21a-b). Though more poorly preserved, the Syrian *Polygonum* material appeared to replicate the *Polygonum aviculare* type, with its slightly more elongated shape and the widest point towards the base of the seed, however the distinctive surface pattern was not visible. With several of the applicable species unable to be consulted, the Syrian material remained as a type level identification.

Table 17 - Number of applicable *Polygonum* species by archaeological site and the number of species with modern reference material available for consultation.

	Number of species		
	Çatalhöyük	Jerf el-Ahmar/ Dja'de	Tell Aswad
Total candidates	27	21	21
Excluded by altitude	16	8	10
Remaining applicable candidates	11	13	11
Reference material available	10	8	7

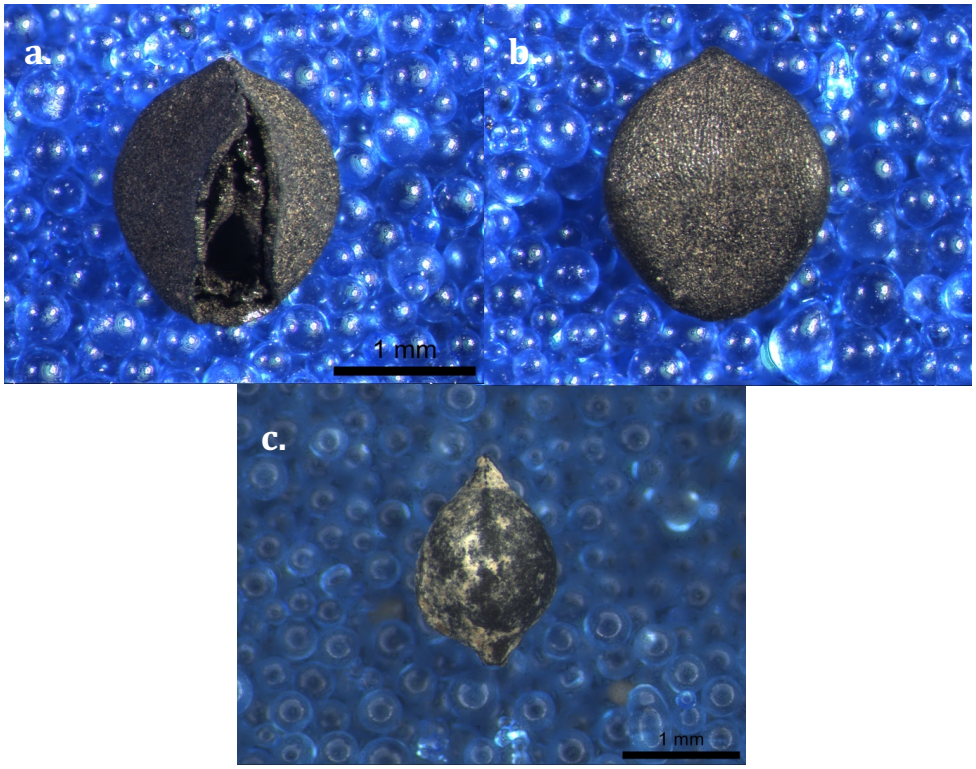


Figure 21 – (a. & b.) Wide Polygonum type identified as *Polygonum convolvulus* (Poly_F10922_4_LG_03) at Catalhoyuk. (c.) *Polygonum aviculare* type specimen (Poly_F6019_16_08) from Catalhoyuk.

Table 18 – Compatibility of the altitude zone for each of the geographically relevant *Polygonum* species able to be consulted. The number of accessions examined for each species is also listed. Accessions were consulted at both the University of Oxford and from the reference collection held at the British Institute of Archaeology at Ankara (BIAA). Floras: FOT = *Flora of Turkey*, FOI = *Flora of Iraq*., NFLS = *Nouvelle Flore du Liban et de la Syrie*.

	Floras			*No. of acc.*		*Altitude range*		
Species Name	**FOT**	**FOI**	**NFLS**	**Oxford**	**Ankara**	**Çatalhöyük**	**Jerf el-Ahmar/ Dja'de**	**Tell Aswad**
Polygonum amphibium	Y		Y	2	0	Y	N	N
Polygonum arenastrum	Y			2	0	Y	-	-
Polygonum aviculare	Y	Y	Y	4	3	Y	Y	Y
Polygonum bellardii	Y			1	4	Y	-	-
Polygonum bistorta	Y			3	1	Y	-	-
Polygonum cognatum	Y	Y	Y	0	1	Y	Y	Y
Polygonum convolvulus	Y			2	0	Y	-	-
Polygonum corrigioloides		Y		0	1	-	Y	N
Polygonum equisetiforme	Y		Y	1	0	N	Y	Y
Polygonum lapathifolium	Y		Y	4	4	Y	Y	Y
Polygonum patulum		Y		1	0	-	Y	Y
Polygonum persicaria	Y		Y	4	0	Y	Y	Y
Polygonum pulchellum	Y			0	2	Y	-	-
Polygonum salicifolium	Y		Y	1	0	N	Y	Y

Rumex

Two different *Rumex* types were identified from the selected samples, with a separate type each distinguished for Çatalhöyük and Dja'de. Many of the species applicable to central Turkey were available for consultation, though the Syrian candidates were slightly more restricted within the reference collection (Table 19). Nevertheless, a comparable species was established at each of the two sites. The Çatalhöyük type was identified as *Rumex conglomeratus*, which corresponded to all features observed; size range, general shape, apex shape, surface texture and the relative sharpness of the keel (Figure 22a-b). The Dja'de type was distinctly rounder in shape with a broader base and had a sharper more pronounced keel that best reflected *Rumex crispus* (Figure 22c-d). These identifications however remained as 'types', as slight variants among accessions were detected, which presented overlaps in seed shape and size.

Table 19 – Number of applicable *Rumex* species by archaeological site and the number of species with modern reference material available for consultation.

	Number of species	
	Çatalhöyük	Jerf el-Ahmar/ Dja'de
Total candidates	23	15
Excluded by altitude	11	4
Remaining applicable candidates	12	11
Reference material available	9	6

Table 20 - Compatibility of the altitude zone for each of the geographically relevant *Rumex* species able to be consulted. The number of accessions examined for each species is also listed. Accessions were consulted at both the University of Oxford and from the reference collection held at the British Institute of Archaeology at Ankara (BIAA). Floras: FOT = *Flora of Turkey*, FOI = *Flora of Iraq*., NFLS = *Nouvelle Flore du Liban et de la Syrie*.

	Floras			***No. of acc.***		***Altitude range***	
Species Name	**FOT**	**FOI**	**NFLS**	**Oxford**	**Ankara**	**Çatalhöyük**	**Jerf el-Ahmar/ Dja'de**
Rumex acetosella	Y		Y	5	0	Y	N
Rumex scutatus	Y			3	2	Y	-
Rumex tuberosus	Y	Y	Y	1	0	Y	Y
Rumex patientia	Y		Y	2	3	Y	Y
Rumex crispus	Y	Y	Y	6	1	Y	Y
Rumex conglomeratus	Y	Y	Y	5	3	Y	Y
Rumex hydrolapathum	Y			3	0	Y	-
Rumex obtusifolius	Y			7	1	Y	-
Rumex pulcher	Y	Y	Y	1	3	Y	Y
Rumex palustris			Y	1	0	-	Y

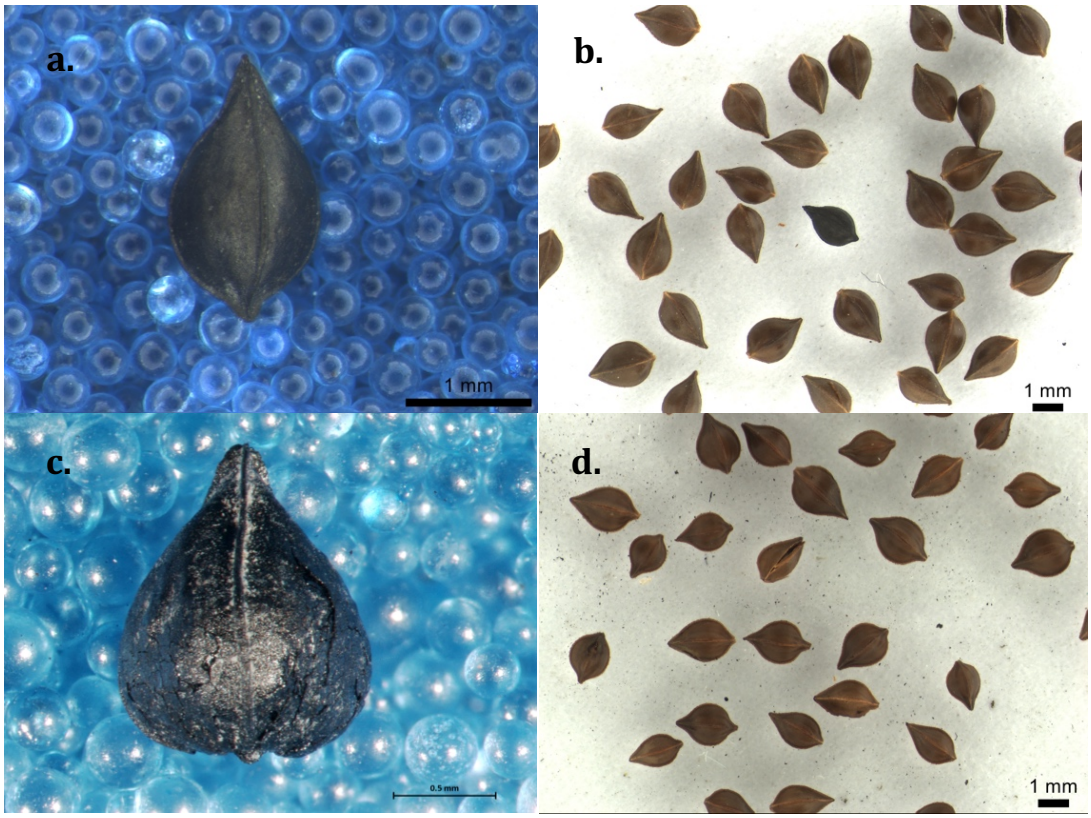


Figure 22 – (a.) Type specimen for *Rumex* at Çatalhöyük (Rume_F516_2_DF_01) identified as *Rumex conglomeratus*. (b.) Comparison with fresh modern material of *Rumex conglomeratus*. (c.) Type specimen for *Rumex* at Dja'de (Poly_DJ_37_04) identified as *Rumex crispus*. (d.) Comparison with fresh modern material of *Rumex crispus*.

Thymelaea

While only a small number of species were applicable for *Thymelaea* in the target regions, only one relevant species—*Thymelaea passerina*—was available for examination (Table 21). Nevertheless, this species was comparable to the single *Thymelaea* type observed from Çatalhöyük and Tell Aswad (Figure 23). *Thymelaea passerina* matched in general size and shape, the angle and extent of the beak and in its surface pattern. The Tell Aswad specimen differed slightly in that it had a different surface texture (Figure 23c), but upon closer examination this was identified as cracking, which likely occurred from charring; the same fine-grained surface pattern could be observed at closer magnifications.

Table 21 – Number of applicable *Thymelaea* species by archaeological site and the number of species with modern reference material available for consultation.

	Number of species	
	Çatalhöyük	Tell Aswad
Total candidates	7	4
Excluded by altitude	2	1
Remaining applicable candidates	5	3
Reference material available	1	1

Table 22 – Compatibility of the altitude zone for the geographically relevant *Thymelaea* species that were able to be consulted. The number of accessions examined for each species is also listed. Floras: FOT = *Flora of Turkey*, FOI = *Flora of Iraq*, NFLS = *Nouvelle Flore du Liban et de la Syrie*..

	Floras				*Altitude range*	
Full Species Name	**FOT**	**FOI**	**NFLS**	**No. of acc.**	**Çatalhöyük**	**Tell Aswad**
Thymelaea passerina	Y	Y	Y	3	Y	Y

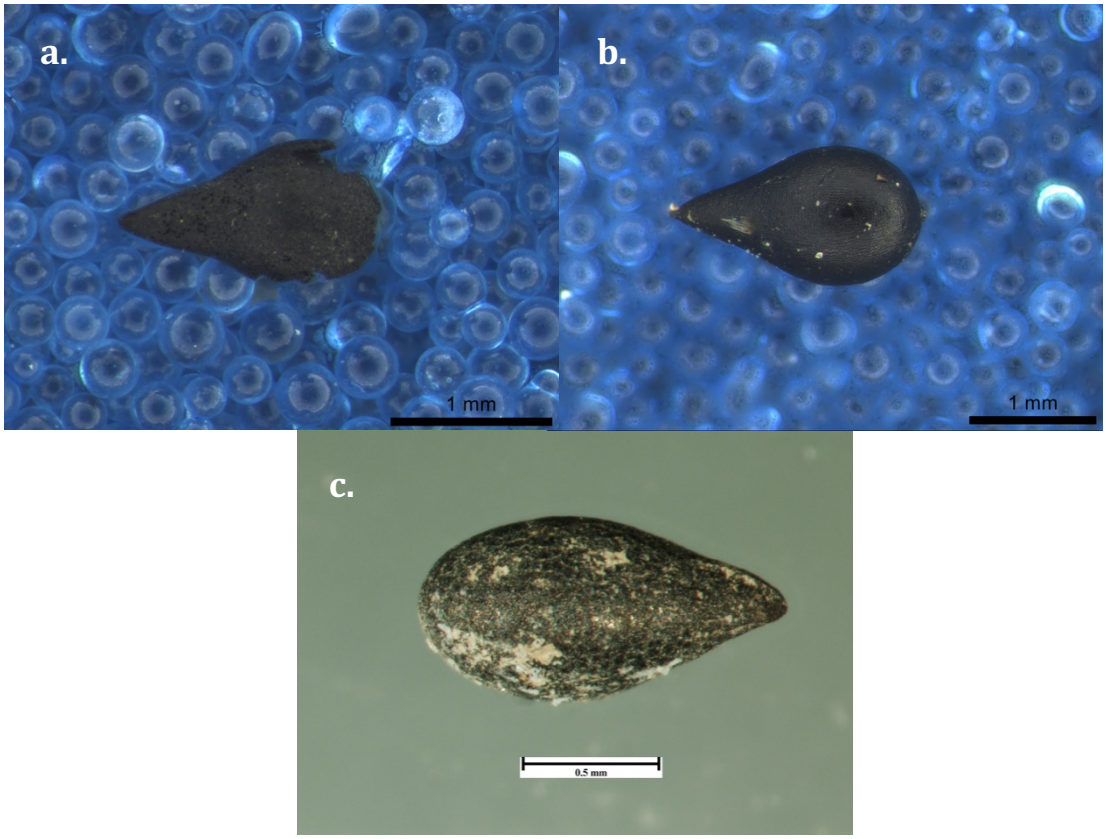


Figure 23 – (a.) Type specimen for *Thymelaea* at Çatalhöyük (Thym_F7906_ME_32_01) identified as *Thymelaea passerina* type (b.) Comparison with fresh modern material of *Thymelaea passerina*. (c.) Type specimen for *Thymelaea* at Tell Aswad (Thym 3 - 476) identified as *Thymelaea passerina* type.

(iv) Conclusions

Though this final set of identifications is not based on tested systematic data, this process replicates some of the traditional procedures commonly undertaken during identification in archaeobotany. The lack of accessions in reference collections is a major problem for refined identification work, but with transparent documentation of the number of species and accessions observed, it is much more straightforward to judge the reliability of a specific identification and to identify where further refinements may be needed. While the documentation of such methods may not be practical for all specimens analysed, it is particularly beneficial for indicating challenging identifications, i.e. for weed identification.

Supplementary material

Lucid 3 can be freely downloaded from the following website:

http://www.lucidcentral.com/Software/Lucid3/Lucidv33FreeOffer.aspx

The file for the *Bromus* identification key can be found on the accompanying CD ROM.

The CD also include raw images that were analysed to construct the key.