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Helmut Kroll • Kelly Reed

Die Archäobotanik

Feudvar III

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Helmut Johannes Kroll · Kelly Reed

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Heidi Peter-Röcher

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Feudvar III

Ausgrabungen und Forschungen in einer Mikroregion am Zusammenfluss von Donau und Theiß

herausgegeben von Frank Falkenstein

Helmut Johannes Kroll · Kelly Reed

Die Archäobotanik

mit Beiträgen von
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Inhalt

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Archaeobotanical analysis of Bronze Age Feudvar

by Kelly Reed

Contents

1. Bronze Age Feudvar

This contribution presents the results of the plant remains from Bronze Age Feudvar (Serbia). The first section outlines the assemblage characteristics (p. 200) in order to explore general patterns in the assemblage. Formation processes at the site will then be explored (p. 200), followed by a detailed discussion of the crops (p. 203) and wild resources (p. 207) found in the Bronze Age levels. The chapter concludes by comparing the Feudvar assemblage with other sites in order to see if any further patterns can be seen through time.

1.1 Assemblage characteristics

Feudvar is a fortified Bronze and Iron Age settlement, situated on the northern rim of a loess plateau in Vojvodina, Serbia. The archaeobotanical assemblage, collected from the 1986–1990 excavations, was previously identified by Helmut Kroll, Kiel. The dataset consists of 524 samples collected from the western cut of the tell site dating to the Bronze and Iron Age. Each sample represented ca. 10 litres of sediment, a total of ca. 5240 litres floated, from which 593,315 carbonised plant remains were recovered. However, within the assemblage 263,780 seeds were of *Chenopodium polyspermum*, recovered from FEU210[1]. The large quantity of seeds recovered were a rare find within the assemblage and would have had a distinct effect on the following results. Therefore the *Chenopodium polyspermum* remains from FEU210 were removed from the following analyses.

The seed density at Feudvar is high at 63 seeds per litre of sediment (Table 1), but the standard deviation for the site is, however, extremely high at 268, showing huge variation between the samples. The median density per litre is slightly lower at 20 and may be a more realistic estimation for the assemblage. Additionally, Table 2, grouping the samples by seed density per litre, shows that the majority of the samples have a seed density of >10.1 (205 samples) and >25.1 (209 samples). Only 39 samples have a seed density per litre between 0 to 5.

The density of each plant group (i.e. grain, chaff, fruits) per litre (Table 3), as well as their relative proportions (Fig. 1), show that grain, chaff and wild / weed seeds dominate the overall assemblage. The mean seed densities for these categories are extremely high, ranging from 133 for wild / weed seeds to 276 for chaff remains per litre. However, they also have extremely high standard deviations e.g. 1,924 for chaff (Table 3). Thus, the median values show that chaff remains have a density per litre of 45, followed by wild / weed seeds at 48 and then grain at 58. The relative proportions show 44 % of the assemblage consists of chaff, 31 % of grain and 21 % of wild / weed seeds (Fig. 1). Pulses, oil plants and fruits have median densities of <5 seeds per litre and account for less than 5 % of the overall assemblage.

1.2 Formation processes

Eight main feature types were indentified from Feudvar, including house floors, pits, yard and hearth areas (Table 4). A vast majority of samples, 257, were allocated as general deposits with no further contextual details. Context details were unclear for a couple of samples and some were from contexts that did not fit in with the main feature types i.e. house, yard or street. Fourteen samples were therefore allocated as miscellaneous features. Only six of the eight features are represented in the 0 to 5 density group at Feudvar (Table 4). The highest percentage of samples with a seed density of between 0–5 were recovered from the container fills (33 %). The remaining feature types all increase in percentage by the 25.1+ density group. For example, pit samples increase from 7 % in the 0 to 5 seed density group to 49% in the 25.1+ category (Table 4). It is unclear, however, whether any correlations exists between certain feature types and seed density.

Only 38 samples had a seed density per litre of over 100. Of these, twelve are dominated by grain, twelve by chaff and seven by wild / weed seeds (Table 5). Of the samples dominated by grain, only FEU047, an occupation layer, and FEU328, from a house level, indicate relatively clean grain deposits. This is

1 Nomenclature follows Polunin (1980) and Zohary and Hopf (2000). The sample numbers differ from Kroll's, see Appendix.

Total number of samples	524
Total volume (litres)	5.240
Total no. of seed items	32.535
Mean seed density per litre	63
Median seed density per litre	20
Standard deviation	268

Table 1. Bronze Age Feudvar. Summary statistics.

Density per litre of soil	No. of samples
0 - 5	39
5.1 - 10.0	71
10.1 - 25.0	205
25.1 +	209

Table 2. Bronze Age Feudvar. Number of samples per density group.

	Total no. of samples	Total volume sampled	Grain	Chaff	Pulse	Oil plant	Fruit	Wild/weed	Feature type
Total no. of items	524	5240	104.448	144.578	8.195	817	1.717	69.780	Multiple
Mean			194	276	19	6	4	133	
Median			58	45	4	2	1	48	
Standard deviation			744	1.924	143	21	40	512	

Table 3. Bronze Age Feudvar. Summary table of seed densities (per litre) of plant remains, grouped by plant category.

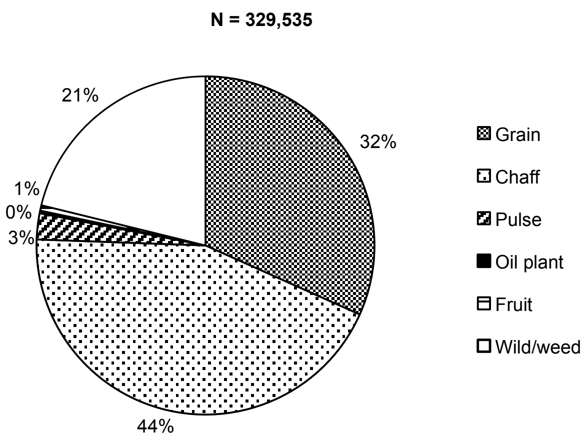


Fig. 1. Bronze Age Feudvar. Pie chart representing the percentages of seeds allocated to a particular plant category.

Density	0 - 5	5.1 - 10.0	10.1 - 25.0	25.1 +	Sum=100%
No. of samples	39	71	205	209	524
House floor deposits	18	17	32	33	115
Container fill	33	22	17	28	18
Pits	7	7	38	49	74
Yard		25	50	25	12
Hearth	14	10	33	43	21
Street deposits		15	31	54	13
Occupation level	1	13	46	40	257
Miscellaneous	7	21	36	36	14

Table 4. Bronze Age Feudvar. Percentage of samples from each feature type per density group.

No. (FEU, Reed)	No. (W, Kroll)	Grain	Chaff	Pulse	Oil plant	Fruit	Wild/weed	Feature Type	Dominant component
487	3574	27	78	0.4	0.6	0.4	17	Occupation layer	Chaff
385	3266	22	89	1		0.8	30	Occupation layer	Chaff
441	3360	20	83	0.2	0.5	0.4	48	Occupation layer	Chaff
035	1274	5	172	0.1		0.1	4	Occupation layer	Chaff
084	1403/1	26	171	0.3		0.1	11	House	Chaff
057	1378	51	152	0.2			47	Occupation layer	Chaff
056	1377	18	271	0.1			16	Occupation layer	Chaff
425	3604	80	277	1		0.2	26	Occupation layer	Chaff
219	2096/14	92	559	3	4		78	House	Chaff
244	2062	10	764	0.2			1	Pit	Chaff
350	3152	199	2.200	50	16	9	504	Occupation layer	Chaff
217	2096/13	646	3.595	5	18		313	House	Chaff
128	2051	776	659			0.1	9	Occupation layer	Chaff/grain
079	1401/39	4	3	280			13	Container fill	Pulse
324	3110	5	19	0.7		90	9	Northwest House, floor	Fruit
220	2096/2	79	10	5			6	Fisher House, floor	Grain
205	2056/6	92	6	1		0.3	23	House	Grain
190	2015/3	93	47	0.6		0.4	7	Pit, Baker House	Grain
209	2073/2	192	1				9	Hearth	Grain
083	1403	198	2				3	Hearth	Grain
042	1408	138	59	0.2	0.3	0.1	17	Occupation layer	Grain
047	1914	295		2			4	Occupation layer	Grain
328	3118	352	2				1	House	Grain
092	1403/51	252	163				3	House	Grain
206	2056/6	729	259	0.4	2		12	Occupation layer	Grain
207	2056/7	871	424	1		1	36	Fisher House	Grain
316	3066	464	3	0.1			298	Yard	Grain
013	1190	57	46	0.3		0.1	4	Pit	Grain/chaff
403	3311	60	39	0.2	0.8	0.2	11	Occupation layer	Grain/chaff
019	1196	63	4	5		0.2	54	Pit	Grain/weeds
237	2045	11	34	0.6		0.1	68	Pit	Weeds
138	2078	21	22	2	0.7	0.1	70	Pit	Weeds
483	3513	28	5	0.2		6	87	Northwest House	Weeds
408	3322	20	45	2	1.5	0.1	61	Occupation layer	Weeds
477	3486	21	34			3	98	Occupation layer	Weeds
396	3287	8	2	0.2		2	161	Occupation layer	Weeds
353	3171	41	1	0.2			384	Occupation layer	Weeds
485	3537	159	7	0.4	0.1	0.3	927	North House	Weeds

Table 5. Bronze Age Feudvar. Density per litre of main plant categories, given for samples with a seed density of >100 per litre.

particularly interesting as FEU047 is dominated by barley grains (>2,900 grains) and FEU328 has over 3,500 einkorn grains and no other crop species present. FEU217 has the highest density per litre of chaff of 3,595 which was also recovered from a house level. The preservation of chaff at sites is notoriously problematic[2]; however, when large deposits are found this is particularly interesting as it could provide information about depositional activities, such as crop processing. FEU485, from the floor of the northwest house, is the only sample with an extremely high wild / weed density of 927 per litre (Table 5). This sample, which also contained barley and einkorn grains, had over 30 different weed species present, including high numbers of *Bromus*, *Lolium* and *Setaria*. Many of these weeds may be found as weeds in arable fields and may suggest the remains of crop processing by-products. These rich deposits therefore show the potential of identifying different crop processing stages within the assemblage and will be examined further in the following chapter.

2 Boardman and Jones 1990.

As well as the samples dominated by grain, chaff and weed / weed seeds, a couple of samples had relatively clean deposits of other food plants. For instance, the container fill FEU079, had a high density of pulses, in particular pea with >2,700 seeds identified. Another sample of note is FEU342, a sample from the floor of the northwest house, which is dominated by 901 strawberry pips (*Fragaria*).

Differences between feature types may also be seen from these rich samples where the vast majority of grain dominant samples are from house or hearth deposits, while the chaff and wild / weed rich samples are more likely to be found in occupation layers (Table 5).

To examine the distribution of the plant remains further within the western trench, the area has been divided into arbitrary 5 m^2 blocks / areas based on the grid pattern of the original excavation. The relative proportions of the main plant categories per block highlights differences in plant deposition across the trench (Fig. 2). Blocks 1, 3 and 5 (northwest house and fisher house) have a high percentage of wild / weed remains. Block 7 (northwest house), 9 (yard area) and 3 (baker house) have extremely high percentages of chaff, wile block 3 (fisher and northwest house) shows a relatively high percentage of pulses, fruits and nuts. This is due to the large number of peas in FEU079 and wild strawberries found in FEU342.

The average seed density per litre across the trench shows an extremely high seed density in block 7, the fisher and northwest house level (Fig. 3). This is likely the result of two particularly large deposits of glume bases recovered from FEU217 (house) and FEU350 (occupation layer). Block 4 (baker house) and 12 (yard area) also have high seed densities of between 76–100 seeds per litre. Block 4 has particularly high numbers of grain in FEU206 and FEU207, while block 12 has large numbers of grain, chaff and wild / weed seeds. Block 8, baker house, 10 (baker house and yard) and 16 (general deposits) have the lowest seed density per litre. The section has therefore identified differences in formation processes with the western trench which may follow further differentiation between activity areas or between different households when examining crop processing and crop husbandry regimes at the site.

1.3 Crops

A total of thirteen different crop plants were found at Feudvar: both one grained and two grained einkorn *Triticum monococcum*, emmer *Tr. dicoccon*[3], spelt *Tr. spelta*, bread / durum wheat *Tr. aestivum / Tr. durum*, barley *Hordeum vulgare*, broomcorn millet *Panicum miliaceum*, broad bean *Vicia faba*, bitter vetch *Vicia ervilia*, grass pea *Lathyrus sativus*, pea *Pisum sativum*, flax *Linum usitatissimum* and gold-of-pleasure *Camelina sativa*. So called rye was also tentatively identified at the site (cf. *Secale*[4]). In total, over 104,000 cereal grains and 144,000 chaff remains were recovered, as well as over 8,000 pulses and 800 oil plant seeds.

1.3.1 Einkorn

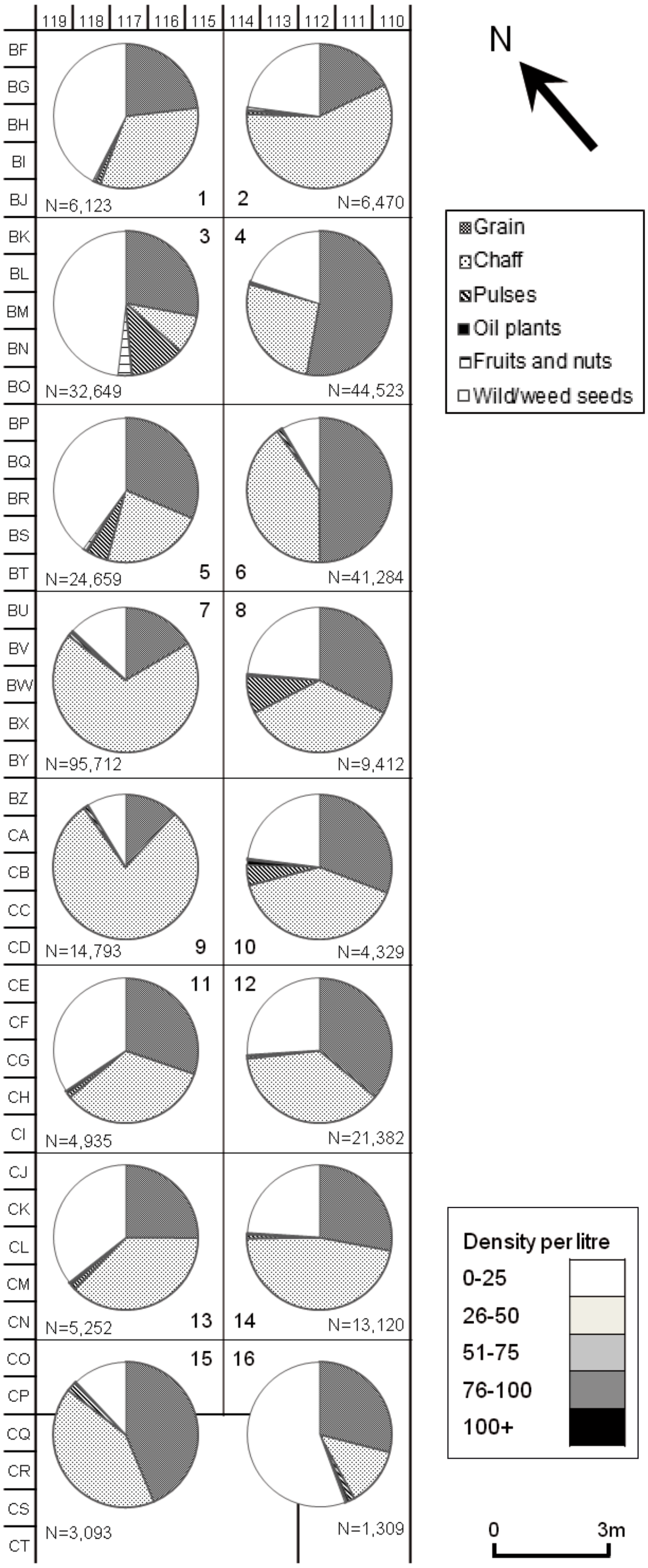
In terms of quantity of remains discovered, one grained einkorn is the most dominant crop found at Feudvar, with 69,586 grains and 136,228 glume bases recovered. Einkorn represents over 80 % of the total crop assemblage and is present in 99 % of the samples (Table 6). The richest deposit of einkorn grain was in FEU207 (fisher house) where 8,256 grains were recovered along with 4,234 einkorn glume bases. Barley, pulses and over 300 wild / weed seeds were also recovered from this sample. FEU217 (house deposit) had the richest einkorn glume bases, totalling 35,244, as well as 6,036 einkorn grains. This sample also contained rich deposits of 525 barley rachis, 184 bread / durum wheat rachis, and 145 seeds of gold-of-pleasure.

Two grained einkorn was also found, but only within 1 % of the samples and in small quantities. The largest deposit of 124 grains was recovered from FEU128, a miscellaneous layer in block 5. This sample was described by Kroll[5] as a relatively pure deposit of einkorn, still in their glumes and thus ready for dehusking, and were found scattered around a broken bowl that once carried the remains. Kroll also stressed

3 The presence of sanduri (Triticum timopheevii) is a later discovery, not mentioned in the sample papers [Kroll].

4 The identification of cf. Secale as Dasypyrum villosum is also a late discovery [Kroll].

5 Kroll 1992.



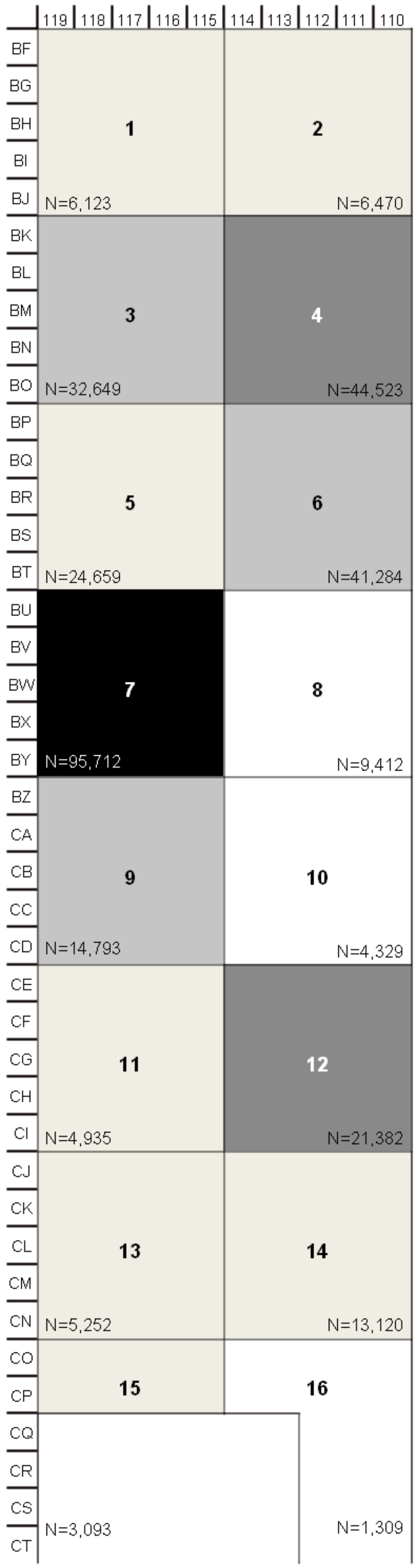


Fig. 2. Bronze Age Feudvar. Pie charts representing the percentages of seeds allocated to a particular plant category per block (5x5m).

Fig. 3. Bronze Age Feudvar. Average seed density per litre of sediment per block (5x5m).

Grain		
Triticum monococcum	Einkorn	99
Tr. monoc., two-grained	Two-grained einkorn	+
Hordeum vulgare	Barley	79
Triticum dicoccon	Emmer	73
Tr. aestivum / Tr. durum	Naked wheat	9
Tr. spelta	Spelt	2
Tr. timopheevii	Sanduri	+
Avena	Oats	+
Chaff		
Tr. monoc., glume base	Einkorn	96
Tri. dic., glume base	Emmer	61
Hordeum vulgare, rachis	Barley	22
Tr. spelta, glume base	Spelt	9
Tr. aest. / Tr. durum, rachis	Naked wheat	5
Tr. timopheevii, glume base	Sanduri	+
Millets		
Panicum miliaceum	Broomcorn millet	31
Setaria italica	Italian millet	+
Pulses		
Lens culinaris	Lentil	64
Vicia ervilia	Bitter vetch	40
Pisum sativum	Pea	22
Lathyrus sativus	Grass pea	4
Vicia faba	Broad bean	1
Oil plants		
Linum usitatissimum	Linseed / Flax	4
Camelina sativa	Gold-of-pleasure	20

Table 6. Bronze Age Feudvar. Presence/absence analysis of crops and chaff (%).

the difficulties in distinguishing two grained einkorn from emmer, unless the grains are well preserved, which may result in two grained einkorn being under represented at Feudvar[6].

1.3.2 Barley

Barley is the second most common crop present at Feudvar being found in 79% of the samples (Table 6). The richest deposit of barley grain was found in FEU074 (occupation layer in block 3) where 2,942 grains were recovered. This deposit is relatively clean, with less than a hundred seed items identified from other species. Naked barley was also found, but in very small quantities and in only four samples (FEU019, 074, 296, 330). Barley rachis was recovered from only 22 % of the samples with the richest deposit of 525 coming from FEU217 (house layer in block 7). Although this will be looked further in the next chapter, the disparity between the number of barley rachis and grains recovered at the site could result from two factors. First, the chaff remains from free-threshing cereals are generally removed during the early stages of crop processing, which could occur away from the site and would therefore reduce the access to fire. Second, the carbonisation process itself may reduce the survival rate of the free-threshing rachis, as they are more likely to be destroyed than glume wheat glume bases.

1.3.3 Emmer (and sanduri wheat)

Emmer is the third most common crop recovered from the site and is present in 73 % of the samples (Table 6)[7]. In particular, a large number of emmer grains, 4,543, were found in FEU316 (yard context in block 12). Einkorn was also present in this sample, although in much smaller quantities, and a large admixture of 2,902 *Setaria viridis* seeds and small quantities of other wild / weed species. Emmer chaff is found in 61% of the sample (Table 6). A rich sample of emmer chaff was identified in FEU084 (house deposit in block 8) which contained 1,698 glume bases. This deposit contained only 108 wild / weed seeds and a small number of einkorn and emmer grains.

1.3.4 Spelt and bread / durum wheat

Both spelt and bread / durum wheat are present but in much smaller quantities. For spelt, only 14 grains were recovered from only 2 % of the samples (Table 6). Spelt glume bases were slightly more prevalent being present in 9 % of the samples. The largest number of glumes recovered in any one sample was 24 glume bases found in FEU034 (occupation layer in block 9). However, the spelt bases were found among large numbers of einkorn and emmer glume bases.

6 Hillman 1981; Boardman and Jones 1990.

7 The famous W 3063 sample of sanduri wheat, Triticum timopheevii, the "new spelted wheat". The identification of this heat in Feudvar is a quite recent one. Sanduri wheat is smaller and narrower than emmer, but very similar. There are more samples with emmer than with sanduri. Sanduri is an additional crop [Kroll].

Bread / durum wheat grains were found in 9 % of the samples (Table 6). The richest deposit was of 198 grains found in FEU425 (occupation layer in block 14). Bread / durum wheat rachis is found only in 5 % of the samples and the richest deposit was FEU217 (a house deposit in block 7) which yielded 184 rachis remains. However, the rachis remains were recovered along with large numbers of einkorn, barley, so called rye and gold-of-pleasure.

1.3.5 Millet, so called rye and oat

Positive identifications of rye (cf. *Secale*), cultivated oat (*Avena sativa*) and foxtail millet (*Setaria italica*) are absent from the samples. The tentative identifications of rye (so called rye, cf. Secale) were found in 63 % of the samples, totalling nearly 3,000 grains within the assemblage. The largest quantity was recovered from FEU217 (house deposit in block 7) yielding 430 grains[8].

Two pit samples, FEU013 and FEU019 (both from block 14) contained the highest numbers of broom-corn millet, that of 552 and 534 grains respectively. Both samples contained other crop species, although in slightly lower quantities, such as einkorn, emmer and barley and FEU019 also contained 385 *Chenopodium* seeds.

There are some grains of weedy oats in the western trench (*Avena* sp.). Foxtail millet is missing in that area[9].

1.3.6 Pulses

At Feudvar, lentil is found in 64 % of the samples, followed by bitter vetch which was found in 40 % (Table 6). A large number of lentils were recovered from FEU182 (hearth deposit in the north house in block 3), which yielded a relatively clean assemblage of 614 lentils. The largest number of bitter vetch, 512 seeds, was found in FEU199 (baker house, floor) which also contained 240 einkorn grains (Table 6).

Pea, on the other hand, was found in only 22 % of the samples, but represented the largest number of items found for all pulses. This is due to sample FEU079 (container deposit), which contained 2,760 peas. Pea numbers are extremely low within the rest of the samples at the site. A similar deposit was found in early Iron Age site of Hissar, southern Serbia, where 2,572 peas were recovered from one deposit suggesting it was indeed a crop at the site[10].

Both, broad bean and grass pea were recovered from only 1 % and 4 % of the samples (Table 6) and in extremely low numbers (<2 seeds per sample). Broad bean is found in Near Eastern archaeological assemblages from the Neolithic[11], but are not commonly found in temperate Europe until the 3rd millennium[12]. The presence of broad bean is particularly interesting as the species is often missing in great parts of Southeast Europe.

1.3.7 Oil plants

Gold-of-pleasure is the most common oil plant found at the site and is present in 20 % of the samples (Table 6) Gold-of-pleasure is not commonly found until the Late Bronze Age in the region[13]. Both FEU350 (occupation layer) and FEU217 (house context, block 7) contained relatively large numbers of 143 and 145 gold-of-pleasure seeds, as well as a number of pod remains. Both assemblages are also dominated by einkorn grain and chaff. Flax seeds were found in only 4 % of the samples in very small quantities

8 This so called Secale is meanwhile identified as Dasypyrum villosum, a weedy species of the Secale and Triticum relationship [Kroll].
9 There are two grains of foxtail millet, Setaria italica, in the eastern trench, younger layers [Kroll].
10 Medović and Horváth 2012.
11 Tanno and Willcox 2006.
12 Zohary and Hopf 2000.
13 Zohary and Hopf 2000, 138.

(Table 6). The preservation of oil plants through carbonisation is, however, particularly problematic as the seeds tend to burn away due to their high oil content.

1.4 Wild resources

1.4.1 Fruits

Nine fruit species were identified at Feudvar; wild strawberry *Fragaria*, cornelian cherry *Cornus mas*, Chinese lantern or winter cherry *Physalis alkengengi*, bird cherry *Prunus padus*, sloe *Pr. spinosa*, dewberry *Rubus caesius*, blackberry *R. fruticosus*, dwarf elder *Sambucus ebulus*, elder *S. nigra*, and wild grape *Vitis vinifera silvestris*). In addition, other plant items were identified to genus, such as pear *Pyrus* sp. and rosehip *Rosa* sp. In total 1,717 fruit seeds were recovered.

The most common fruit is dwarf elder *Sambucus ebulus* which is present in 20 % of the samples. The largest deposit consists of 60 seeds found in FEU483 (northwest house). The remaining fruit species are found in <15 % of the samples and are generally represented by small quantities of remains. Fruit remains are found in all feature types, especially general deposits, house floors and pits. Most of the fruit remains can be eaten, with the possible exception of the bird cherry, which is extremely bitter and dawrf elder, suggesting that they were collected from the local environment to supplement the diet. Their presence at the site therefore provides further evidence of the possible environment around Feudvar, especially as many of the fruits, such as *Prunus spinosa*, *Rubus fruticosus*, *Rosa* sp., *Fragaria vesca* and *Sambucus nigra*, are indicative of open woodland which usually grow in clearings and along wood edges.

Only one wild grape pip was found in the assemblage from FEU164, a house floor deposit in block 3. Of particular note from this assemblage is the large deposit of wild strawberries from FEU342, a house floor deposit from the northwest house in block 3. Wild strawberry is present in 17% of the samples. Wild strawberry is found throughout Europe today growing in forests and along hedges, particularly in areas rich in soil nitrates and can be collected for consumption between May and August.

1.4.2 Wild / weed species

A total of 129 wild / weed species were identified from the Feudvar assemblage, totalling 69,780 seeds. The vast majority consist of those species commonly found in arable environments such as *Chenopodium album*, *Bromus* arvensis and *Agrostemma githago*. Nine species are from wetland or aquatic environments, including sedges *Carex* and water chestnut *Trapa natans*, and four are seeds from trees, including lime *Tilia* and oak *Quercus*. A number of uses may also be attached to some of the species present, i.e. as food, medicine, fodder or building materials.

Kišgeci and Medović presented a case for the prehistoric use of medicinal and aromatic plants at Feudvar and a number of other Neolithic, Bronze and Iron Age sites in the region[14]. They suggested that vervain *Verbena officinalis*, high mallow *Malva sylvestris*, black henbane *Hyoscymus niger*, white mallow *Althaea officinalis*, mint *Mentha* and poppy *Papaver somniferum* could have been collected for herbal medicine. Many of these are found at Feudvar, although in relatively small quantities and are all present in relatively mixed deposits. Vervain is the most prevalent species, being found in 10 % of the samples and totalling 196 seeds.

The concentrated find of 263,780 seeds from the many-seeded goosefoot *Chenopodium polyspermum* found in FEU210 (occupation layer in block 3) would suggest the deliberate gathering of the plant. Behre also suggests that *Polygonum lapathifolium*, *Chenopodium album* and *Bromus secalinus* could have been deliberately collected and used for human consumption in prehistoric times[15]. Only two samples at Feudvar contained *Chenopodium album* and all but one seed was recovered from FEU350 (house deposit in block 7), which contained 654 seeds. *Chenopodium* is present in 94 % of the samples and totals nearly 25,000 seeds, with the largest deposit of 1,325 seeds recovered from FEU485 (house deposit in block 4).

14 Kišgeci and Medović 2006.
15 Behre 2008.

Of the other two species, only 14 seeds of *Polygonum lapathifolium*, and 1 of *Bromus secalinus* were found in the assemblage.

Another plant which may have been utilised is that of *Lallemantia iberica*, which was suggested to have been grown and stored for oil in northern Greece in prehistoric times[16]. *Lallemantia iberica* is found in 14 % of the samples and totals 671 seeds, the largest concentration of 297 seeds being found in the house deposit FEU350. Other edible foods could also have been consumed at the site, such as wild parsnip *Pastinaca sativa*, lettuce *Lactuca* and carrot *Daucus*. In addition, the nature of preservation may also result in an under representation of plants whose vegetative parts are usually picked and consumed.

Also of note is the presence of water chestnut *Trapa natans* at Feudvar, which has a high frequency of 22 %, though no one sample has more than 2 seeds present. The importance of water chestnuts as a human food source for prehistoric farmers has been recently explored. At Opovo, water chestnuts would have been collected from areas of shallow water around the settlement in late summer / early autumn[17]. The seed, which is comparable in starch (c. 50 %) and protein (c. 10 %) to cereals, would then be extracted from the outer shell and either eaten raw, roasted, boiled or ground down into flour[18]. During the Roman period, for example, it was noted that the Thracians made bread from the flour of water chestnuts.

It is also important to add that some taxa may have been grown and / or collected as animal fodder. Although, there is no evidence of large concentrations of wild / weed species that may suggest this practice occurred, especially as the number of small legumes and possible pasture species may also be classed as arable weeds.

In addition, some species would have been used as building materials, whether in constructing a house or a basket. For example, reeds *Phragmites australis* are commonly used for thatching, while bulrush *Schoenoplectus lacustris* is used still today as a weaving material for mats or baskets. At Feudvar, imprints within burnt clay indicate that reeds were used in the construction of the houses[19]. The archaeological evidence indicates that bundles of reeds were bound with rope, made from reed fibres, within a wooden frame that was covered with clay, which contained elements of straw and other plant materials (*ibid.*). Thus, wild species would have continued to be an important resource to the Bronze Age inhabitants.

1.5 Conclusion

An extremely high density of grain, chaff and wild / weed seeds within the Feudvar assemblage highlights the potential for complex statistical analyses in relation to crop processing and crop husbandry regimes. In addition, differences in formation processes at the site, identified from the distribution of seed densities and plant groups, suggest that further differentiation between activity areas or between different households may be possible when examining crop processing and crop husbandry regimes at the site.

Overall, the plant assemblage recovered from the western cut at Feudvar contained a wide range of crops, fruits and wild / weed seeds. The site is dominated by einkorn grain and chaff, present in over 99 % of the samples, closely followed by a high frequency of barley, then emmer. The site also yielded the first evidence of broad bean and gold of pleasure in the study area. The number of 'clean' deposits highlighted above may also point to food catches, supporting not only a case for the consumption of certain cereals but of other plant species such as *Chenopodium polyspermum*, as well as further collection and utilisation of wild / weed species at the site. The next chapter will explore in more detail the formation processes at Feudvar through the examination of crop processing within the samples.

16 Megaloudi 2006.
17 Borojević 2006, 140.
18 Karg 2006.
19 Hänsel and Medovic 1998, 73–74.

2. Crop processing analysis at Feudvar

In this chapter, formation processes within the Feudvar assemblage are examined. The purpose of this is to investigate formation processes at the site and to determine which samples can be directly compared when examining crop husbandry regimes. This chapter begins with a brief discussion on formation processes in archaeobotany with a particular focus on crop processing and its effect on assemblage composition. The methods and results of the crop processing analysis on the Feudvar dataset will then be presented. In order to further corroborate these results, correspondence analysis is employed to assess the composition of the samples in relation to their identified crop processing stage. In addition, intra-site variability will be examined by exploring the distribution of crop processing within the trench, followed by a discussion on the crop processing activities identified at the site and final conclusions.

2.1 Crop processing and other formation processes

2.1.1 Crop processing in archaeobotany

Archaeobotanical remains represent only a fraction of the original plant assemblage that, through a series of natural and / or anthropogenic processes, became deposited within the archaeological site. The most common form by which plant material is preserved on archaeological sites is through carbonisation or charring, which results when organic material is exposed to heat either accidentally or deliberately, such as cooking, burning rubbish or fuel. Experimental research suggests carbonisation occurs in the range of approximately 200 to 400°C, or to higher temperatures in the absence of oxygen, such as when the material is smothered in ash[20]. It is generally the harder, denser parts of the plants such as seeds, grains, wood and nutshells that are more likely to preserve[21], although in some instances soft organs such as grapes or tubers have been recovered in a carbonised form[22]. Preservation in these instances will therefore be affected by the physical character of the plant material. For example, Boardman and Jones found that barley was more sensitive than glume wheat to the effects of charring[23]. Similarly, since oil is flammable, the higher the oil content of the seed, the less likely it is to preserve under charring conditions. Carbonised plant remains will also be heavily biased towards items that come more frequently in contact with fire and subsequently survive the charring process[24].

Knörzer first suggested that the general uniformity seen in the composition of carbonised seed assemblages from Neolithic settlements in the Lower Rhine, namely cereal grain, chaff and weeds, meant that these assemblages represented the remains of harvested cereals[25]. In addition, Dennell noted that contexts within which carbonised remains are recovered are more likely to result from processes of food production than as a result of food consumption and therefore provide a record of the crop husbandry and processing methods employed[26]. Although Dennell began to explore the sequence of crop processing and its effects on the composition of archaeobotanical assemblages[27], Hillman and Jones[28] were the first to develop more predictive models that could be applied to archaeobotanical remains. Through detailed ethnographic studies of traditional crop processing in Greece and Turkey, they determined that each stage of the processing sequence produced characteristically different compositions of cereal, chaff and weeds that could be calculated and identified within the archaeological assemblages.

20 Braadbaart 2008; Hillman 1981; Wright 2003.
21 Boardman and Jones 1990; Hillman 1981.
22 Hather 1991; Valamoti 2007.
23 Boardman and Jones 1990.
24 Boardman and Jones 1990; Dennell 1972; Hillman 1981; Jones 1985; van der Veen 2007.
25 Knörzer 1971.
26 Dennell 1974; id. 1976.
27 Dennell 1972.
28 Hillman 1984 a; Jones 1984.

Although ethnographic research is particularly useful in examining traditional methods first hand, it is important to note that direct comparisons with the past are problematic. Not only are modern environments and cultural traditions different than past societies but technology has also evolved which may affect agricultural methods. In spite of this, both Hillman and Jones argue that different methods of processing crops within a non-mechanised farm, regardless of the technology, would have been small, resulting in a limited number of ways to process them and so the effects on assemblage composition would remain the same. Ethnographic models on crop processing activities therefore allow the building of 'cause and effect' models for archaeological interpretation[29]. However, it is important to note this uniformitarian approach and be aware of possible changes in attitude to the purposes and mechanisms of crop processing, especially when making inferences about past communities.

The principle behind these studies is that a crop is processed through a number of stages before it is ready for consumption and each stage has a measurable effect on the composition of grain, chaff, straw and weeds. Each stage produces two assemblages; a crop product, which continues through each stage, and a crop by-product or residue, which is removed from the remaining processes. Simplified, the stages for processing free-threshing cereals (i.e. bread and durum wheat and barley) are as follows[30]:

- Harvesting to gather the mature crop from the field possibly by uprooting or cutting the grain-bearing part of the plant
- Threshing to release the grain from the chaff possibly by beating with a stick or trampling by cattle
- Winnowing: to remove the light chaff and weeds from the grain possibly by wind or by shaking in a winnowing basket
- Coarse sieving to remove larger items such as weed heads, seeds, un-threshed ears and straw with large meshes
- Fine sieving to remove the small weed seeds from the grain with narrower meshed sieves

Glume wheats (i.e. einkorn, emmer, sanduri and spelt) on the other hand require further processing stages to release the grain from the tight glumes. The additional processes involved in the dehusking of glume wheats are as follows:

- Parching to dry the grain and render the glumes brittle
- Pounding to release the grain from the glumes possibly in a wooden mortar or quern
- 2nd winnowing to remove the light chaff and weeds from the grain
- 2nd coarse sieving to remove the remaining large items, such as un-threshed ears or chaff and remaining culm nodes and large weeds in heads
- 2nd fine sieving to remove the glume bases and remaining small weed seeds from the grain

However, the most effective way of dehusking glume wheats is debated[31]. Both Küster and Meurers-Balke / Lüning, through experimental dehusking of glume wheats, found that the second winnowing stage alone was sufficient to separate the glume material from the grains after using either a quern or pounding the grain in a mortar[32]. They suggest that the second coarse and fine sieving stages are superfluous as the arable weeds and straw would have been removed at the first winnowing and sieving stages. Therefore, only a second winnowing stage would be required to remove the remaining light chaff from the grain without any further need to sieve. The composition of the second winnowing stage would have a different composition from the first, with the winnowing by-products, prior to dehusking, containing more light weeds and little chaff, while the second winnowing stage by-products, after dehusking, would consist mostly of chaff with few weeds. Sample composition will also be dependent on the varying degrees of

29 Hillman 1984 a; Jones 1984; id. 1987.
30 Hillman 1984 a; van der Veen 1992.
31 Nesbitt and Samuel 1996.
32 Küster 1984; Meurers-Balke and Lüning 1992.

thoroughness used through the crop processing stages[33], whether stages are missed[34] or whether stages are performed in different ways[35]. Pulses, in particular vetches, peas, lentils and grass peas, have also been studied ethnographically by Jones and Butler[36]. They found that *Vicia* and *Lathyrus* could be processed similarly to free-threshing cereals. However, ethnographic processing of *Vicia* / *Lathyrus* revealed that there was a spectrum of 'threshability', as many pods did not shatter during the first threshing and therefore needed multiple threshing stages (*ibid.*). Millets, such as *Digitaria*, *Echinochloa*, *Panicum*, and *Setaria*, on the other hand, share similar processing stages with glume wheats, as millets also require dehusking[37]. Young exploring the traditional processing of finger millet *Eleusine coracana* in Uganda, identified a series of roasting, pounding and winnowing stages aimed at softening the grains and loosening the chaff before grinding into flour[38].

2.1.2 Other formation processes

Distinguishing routine activities and occasional accidental or deliberate burning episodes is particularly important not only to determine formation processes at a site but also when comparing different samples. Jones and van der Veen / Jones advocate the need to differentiate between regular routine activities and rare accidental or deliberate events in order to restrict their contribution to the overall pattern on a site or to assist in the detection of repeated episodes of accidental or deliberate burning that may signify a specific practice[39]. They also suggest that differentiation between the samples allows samples of the same crop processing stage, and thus the same relative composition, to be compared. This is particularly important when exploring weed ecology, as weeds with different physical characteristics (i.e. size or shape) are removed through each processing stage and would therefore bias the assemblage towards certain species.

Exploring the deposition of carbonised remains, van der Veen, referring back to Hillman[40], highlighted five 'routes of entry' on archaeological sites, the most common being: plant remains used as fuel, both intentionally and through casual discard, and foods accidentally burnt during food preparation, such as through cooking or roasting[41]. The least common routes include: accidental or deliberate destruction of food and fodder stores, the use of fire to clean out grain storage pits, and the destruction of diseased or infested crop seeds. Deposition of plant remains through ritual activities can also result in carbonised plant remains, such as from cremation burials or votive offerings. Ritual assemblages may contain special plant remains that are not typical foodstuff at a site or have other ritual connotations which cannot be directly compared with plant remains resulting from general day to day activities.

Ethnographic models are particularly helpful in exploring types of activities that may result in the charring of crop processing products and by-products and their deposition into the archaeological record. Hillman observed that the daily processing of stored glume wheat within households in Turkey allowed the by-products to be easily swept into the fire[42]. This model of daily spikelet processing and the subsequent charring of residue in the hearth is often cited as the most common form by which charred plant remains (namely glume wheat glume bases) occur on Linearbandkeramik and later sites in Central Europe[43]. It is

33 Jones 1992.
34 Jones 1984.
35 Hillman 1984 a; id. 1985; Peña-Chocarro 1999.
36 Jones 1984; Butler 1992; Butler et al. 1999.
37 Harvey and Fuller 2005.
38 Young 1999.
39 Jones 1991; van der Veen and Jones 2006.
40 Hillman 1981.
41 van der Veen 2007.
42 Hillman 1981.
43 Gregg 1989; Meurers-Balke and Lüning 1992.

also suggested that the roasting or parching stage within the processing of glume wheats and millets will also generate a number of discarded charred grains[44].

The use of dung as fuel has also been identified as a route by which plant material, especially glume wheat glume bases, becomes incorporated in the archaeobotanical assemblage[45]. Although research has largely focused on sites in the Near East and Asia[46], dung is slowly becoming recognised in European assemblages. Valamoti and Jones, studying Late Neolithic and Early Bronze Age sites in northern Greece, were able to identify the use of dung fuel and a variety of animal feeding strategies from the characteristics of the wild plant species and the combination of cereal parts and fruits[47]. This is particularly important in the interpretation of archaeobotanical assemblages, as samples derived from dung cannot automatically be used to reconstruct crop husbandry practices. Whether dung fuel would have been used in European contexts is still debated. Some propose that the likely abundance of wood in the landscape during the Neolithic and Bronze Age would negate the need to use dung as fuel[48]. On the other hand, some suggest that the use of dung is not reliant on the availability of wood but a distinct preference for that type of fuel[49].

2.1.3 Analytical approaches to crop processing

From the ethnographic work conducted by Hillman and Jones, two methods for analysing crop processing within archaeobotanical samples developed[50]. These two methods were first implemented by van der Veen[51], and involved the use of ratios to classify samples based on their crop content, i.e. the crop type and plant part, and to categorise samples based on the physical properties of the weed seeds present. The first method involves the calculation of ratios of the straw, chaff, grain and weeds in each sample, using known proportions of plant parts in each whole species. For example, einkorn has two glume bases to one grain i.e. 2:1, while six-row barley has one rachis to three grains i.e. 1:3.

The second weed based method categorises weeds according to the degree to which the weed seeds either accompany the crop through processing or are removed, depending on their shape (aerodynamic properties), their 'headedness' (whether seeds come in capsules), size ('sievability') and density ('winnowability'). Jones devised weed categories to group the weeds according to their characteristics and identified the stages at which they would be removed during the crop processing sequence. The weed categories used are big-heavy-headed (BHH), big-free-heavy (BFH), small-headed-heavy (SHH), small-free-heavy (SFH), and small-free-light (SFL)[52]. Thus weeds removed by winnowing tend to be small-free-light (SFL), weeds removed by coarse sieving are mostly headed weeds (SHL, SHH, BHH), while fine-sieving removes the small-free-heavy weeds. By examining the data through discriminant analysis, Jones was able to separate samples indicative of by-products from early (winnowing and coarse sieving) and late (fine sieving) crop processing stages, as well as final crop products.

However, the criteria to determine the weed categories are not clear cut, resulting in variation between authors and where species are grouped. Van der Veen investigated whether small grasses should be categorised as light or heavy but found, when tested, that there were no discernable differences in the results[53]. Stevens also compared the weed seeds from his British Iron Age samples, where large seeds were grain sized or larger (>2.5 mm) and small seeds were <2.5 mm[54]. This led to some differences between the classifications determined by Stevens and van der Veen. For example, *Polygonum aviculare* was classified as

44 Hillman 1985.
45 Charles 1998; Miller and Smart 1984; Valamoti 2005 b.
46 Anderson and Ertuğ-Yaraş 1998.
47 Valamoti and Jones 2003; Valamoti 2005 a.
48 van der Veen 1992.
49 Anderson and Ertuğ-Yaraş 1998.
50 Hillman 1984 a; Jones 1984.
51 van der Veen 1992.
52 Jones 1984.
53 van der Veen 1992.
54 Stevens 2003.

Stage	Ratio	High value	Low value
1	Cereal straw nodes : grains	By-product, early processing stage	Grain product
2	Glume wheat glume base : grains	By-product, late processing stage	Grain product
3	Free threshing cereal rachis : grains	By-product, early processing stage	Grain product
4	Weed seeds : cereal grains	By-product, late processing stage	Grain product
5	Small : large weed seeds	By-product, sieving	Product, sieving or by-product, hand sorting
6	No. of crop items per litre	Rapid / single deposition	slow / repeated deposition

Table 7. Bronze Age Feudvar. The grain, chaff and weed ratios used to identify crop processing stages and their interpretation (after van der Veen 1992; van der Veen and Jones 2006).

large and heavy by Stevens but as small-free-heavy by van der Veen[55]. In contrast, Bogaard suggested that seeds are big if they are ≥1.5 mm diameter and small if they are <1.5 mm in diameter[56]. These differences in criteria may have been determined by the assemblages each author was studying; for example, Van der Veen examined mainly spelt and barley assemblages, Stevens mainly barley crops, while Bogaard[57] analysed mainly emmer and einkorn. Further work is needed, however, to look at whether disparities exist between the different size categories on the interpretation of crop processing stages.

The two methods proposed by Hillman and Jones were first implemented and compared by van der Veen, who examined crop processing as part of her study on agriculture in Iron Age and Roman northern England. Three ratios were first calculated from the data, glume : grain, rachis : grain and weed : grain, followed by a discriminant analysis of the weed seeds, using Jones's aerodynamic properties of the weeds. When comparing the results of each method, van der Veen found that there was little difference, suggesting that one method would be enough to address crop processing at a site.

The three ratios used by van der Veen[58] were later revised by van der Veen / Jones[59], who presented a further three ratios: ratio 1, 5 and 6 (Table 7). Previously, van der Veen used discriminant analysis to explore the aerodynamic properties of the weeds. However, van der Veen / Jones reduced this method to a simple ratio that could be used in conjunction with the other ratios. The calculation of seed density per litre (ratio 6) also allows samples to be broadly assessed as to their rate of deposition and thus the possible nature of the deposit (i.e. primary, secondary or tertiary context).

Subsequent work by van der Veen proposed a further two ratios[60]: the number of germinated to non-germinated grains and the number of diseased / insect damaged to 'normal' grains. These ratios were proposed in order to help determine the presence of accidental grain spoilage, deliberate burning of storage pits, malting residue or spoiled grain. Van der Veen also highlighted here that these ratios should only be calculated where adequate numbers of plant items are available[61]. Previously van der Veen used a cut off of point of 50 identified items per sample as an adequate figure to analyse crop processing within samples. Other authors have also implemented this strategy, for example Bogaard analysing crop husbandry regimes in Neolithic Central Europe only examined samples with over 50 cereal grains and 30 weed seeds[62].

In summary, crop processing stages successively alter the composition of the crop assemblage, creating at each step a product and a by-product. It is important to determine which processing stage samples represent in order to compare like with like when analysing the assemblage for crop husbandry regimes. The following sections will present the methodology and results of the crop processing analysis applied to the plant assemblage from Feudvar. The results will be used to determine which samples will be selected for analysis in the following chapter.

55 van der Veen 1992, 207 Table 7.4.
56 Bogaard 2002.
57 Bogaard 2002; id. 2004.
58 van der Veen 1992, 82.
59 van der Veen and Jones 2006.
60 van der Veen 2007.
61 van der Veen 2007, 25.
62 Bogaard 2004 chapt. 2.

2.2 Methodology

The methodology applied here is based on the ratios presented by van der Veen and van der Veen / Jones[63]. In addition, the weed seeds will be categorised according to their aerodynamic properties but only primarily as a tool to determine whether a weed seed is categorised as big or small for the calculation of ratio 5[64]. As ratio 5 does not differentiate between small weeds removed after winnowing or big and small species removed after coarse and fine sieving, the aerodynamic properties will also be used to aid in the overall interpretation of each sample. The methods applied to the Feudvar dataset are detailed in the following section.

2.2.1 Standardisation of the data

In order to carry out the analysis, the data needed to be standardised and simplified to allow an accurate interpretation of the assemblage. Non-cereal crops, such as pulses and oil-rich seeds, fruits and other non-cereal wild / weed seeds, such as *Crataegus* and *Tilia*, were excluded from the analysis. To allow for poor preservation, species identified to cf., such as *Triticum* cf. *spelta*, were amalgamated with the identified species, e.g. *Triticum spelta*, if the species was present in the sample. In addition, to reduce the number of calculations, both hulled and naked barley were combined as they are both free-threshing varieties. All glume bases are counted as one and spikelets were counted as two (i.e. two glume bases). In order to determine more accurately the numbers of grains present in the samples, grains categorised as Cerealia indet. were reallocated to the cereal species present in that sample, with the exception of *Panicum miliaceum*. This was achieved by calculating $\Sigma = s + (c \times s:t)$, for each species in each sample, where s is the number of items per species, c the total number of cereal indet., and t the total number of identified cereal items (not including cereal indet.). Only weeds identified to species or genus were included in the calculations, as those identified to family generally contained species with different size and aerodynamic characteristics. In accordance with the criteria applied by van der Veen, samples with less than 50 identified items were removed[65]. This reduced the number of Feudvar samples from 524 to 484.

2.2.2 Weed seed categorisation

In order to determine the small : large weed ratio as well as determining the stage at which the species may have been removed during crop processing, each weed species was categorised according to their aerodynamic properties. The length and width of each species was recorded and categorised (Table 8). The measurements were obtained from two sources; the online Digital Seed Atlas[66] and from the University of Leicester seed collection. To establish the size of seeds identified to genus, species measurements recorded in the Digital Seed Atlas were averaged. In addition, the length and width of each cereal species was also recorded (Table 9). The purpose of this was to help identify possible differences in grain size between the different cereals, as this may ultimately affect the size of the sieves used to process them, and will help to determine the cut off point at which a weed seed is large or small. Jones also suggests that for sieves where the grain passes vertically, the maximum width of the grain is the most important dimension[67].

In addition to categorising weeds by size, further attributes were assigned to each species based on their aerodynamic properties[68]. To help determine these properties, previous identifications were compiled

63 van der Veen 1992; van der Veen and Jones 2006.
64 Jones 1984.
65 van der Veen 1992 chapt. 7.
66 Cappers et al. 2006.
67 Jones 1996.
68 following Jones 1984.

Big free heavy	**Big free heavy (cont.)**	**Small, free, heavy**	**Small, free, heavy (cont.)**
Adonis	Polygonum aviculare	Anthemis	Stellaria media
Agrostemma githago	Polygonum convolvulus	Aphanes	Teucrium
Ajuga chamaepitys	Polygonum hydropiper	Asperula arvensis	Thymelaea passerina
Althaea officinalis	Polygonum persicaria	Atriplex hastata	Trifolium
Anethum	Potamogeton	Atriplex patula	Urtica dioica
Avena	Ranunculus	Carex vulpina	Verbena officinalis
Bromus arvensis	Ranunculus acris-type	Carex, sect. Vignea	**Small free light**
Bromus mollis-type	Schoenoplectus lacustris	Cerastium	Dianthus
Bromus secalinus	Sherardia arvensis	Chenopodium	Hypericum
Carduus	Torilis arvensis	Ch. glaucum / Ch. rubrum	Juncus
Carex, sect. Eucarex	Valerianella dentata	Ch. hybridum	Mentha
Carthamus lanatus	Vicia	Chenopodium album	Petrorhagia saxifraga
Centaurea	**Big headed heavy**	Consolida regalis	Verbascum
Daucus	Agrimona	Cyperus	Veronica
Euphorbia palustris	Allium	Digitaria	**Small headed heavy**
Galium aparine	Bupleurum rotundifolium	Echinochloa crus-galli	Anagallis arvensis
Galium spurium	Cichorium intybus	Echium	Barbarea
Geranium	Conringia orientalis	Euphorbia	Glaucium corniculatum
Knautia arvensis	Convolvulus arvensis	Euphorbia helioscopia	Kickxia spuria
Lactuca	Coronilla	Galium	Malva sylvestris
Lallemantia iberica	Malva	Hyoscyamus niger	Portulaca oleracea
Lapsana communis		Luzula	Scleranthus annuus
Leontodon hispidus		Legousia	Scrophularia
Lithospermum arvense		Phragmites	Silene
Lithospermum officinale		Plantago	**Small headed light**
Lolium (small)		Rumex	Papaver dubium
Lolium remotum		Rumex crispus-type	Papaver somniferum
Lolium temulentum		Scirpus	Rorippa
Onopordum acanthium		Setaria viridis	
Pastinaca sativa		Sisymbrium	
Picris hieracioides		Solanum nigrum	
Plantago lanceolata		Stachys annua	

Table 8. Classification of wild/weed taxa into physical weed categories: Big free heavy (BFH); big headed heavy (BHH), small free heavy (SFH), small free light (SFL), SHH = small headed heavy (SHH), and small headed light (SHL). Following Jones 1984; van der Veen 1992; Peña-Chocarro 1999; Bogaard 2002.

from Jones, van der Veen, Peña-Chocarro and Bogaard[69]. Where the classification was not recorded by the authors, the weeds were examined first to see whether the seeds grew within a seed head or capsule and if so whether the seeds would be released during the winnowing process. This was primarily determined by the properties of the capsule, such as wall thickness and whether the capsule is tightly closed or open. Weeds identified as light were those that were extremely small or small seeds that had wings, making them more aerodynamic.

2.2.3 Analysis

Ratios 2–6 (Table 7) were calculated, while ratio 1 was omitted due to the absence of straw nodes in the assemblage. In order to interpret the results, the whole plant ratio, i.e. glume bases or rachis to grain, was calculated for each cereal (Table 10). To determine ratio 4 and 5 as either high or low, an arbitrary value of 1 was given.

2.3 Results

Three main crop processing groups were identified: namely those of spikelets, fine-sieving by-products and products (see Table 10 for the calculation of ratios 2 to 5 per sample). Two further subdivisions were also recognised for each group, these included sieved and unsieved spikelets, sieved and unsieved fine sieving by-products and sieved and unsieved products. Each group is explained further in the following sections.

69 Jones 1984; van der Veen 1992; Peña-Chocarro 1999; Bogaard 2002 Table 8.

Cereal	Length	Width
Hordeum vulgare	8.00	3.37
Triticum aestivum /Tr. durum	8.00	3.50
Tr- dicoccon	7.50	2.50
Tr. monococcum	7.50	2.75
Tr. spelta	8.56	2.84
Secale cereale	8.95	3.48
Avena sativa	8.95	2.92
Panicum miliaceum	2.29	2.19

Table 9. The average length and width (mm) of grain per cereal species. Measurements from Cappers et al. 2006.

2.3.1 Spikelets

Sieved Spikelets

Samples identified as sieved spikelets contained large numbers of grain and glume bases with a ratio indicating the complete ear of the crop and few weed seeds present. Twenty one samples were identified as containing sieved einkorn spikelet remains. These samples were characterised by ratio 2, for einkorn, having a value of between 1.6 and 2.1 and a low value for ratio 4, which indicates that there are few weeds compared to the number of grains. Where ratio 4 had an approximately equal number of weeds to grains, the sample was assessed on the size of the weed seeds present and their aerodynamic properties. The purpose of this was to assess whether they could represent weeds similar in size to the spikelets, which may be removed through handpicking at the end of the crop processing sequence, or whether they represent fine sieving by-products, i.e. small seeds, which would suggest that the spikelets had not been previously fine sieved.

To account for differential preservation of the chaff remains (i.e. glume bases and rachis), which are less likely to preserve compared to the denser grains and seeds, it was decided that samples with a low ratio 2, for einkorn, of between 0.6 and 1.5 could also indicate sieved einkorn spikelets. As a result, an additional 64 samples were categorised as possible sieved einkorn spikelets, were the glume bases are under-represented.

Unsieved spikelets

Samples identified as unsieved spikelets contained large numbers of grain and glume bases with a ratio indicating the complete ear of the crop as well as large numbers of weed seeds. Twenty two samples were identified as containing unsieved einkorn spikelets. These samples were characterised by ratio 2, for einkorn, having a value of between 1.6 and 2.1 and a high value for ratio 4, indicating that there are more weeds compared to the number of grains. In addition, a further 30 samples were identified as indicating possible unsieved einkorn spikelets, were the glume bases are under-represented. Two samples, FEU095 and 439, were also identified as possible unsieved spikelets, however, they both have <55 items which makes their interpretation difficult. The composition of these samples will be looked at further below (section 2.4.2).

2.3.2 Fine sieving by-products

Sieved fine sieving by-products

Samples identified as sieved fine sieve by-products contained large quantities of glume wheat glume bases and only a few weed seeds. This means that the glume wheat spikelets had been previously sieved before dehusking, resulting in fewer weed seeds in the 2nd fine sieving by-products. Seventy nine samples were identified as being previously sieved einkorn fine sieving residue. These samples were characterised by ratio 2, for einkorn, having a value of ≥2.2, and a low value for ratio 4. Three samples, FEU009, 065 and 084, were identified as being previously sieved emmer fine sieving by-products. The samples here were dominated by emmer remains with a high ratio 2 value of ≥1.5 as well as a low value for ratio 4.

FEU425 is the only sample with relatively equal numbers of einkorn and emmer glume bases which dominate the sample, suggesting either a possible mixture of the sieving residue of the two crops or evidence of the growing of einkorn and emmer together. In addition, the sample also contains remains of barley and bread / durum wheat grains, as well as a few rachis remains, although these may be under-represented through differential preservation. FEU217 and 219 are tentatively identified as sieved fine sieving residue of einkorn and barley as they also contain early crop processing residue from barley and bread / club wheat. This may suggest mixing within the context of both early and later crop processing residue of free-threshing cereals and glume wheats. However, the extremely large number of einkorn glume bases

Stage	Species	Ratio	Value	Low value	High value
2	Einkorn glume base : grain	2 : 1	2	<0.4	>2.2
2	Emmer glumne base : grain	2 : 2	1	<0.6	>1.5
2	Spelt glume base : grain	2 : 2	1	<0.6	>1.5
3	Bread/durum wheat rachis : grain	1 : 2-6	0.2-0.6	<0.1	>1
3	Barley rachis : grain	1 : 3	0.3	<0.2	>1
3	Rye rachis : grain	1 : 3	0.3	<0.2	>1
4	Weed : grain		1	<0.8	>1.2
5	Small : large weed		1	<0.8	>1.2

Table 10. Ratio table for crop processing analysis, showing the whole plant ratio per cereal, the grain, chaff and weed ratio values and what constitutes a low and high value.

may suggest that the samples predominantly represent sieved einkorn fine sieving by-products. These two samples will be looked at further in the following section.

Unsieved fine sieving by-products

Samples identified as unsieved fine sieving by-products contained large quantities of glume wheat glume bases but with far more weeds. This means that the glume wheat spikelets had not been previously sieved before dehusking, resulting in more weed seeds in the second fine sieving by-products. Eighty seven samples were identified as being einkorn fine sieving residue that had not been previously sieved. These samples were characterised by ratio 2, for einkorn, having a value of >2.2 and a high value for ratio 4. FEU350 contained not only remains of einkorn fine sieving residue but the remains of barley early crop processing by-products seen from the high value for ratio 3. However, the extremely large number of einkorn glume bases would suggest that the sample primarily represents einkorn fine sieving residue that had not been previously sieved.

Three samples, FEU037, 257 and 262, were identified as possible einkorn fine sieving by-products that had been previously unsieved. However, the approximately equal number of weed seeds compared to the number of grains (ratio 4) and the small number of items recovered per sample made interpretation difficult. These samples will be addressed further below (section 2.4.2).

2.3.3 Products

Sieved products

Samples identified as a sieved product contained large quantities of 'clean' grain i.e. grain with little to no chaff and few weed species present as a result of systematic sieving. One hundred and three samples were identified as deriving from sieved einkorn products. These samples were characterised by a value of ≤0.4 for ratio 2, for einkorn, and a low value for ratio 4. In addition, four samples were tentatively identified as sieved einkorn products, due to the low number of einkorn grains (<25 items). Whether these samples should be allocated here can be explored further below (section 2.4.2).

Two samples, FEU083 and 316 were identified as emmer products. They were characterised by ratio 2, for emmer, having a ratio of 0.001 and a low value for ratio 4. However, the samples do differ in the composition of the weed remains. FEU083 had very few weeds (ratio 4 of 0.01) that were mainly large (BFH), while FEU316 had a much larger number of weeds (ratio 4 of 0.6) that were mainly small (SFH). The differences may be an indication of taphonomic factors as FEU083 was recovered from a hearth, potentially resulting in the loss of smaller weeds through differential preservation, while FEU316 was recovered from a yard area. Twelve further samples were identified as originating from sieved barley products and were characterised by a value of ≤0.2 for ratio 3, barley, and a low value for ratio 4. FEU029, 030, and 079 were identified as containing both einkorn and barley sieved products, an additional five were tentatively identified as einkorn and barley products, and FEU018 was interpreted as containing both barley and broomcorn millet sieved products.

FEU013 and 402 contained sieved broomcorn millet products. Broomcorn millet has no spikelets and therefore the identification of broomcorn millet products is more speculative. FEU049 is tentatively identified as deriving from broomcorn millet products as the number of millet grains in the sample was slightly larger than the remains of einkorn fine sieving residue. The presence of einkorn fine sieving residue in the sample may suggest that broomcorn millet represents a weed instead of a crop. The sample would then become indicative of unsieved einkorn fine sieving residue which is dominated by small weeds. FEU021 was identified as sieved so called rye products. However, rye is only tentatively identified at Feudvar and no rye rachis was recovered at the site. The composition of FEU021 contains a relatively high number of large weeds and barley grain, which may suggest that the so called rye grains represent a weed instead of a crop[70]. This will be examined further in the following section.

Unsieved products

Samples identified as unsieved products contained large quantities of 'clean' grain i.e. grain with little to no chaff and lots of small weed seeds. Unlike the sieved products, these samples represent products that have not been thoroughly sieved, possibly missing stages of the later processing sequence. Twenty six samples were allocated as unsieved einkorn products, characterised by a value of ≤ 0.4 for ratio 2, einkorn, and a high value for ratio 4. In addition, samples FEU203, 346, 446 and 478 have been tentatively identified as unsieved einkorn products as they have approximately equal numbers of weeds compared to the number of grains.

FEU353 and 485 were identified as unsieved barley products due to the low value of ratio 3, for barley, and although the value for ratio 4 was ca.1, it was decided that the large numbers of seeds present would more likely represent an unsieved deposit. FEU068 was also tentatively identified as containing unsieved barley products due to the approximately equal value of ratio 4. A further three samples, FEU017, 019, and 050, were tentatively identified as unsieved broomcorn millet products due to the dominance of millet grains. However, FEU017 and 050 have less than 100 broomcorn millet grains between them. All three samples also have relatively large numbers of small weed species which may suggest that the millet grains may have arrived at the site as a weed instead of a crop. The large number of broomcorn millet grains in FEU019 may, however, contradict this theory. This sample in particular is the most likely broomcorn millet product. The only other ambiguity is whether the sample can be classed as sieved or unsieved due to the large number of small weeds present. However, a sieve specifically designed for broomcorn millet is likely to collect a number of small weeds of the same size during the sieving stages. These samples will be looked at further below (section 2.4.2).

2.3.4 Summary

The analysis of crop processing at Feudvar, through the application of ratios 2–6 after van der Veen and Jones, has identified six different processing stages: sieved and unsieved spikelets, sieved and unsieved fine sieving residue and sieved and unsieved products. Of the 482 samples analysed, a total of 445 were identified as resulting from einkorn remains, fourteen from barley, six from broomcorn millet, five from emmer, and twelve from two or more crops. Table 11 summarises the results. Only einkorn spikelets were identified and only einkorn and emmer fine sieving by-products. Two samples represented a mixture of einkorn fine sieving by products and the possible remains of earlier crop processing stages of barley and bread / durum wheat, identified from the large number of rachis remains. The majority of the products resulted from einkorn remains. However, a much wider variety of crops were identified including barley and broomcorn millet. Only 35 samples were identified as unsieved products, with the majority having been systematically sieved. The following section will look at these results further, through the use of correspondence analysis, in order to assess whether the internal composition of the samples identifies similar / identical groupings in the samples as the calculations using ratios. In addition, correspondence analysis will explore whether the tentative identifications are indeed associated with their group or not.

70 The so called rye of Feudvar is the weed Dasypyrum villosum; this is a late discovery [Kroll].

Crop	Spikelet, sieved	Spikelet, unsieved	Fine-sieving by-product, sieved	Fine-sieving by-product, unsieved	Product, sieved	Product, unsieved	Total
Einkorn	21 (64)	22 (32)	79	87 (3)	103 (4)	26 (4)	445
Einkorn / emmer			1				1
Einkorn / barley					3 (5)		8
Einkorn / barley /			(2)				2
Bread / durum wheat							
Emmer			3		2		5
Barley					12	2	14
Barley / broomcorn millet					1		1
Broomcorn millet					2 (1)	(3)	6
Total	85	54	85	90	133	35	482

Table 11. Bronze Age Feudvar. Summary of the number of samples identified for each crop processing stage, based on the ratio analysis. (no.) = tentative identifications.

2.4 Correspondence analysis

Correspondence analysis is used here to examine the results of the crop processing analysis in order to assess whether the samples cluster into their identified groups and explore whether the tentative identifications are associated with their groupings. This multivariate technique is particularly useful as it allows each sample to be plotted along two axes depending on their similarities and differences in species composition. The following section will present the methodology applied to the dataset and the results of the analysis.

2.4.1 Standardisation of the data

Before correspondence analysis could be applied to the dataset certain samples and species were excluded from the analysis. All 484 samples used in the crop processing analysis were included here, as they represent samples with over 50 cereal and weed items. This cut off point was applied by van der Veen in the application of multivariate techniques (i.e. principle components, cluster and discriminant analysis) in order to reduce the level of unreliability caused by such small samples[71]. The presence of rare species within the samples is also problematic as they may not be associated with the crop but result from other activities or come from the local environment. However, variation exists as to how authors address this. Some advocate the exclusion of weed species found in either <5 % or <10 % of samples[72]. Van der Veen found that a 10 % cut off point was more than adequate to account for rare species in the dataset. It was therefore decided that weed species in <10% of the samples would be excluded. This reduced the weed species from 122 down to 28 (see Table 12 for species codes). With the exclusion of these species, two samples, FEU091 and 043, fell below the 50 items cut off point. However, both samples were only a few seeds below this point, 46 and 45 items respectively, and were therefore included in the analysis. The dataset was then entered into CANOCO 4.5 and CANODRAW where each sample was coded to their identified crop processing stage.

71 van der Veen 1992, 25.

72 Bogaard 2004.

Species	Code	Species	Code	Species	Code
Agrostemma githago	AGROGIT	Galium spurium	GALISPU	Schoenoplectus lacustris	SCHOLAC
Ajuga chamaepitys	AJUGCHA	Glaucium corniculatum	GLAUCOR	Setaria viridis	SETAVIR
Allium	ALLISPE	Gramineae	GRAMINE	Sherardia arvensis	SHERARV
Atriplex patula-type	ATRIPAT	Hordeum vulgare	HORDSAS	Silene	SILESPE
Bromus	BROMSPE	H. vulgare, rachis	HORDSRS	Solanum nigrum	SOLANIG
Bromus arvensis	BROMARV	Hyoscyamus niger	HYOSNIG	Teucrium	TEUCSPE
Bupleurum rotundifolium	BUPLROT	Labiatae	LABIATA	Thymelaea passerina	THYMPAS
Caryophyllaceae	CARYOPH	Lolium (small)	LOLISPE	Trifolium-type	TRIFSPE
socalled Secale	SECACEG	Malva	MALVSPE	Triticum dicoccon	TRITDIC
Chenopodium	CHENSPE	Panicum miliaceum	PANIMIL	Tr. dic., glume base	TRITDIG
Chenopodium hybridum	CHENHYB	Plantago lanceolata	PLANLAN	Tr. monococcum	TRITMOT
Cornringia orientalis	CONRORI	Polygonaceae	POLYGON	Tr. monoc, glume base	TRITMOG
Cruciferae	CRUCIFE	Polygonum aviculare	POLYAVI	Tr. spelta	TRITSPL
Cyperaceae	CYPERAC	Polygonum convolvulus	POLYCON	Tr. spelta, glume base	TRISPLG
Digitaria	DIGITSPE	Polygonum persicaria	POLYPER	Tr. aestivum/ Tr. durum	TRITAESD
Echinochloa crus-galli	ECHICRG	Portulaca oleracea	PORTOLE	Verbena officinalis	VERBOFF
Euphorbia palustris	EUPHPAL	Rumex crispus-type	RUMECRI	Vicia	VICISPE

Table 12. Bronze Age Feudvar. Species codes used in the correspondence analysis of the archaeobotanical data.

2.4.2 Results

All the samples classified to a crop processing stage were first examined through correspondence analysis to identify whether each stage formed a distinct group. Each sample was coded to their basic crop processing stage (i.e. all samples identified as sieved or unsieved spikelets were combined) regardless of cereal type and all tentative identifications were included within their possible groups. Initial analyses identified a separate cluster of seven samples near broomcorn millet along axis 2. These samples, FEU013, 017–019, 049, 050 and 402, had been previously identified as containing broomcorn millet products. Once removed, *Chenopodium* had a distinct affect on the dataset pulling a number of samples along axis 2. To reduce the effects, it was decided to down weigh this species. Lastly, sample FEU425 separated from the main group of samples due to the high number of bread / durum wheat grains. This sample was subsequently removed. Figure 4 presents the results plotted along axes 1 and 2.

All the cereals, except so called rye and barley rachis, are located on the negative end of axis one, while the majority of the weeds are located on the positive end. Along axis 2 the glume bases are located at the negative end while the cereal grains are found along the positive end. This distribution therefore resulted in the fine sieving by-products clustering to the bottom left, near the glume bases, the spikelets in the middle of the glume bases and the grains, and the products at the top near the cereal grains. Clustered with the products are a few samples identified as fine sieving by-products. These samples contain little chaff, a few grains but lots of small weeds (SFH), which would suggest that they are indeed fine sieving by-products and not products. The clear clustering of different crop processing stages would suggest that the ratio cut off points were acceptable, especially in the case of the spikelet remains. The dispersal of samples towards the positive end of axis 1 may result from unsieved crop processing stages, as the majority of the weed species are located in this area. These will be explored further in the following sections, as each crop processing stage is analysed separately.

Discrete clusters of species can also be seen and although weed ecology will be looked at in chapter 7, these associations are interesting to note. First, a large group consisting of Compositae, *Chenopodium*, *Echinochloa crus-galli*, *Solanum nigrum*, *Digitaria*, Labiatae, and *Teucrium* cluster together (see Table 12 for species codes). Second, *Bupleurum rotundifolium*, Gramineae, *Bromus*, *Bromus arvensis*, *Plantago lanceolata*, *Polygonum persicaria*, *Polygonum convolvulus*, *Trifolium* sp., and *Verbena officinalis* cluster near so called rye. The third group includes *Lolium*, Polygonaceae and *Polygonum aviculare* clustering near barley rachis.

Spikelets - sieved / unsieved

A correspondence analysis was run on the samples categorised as einkorn spikelets. A large number of *Galium spurium* seeds in FEU138 and *Agrostemma githago* seeds in FEU092 made these samples outliers and prevented the rest of the samples from being clearly seen. As a result they were removed from the analysis.

Fig. 4. Bronze Age Feudvar. Correspondence analysis of the Feudvar samples (>50 identifications and >10% weed species) classified by the crop processing stage, as identified by the ratio analysis, on the first two principal axes (axis 1 horizontal, axis 2 vertical).

The clear separation of the sieved and unsieved spikelets supports the results from the ratio analysis (Fig. 5). The sieved samples cluster in the bottom left of the plot, with all the cereals, suggesting little variation between the samples. The spread of the unsieved samples along the positive ends of axes 1 and 2 and their proximity to the wild / weed species, including broomcorn millet and so called rye, suggests greater variation between the samples. The location of broomcorn millet and so called rye may suggest that in these samples they represent weeds within the main einkorn crop. There is also a distinct cluster of samples near *Chenopodium*, at the positive end of axis 1. This results from the large numbers of *Chenopodium* seeds in the samples. Whether these samples represent unsieved remains or the collection of *Chenopodium* as a food is unclear, especially as the remains were not identified to species and the genus is commonly found growing as weeds in crops.

Only FEU128, classified as sieved, is distinctly separate from the main cluster, towards the top of axis 2. The sample has very few weed remains compared to the quantity of grain and glume bases present, so it is unlikely to be unsieved. The low glume : grain ratio 2, for einkorn, of 0.9 may suggest unsieved einkorn products rather than spikelets with underrepresented glume bases. However, the sample is particularly dominant in one weed species which may explain why it is plotted near *Echinochloa crus-galli*. The samples along the border of sieved and unsieved are largely characterised by an approximately equal value for ratio 4, making it difficult to determine their classification. Re-examining FEU497, 133 and 086, which are located furthest away from the main cluster of sieved spikelets, it may be possible to change these to unsieved spikelets as the number of weeds are slightly higher than the einkorn remains. These 'uncertain' samples will need to be explored with caution when examining weed ecology in the following chapter.

Fine sieve by-products - sieved / unsieved

A correspondence analysis was run on the samples categorised as fine sieve by-products. Both samples FEU079 and 425 were removed as they contained large numbers of *Vicia* sp. and bread / durum wheat respectively, making them outliers in the analysis. FEU425 in particular was identified as emmer and einkorn sieved fine sieving residue. However, the relatively large number of bread / durum wheat and

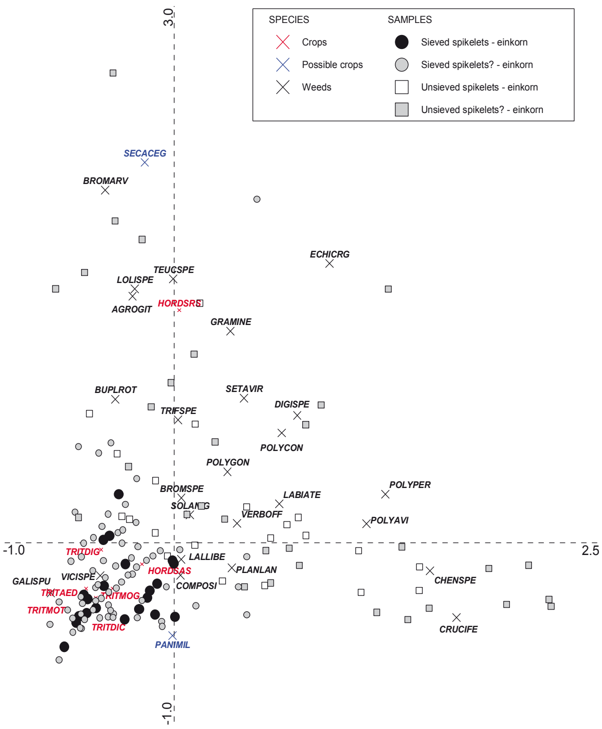


Fig. 5. Bronze Age Feudvar. Correspondence analysis of samples identified as sieved and unsieved einkorn spikelets.

barley grains in the sample prevented any clear interpretation and may suggest that the assemblage is the result of mixing of different crop processing stages during deposition.

FEU056 and 057, identified as sieved remains from method 1, are located in the unsieved area along the positive end of axis 2 (Fig. 6). The value of ratio 4 implies sieved remains, but if the broomcorn millet grains are interpreted as a weed then the samples may suggest unsieved remains. As a result, these samples have been re-identified as unsieved samples. Two further samples, FEU217 and 219, located along the positive end of axis 1, were identified as sieved einkorn by-products with possible remains of free-threshing early crop processing by-products. Both have low values for ratio 4 but due to the high number of bread / durum wheat and barley rachis they have separated from the rest of the sieved remains. This would suggest that the samples likely represent a mix of glume wheat fine sieving by products and free-threshing early crop processing waste.

The samples along the border of sieved and unsieved are largely characterised by an approximately equal value for ratio 4, making it difficult to determine their classification. A re-examination of FEU327 and 435, identified as unsieved remains, are located within the cluster of samples identified as sieved and may suggest that they actually represent sieved fine sieving residue, especially as the number of weeds are lower than the number of einkorn glume bases. However, these 'uncertain' samples will need to be explored with caution when examining weed ecology in the following chapter.

Products - sieved / unsieved

A correspondence analysis was run on the samples categorised as products. Initial analysis identified a distinct cluster of seven samples, FEU402, 013, 019, 049, 050, 018 and 017, which were all identified as containing broomcorn millet products. FEU018 was identified as containing both barley and broomcorn millet products and although the correspondence analysis may suggest that it is mainly broomcorn millet products, the similar number of barley and millet grains support the original interpretation. In addition, FEU483 was an outlier in the analysis as a result of the large number of Cruciferae seeds recovered (402 seeds). These samples were subsequently removed to allow further analysis of the remaining products.

Correspondence analysis was first run on the sieved and unsieved products regardless of the species of the product in order to determine whether differences could be seen between the samples (Fig. 7). The sieved samples generally cluster in the bottom left of the plot, while the unsieved samples are spread along the right. The tentatively identified sieved and unsieved products were also plotted. From Figure 7, it is difficult to determine whether the possible sieved or unsieved are correct identifications as they are located among both types of samples. As a result, the samples have been left to the classifications determined from the ratio analysis. Similar to the previous crop processing groups a number of samples also cluster near *Chenopodium*.

A second correspondence analysis was run to determine whether the different crops identified as products clustered together. Due to the effects of *Chenopodium* on sample composition, it was decided that it would be removed from this analysis. The most distinct group of samples are those identified as sieved barley products (Fig. 8). Of the 12 samples, 11 are found clustered at the positive end of axis 2. The last

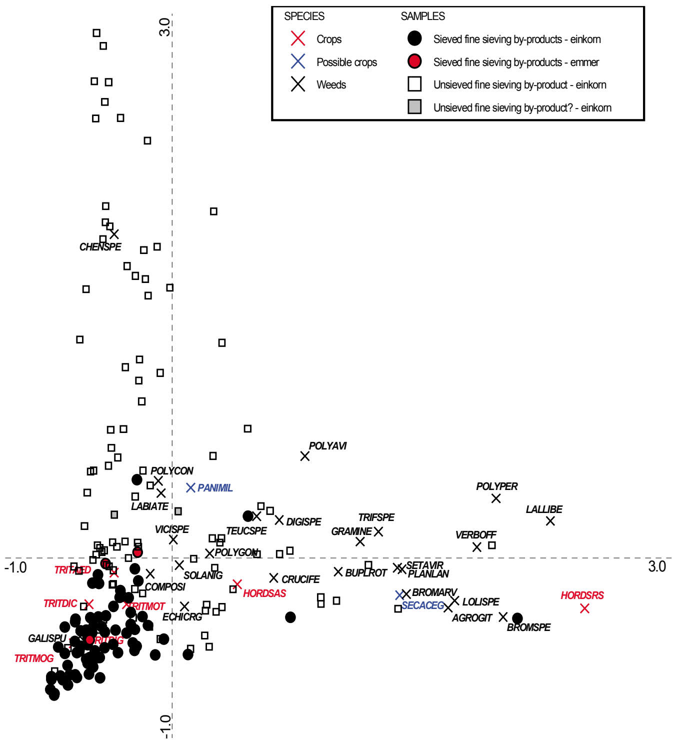


Fig. 6. Bronze Age Feudvar. Correspondence analysis of samples identified as sieved and unsieved fine sieving by-products.

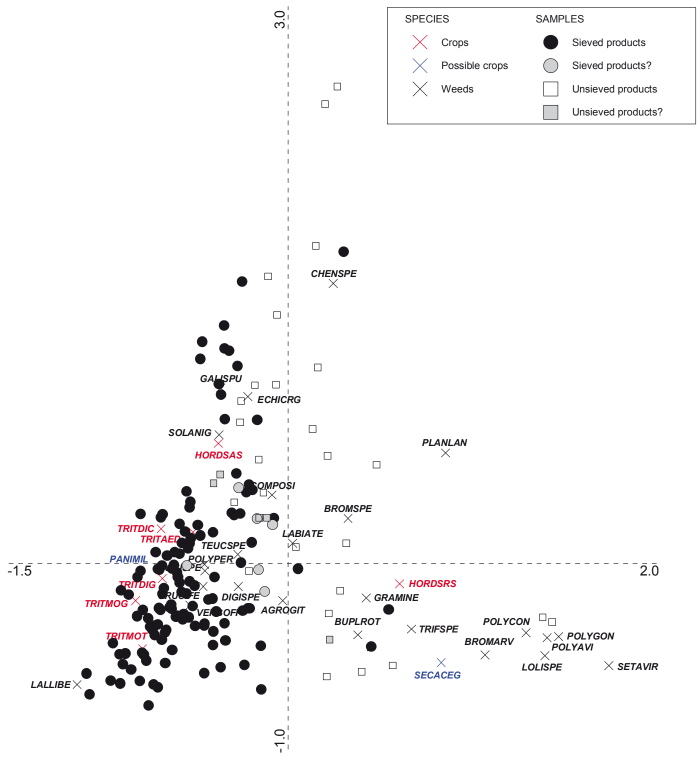


Fig. 7. Bronze Age Feudvar. Correspondence analysis of samples identified as sieved and unsieved products.

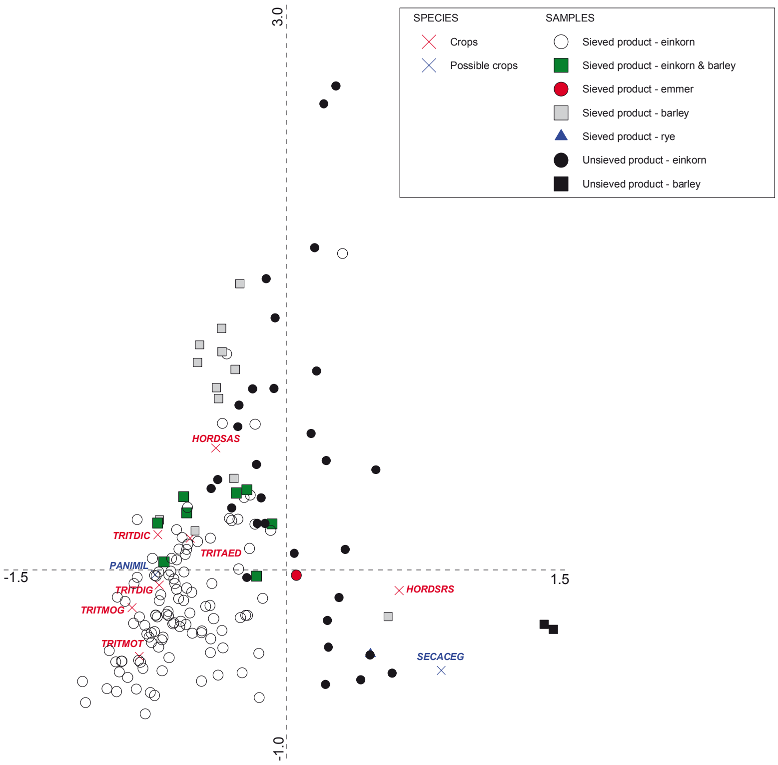


Fig. 8. Bronze Age Feudvar. Correspondence analysis of samples identified to specific crop products.

sample, FEU047, is located on the positive end of axis 1 near so called rye and barley rachis. However, looking at the ratios it is clear that this sample represents a sieved barley product. The second distinct group is the two samples identified as unsieved barley which are located at the positive end of axis 1. It is also interesting to note that a number of grasses (e.g. *Lolium*) and knotgrasses (e.g. *Polygonum aviculare*) also cluster here.

FEU029 and 030 are located between einkorn and barley, supporting their identification as a mixed crop or deposit of einkorn and barley products. The composition of FEU083 is clearly that of an emmer product, so the location of the sample may result from the composition of the few weed seeds present in the sample. Finally FEU021, identified as a sieved so called rye product, is located near the so called rye but is also near samples identified as unsieved einkorn products. The sample also includes a number of barley and einkorn remains which suggests that the so called rye is a weed in another crop, especially as there are a lot of large weed seeds present, or the sample may contain a mix of different crop products[73].

2.4.3 Summary

Correspondence analysis was used here to assess the identifications attained from the ratio analysis. This proved successful as the samples identified to different crop processing groups did indeed cluster together and tentative identifications were reinforced by the analysis. Correspondence analysis was also useful in highlighting certain samples that did not conform to the clusters and therefore required reassessing.

Table 13 presents a summary of the number of samples identified to each crop processing stage before and after the correspondence analysis. Only three samples previously identified as sieved spikelets were re-examined and changed to unsieved spikelets. For the fine sieving residue, samples FEU056 and 057,

73 This so called rye, cf. Secale, is a weed: Dasypyrum villosum, a genus near Triticum and Secale. This is a recent discovery [Kroll].

Processing stage	Analysis type	Einkorn	Einkorn / emmer	Einkorn / barley	Einkorn / barley / naked wheat	Emmer	Barley	Barley / broomcorn millet	Broomcorn millet	Total
Spikelets, sieved	RA	21 (64)								85
	CA	82								82
Spikelets, unsieved	RA	22 (32)								54
	CA	57								57
Fine-sieving by-product,	RA	79	1		(2)	3				85
sieved	CA	79	1		2	3				85
Fine-sieving by-product,	RA	87 (3)								90
unsieved	CA	90								90
Product, sieved	RA	103 (4)		3 (5)		2	12	1	2 (1)	133
	CA	107		8		2	12	1	3	133
Product, unsieved	RA	26 (4)					2		(3)	35
	CA	30					2		3	35
Total	RA	445	1	8	2	5	14	1	6	482
	CA	445	1	8	2	5	14	1	6	482

Table 13. Bronze Age Feudvar. Summary of the number of samples identified for each crop processing stage from the ratio analysis (RA) and after correspondence analysis (CA). (no.) = tentative identifications.

Chenopium	Spikelets, unsieved	Fine-sieving by-products, unsieved	Products, unsieved
>90 %	-	135; 165	-
>70 %	023; 136; 208; 233; 468	005; 006: 041; 053; 070; 094; 182; 279; 395	396; 461

Table 14. Bronze Age Feudvar. Samples with <90% and >70 % Chenopodium content per identified crop processing group (FEU … sample no.).

previously identified as sieved were changed to unsieved. In addition, FEU327 and 435, previously identified as unsieved fine sieving residue were changed to sieved.

A number of issues were also brought to light. The first involved the dominance and effect of *Chenopodium* on many of the samples in the assemblage. Two samples identified as unsieved fine sieving by-products have >90 % *Chenopodium*, while a further 16 samples identified as unsieved spikelets, fine sieving by-products and products contain >70 % *Chenopodium* (Table 14). These samples may therefore suggest that within these samples *Chenopodium* represents food collection rather than a crop weed. However species within the *Chenopodium* family can be found as a weed in crops and each individual plant can produce large numbers of seeds. For example, Williams observed that *Chenopodium* plants in nitrogen-poor soils produced <20 seeds per plant, however those on nitrogen-rich soils can produce >200,000 seeds per plant[74]. It is therefore difficult to determine its significance within the samples and will need to be explored further when examining weed ecology in the samples.

Second is the role of broomcorn millet. However, broomcorn millet is found as a small component of many of the samples which may support the idea that it is also a weed within the main crop. The identifications of broomcorn millet as a product from the ratio and correspondence analysis will remain, although it is important to note the issues that surround the identification.

74 Williams 1969, 837.

2.5 Intra-site variability

2.5.1 General trends

The location of each sample identified to a crop processing stage within the western trench at Feudvar is presented below. The aim of this is to see whether certain crop processing remains are found within particular features or areas within the trench. The trench is divided into 5 x 5 m areas to help determine any differences in spatial deposition. This will contribute to the overall depositional history of the samples.

Feature type	Spikelets	Fine-sieved by-products	Products	Total no.
Container fill	27	64	9	11
Occupation layer	29	38	33	253
Hearth	22	50	28	18
House	33	33	33	93
Miscellaneous	15	46	37	12
Pit	27	33	40	70
Street	15	15	69	13
Yard	33	8	58	12
Total	139	175	168	482

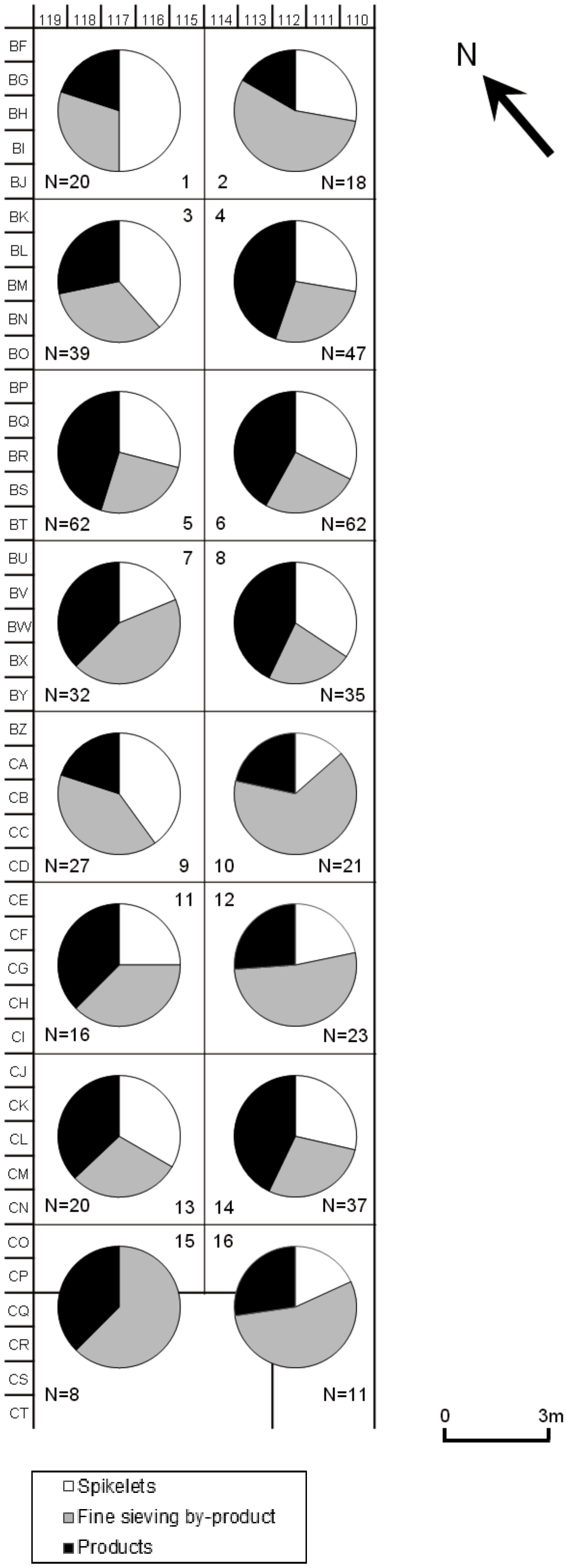
Table 15. Bronze Age Feudvar. Percentage of samples per feature type based on their crop processing identifications.

The samples identified to crop processing stages were first examined as to their percentage presence within each feature type (Table 15). The majority of samples were recovered from general deposits, houses and pits, however the percentage of samples identified to each crop processing stage varies. General deposits along with container fills, hearths and miscellaneous deposits have a higher percentage of samples identified as fine sieving by-products. Pit, street and yard deposits have a higher percentage of products, while the house deposits contain an approximately equal percentage of spikelets, fine sieving by-products and products. The street deposits are the only feature that contains mainly products, while the yard samples contain mainly products and spikelets and the container fills have more samples identified as fine sieving residue and spikelets. However these features are represented by a small number of samples, so it is difficult to determine how accurate these trends are.

Looking at the distribution of samples across the site seen in Figure 9, some distinctions may be identified. First, a high percentage of spikelets can be seen in area 1 and 3. The samples here come from mainly general deposits, houses and pits (Table 16). Second, the majority of samples containing fine sieving by-products are located in areas 2, 7, 12, 15 and 16 from a wide range of features, although mainly general, house and pit deposits. Areas 7 and 12 also have extremely high plant seed densities per litre of soil (Fig. 3). Third, areas 4 to 6, 8 and 14 have slightly higher percentages of samples identified as products which are mainly from general deposits, pits and house areas with only a few being found in street and yard deposits (Table 16). In addition, the distribution of sieved and unsieved samples (Fig. 10), shows that areas 6, 9 and 15 have a high percentage of sieved remains (>85 % of samples) while areas 3, 13, 14 and 16 have over 50 % of the samples identified as unsieved. The later areas were generally identified as containing high percentages of spikelets and fine sieving residue, while the former contained products and fine sieving residue.

2.5.2 Cereal distribution

In order to determine whether these areas show any consistency distribution that may suggest differences in households or storage facilitates the distribution of crop remains were also examined. The majority of the crop processing remains have been identified as einkorn crops and as such is found in all the feature types sampled at the site (Table 17). General, house and pit deposits have the greatest variety of samples identified to a certain crop, however no further patterns can be distinguished. Looking at the percentage presence of each crop as well as the weeds per feature for all the samples a number of patterns can be seen (Table 18). Overall occupation layers and house floors contain the highest percentage of remains from most of the cereals and weeds. Only broomcorn millet and emmer deviate from this trend with of the millet remains being found in pits and 48 % of emmer grain found from hearth features. 33 % of emmer glume bases however are found from house floors along with einkorn glume bases and barley rachis.



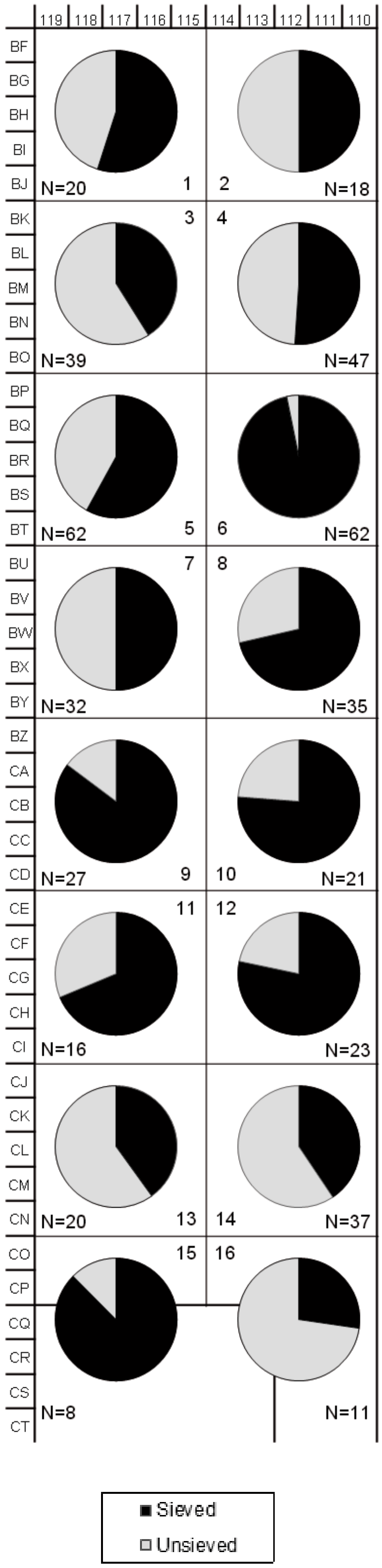


Fig. 9. Bronze Age Feudvar. Pie charts representing the percentages of samples identified as spikelets, fine sieving by-products and products per block (5x5m).

Fig. 10. Bronze Age Feudvar. Pie charts representing the percentages of samples identified as sieved and unsieved (regardless of crop processing stage) per block (5x5m).

Block no.	Container fill	Occupation layer	Hearth	House	Miscellaneous	Pit	Street	Yard	Total no.
1		55			35	10			20
2		39			33	28			18
3	3	59	13		15	10			39
4		40	9	6	17	23	4		47
5	10	65	2		18	5	2		62
6		42	10	2	31	6	10		62
7		56			34	3	6		32
8	3	63		6	17	11			35
9		59		4	4	22		11	27
10		57			10	14		19	21
11		31			13	38	6	13	16
12		57		9		22		13	23
13	10	30		5	20	30	5		20
14		57		8	16	19			37
15		25	25		25	25			8
16	9	73			9	9			11

Table 16. Bronze Age Feudvar. Percentage of samples per block in relation to feature type.

Cereal	Container fill	Occupation layer	Hearth	House	Miscellaneous	Pit	Street	Yard	Total no.
Einkorn	10	241	14	82	12	62	13	11	445
Emmer		1	1	1		1		1	5
Barley		4	3	6		1			14
Broomcorn millet		2				4			6
Mixed	1	5		4		2			12
Total no.	11	253	18	93	12	70	13	12	482

Table 17. Bronze Age Feudvar. The number of samples identified to each cereal per feature.

The differences seen between house deposits and pits was examined further in relation to the percentage of cereal and weed remains per areas within the trench for each crop processing stage i.e. spikelets, fine sieving residue and products (Tables 19–21).

Spikelets

House levels which contain spikelets occur in areas 1 to 9, 13 and 14, while pits containing spikelets are found in blocks 1 to 4, 6 to 9 and 12 to 14 (Table 19). Although the areas are largely dominated by einkorn spikelets a number of observations can be made between the two feature types and areas. Area 14 has a high number of barley grains and weeds in the house levels. Both area 14 and 3 contain a high percentage of weeds for both house and pit features, while areas 6 and 12 have an extremely low percentage of weeds. Area 7 shows a high percentage of broomcorn millet grains and a low percentage of weeds within the pits, while a high percentage of weeds are located in area 9 within the house deposits.

Fine sieving by-products

House levels which contain fine sieving by-products occur in areas 1 to 8, 11 and 13 to 16, while pits containing fine sieving by-products are found in blocks 2 to 4, 6, and 8 to 15 (Table 20). Although the areas are largely dominated by einkorn spikelets a number of observations can be made between the

	Container fill	Occupation layer	Hearth	House	Miscellaneous	Pit	Street	Yard	Total no.
Barley grain	1	52	4	29	2	9	2	1	15102
Barley rachis		46		50		3	1		1232
Einkorn grain		35	1	40	14	6	3	1	73493
Einkorn glume base	1	40	1	39	7	11	1		135994
Emmer grain		26	48	11	2	10	1	2	4207
Emmer glume base	1	51		33	4	9	1	1	6602
Naked wheat grain		90		2	6	2			471
Broomcorn millet		23	1	3	9	63		1	2660
Weeds	1	50	2	31	3	11	1	1	65485

Table 18. Bronze Age Feudvar. Percentage of each cereal per feature type.

	Barley grain		Barley rachis		Einkorn grain		Einkorn glume base		Emmer grain		Emmer glume base		Broomcorn millet grain		Weeds		Total no. of items	
Block no.	House	Pits	House	Pits	House	pits	House	Pits	House	Pits	House	Pits	House	Pit	House	Pit	House	Pits
1	2	7		1	26	24	27	29	1	11	1	4		1	43	23	866	497
2	2	4		1	19	14	40	21	2	3	3	10	1	1	33	46	530	135
3	4	2			19	8	17	16	1	1	1	1	1	4	57	68	720	1789
4	10	2			23	23	32	31	1	1	3	4			31	39	412	647
5	4				26		48		2		1		2		17		438	
6	2	3			55	53	38	36		2			1		4	6	5058	1657
7	7	8			30	32	26	24	1	2				12	36	22	1069	304
8	16	3			25	26	23	37		3	1	8			35	23	398	174
9	5	4	1		14	20	21	19	5	16		14			54	27	161	250
10																		
11																		
12		31				18		38		2		2		2		7		173
13	6	12			24	17	41	23	6		9			4	14	44	93	464
14	23	4			8	8	13	8					1	2	55	78	167	190
15																		
16																		

Table 19. Bronze Age Feudvar. Percentage of each cereal per block for house and pit features from samples identified as spikelets.

two feature types and areas. Area 14 has a high number of barley grains and weeds in the house levels. Areas 3 to 4 and 13 to 14 contain a high percentage of weeds for both house and pit features, while generally areas 6 to 9 have a lower percentage of weeds. Broomcorn millet is largely absent from the house levels. A large percentage (77 %) of emmer glume bases are present in area 8 of the house level, however this results from FEU084 which was identified as sieved emmer fine sieving by-products.

Products

House levels which contain products occur in areas 3 to 8, 10 to 11 and 13 to 14, while pits containing products are found in blocks 1 to 2, 4 to 6, 8 to 11, 14 and 16 (Table 21). Although the areas are largely dominated by einkorn spikelets a number of observations can be made between the two feature types and areas. Area 14 has a high number of barley grains and weeds in the house levels. Areas 3, 11 and 13 have

Block no.	Barley grain		Barley rachis		Einkorn grain		Einkorn glume base		Emmer grain		Emmer glume base		Broomcorn millet grain		Weeds		Total no. of items	
	House	Pits	House	pits	House	Pits	House	Pits	House	Pits	House	Pit	House	Pit	House	Pits	House	Pits
1					3		8		1		1				87		774	
2	4			1	14	7	55	82	1	1	1	1		1	25	7	1050	1659
3	3	1	1		8	2	56	24	4	1	1	2			27	70	335	207
4	6	3			13	11	35	30	1	1	7	1		1	38	53	204	439
5	2				21		61		1		1				14		649	
6	7	1			13	4	62	88	1	1	2	1			15	5	1743	520
7	1		1		13		79								6		52720	
8	1	13			6	12	2	51	6		77	3		1	8	20	2192	75
9						1		96		1						2		8907
10		5				13		37				1				44		318
11	4	1	1		13	13	63	71			2	1	2		15	14	231	260
12		11				8		39		1		2				39		2049
13	4	2			10	5	31	16	1	3		18			54	56	236	1242
14	16	6			12	12	2	45	3	1				2	67	34	89	194
15	5	15			7	14	50	49	1	3	26	3			11	16	853	152
16	2				4										94		55	

Table 20. Bronze Age Feudvar. Percentage of each cereal per block for house and pit features from samples identified as fine sieving by-products.

Block no.	Barley grain		Barley rachis		Einkorn grain		Einkorn glume base		Emmer grain		Emmer glume base		Broomcorn millet grain		Weeds		Total no. of items	
	House	Pits	House	pits	House	Pits	House	Pits	House	Pits	House	Pit	House	Pit	House	Pits	House	Pits
1		1				61		16		2				1		19		352
2		7				6		19		1		2		32		33		506
3	11				18										71		12213	
4	5	16			62	30	29	11	1	1		3		1	3	38	15828	1620
5	5	6			38	46	6	15		1					51	32	3198	878
6	16	11			43	62	11	13	2	3	2		1		25	11	1163	238
7	2				87		2								9		4438	
8	19	18			28	39	17	7	1	2	2	11	0	2	33	21	1023	106
9		12				41		1		8		3		1		34		125
10	16	5	1		34	23	11	12	6	1	6	15	1	1	25	43	142	146
11	5	17			32	18	5	7	6	3		1		13	52	41	101	1490
12																		
13	2				26		8								64		154	
14	54	2			6	6	9	20		1		2		45	31	24	806	2437
15																		
16		7				29		18		1		3		8		34		77

Table 21. Bronze Age Feudvar. Percentage of each cereal per block for house and pit features from samples identified as products.

a high percentage of weeds within the house levels, while areas 4 and 7 have the lowest. Area 11 shows a high percentage of broomcorn millet grains within the pits.

2.5.3 Correspondence analysis

Each crop processing group was re-examined in relation to the distribution of feature types and areas with the trench in correspondence analysis. This was conducted in order to determine whether the distribution of samples may also be linked with feature type of area, especially as a number of patterns have been identified above.

Spikelets

A correspondence analysis was run on the samples identified as spikelets. Each sample was first coded as to their feature type and second to the area within which they were recovered within the trench. Figure 11 shows that pit features are located to the bottom of the plot near the wheats, broomcorn millet and *Chenopodium*. In addition, samples recovered from the southern areas of the trench (blocks 13–16) are also located along the bottom of the plot (Fig. 12). Hearth deposits are located in the bottom left of the plot, while the remaining features have no clear associations (Fig. 11). There are also no further associations with area although there is a small cluster of samples from blocks 7 to 12 located near so called rye at the top of the plot (Fig. 12).

Fine sieving by-products

A correspondence analysis was run on the samples identified as spikelets. Each sample was first coded as to their feature type and second to the area within which they were recovered within the trench. Figure 13 shows that pit features are located to the right of the plot near the wheats, broomcorn millet and *Chenopodium*. In addition, samples recovered from the southern areas of the trench (blocks 13–16) are also located along the right of the plot (Fig. 14). Hearth deposits are more dispersed but are mainly found along the right of the plot, while the remaining features have no clear associations (Fig. 13). There are also no further associations within the areas (Fig. 14).

Products

A correspondence analysis was run on the samples identified as spikelets. Each sample was first coded as to their feature type and second to the area within which they were recovered within the trench. Figure 15 shows that pit features are located to the right of the plot near the wheats, broomcorn millet and *Chenopodium*. In addition, samples recovered from the southern areas of the trench (blocks 13–16) are also located along the right of the plot (Fig. 16). Hearth deposits are located in the middle left, street deposits in the bottom left and yard deposits are also located to the left. Only general and house deposits seem to be associated with barley and so called rye to the right of the plot (Fig. 15). There are also no further associations within the areas (Fig. 16).

2.5.4 Summary

The general trends of crop processing distribution at Feudvar suggests that products are more commonly associated with pit, street and yard deposits, fine sieving remains with general deposits, containers and hearths, while the house deposits have all three crop processing stages. In addition, samples tend to be unsieved in areas 3 and 14 within the trench which correspond with the fisher house to the northeast of the trench and the southern house possibly indicating crop processing areas within the house. Block 14 also has a consistently high percentage of barley grain which may suggest a greater preference for barley within the household or may indicate an area within which animals are kept. This may also be supported by the increase in fine sieving remains found in pits near the southern end of the trench and the reduction in presence of samples identified as spikelets and products in this area. However from the correspondence analysis there also seems to be a strong association with broomcorn millet and *Chenopodium* within the southern area of the trench. Unfortunately further archaeological details are unavailable at present.

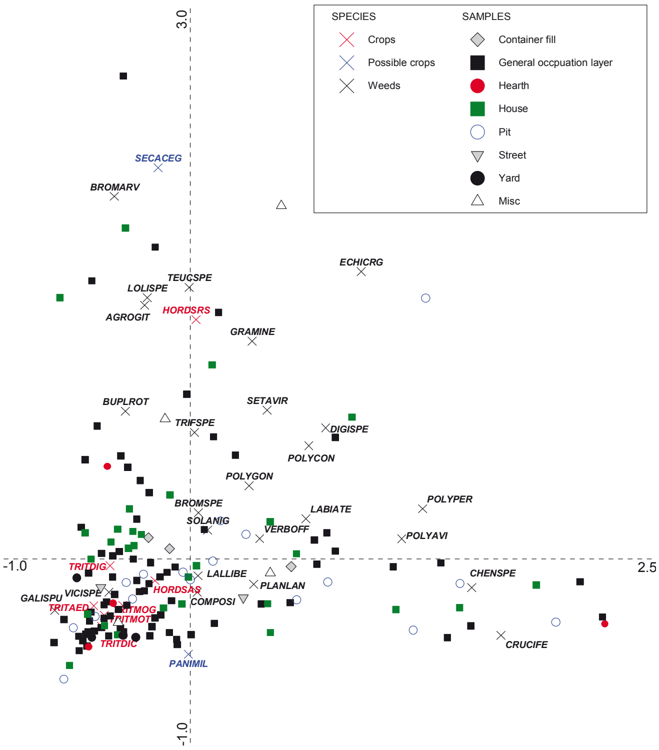


Fig. 11. Bronze Age Feudvar. Correspondence analysis of samples identified as spikelets per feature type.

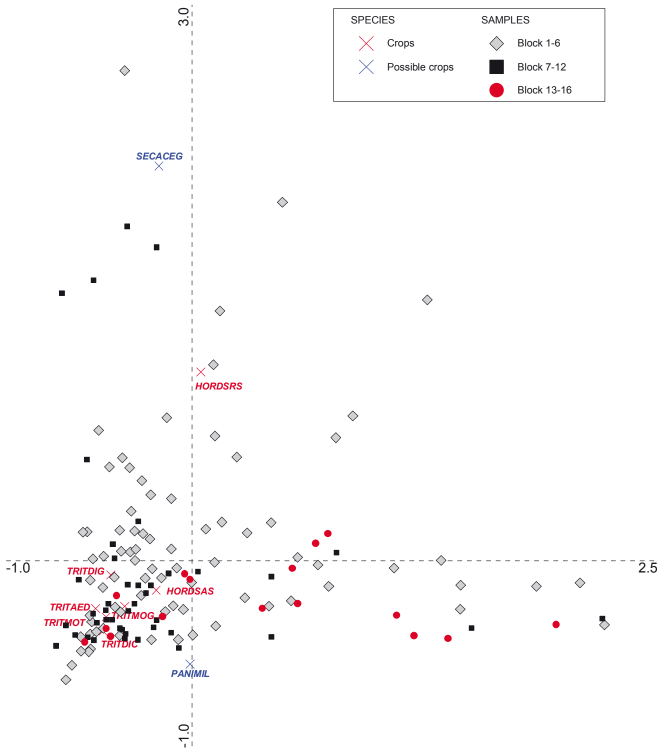


Fig. 12. Bronze Age Feudvar. Correspondence analysis of samples identified as spikelets per block (5x5m).

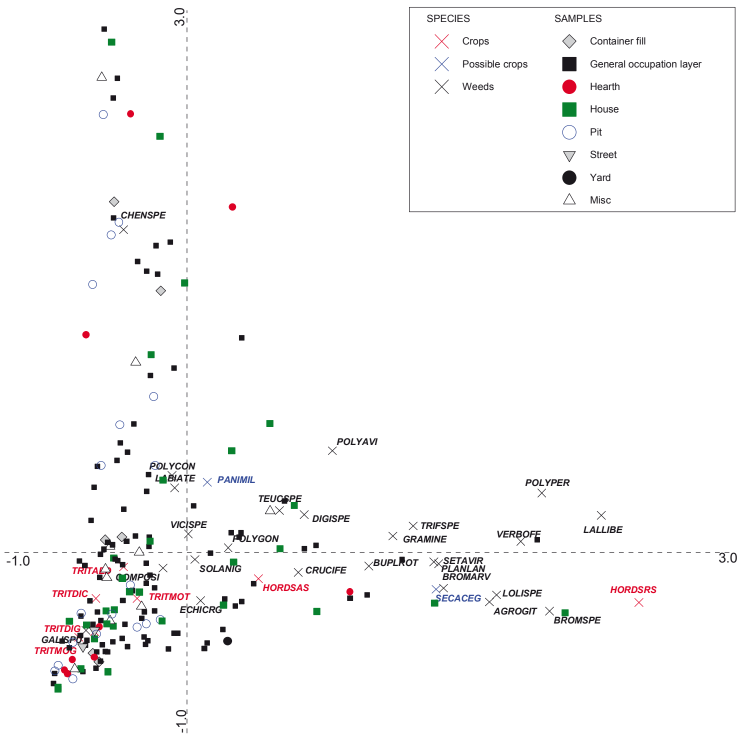


Fig. 13. Bronze Age Feudvar. Correspondence analysis of samples identified as fine sieving by-products per feature type.

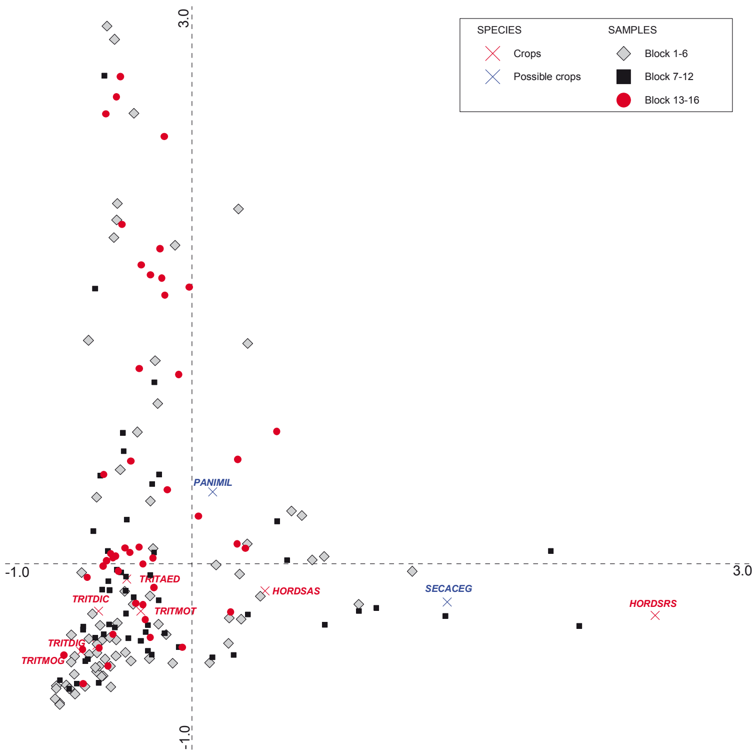


Fig. 14. Bronze Age Feudvar. Correspondence analysis of samples identified as fine sieving by-products per block (5x5m).

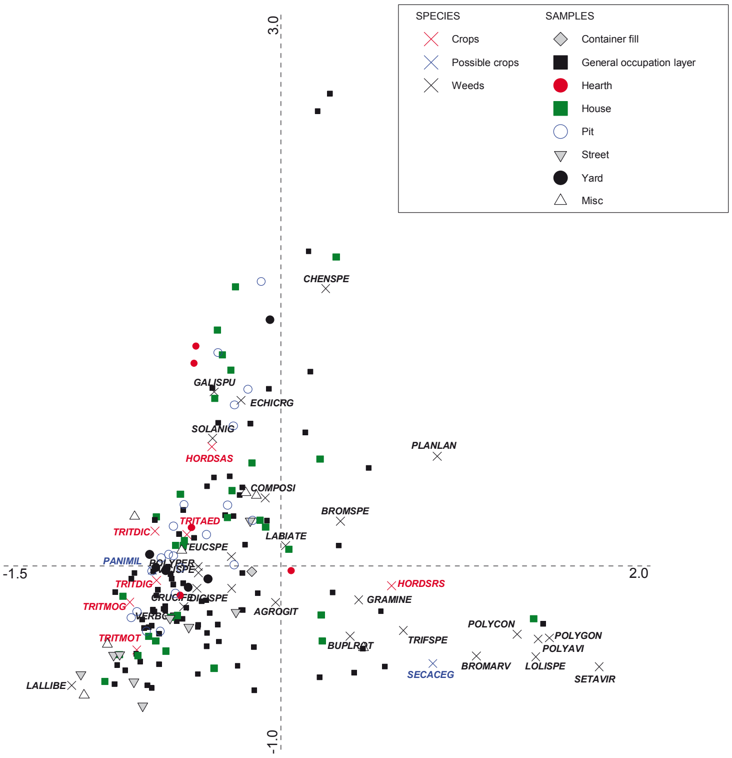


Fig. 15. Bronze Age Feudvar. Correspondence analysis of samples identified as products per feature type.

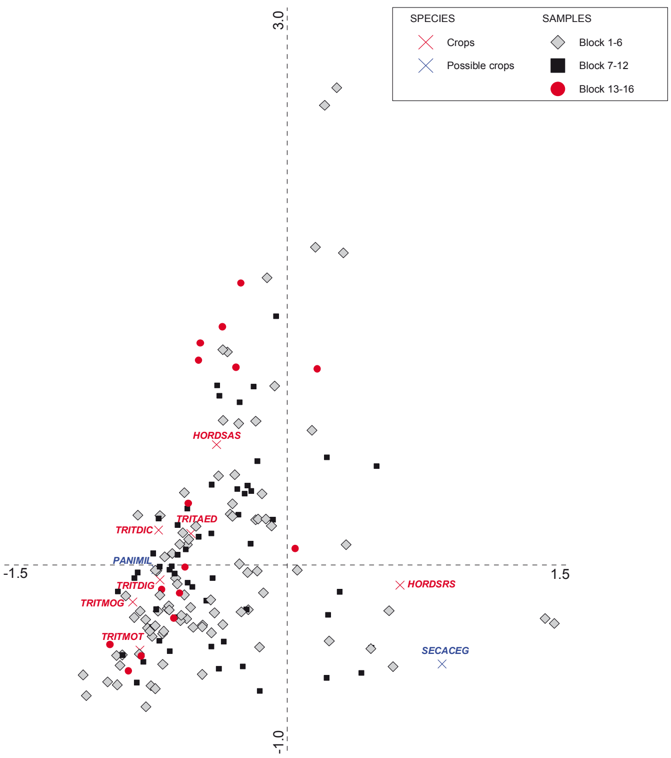


Fig. 16. Bronze Age Feudvar. Correspondence analysis of samples identified as products per block (5x5m).

In contrast, sieved samples seem to occur more regularly in the centre of the trench especially in the bottom half of the 'fish' house. From the correspondence analysis the north and central parts of the trench seem to have the greatest variance and are unassociated with any particular crop or weed. Further patterns can be seen where so called rye grains correspond with house floors and broomcorn millet has a greater association with pits. From the correspondence analysis the location of broomcorn millet, near the crops, and so called rye, located near the weeds, may suggest that rye is a weed[75]. This may explain why so called rye is regularly found in house deposits, which contain all three crop processing stages, while broomcorn millet is stored within pits, which have a greater association with products and few weeds, suggesting it may be an admixture or crop in its own right.

2.6 After the harvest: crop processing at Feudvar

The growing of crops involves a yearly cycle of activities such as preparing the soil, sowing, harvesting and crop processing. Each activity relies on variables such as man power, technology, the environment and society. By analysing the crop processing stages at Feudvar the activities conducted by the community are brought to light. The main crop grown was einkorn with potential minor crops of emmer, barley, bread / durum wheat and possibly broomcorn millet and so called rye. The identification of sieved and unsieved spikelets, sieved and unsieved fine sieving residue and sieved and unsieved products shows a clear separation in the activities performed at the site. The following sections will discuss further the different crop processing stages identified from the Feudvar assemblage, what activities they may represent and how this impacted on social organisation.

2.6.1 Early stages of crop processing

As outlined above early stages of crop processing, i.e. threshing and winnowing, are performed to break the ears of the cereals into either spikelets for the glume wheats or to separate the grain from the chaff in the case of free-threshing cereals. Ethnographic evidence from Greece, Turkey and Spain show that stone threshing floors are used as well as numerous methods to thresh the crops[76]. For example, for the threshing of spelt in different regions of Asturias farmers employ human trampling, wooden mallets and flailing to release the spikelets from the straw. Areas known as threshing floors are usually built just outside the settlement in an open space where the wind is able to aid the winnowing process[77]. In Karpathos, teams of animals were used to trample the cereals and in rare cases a threshing sledge was employed. The cereals also needed to be dry before threshing and in Karpathos threshing would typically take place in the heat of the midday sun. The level of dryness would therefore impact on the time it would take to process the cereals at this stage[78].

Once the crop has been broken apart the next stage is to winnow the remains to separate the grain from the light chaff, straw and weeds. In the region of Asturias this is done by using a winnowing drum to either pour the remains from a height allowing the wind to blow away the light remains or they can be thrown into the air. A steady breeze seems to be required for the efficient winnowing of cereals. In Armogos branches from local bushes, such as Juniper, were placed at the edges to catch fragments of chaff and straw and prevent it from being blown away[79].

Evidence of early crop processing by-products will therefore largely include straw fragments, culm nodes and bases, awn fragments and, in the case of free-threshing cereals, rachis internodes. At Feudvar there is no written evidence of straw, culm nodes or awn fragments[80]. As the area excavated includes a number

75 This so called rye is a weed: The coastal grass Dasypyrum villosum. A recent discovery [Kroll].
76 Halstead and Jones 1989; Hillman 1981.
77 Peña-Chocarro 1999, 34–35.
78 Halstead and Jones 1989, 44.
79 Halstead and Jones 1989, 44.
80 It is not useful to count straw, culm nodes and awn fragments. These remains are neglected in the data sheets of the Feudvar samples [Kroll].

of houses and streets it is likely that the threshing and winnowing would have occurred away from this area possibly on the outskirts of the settlement. Thus, the likelihood of the remains becoming charred and deposited within these features is unlikely. Evidence of rachis remains from barley and bread / durum wheat at the site may suggest remains of early crop processing waste but as they are incorporated within a deposit of einkorn fine sieving waste they may also represent the by-products of sieving.

Building material

Evidence from the excavations at Feudvar has shown that the house walls were built of reeds and clay strengthened with straw and other plant parts[81]. This would suggest that by-products from crop processing were regularly utilised in the construction of housing at the site[82].

2.6.2 Spikelets

Human consumption

After threshing and winnowing the remaining products for glume wheats would include the spikelets some chaff and weeds, while the free-threshing cereals would include the grain, some chaff remains and weeds. At this point the grain / spikelets can be stored semi-clean or processed further, i.e. coarse and fine sieved. In regards to glume wheats, whether the spikelets are sieved prior to dehusking may depend on a number of factors such as what the intended product is, climate, labour availability as well as possibly being a cultural preference. In Morocco ethnographic observations showed that when einkorn was used for human consumption the grain was not sieved until after dehusking on a smaller scale within the house on a day-to-day basis before the grain was milled for flour[83]. Similarly, in regions of Asturias spelt is stored semi-cleaned but is later dehusked en masse at a local mill, where it is sieved and the clean grain is stored again to be used on a piecemeal basis. The remains of fine sieving by-products at Feudvar suggest that a certain proportion of the cereals were intended for human consumption as dehusking glume wheats is time consuming and is unlikely to be performed for animal feed[84].

Animal fodder

It is also important to consider that semi-cleaned spikelets / grain may represent animal fodder. Ethnographic studies on traditional einkorn crop processing in Spain identified that einkorn spikelets were not thoroughly sieved as the final product was intended to feed animals. Einkorn spikelets, either on their own or mixed with barley, were then fed to mules, donkeys, goats and chickens. However einkorn is grown as a minor crop at these sites. In addition, Peña-Chocarro also points out that emmer and spelt are not commonly used for animal feed unless absolutely necessary[85]. Ethnographic observations in Romania however found that minor crops of einkorn and emmer intended for animals were also usually grown in distant plots that had become overgrown with weeds[86]. As a result the crop remains had a high weed content. The high weed content found in a number of the spikelet samples at Feudvar could also be intended for animal fodder.

Seed corn

Another consideration is the processing of grain for seed corn that will be used to plant the fields the following year. In the region of Asturias einkorn, emmer and spelt is always sown by broadcasting the spikelets. This is also observed for the cultivation of einkorn in Morocco, as well as the sowing of emmer

81 Hänsel and Medović 1991.
82 There are myriads of imprints of chaff in the sun-dried bricks of Feudvar. We concentrated on the carbonized plant remains [Kroll].
83 Peña-Chocarro et al. 2009.
84 Hillman 1984 a; id. 1984 b; Meurers-Balke and Lüning 1992; Nesbitt and Samuel 1996; Peña-Chocarro 1999.
85 Peña-Chocarro 1999, 39; 44.
86 Hajnalová and Dreslerová 2010.

spikelets in south-central Tigrai, Ethiopia. The ethnographic study by D'Andrea and Mitiku in south-central Tigrai also noted that an area of c. 1250 square meters was sown with 46 litres of emmer spikelets, while in the region of Asturias farmers roughly pick out the largest spikelets for next year's sowing, approximately 250 kg per hectare[87]. Thus, a proportion of the einkorn spikelet remains found at Feudvar are likely to have been intended for sowing.

Storage

Unfortunately details of the excavation are not available at present for Feudvar, preventing further analysis of the location or size of possible storage facilities. However, many of the pits excavated within the houses were interpreted at storage pits as they usually contained concentrations of cereal remains[88]. In addition, the identification of different crop processing stages, which may have allowed further spatial interpretation, have revealed little to suggest differences in storage areas within the trench. Only area 6, the baker house, in the western trench seems to contain a much higher number of pits containing sieved einkorn spikelets, products and by-products. No other discernable differences can be seen within the trench to suggest, for example, any particular areas for the storage of sieved or unsieved products.

From the analyses there was also a high association of broomcorn millet with pit features which may suggest simply result from storage of these crops but could also be associated with methods of storage. For example, the adding of broomcorn millet grains to wheat has been observed in France to increase the preservation of the crop by reducing voids that can be penetrated by weevils[89]. By sieving the mixture the broomcorn millet can then be easily removed from the main wheat crop when needed.

2.6.3 Fine sieving by-products

As already mentioned evidence of fine sieving by-products at Feudvar suggests that a certain proportion of the cereals remains were intended for human consumption. The majority of the remains found throughout the trenches are therefore likely to represent the discard of day-to-day dehusking where the fine sieving by-products are thrown into the fire. The fine sieving by-products however can also have an additional value such as for the feeding of animals, as a building material or intentionally collected for fuel. For example, 64 % of the samples collected from containers at Feudvar were identified as fine sieving by-products. As these were recovered in the area of houses it suggests that the by-products were deliberately collected, it is unclear however whether this was for fuel, fodder or temper.

Animal fodder

The use of chaff remains for the feeding of cattle has been recorded ethnographically from a number of areas. For example, in central Anatolia households were noted as using a common fodder type (zavar) which contained a mixture wheat, barley, rye, oats, vetch, beet and clover, mixed with cereal bran and crop processing residues from cereals and legumes[90]. Archaeobotanical work on distinguishing animal dung remains has also highlighted that animals were regularly fed a combination of cereal components as well as wild species. This practice is also suggested at a number of Late Neolithic sites in Greece where glume wheat chaff and fig seeds were identified from 'dung' samples[91].

Temper

Fine sieving by-products are used for temper within the clay bricks of the houses at Feudvar. A number of miscellaneous deposits from wall slumps have been identified as fine sieving by-products, which may suggest they result from inclusion into the clay walls of the houses before it was burnt.

87 Peña-Chocarro 1999, 39; Peña-Chocarro et al. 2009; D'Andrea and Mitiku 2002.
88 Hänsel and Medović 1998.
89 Marinval 1992.
90 Anderson and Ertuğ-Yaraş 1998.
91 Valamoti 2004; Valamoti and Jones 2003.

Fuel

The charring of glume wheat glume bases has been regularly cited as resulting from their use as a fuel[92]. The use of fine sieving by-products as fuel, whether intentionally or accidentally, may be seen at Feudvar as 50 % of the hearth remains are fine sieving by-products. At the Late Neolithic sites of Galini, Makriyalos and Apsalos, Greece, glume wheat processing by-products were encountered around hearths, ovens and inside pits and were interpreted as remains of spent fuel[93].

2.6.4 Products

Einkorn products dominate this category of samples although there is evidence of products of barley and broomcorn millet. Two types of products were identified from Feudvar those that had been sieved and those that were unsieved, which contained large numbers of weed seeds[94].

Human consumption

Of the samples identified as products from Feudvar, 63 % are sieved einkorn products. These remains most likely represent products intended for human consumption. Ethnographic observations from Morroco identified that einkorn was sieved again just before the grains were milled for human consumption to remove any remaining weed species[95]. This last sieving may also suggest that einkorn products intended for human consumption were not thoroughly cleaned prior to this stage. The samples which were identified as unsieved product may therefore be remains of unsieved einkorn grain prior to this final sieving and milling.

Twelve samples were identified as originating from sieved barley products which would suggest that these were intended for human consumption. On the Greek islands of Amorgos and Karpathos Halstead and Jones[96], observing the local barley and bread / durum wheat harvest, found that fine sieving usually occurred piecemeal throughout the year as part of food preparation and that fodder crops were not usually fine sieved.

Animal fodder

Numrous ethnographic studies show that barley is an important fodder crop[97]. For example, Jones and Halstead [98], studying traditional farming practices on the Greek island of Amorgos, found that a deliberate wheat (free-threshing)-barley maslin crop was commonly grown. After harvest the crops were sometimes sorted by sieving into wheat rich and barley rich remains. The wheat rich remains were subsequently used for human consumption while the barley rich remains were used for animal fodder[99]. Eight samples were identified as einkorn and barley products and although these may represent depositional mixing they may suggest that a small proportion of the einkorn crop was grown with barley. In addition, the presence of sieved barley products may also result from the processing of a mixed crop which would separate out the wheat and barley and result in fewer weed species. The barley may then be used for animal fodder instead of for human consumption.

From previous analyses by Borojević on the Early Bronze Age plant remains from Feudvar, the immature size of emmer grains recovered and the high proportion of small seeds (e.g. *Setaria viridis*) suggested that they were intended for cattle feed. From the current analysis, no unsieved emmer remains were identified.

92 Charles 1998; Hillman 1981; van der Veen 2007.
93 Valamoti 2005 a.
94 In the older phases of Feudvar, broomcorn millet has been a weed; in the younger phases a crop, for sure [Kroll].
95 Peña-Chocarro et al. 2009.
96 Halstead and Jones 1989.
97 e.g. Halstead and Jones 1989; Miller 1984b; Palmer 1996.
98 Jones and Halstead 1995.
99 Jones and Halstead 1995.

However, the unsieved nature of some of the einkorn remains, which may also contain a certain amount of emmer, could have been used as an animal supplement[100].

Broomcorn millet

Three samples have been identified as sieved broomcorn millet products and three as unsieved. Ethnographic work on the crop processing of millets has shown that only winnowing and raking are likely to have been used to remove the weed species[101]. If this is the case then the unsieved remains may simply be those crops that had not been processed as thoroughly. Four of the six samples were also recovered from pits within house areas which may support the theory that broomcorn millet was grown for human consumption.

2.7 Conclusion

The purpose of this chapter was to examine formation processes within the Feudvar assemblage and determine variation between the samples before further weed analysis in chapter 3. The main formation process influencing the composition of the plant assemblage is that of crop processing. Ratio analysis[102] was used to identify each sample to a crop processing stage and correspondence analysis was then used to corroborate and clarify these identifications. The three crop processing stages identified are spikelets, fine sieving by-products and products. Two further steps were also identified within these stages those that were sieved and unsieved. Sieved remains include those that have been sieved prior to dehusking and thus have fewer weed species in the assemblages. Unsieved remains indicate those samples that were not previous sieved before dehusking and so have a greater number of weed species within the samples. The crop processing analyses has therefore identified six different groups of remains which can be analysed separately and compared on the ecological behaviour of the weed species in the following chapter.

Correspondence analysis also highlighted a number of observations which may impact on further crop husbandry analyses. First, distinct clusters of samples near *Chenopodium* were observed when each crop processing stage was examined. The high frequency, and in some cases quantity, of *Chenopodium* within the samples will have a distinct impact on sample composition and will need to be assessed when using correspondence analysis to examine weed ecology. Second, while running correspondence analyses to assess sieved and unsieved identifications within each crop processing stage, a number of samples remained ambiguous, especially those with an approximately equal value for ratio 4 (weed : grain). As a result these samples will need to be monitored in order to reduce bias within the assemblage caused by an incorrect identification.

The identification of crop processing at Feudvar has also provided evidence of human behaviour. Whether a crop is sieved or not may result from factors including climate, time, and labour availabilities as well as the intended purpose of the crop. For example, more time is spent on crops intended for human consumption, so samples identified as unsieved products may be intended as animal fodder. The distribution of samples between features and areas were also seen from the crop processing remains.

First, the southern area of the trench was identified as containing a high percentage of barley remains as well as fine sieving residue and compared to the rest of the trench and may indicate an area where a household is choosing to include barley in their diet or may possibly be an area for animals. Second, broomcorn millet showed a close association with pits. So called rye is indeed a weed within the crops while broomcorn millet, which was also closely associated with the wheats, represents a crop at the site. Third, crop processing areas seem to occur within the centre of each house, where there is a higher incidence of unsieved remains and a greater variance in weed species present. However, no clear differences could be seen in the presence of crop species to distinguish between the two northern households.

100 Borojević 1991. This „immature emmer“ is sanduri wheat, Triticum timopheevii, the “new spelted wheat” with small grains. It is not immature, it’s ripe [Kroll].

101 Harvey and Fuller 2005.

102 after van der Veen and Jones 2006.

Variation between features and areas will be examined further in the following chapter to determine whether differences can be seen between crop processing regimes and different households within the trench. Ultimately, however the presence of all three crop processing stages from house floors confirms that crop processing not only occurred at the site but within certain areas of the house.

3. Weed Ecology at Feudvar

This chapter presents the analysis of weed ecology within the Feudvar assemblage. The purpose of this is to investigate crop husbandry regimes from the ecological characteristics of the weed species that accompany the cereal crop. This chapter begins with a discussion on the approaches used to examine weed ecology and their application in archaeobotany. This is followed by the methods employed to analyse weed ecology within the Feudvar dataset and the results of the analysis. Intra-site variability will then be examined in order to explore further patterns in the data. This chapter concludes with a discussion of crop husbandry regimes during the Bronze Age at Feudvar, exploring the possible relationships between the farmers and the crops grown.

3.1 Approaches to weed ecology

Weed ecology is the study of how individual plants interact with their biotic and abiotic environment[103]. Biotic components are living organisms, such as plants and animals, which make up an ecosystem. The abiotic environment incorporates non-living factors such as climate, including light and temperature, and edaphic properties such as nitrogen, pH and moisture. The impact of anthropogenic activities, such as tilling and manuring, will also affect biotic and abiotic factors within an environment. By studying the weed species present in archaeobotanical assemblages, information about these environmental factors can be obtained and used to infer possible anthropogenic activities resulting from certain crop husbandry regimes.

The link between archaeological weed species and the environment in which they grew can only be provided by modern weed ecology data. As such the need for an appropriate source of such data and appropriate interpretative methods has often been emphasised[104]. Within the study of archaeobotanical weed ecology three main analytical methods have been used to infer agricultural practices, namely phytosociology, which studies biotic interactions between organisms (i.e. vegetation communities), autoecology, which studies single organisms and their interactions with their environment and other species, and more recently Functional Interpretation of Botanical Surveys (FIBS), which classify species into a 'functional type'. These methods are assessed below.

3.1.1 Phytosociology approach

Developed in Central Europe, phytosociology (or Braun-Blanquet system) is a subdiscipline of plant ecology that describes the co-occurrence, or compositional patterns, of plant species in communities, or 'syntaxa'[105]. Within this method, the fundamental unit of vegetation is the Association, which is defined entirely by floristic composition, and not by habitat. Each Association comprises characteristics of the community based on the fidelity, presence, constancy and dominance of a certain species within any stand of an association[106]. This results in 'character species', of narrow ecological range, becoming restricted or central to particular syntaxa; 'differential species' or species which distinguish closely related syntaxa by their presence; and 'constant companions' that are species not restricted to a given syntaxon

103 Booth et al. 2003.
104 Hillman 1991; Küster 1991; van der Veen 1992.
105 Braun-Blanquet 1964.
106 Poore 1955.

but help characterise it[107]. By exploring the presence and absence of these characteristics within a given stand, Associations are constructed and placed within the hierarchical classification system of Alliances, Orders and Classes.

The categorisation of species is, however, largely subjective and some have highlighted the lack of consistent criterion for distinguishing or classifying vegetation units, as well as lacking clear distinctions between the groups, which can obscure the successional series[108]. The focus on the group rather than the individual may also obscure distinct species characteristics, for example, individual species may be characterised within their community as moisture loving when in fact they only tolerate wet environments. In addition, some have suggested that little account is taken of ecotypic differentiation and change of tolerance species within their range, making comparisons problematic outside the observation zone, and through time[109].

3.1.2 Autecological approach (Ellenberg numbers)

In contrast to phytosociology, autoecology or Ellenberg numbers is an approach that examines the ecology of individual plant species rather than the plant community as a whole. Ellenberg numbers refer to a relative scale of six major environmental factors linked to climatic variables: light regime (L), temperature (T) and continentality of climate (K), and edaphic conditions; moisture of soils (F), reaction or pH (R) and nitrogen availability (N)[110]. Based on modern field observations an ordinal scale of between 1 and 9 (F ranges between 1 and 12) is used to denote each environmental factor per species based on its optimal ecological requirements when in competition with other species. For example, L1 is a full-shadow species while L9 is a full light plant. In addition, indifferent behaviour to environmental factors is indicated with an X. Other factors associated with morphological and anatomical adaptations are also noted; these include salt tolerance (sonst.), persistence of leaves (B), anatomical structure (Anat.) and phytosociological behaviour. However, Ellenberg does stress that the indicator values do not denote the preference of a species but reflects the conditions it can tolerate compared to other species[111]. *Luzula luzuliodes*, for example, has an indicator value of R3, suggesting a preference for acidic soils. However, when grown without competition from other species, its optimal productivity is around pH 6.5, which is only slightly acidic. The principle advantage of this approach is that indicator values have been assigned to over 3000 species in temperate Europe.

Nevertheless, field observations only address where a species is found and not why it is there, thus ignoring other ecological factors that may determine its presence at a certain location[112]. Methods of data collection, genetic variation within populations, the relative constancy of habitat requirements needed, and differences between ecological and physiological behaviour can also affect interpretation[113]. The use of indicator values and their extrapolation to other regions can be problematic, as species behaviour will vary widely from one region to another, especially as the Ellenberg indices are not related to ecological optimum of a species but to its synecological optimum[114]. Despite this, Ellenberg's system has been successfully applied to other regions in Europe[115] and new regional databases are providing important extensions to the original Ellenberg system[116].

107 Dierschke 1994.
108 Becking 1968; Pignatti et al. 1995; Poore 1955.
109 Holzner 1978.
110 Ellenberg 1979; Ellenberg et al. 1992.
111 Ellenberg 1979, 107.
112 Charles et al. 1997.
113 Kowarik and Seidling 1989.
114 Jean-Claude and Eva 2003; Pignatti et al. 2002.
115 Diekmann and Dupré 1997; Koerner et al. 1997; Persson 1981; ter Braak and Gremmen 1987; van der Maarel 1993.
116 e.g. Britain: Hill et al. 1999; Hungary: Borhidi 1995. Italy: Böhling 2002; Pignatti et al. 2001.

Ellenberg numbers have been used in archaeobotany on their own and in conjunction with phytosociological classifications[117]. The main advantage of using Ellenberg numbers in archaeobotany is that the environmental values identified are precisely the types of information required to infer soil fertility, moisture, disturbance etc., in relation to different crop husbandry practices[118]. The use of Ellenberg numbers is also well suited to archaeobotanical assemblages as the absence of species causes fewer problems[119]. In addition, all the species present can be examined, making it more reliable, rather than character species or differential species of a particular syntaxon, which can be particularly rare thus restricting the archaeobotanical database. Issues of temporal change, seen particularly with the phytosociological approach, are still relevant here. Nevertheless, Ellenberg numbers focus mainly on the plant's behaviour which is genetically determined and is less likely to change or will change less rapidly than the co-occurrence of species[120]. In addition, even if changes exist in the ecological behaviour of certain species, by examining all the species together these changes are largely mitigated[121]. The autecology approach is therefore more applicable to archaeobotanical analysis.

3.1.3 Functional Interpretation of Botanical Surveys (FIBS)

The Functional Interpretation of Botanical Surveys or FIBS, as described by Charles et al., is a floristic analysis for the investigation of ecological processes on species distribution in a range of habitats[122]. FIBS classifies species by relating the behaviour of the individuals to specific ecological characteristics and thus a distinct 'functional type', rather than basing analyses on the floristic identity and coexistence of communities as in phytosociology. Only attributes that can be rapidly measured and validated against experimental or distributional data are used. Functional attributes measure the potential rather than the performance of species which is particularly suited to archaeobotanical analysis[123]. Through the application of FIBS, modern studies have revealed causal relationships between crop husbandry practices, such as irrigation, and certain suites of attributes identifying characteristic weed species[124].

The archaeobotanical application of FIBS has worked particularly well in identifying past crop husbandry practices such as crop rotation[125], cultivation intensity[126], crop sowing times[127], and irrigation[128]. In these instances, functional attributes were specifically selected to address each type of analysis such as drought tolerance or avoidance in relation to irrigation. However, while it is possible to identify one suite of functional attributes as indicative of a certain husbandry regime, that regime may have more than one functional type or may have the same range of functional attributes as that of another regime[129]. In addition, only the extreme values for an attribute will indicate a husbandry regime while moderate values are generally seen as of little diagnostic importance. Therefore, the application of FIBS to archaeobotanical data is only appropriate where variation exists within the archaeological dataset. This is because FIBS can only identify whole husbandry regimes (based on a suite of functional attributes) with limited abilities to disentangle individual husbandry practices[130]. Despite this, the FIBS approach is able to deal with fragmentary and

117 Jacomet et al. 1989; van der Veen 1992; Wasylikowa 1978; id. 1981; Willerding 1978; id. 1980; id. 1983.
118 van der Veen 1992, 108.
119 Jones 2002.
120 van der Veen 1992, 108–109.
121 Jones 1992.
122 Charles et al. 1997.
123 Jones 2002.
124 Bogaard et al. 2001; Charles et al. 1997; id. 2003, Jones et al. 2000; id. 2010.
125 Bogaard et al. 1999.
126 Jones et al. 2000.
127 Bogaard et al. 2001.
128 Bogaard et al. 1999; Jones et al. 2000 ; Bogaard et al. 2001; Charles et al. 2003.
129 Jones 2005.
130 Jones et al. 2010.

mixed records of past plant communities better than phytosociology[131]. It is also particularly well suited to identify husbandry regimes at a regional scale or to identify changes through time, as FIBS focuses on functional characteristics rather than individual taxa which is less vulnerable to biogeographical changes in the species[132]. Temporal changes in functional attributes of suites of species are also far less likely than changes in individual species or changes in the composition of phytosociological groupings[133]. Although this method is particularly suited to the analysis of archaeobotanical material, much of the information is as yet not publically available.

3.1.4 Conclusion

The phytosociological approach is largely inadequate for the analysis of archaeobotanical samples as it relies heavily on character species to determine ecological groups. It ignores the fragmentary nature of past assemblages, which it compares to complete modern plant communities. In addition, past vegetation communities may not exist in modern analogies, making comparisons unreliable. The FIBS approach uses functional traits of species which may be less susceptible to temporal and geographic changes, as well as being able to cope with archaeobotanical material. Nevertheless, this method only works when variation exists within the dataset. At Feudvar, only one main crop type is identified and as a consequence may not exhibit extreme values. In addition, this approach is also restricted in its application, as at present species data are not publicly available. The autecological approach is therefore the most appropriate method to apply to the Feudvar dataset as it allows all the weed species to be analysed individually, making the results more reliable. In addition, Borhidi provides data on over 2,500 species within Hungary that are more directly relevant to the region under study[134].

3.2 Methodology

3.2.1 Dataset

From the crop processing analysis of the Feudvar assemblage (chapter 2.6), six different groups of samples were identified to a particular crop processing stage (Table 22). As each stage of crop processing has an effect on the types of weed seeds present in the sample, only 'like' samples can be examined and only those with adequate numbers of weed remains per sample[135]. In order to assess whether each dataset had sufficient numbers of weed seeds per sample to allow further weed analyses, each sample was initially standardised. First, to reduce potential environmental 'noise', caused by rare species in the samples, species present in < 10 % of the samples were removed[136]. Seeds identified to the family level were also excluded, resulting in the removal of up to 80 % of the species (Table 22).

Second, the number of weed seeds present per sample was calculated and those with <25 weed seeds were removed (Table 22). For the three unsieved groups, this resulted in only a few samples being removed (up to 8% of the samples). However, for the sieved remains, up to 40 % of the samples were removed. In addition, the number of samples with >100 weed seeds was significantly lower in the sieved samples. For example, only 6 % of samples in the sieved spikelet group had over 100 seeds, while the unsieved spikelets had over 100 seeds in 41 % of samples. Therefore, in order to maximise the amount of information that can be gained through the analysis of the weed species at Feudvar, it was decided that only the three unsieved groups of samples would be separately analysed, as they contained the highest number of species and samples with adequate numbers of weed seeds.

131 Hodgson et al. 1999.
132 Jones et al. 2010.
133 Charles et al. 1997.
134 Borhidi 1995.
135 Jones 1991.
136 van der Veen 1992 chapt 3.

Crop processing group	No. of species present	No. of species in >10% of samples	No. of samples	No. of samples with >25 weed seeds
Spikelets, sieved	84	16 (19%)	83	51 (61%)
Spikelets, unsieved	89	27 (30%)	56	54 (96%)
Fine-sieving by-product, sieved	89	16 (18%)	85	59 (69%)
FIne-sieving by-product, unsieved	94	22 (23%)	90	83 (92%)
Product, sieved	96	18 (19%)	134	86 (64%)
Product, unsieved	80	30 (38%)	36	35 (97%)

Table 22. Bronze Age Feudvar. The number of species present in >10 % of each of the six crop processing groups and the number of samples with >25 weed seeds.

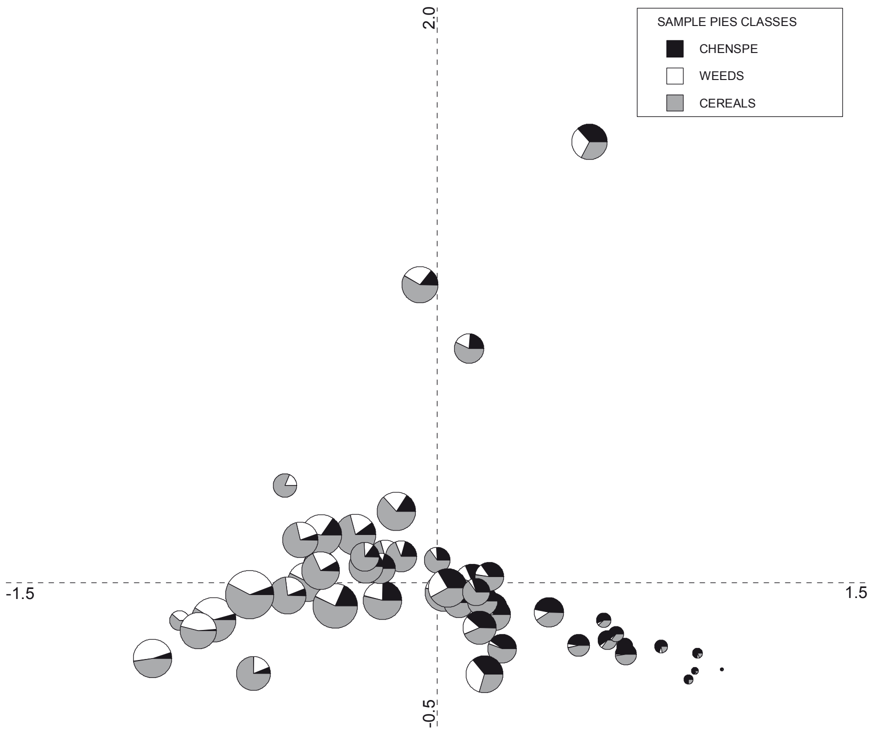


Fig. 17. Bronze Age Feudvar. Unsieved spikelets. Shannon diversity examining the impact of Chenopodium on sample composition.

Of note from the crop processing analysis were the large numbers of *Chenopodium* seeds within some of the samples, which may suggest collected food deposits rather than crop weeds. To assess the extent to which *Chenopodium* affects the three datasets, a correspondence analysis plotting the Shannon diversity for each sample was created for each group using Canodraw (Fig. 17–19). This is illustrated by the size of the pie, which gets bigger as the diversity increases. Each plot confirms that a number of samples from each group contain a high proportion of *Chenopodium* seeds, as well as having an extremely low species diversity. Although species of *Chenopodium* can produce large numbers of seeds per plant, the low species diversity may suggest that these samples do indeed represent collected food remains rather than weeds. In addition, Bogaard classified samples as deriving from one crop type if the sample contained at least 70 % of one crop[137]. Thus, to reduce ambiguity caused by these rich *Chenopodium* samples, those with a content of >70 % *Chenopodium* were removed from the subsequent analyses (Table 23).

137 Bogaard 2004.

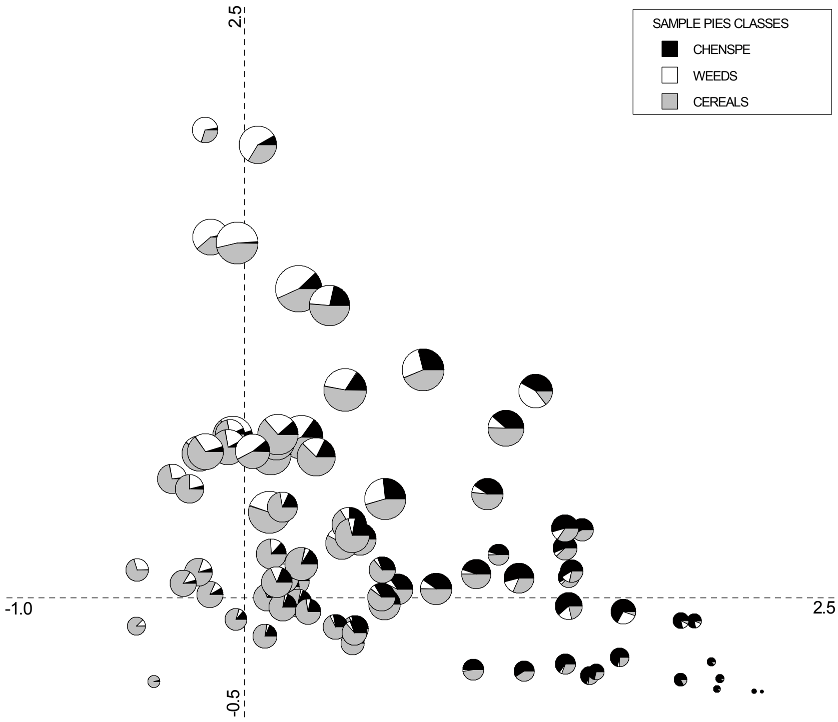


Fig. 18. Bronze Age Feudvar. Unsieved fine sieving by-products. Shannon diversity examining the impact of Chenopodium on sample composition.

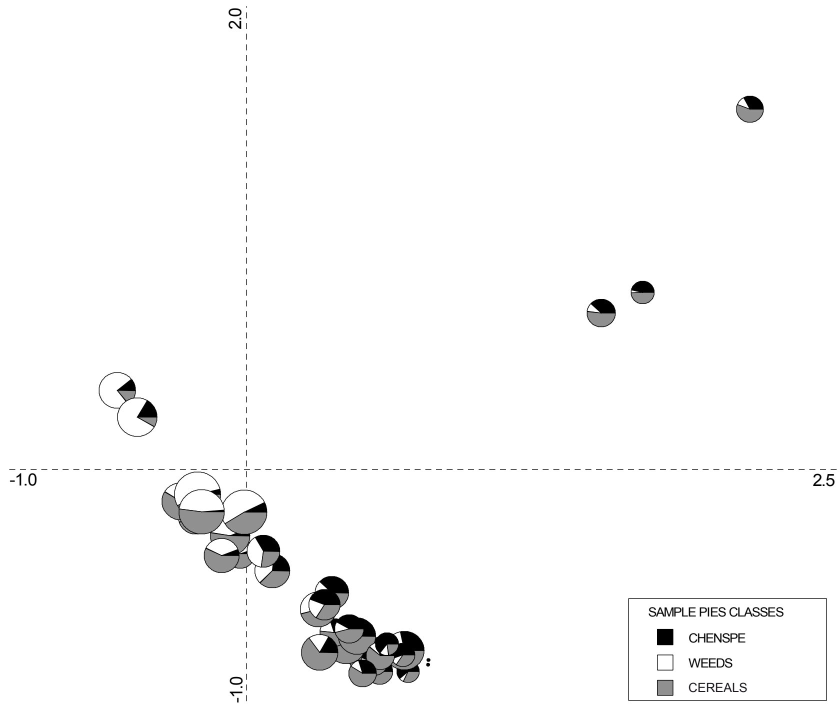


Fig. 19. Bronze Age Feudvar. Unsieved products. Shannon diversity examining the impact of Chenopodium on sample composition.

Spikelets, unsieved	Fine-sieving by-product, unsieved	Product, unsieved
023	005	396
136	006	461
208	041	
233	053	
468	070	
	094	
	135	
	165	
	182	
	279	
	395	

Table 23. Bronze Age Feudvar. Samples with >70% Chenopodium content within the unsieved spikelets, fine-sieving by-products and product group. FEU … no.

3.2.2 Analysis

Correspondence analysis was conducted using CANOCO 4.5 and Canodraw[138]. In order to examine weed ecology within the three datasets, the six main indicator values were recorded for each weed species, following the autoecology approach (Table 24). Where seeds are identified only to genus, an average indicator value was calculated where the indicator values do not range too greatly. These will be treated with caution. Indicator values published by Borhidi and Ellenberg were recorded in order to see whether any significant differences can be seen between the indicator values assigned for the Hungarian flora and those in Central Europe (Table 24)[139]. Generally, similarities exist between the two authors. However, different values are assigned for species such as *Agrostemma githago, Polygonum aviculare and Polygonum convolvulus*. In these cases, Ellenberg identifies these species as indifferent to temperature, moisture, pH (reaction) and nitrogen, while Borhidi assigns particular indicator values. Although some variations exist between the two authors, Borhidi's indicator values are used in the following analyses as they are more geographically relevant to the study area.

Correspondence analysis will be used to establish whether there are distinct associations between certain crops and certain weeds and certain ecological conditions. Each ecological factor will be grouped into high, medium and low values to allow clearer interpretation of the plots. For example, where 9 ecological factors occur, values 1 to 3 are low, 4 to 6 are medium and 7 to 9 are high. For moisture, which ranges from 1 to 12, values 1 to 4 are low, 5 to 8 are medium and 9 to 12 are high.

In addition to environmental factors, anthropogenic, or human actions will also have a significant impact on the formation of arable weed communities, as well as influencing which seeds are ultimately found in the archaeobotanical assemblage. The three main factors explored here are harvesting methods, soil disturbance and sowing time. The maximum height a weed grows provides an indicator of the possible height at which the crop was cut. For example, if low growing weeds are recovered then this may suggest the crop was cut low to the ground, therefore simultaneously collecting both the straw and ears. The

138 ter Braak and Smilauer 2002.

139 Borhidi 1995; Ellenberg 1979.

		L	L	T	T	K	K	F	F	R	R	N	N
Taxon	**Taxon code**	**BOR**	**ELL**	**BOR**	**ELL**	**BOR**	**ELL**	**BOR**	**ELL**	**BOR**	**ELL**	**BOR**	**ELL**
Agrostemma githago	AGROGIT	7	7	6	x	5	x	5	x	6	x	5	x
Ajuga chamaepitys	AJUGCHA	8	7	8	8	2	2	3	4	8	9	2	2
Allium	ALLISPE	7′	7′	7′	5′	5′	5′	4′	4′	7′	7′	4′	4′
Atriplex patula	ATRIPAT	7	6	5	6	4	x	5	5	7	7	4	7
Bromus arvensis	BROMARV	7	6	6	x	4	4	4	4	8	8	5	4
Bromus	BROMSPE	7′	6′	6′	6′	3′	3′	4′	x	7′	6′	5′	x
Bupleurum rotundifolium	BUPLROT	8	8	7	7	4	4	3	3	8	9	4	4
Chenopodium hybridum	CHERNHB	7	7	6	6	7	7	6	5	8	8	8	8
Chenopodium	CHENSP	7′	8′	6′	6′	7′	7′	6′	6′	8′	x	8′	8′
Conringia orientalis	CONRORI	7	7	6	6	5	5	3	3	9	9	4	4
Digitaria	DGISPE	7′	7′	7′	7′	4′	4′	4′	4′	5′	4′	4′	4′
Echinochloa crus-galli	ECHICRG	8	6	7	7	5	5	7	5	7	x	8	8
Euphorbia palustris	EUPHPAL	8	8	6	6	6	6	9	8	8	8	5	x
Galium spurium	GALISPU	7	7	6	x	5	5	5	5	7	8	5	5
Glaucium corniculatum	GLAUCOR	9	7	8	7	6	6	4	4	8	9	4	4
Hyoscyamus niger	HYOSNIG	8	8	6	6	4	x	4	4	7	7	9	9
Lolium	LOLISPE	7′	7′	7′	7′	4′	4′	4′	5′	8′	6′	4′	x
Malva	MALVSPE	8′	8′	7′	6′	5′	5′	4′	4′	7′	7′	8′	7′
Plantago lanceolata	PLANLAN	7	6	5	x	3	3	4	x	6	x	5	x
Polygonum aviculare	POLYAVI	9	7	5	x	3	x	4	x	6	x	5	x
Polygonum convolvulus	POLYCON	7	7	5	x	3	x	5	x	5	x	3	x
Polygonum persicaria	POLYPER	6	6	5	5	3	3	7	3	6	x	7	7
Portulaca oleracea	PORTOLE	7	7	8	8	3	3	4	4	7	7	7	7
Rumex crispus-type	RUMECRI	7	7	5	5	3	3	6	7	6	x	7	6
Setaria viridis	SETAVIR	7	7	6	6	5	x	4	4	7	x	7	7
Sherardia arvensis	SHERARV	6	6	6	6	3	3	5	5	8	8	5	5
Silene	SILESPE	8′	8′	7′	5′	5′	4′	3′	4′	7′	7′	3′	3′
Solanum nigrum	SOLANNIG	7	7	6	6	3	3	6	5	7	7	8	8
Teucrium	TEUCSPE	8′	7′	6′	6′	4′	4′	4′	3′	8′	7′	2′	2′
Thymelaea passerina	THYMPAS	8	7	7	7	6	6	4	4	8	8	4	4
Trifolium	TRIFSPE	8	7	6	5	5	4	4	4	7	6	3	3
Verbena officinalis	VERBOFF	9	9	6	6	3	3	4	5	8	7	6	7
Vicia	VICISPE	7′	7′	6′	6′	5′	4′	4′	4′	6′	6′	4′	4′

Table 24. Ecological indicator values per species or genus. After Borhidi 1995 (BOR) and Ellenberg 1979 (ELL). With ′: uncertain. x: indifferent. Light L, temperature T, continentality K, moisture F, reaction R, nitrogen N.

maximum growing height of each species was therefore recorded (Table 25). The average height of each taxa identified to genus was also calculated.

To explore soil disturbance, which relates to possible tillage and weeding practices, the regenerative properties and the life cycle of the weed species were recorded. Previous research suggests that tillage significantly reduces the number of perennials[140] and only those with extensive networks of rhizomes, stolons and roots can regenerate[141]. Therefore, to explore the level of disturbance within the Feudvar assemblage, the weed species were identified as either an annual, biennial or perennial, with or without rhizomes (Table 25). Only those taxa that were identified to genus and contain both annuals and perennials were excluded in order to reduce potential bias in the analysis.

Finally, the germination time of species, which has been shown to correspond with the sowing time of crops[142], were recorded. In the past some authors have assessed cereal sowing times by applying phytosociological classes, i.e. the proportion of Chenopodietea (summer annuals) verses Secalietea (winter annuals), to an archaeobotanical assemblage (see p. 241). Although this approach is deemed inappropriate for archaeobotanical analysis (above) authors still use these classes to indicate groups of species or to use as a comparative approach with other ecological methods[143]. In order to compare the two methods, the phytosociological class of each species was also recorded (Table 26). Germination times based on these Classes alone are, however, problematic. For example, *Galium spurium*, a species of the Chenopodietea

140 Hillman 1981; van der Veen 1992; Zimdahl 2007.

141 Bogaard 2002, 78.

142 Bogaard et al. 2001; Groenman-Van Waateringe 1980; Kreuz and Schäfer 2011.

143 Ernst and Jacomet 2006; Jones 1992; Karg 1995; van der Veen 1992.

Taxon	Taxon code	Height (cm)	Life cycle	Germination time
Agrostemma githago	AGROGIT	30-100	A	W
Ajuga chamaepitys	AJUGCHA	10-40	A / B	S
Allium	ALLISPE	20-100	P	
Atriplex patula	ATRIPAT	30-150	A	S
Bromus arvensis	BROMARV	30-100	A / B	W
Bromus	BROMSPE	30-120	A / B	W
Bupleurum rotundifolium	BUPLROT	22190	A	W
Chenopodium hybridum	CHERNHB	30-100	A	S
Chenopodium	CHENSP	30-150	A	S
Conringia orientalis	CONRORI	22190	A	W
Digitaria	DGISPE	22190	A	S
Echinochloa crus-galli	ECHICRG	30-100	A	S
Euphorbia palustris	EUPHPAL	50-150	P	
Galium spurium	GALISPU	40-150	A	S / W
Glaucium corniculatum	GLAUCOR	30-40	A / B	S
Hyoscyamus niger	HYOSNIG	20-100	A / B	S
Lolium	LOLISPE	30-120	A	S
Malva	MALVSPE	30-200	P	
Plantago lanceolata	PLANLAN	10-50	P	
Polygonum aviculare	POLYAVI	10-50	A	S
Polygonum convolvulus	POLYCON	>100	A	S
Polygonum persicaria	POLYPER	20-60	A	S
Portulaca oleracea	PORTOLE	<50	A	S
Rumex crispus-type	RUMECRI	30-150	P	
Setaria viridis	SETAVIR	10-100	A	S
Sherardia arvensis	SHERARV	>40	A	W
Silene	SILESPE	5-100	A / B / P	
Solanum nigrum	SOLANNIG	10-70	A	S
Teucrium	TEUCSPE	10-60	A / P	
Thymelaea passerina	THYMPAS	10-40	A	?
Trifolium	TRIFSPE	5-60	A / P	
Verbena officinalis	VERBOFF	30-60	P	
Vicia	VICISPE	20-120	A / B / P	

Table 25. The height, life cycle and germination times of each species. A: Annual; B: Biennial; P: Perennial; W: Winter; S: Summer (after Bojnanský and Fargašová 2007; Ellenberg et al. 1992; Häfliger and Brun-Hool 1968; id. 1978).

Phytosociological Class	Species
Chenopodietea	Atriplex patula
	Bromus arvensis
	Chenopium hybridum
	Digitaria
	Echinochloa crus-galli
	Hyoscamus niger
	Polygonum aviculare
	Polygonum persicaria
	Portulaca oleracea
	Setaria viridis
	Solanum nigrum
	Verbena officinalis
Secalinetea	Agrostemma githago
	Ajuca chamaepitys
	Bupleurum rotundifolium
	Conringia orientalis
	Glaucium corniculatum
	Sherardia arvensis
	Thymelaea passerina
Molinio-Arrhenatheretea	Plantago lanceolata
Plantaginetea	Rumex crispus

Table 26. Character species identified within the Feudvar assemblage under the phytosociological classes (Ellenberg 1979).

Class, has been identified as both a spring and autumn germinator within studies in Central Europe[144]. In addition, not all the species are found under Chenopodietea and Secalinetea.

In summary, three groups of samples, namely unsieved spikelets, unsieved fine sieving by-products and unsieved products (identified in chapter 2.6), will be analysed. Each group will be examined separately in relation to the six main ecological factors, i.e. light, temperature, continentality, moisture, reaction and nitrogen, according to Borhidi[145]. In addition, three further analyses will be conducted on each dataset examining the height, life cycle and germination times of each species. As such, the nine analyses are repeated for each of the three sample groups. The results are presented in the following section.

3.3 Results

3.3.1 Introduction: Crop and weed associations

Spikelets, unsieved: A correspondence analysis was carried out on the unsieved spikelet group (54 samples). This group is dominated by einkorn spikelets (see p. 220 for details). Five outlying samples were removed from the analysis (FEU138, 184, 211, 373, 409). Species were initially coded as either a crop, a possible crop or a weed (Fig. 20). From Figure 20, einkorn grain and chaff are closely associated at the bottom of the plot, emmer is to the left of the plot, while barley and so called rye are at the top of the plot. Broomcorn millet is clearly separate from the other cereals to the top left of the plot. Close crop and weed associations include: einkorn, *Portulaca oleracea* and *Atriplex patula;* emmer, *Sherardia arvensis*, *Glaucium corniculatum*, *Setaria viridis* and *Vicia*; barley, *Polygonum persicaria* and *Echinochloa crus-galli*; so called rye[146] and *Teucrium*. The cereal composition of each sample shows that einkorn is the dominant cereal in all samples except one to the top left, which has a higher barley content (Fig. 21). In addition, five samples in the top right of the plot contain so called rye and one sample to the left contains broomcorn millet. Samples to the right of the plot also have a greater association with pits and blocks 13 to 16, i.e. the southern end of the trench (Fig. 22; 23). A divide is therefore seen between the left of the plot (i.e. einkorn, emmer and broomcorn millet) and the top right of the plot (i.e. barley and so called rye). Possible differences in depositional patterns will be examined further below.

Fine sieving by-products, unsieved (83 samples): This group is also dominated by einkorn glume bases (see above p. 221 for details). Eight outlying samples were removed from the analysis (FEU046, 056, 057, 344, 350, 329, 407, 085). Species were initially coded as either a crop, a possible crop or a weed (Fig. 24). From Figure 24, einkorn and emmer grain and chaff are closely associated in the top centre of the plot, spelt, bread / durum wheat and broomcorn millet to the left of the plot, while barley is in the centre right of the plot. So called rye is clearly separate from the other cereals in the bottom right of the plot. Close crop and weed associations include: einkorn, emmer and *Silene*; barley, *Solanum nigrum* and *Polygonum persicaria*; bread / durum wheat, broomcorn millet and *Chenopodium*. In addition, there seems to be a greater number of weed species associated with barley to the right of the plot than with the wheats (i.e. einkorn, emmer, spelt and bread / durum wheat) in the left of the plot. The cereal composition of each sample shows that einkorn is the dominant cereal in all samples except a number of samples to the bottom of the plot which contain higher proportions of emmer and barley (Fig. 25). In addition, eight samples in the top right of the plot contain so called rye and three sample to the left contain broomcorn millet. Samples to the top left of the plot also have a greater association with pits and hearths as well as with blocks 13–16, i.e. the southern end of the trench (Fig. 26; 27). A divide is therefore seen between the top left of the plot (i.e. einkorn, emmer, spelt, bread / durum wheat and broomcorn millet) and the bottom right of the plot (i.e. barley and so called rye).

Products, unsieved (35 samples): This group is dominated by einkorn grains (see above p.222 for details). No outlying samples were removed from the analysis. Species were initially coded as either a crop,

144 Karg 1995; Kreuz and Schäfer 2011; Royo-Esnal et al. 2010.
145 Borhidi 1995.
146 This so called rye is the weed Dasypyrum villosum [Kroll].

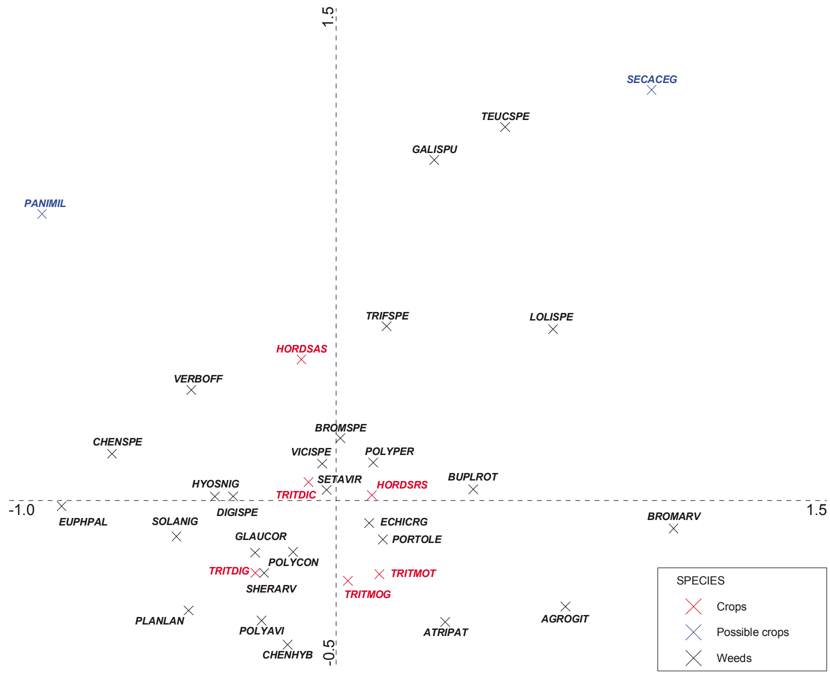


Fig. 20. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species for samples identified as unsieved spikelets on the first two principal axes (axis 1 horizontal, axis 2 vertical).

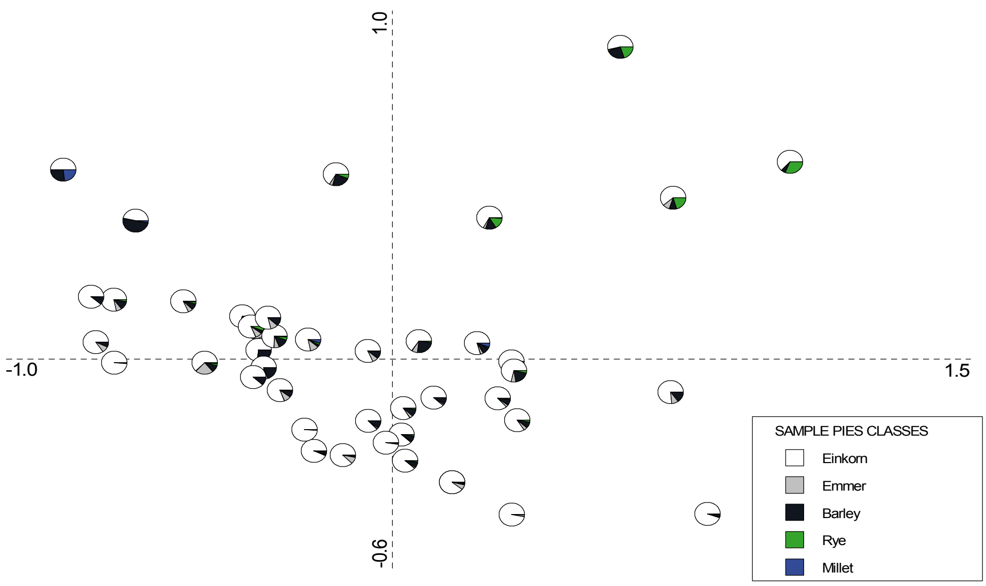


Fig. 21. Bronze Age Feudvar. Correspondence analysis of the proportions of cereals per sample identified as unsieved spikelets.

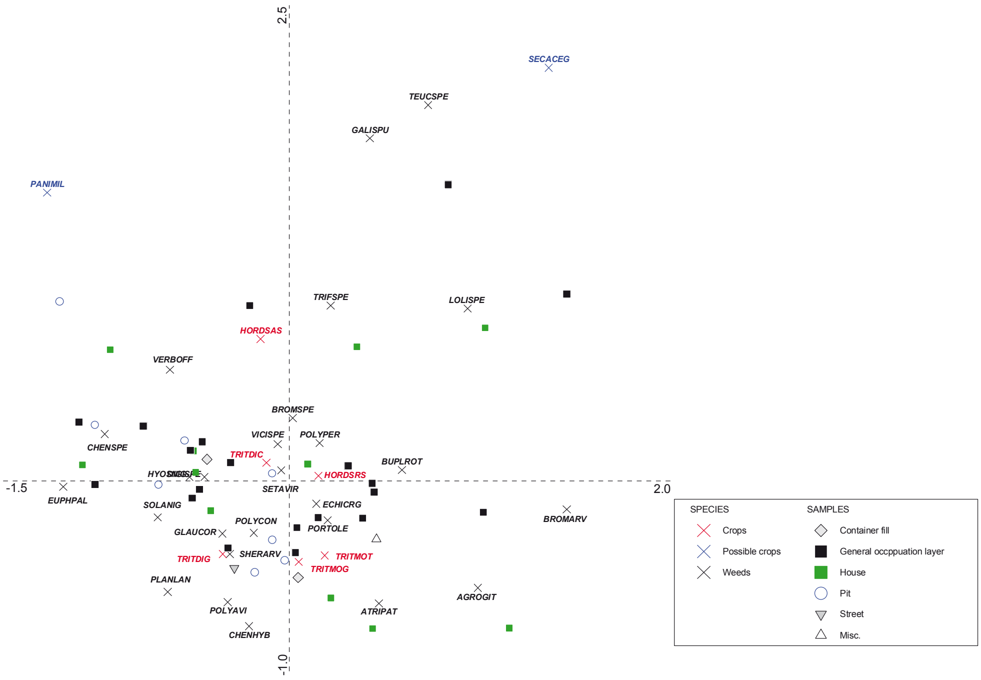


Fig. 22. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species for samples identified as unsieved spikelets per feature type.

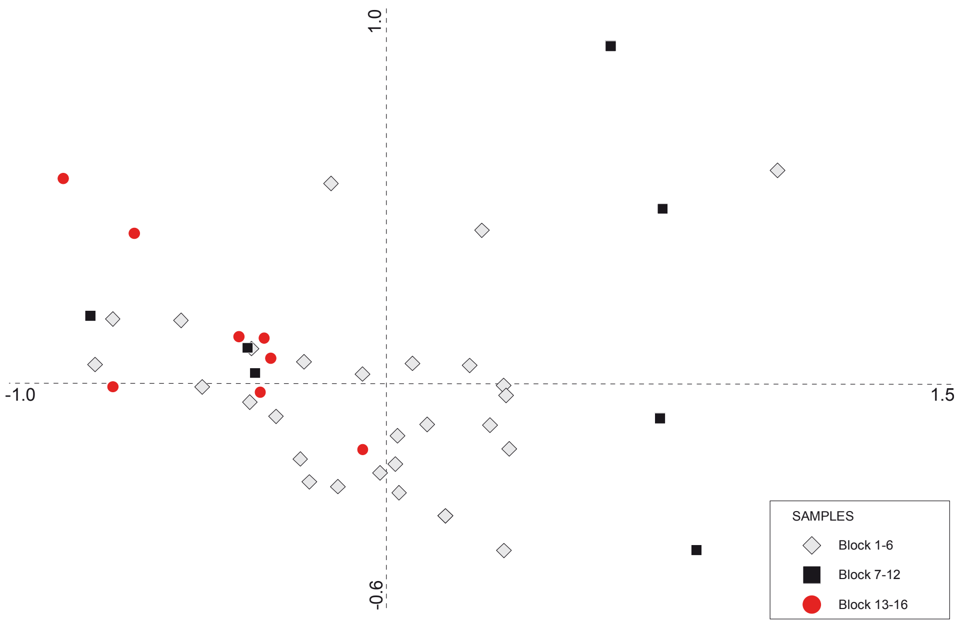


Fig. 23. Bronze Age Feudvar. Correspondence analysis of each samples identified as unsieved spikelets per block group.

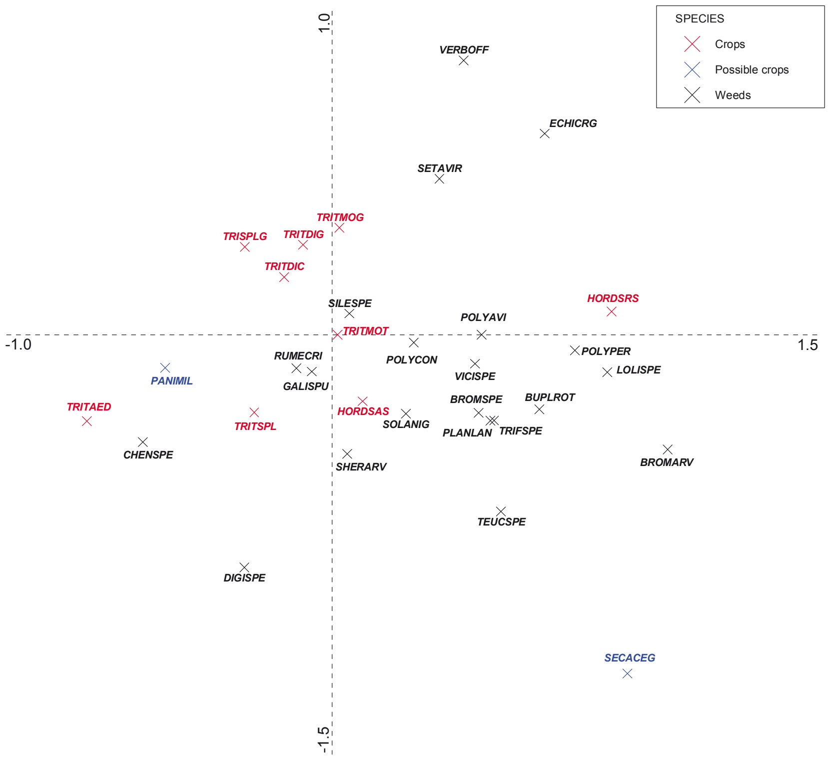


Fig. 24. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species for samples identified as unsieved fine sieving by-products on the first two principal axes (axis 1 horizontal, axis 2 vertical).

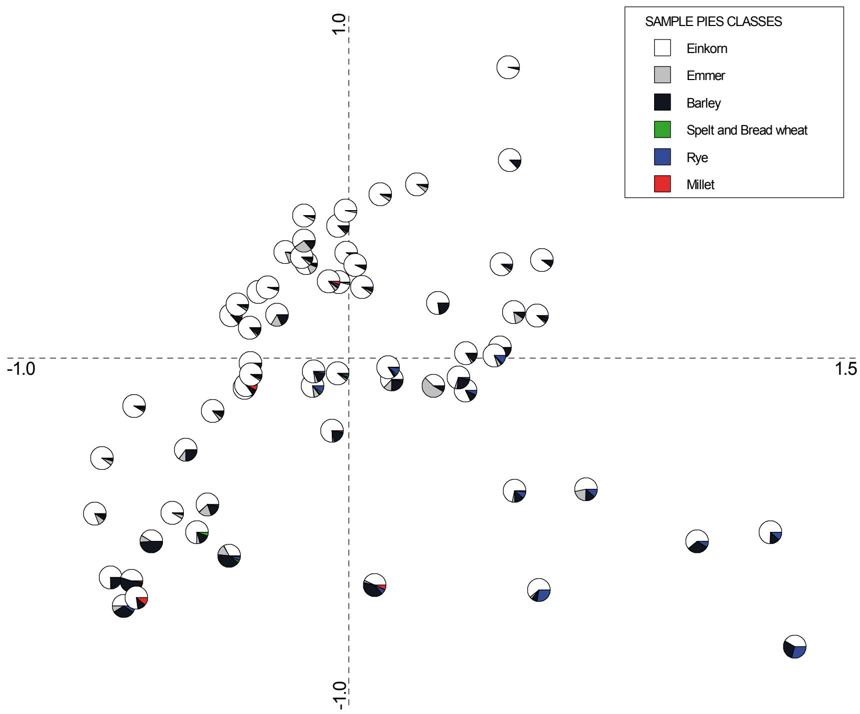


Fig. 25. Bronze Age Feudvar. Correspondence analysis of the proportions of cereals per sample identified as unsieved fine sieving by-products.

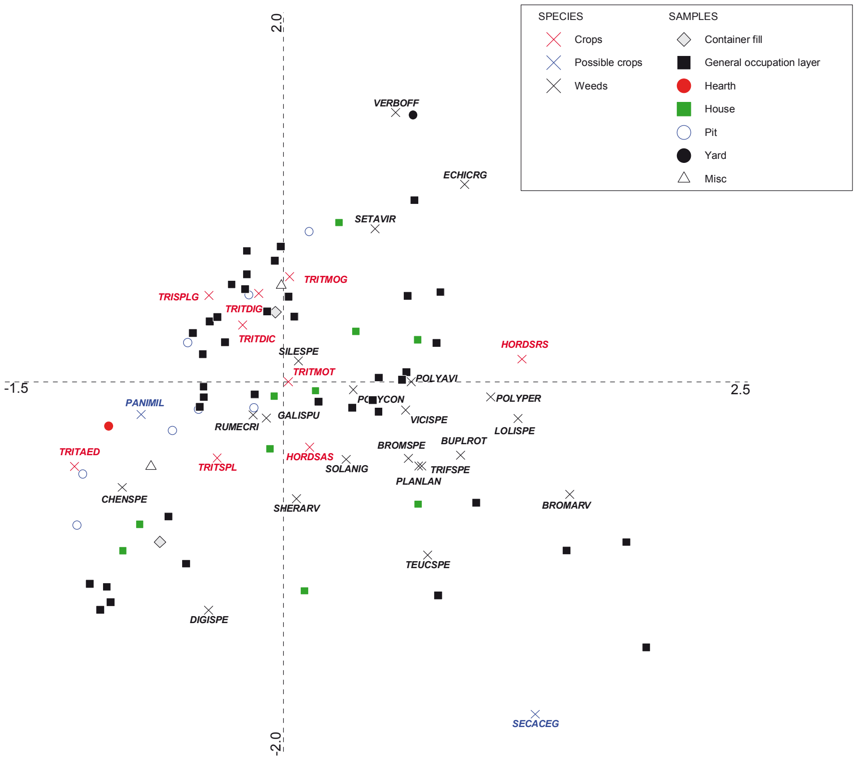


Fig. 26. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species for samples identified as unsieved fine sieving by-products per feature type.

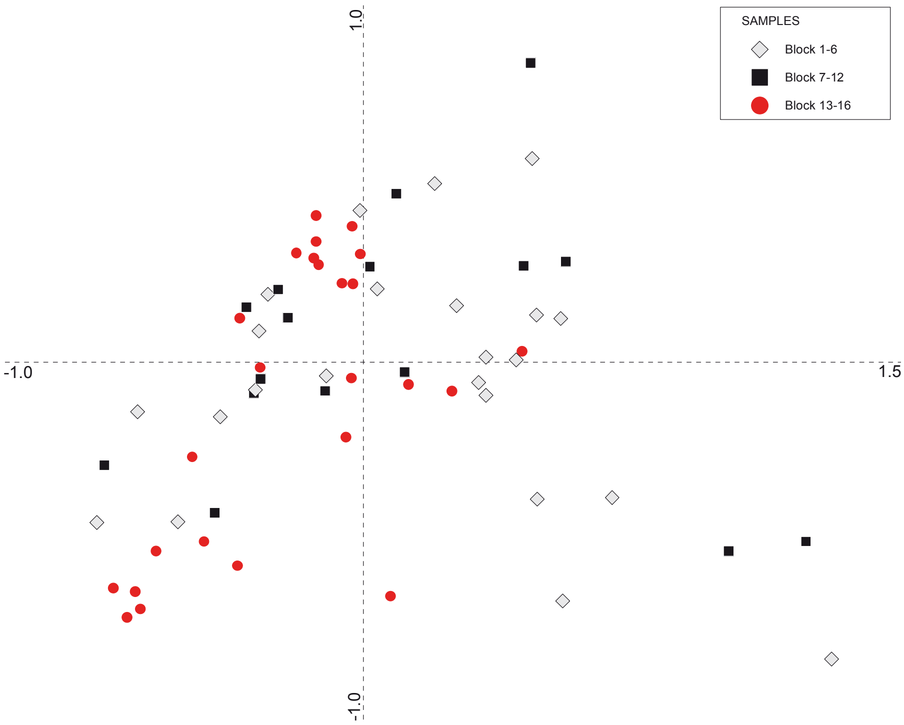


Fig. 27. Bronze Age Feudvar. Correspondence analysis of each sample identified as unsieved fine sieving by-products per block group.

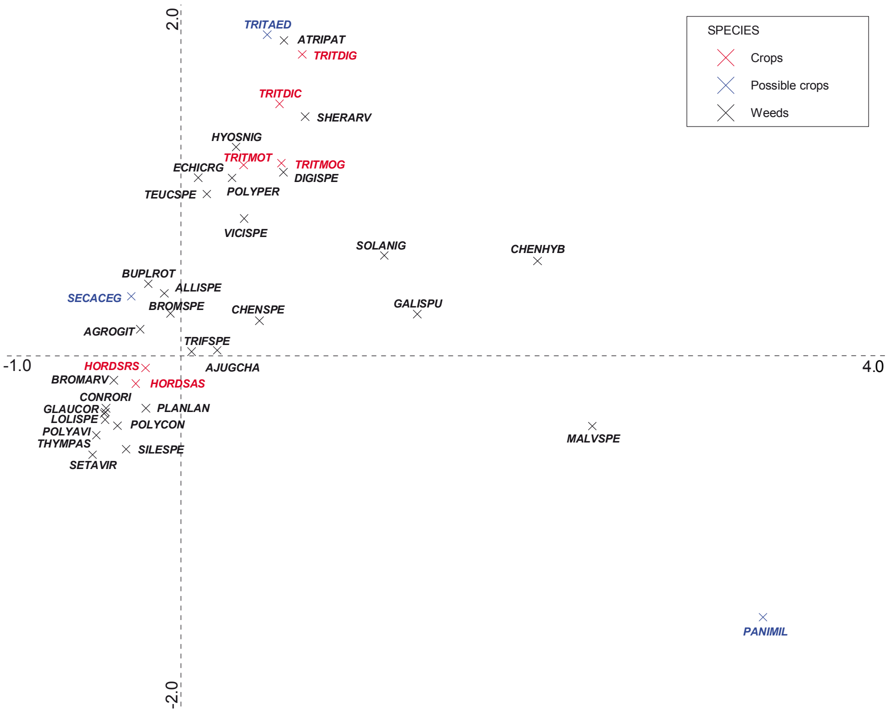


Fig. 28. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species for samples identified as unsieved products on the first two principal axes (axis 1 horizontal, axis 2 vertical).

a possible crop or a weed (Fig. 28). Here a clear separation is seen between so called rye and barley in the centre-left of the plot, broomcorn millet in the bottom right, and emmer and einkorn at the top of the plot. A large number of species are associated with so called rye and barley including close associations with *Bromus arvensis*, *Plantago lanceolata* and *Bupleurum rotundifolium*. Einkorn is closely associated with *Hyoscyamus niger*, *Digitaria* and *Polygonum persicaria*. The cereal composition of each sample shows that einkorn is the dominant cereal in all samples except six. Three samples to the bottom right have a high proportion of broomcorn millet, two to the bottom left of barley and one sample in the centre left has a high proportion of so called rye (Fig. 29). Samples to the top and right of the plot also have a greater association with pits and blocks 13 to 16, i.e. the southern end of the trench (Fig. 30; 31). A divide is therefore seen between the top and right of the plot (i.e. einkorn, emmer, bread / durum wheat and broomcorn millet) and the bottom left of the plot (i.e. barley and so called rye).

Light

Each species was coded to their light indicator value after Borhidi, which is based on the occurrence of plants in relation to relative light intensity during the summer. Spikelets, unsieved: All the species have a high light indicator value except *Polygonum persicaria* and *Sherardia arvensis,* which have a slightly lower light indicator value of L6 (Fig. 32). Fine sieving by-products, unsieved: Similar results. Products, unsieved: Similar results.

Temperature

Each species was coded to their temperature indicator value after Borhidi, which reflects the heat, vegetation zone and altitudinal belt of the habitat where the species occur. Spikelets, unsieved: Weed species characterised by moderate and high temperatures are associated with einkorn and barley (Fig. 33). Overall, the samples are largely dominated by weed species characteristic of moderate temperatures (Fig. 34). Fine sieving by-products, unsieved: Similar results. Products, unsieved: Similar results.

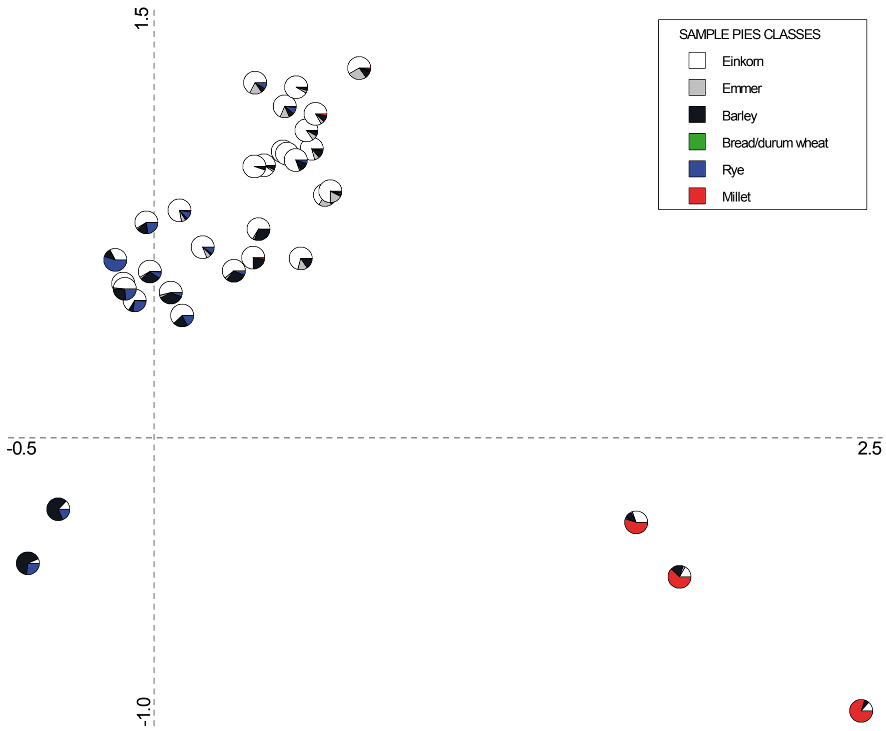


Fig. 29. Bronze Age Feudvar. Correspondence analysis of the proportions of cereals per sample identified as unsieved products.

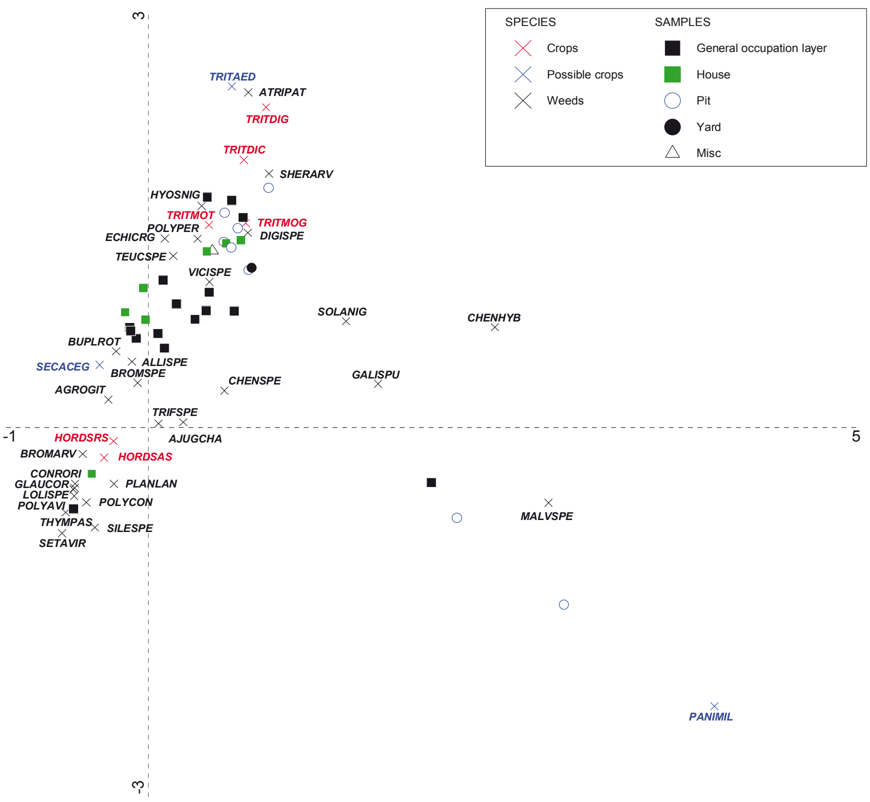


Fig. 30. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species for samples identified as unsieved products per feature type.

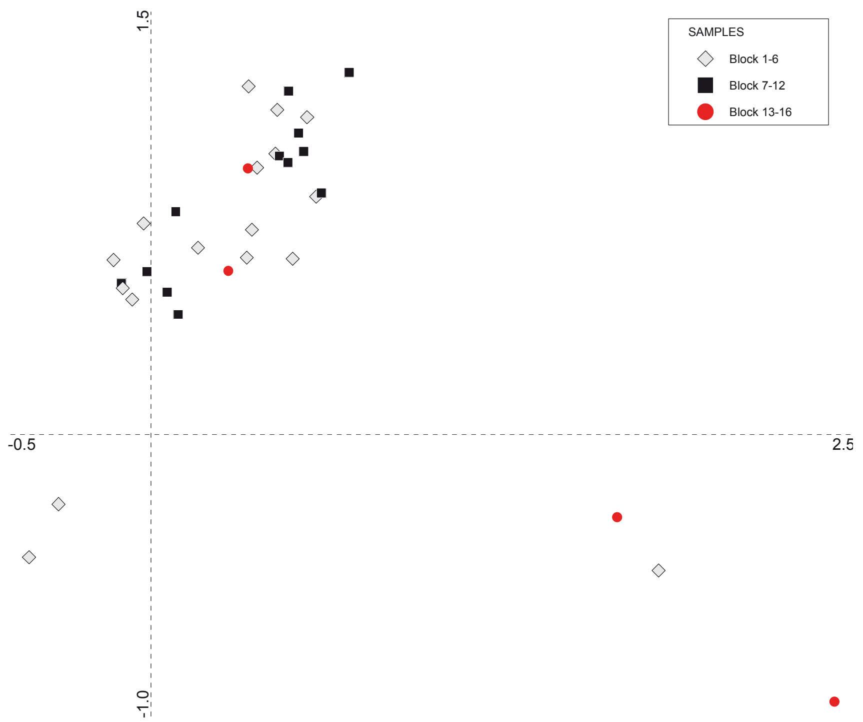


Fig. 31. Bronze Age Feudvar. Correspondence analysis of each sample identified as unsieved products per block group.

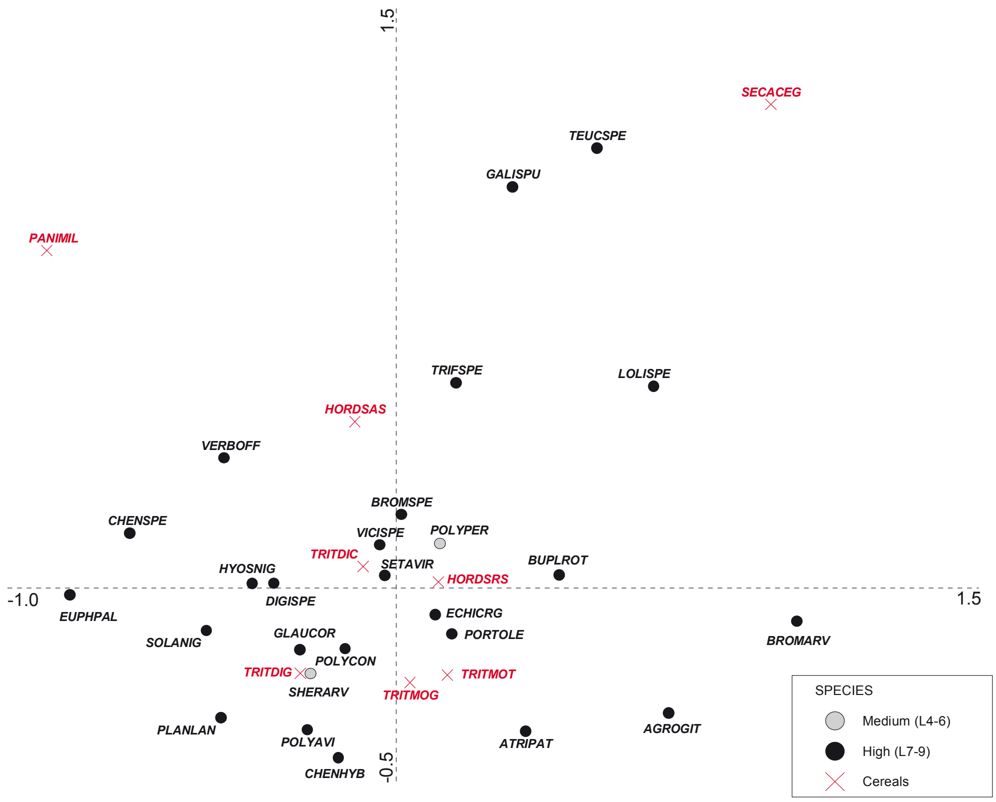


Fig. 32. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the ecological indicator values for light (after Borhidi 1995).

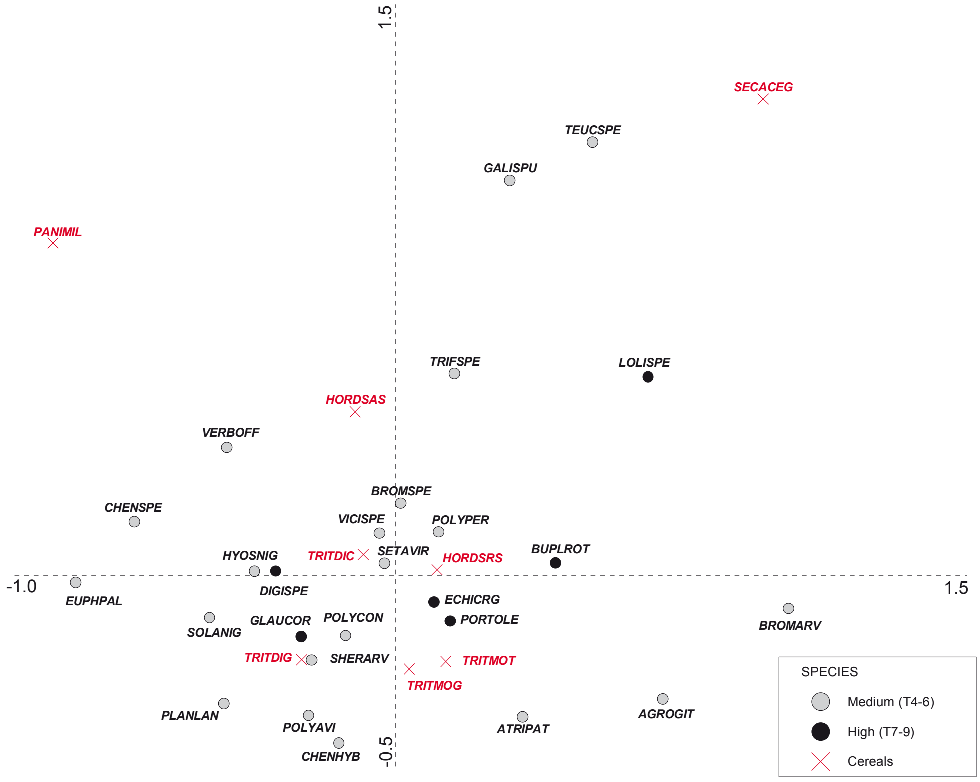


Fig. 33. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the ecological indicator values for temperature (after Borhidi 1995).

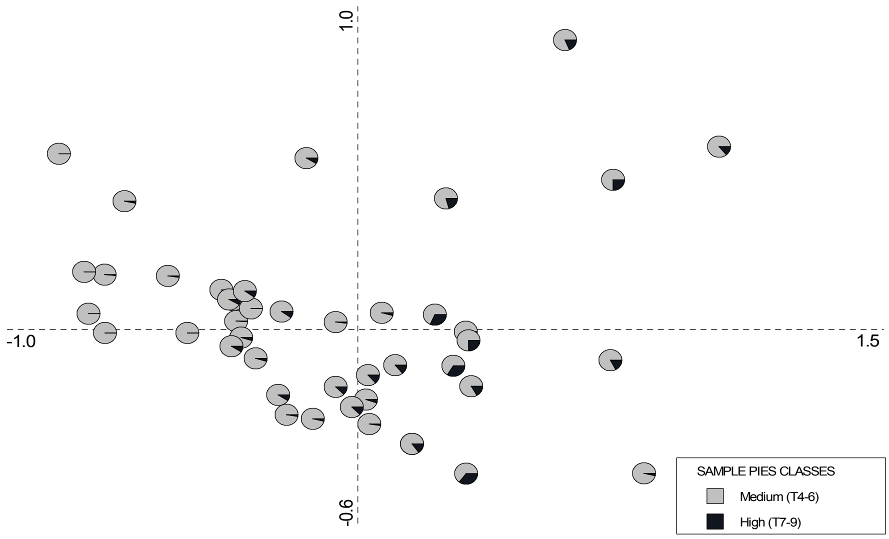


Fig. 34. Bronze Age Feudvar. Correspondence analysis of the proportions of weed species according to their temperature indicator value for samples identified as unsieved spikelets (after Borhidi 1995).

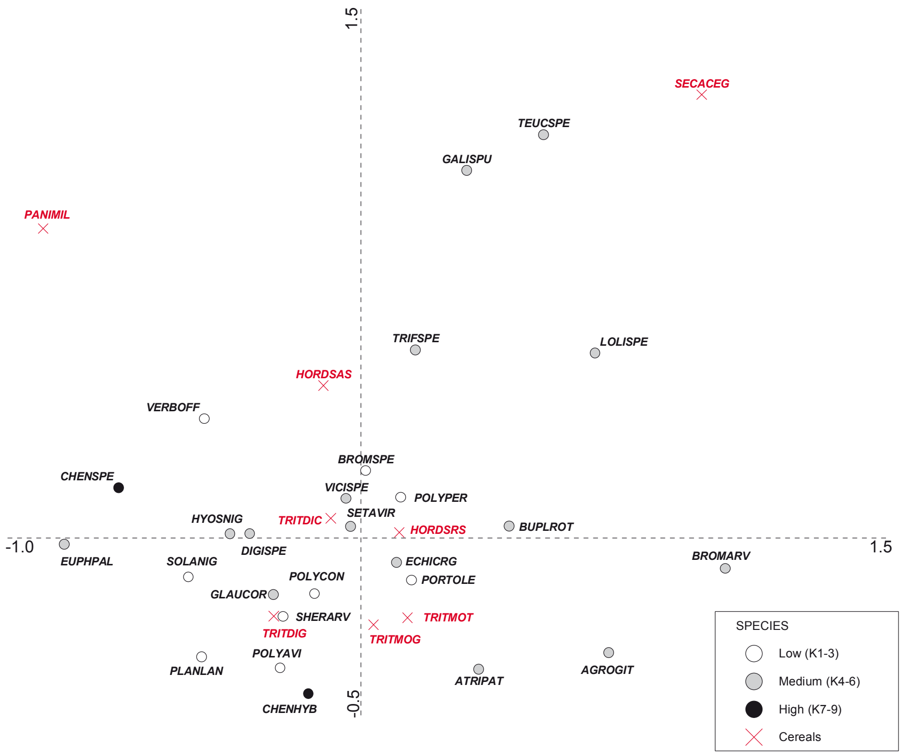


Fig. 35. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the ecological indicator values for continentality (after Borhidi 1995).

Continentality

Each species was coded to their continentality indicator value after Borhidi, which indicates the general continentality of the general climate. Spikelets, unsieved: The majority of the indicator values for the weed species ranged from low to medium and only *Chenopodium* and *Chenopodium hybridum* had high continentality values of K 7 (Fig. 35). Einkorn, emmer and barley are associated with species characteristic of low and medium continentality. Sample composition shows that there is a divide in those samples dominated by species characteristic of medium continentality to the left of the plot and those dominated by species characteristic of high climate continentality to the right (Fig. 36). However, this is due to the large number of *Chenopodium* seeds within the samples. Once removed, the samples are dominated by weed species characteristic of medium continentality, although there is a slight increase in low values to the left of the plot (Fig. 37). Fine sieving by-products, unsieved: Similar results. Products, unsieved: Similar results.

Moisture

Each species was coded to their moisture indicator value after Borhidi, which relates to soil moisture or the water table. Spikelets, unsieved: The majority of the indicator values for the weed species ranged from low to medium and only *Euphorbia palustris* had a high moisture value of F 9. Einkorn, emmer and barley are associated with species characteristic of low and medium soil moisture levels (Fig. 38). Sample composition shows that there is a divide in those samples dominated by species of dry soils to the right of the plot and species of wetter soil to the left (not shown). This is largely due to *Chenopodium* and once removed, the plot shows a dominance in species characteristic of low moisture levels in all but one sample to the left of the plot (Fig. 39). Fine sieving by-products, unsieved: Similar results. Products, unsieved: Similar results.

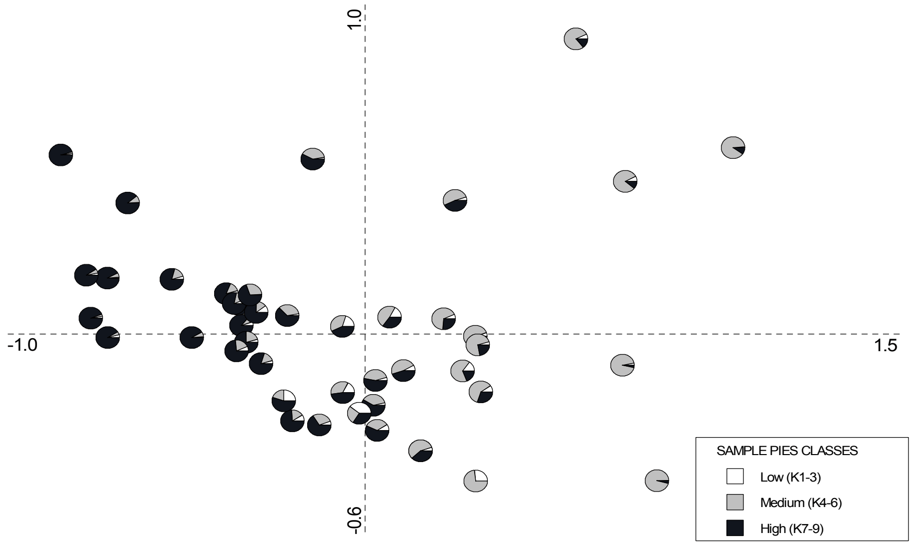


Fig. 36. Bronze Age Feudvar. Correspondence analysis of the proportions of weed species according to their continentality indicator value for samples identified as unsieved spikelets (after Borhidi 1995).

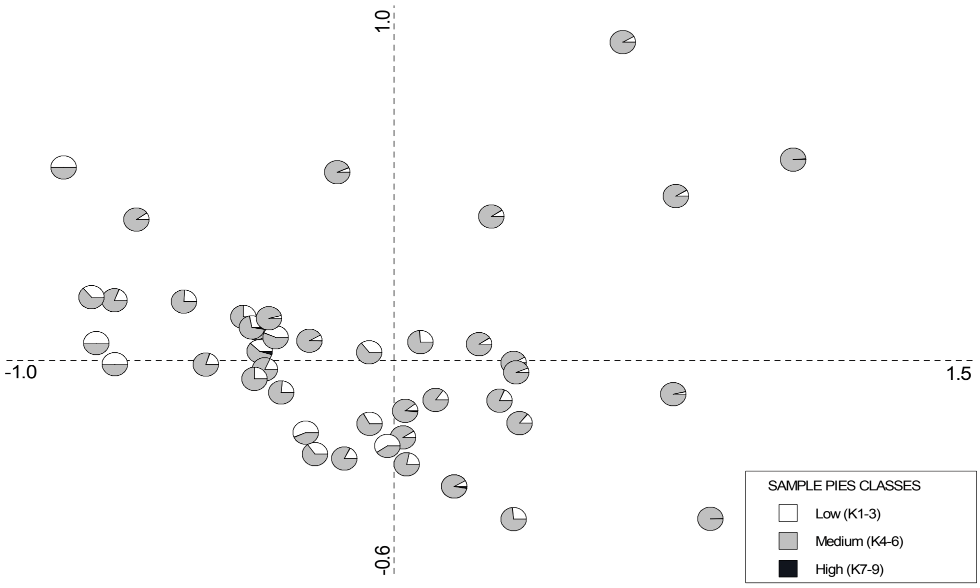


Fig. 37. Bronze Age Feudvar. Correspondence analysis of the proportions of weed species without CHENSPE according to their continentality indicator value for samples identified as unsieved spikelets (after Borhidi 1995).

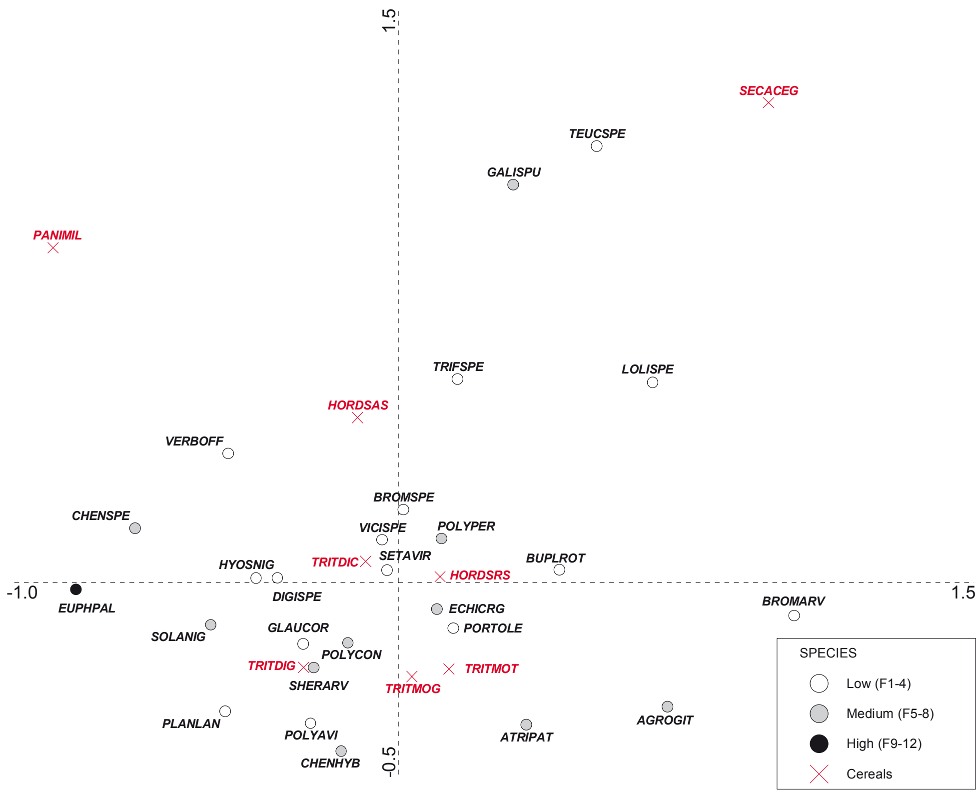


Fig. 38. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the ecological indicator values for moisture (after Borhidi 1995).

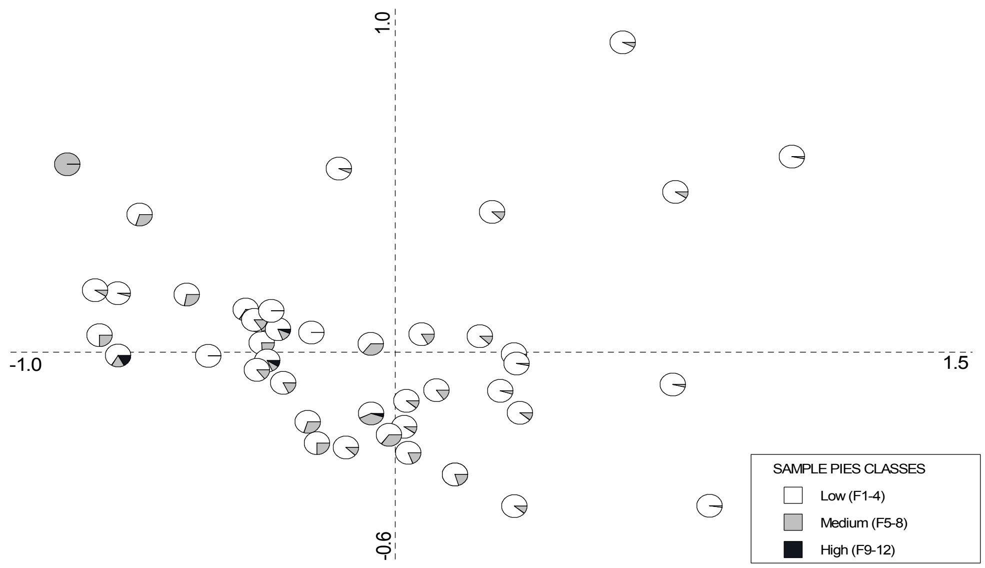


Fig. 39. Bronze Age Feudvar. Correspondence analysis of the proportions of weed species without CHENSPE according to their moisture indicator value for samples identified as unsieved spikelets (after Borhidi 1995).

pH (Reaction)

Spikelets, unsieved: Each species was coded to their reaction indicator value after Borhidi, which reflects plant occurrence in relation to soil reaction or pH. The majority of weed species are characterised by high indicator values i.e. typical of alkali soils (Fig. 40). Sample composition corroborates this, with the majority of samples containing a high proportion of weeds characteristic of alkali soils (Fig. 41). Fine sieving by-products, unsieved and products, unsieved give similar results.

Nitrogen

Spikelets, unsieved: Each species was coded to their nitrogen indicator value after Borhidi, which is related to the availability of ammonia and nitrate in the habitat. The majority of the weed species indicate medium to high nitrogen availability and only *Silene*, *Plantago lanceolata* and *Polygonum convolvulus* have low nitrogen values (Fig. 42). Sample composition shows a divide in those samples dominated by weed species characteristic of high nitrogen availability to the left of the plot and species characteristic of medium nitrogen availability to the right (not shown). This is largely due to *Chenopodium* and once removed, the plot shows a dominance in species characteristic of medium nitrogen availability (Fig. 43). Fine sieving by-products, unsieved: Similar results. Products, unsieved: Einkorn, emmer and broomcorn millet have a greater association with species typical of a high nitrogen environment (not shown).

3.3.2 Anthropogenic factors

Harvesting height

Spikelets, unsieved: A correspondence analysis was run to show the maximum flowering height of the weed species (Table 25). The height of the weed species ranged from low to high with no particular associations with any of the cereals (Fig. 44). Sample composition shows a divide in those samples with a dominance of tall weeds to the right of the plot and those with a dominance of medium height weeds to the left (not shown). However, with the removal of *Chenopodium* it is clear that the vast majority of samples contain low growing weeds (Fig. 45). Fine sieving by-products, unsieved: Similar results. The majority of the low growing weed species are associated with barley in the bottom right of the plot (not shown). Products, unsieved: Similar results.

Soil disturbance

Spikelets, unsieved: A correspondence analysis was run to examine the relative proportion of annuals, perennials and perennials with rhizomes within each sample. Of all the species present, only *Euphorbia palustris* is a perennial and only *Plantago lanceolata* is a perennial with rhizomes; the rest are all annuals (Fig. 46). This is also visible in the pie charts, where sample composition highlights the predominance of annuals (Fig. 47). Fine sieving by-products, unsieved: Similar results. *Rumex crispus* and *Verbena officinalis* are perennials. Products, unsieved: Similar results. *Malva* sp. and *Allium* are perennials and only *Plantago lanceolata* is a perennial with rhizomes; the rest are all annuals (not shown).

Sowing time

Spikelets, unsieved: A correspondence analysis was run to examine the relative proportion of winter and summer annuals within the samples. Only five species, *Agrostemma githago*, *Bromus, B. arvensis*, *Bupleurum rotundifolium* and *Sherardia arvensis*, are winter annuals and are largely associated with barley to the top right of the plot (Fig. 48). Einkorn has a greater association with summer annuals. Looking at sample composition there is a clear divide between those samples dominated with summer annuals to the left and winter annuals to the right of the plot (not shown). Once *Chenopodium* is removed, however, the majority of samples have an approximately equal proportion of summer and winter annuals (Fig. 49). Fine sieving by-products, unsieved: Similar results. Products, unsieved: Similar results: *Conringia orientalis* also is a winter annual and is largely associated with barley and so called rye in the bottom left of the plot (not shown).

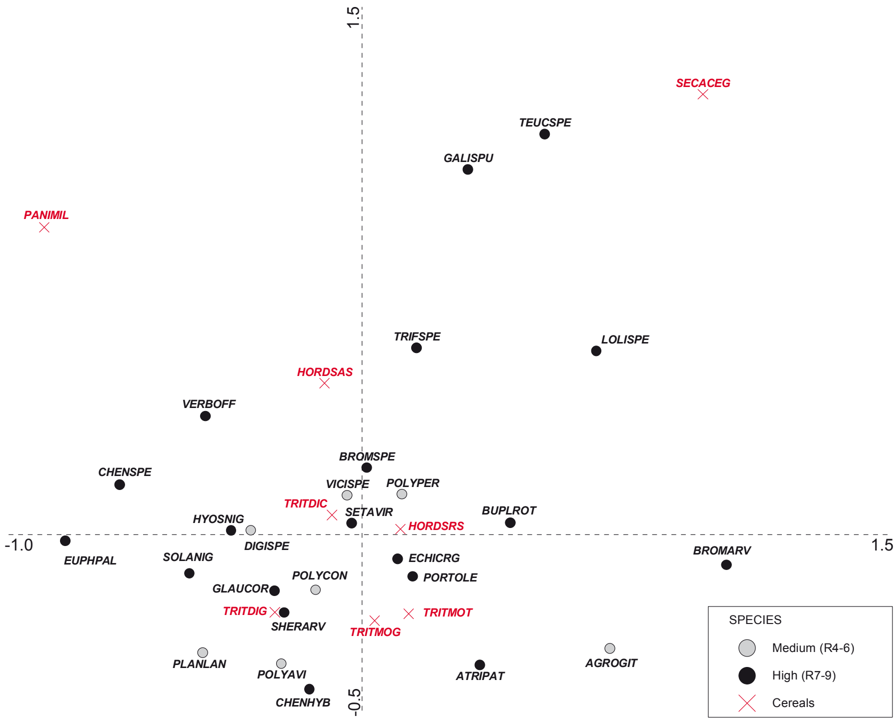


Fig. 40. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the ecological indicator values for reaction (after Borhidi 1995).

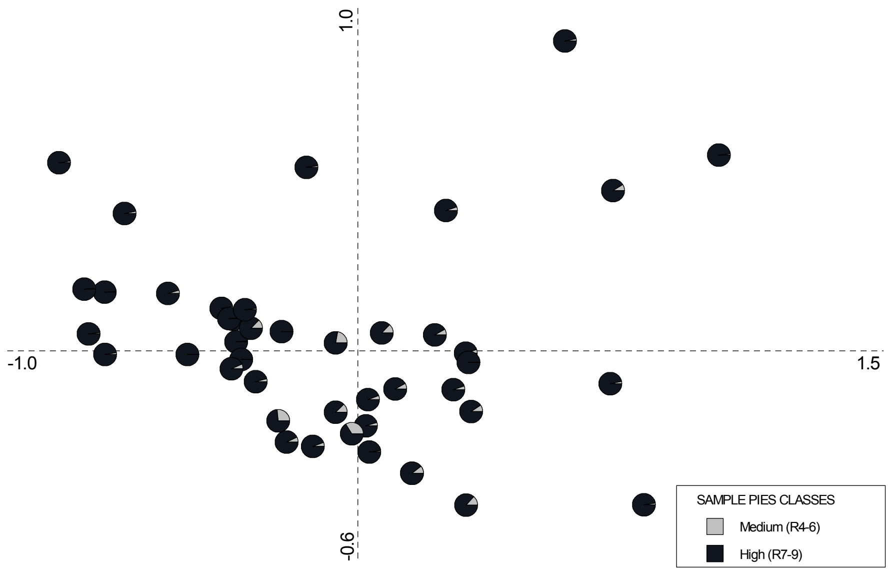


Fig. 41. Bronze Age Feudvar. Correspondence analysis of the proportions of weed species according to their reaction indicator value for samples identified as unsieved spikelets (after Borhidi 1995).

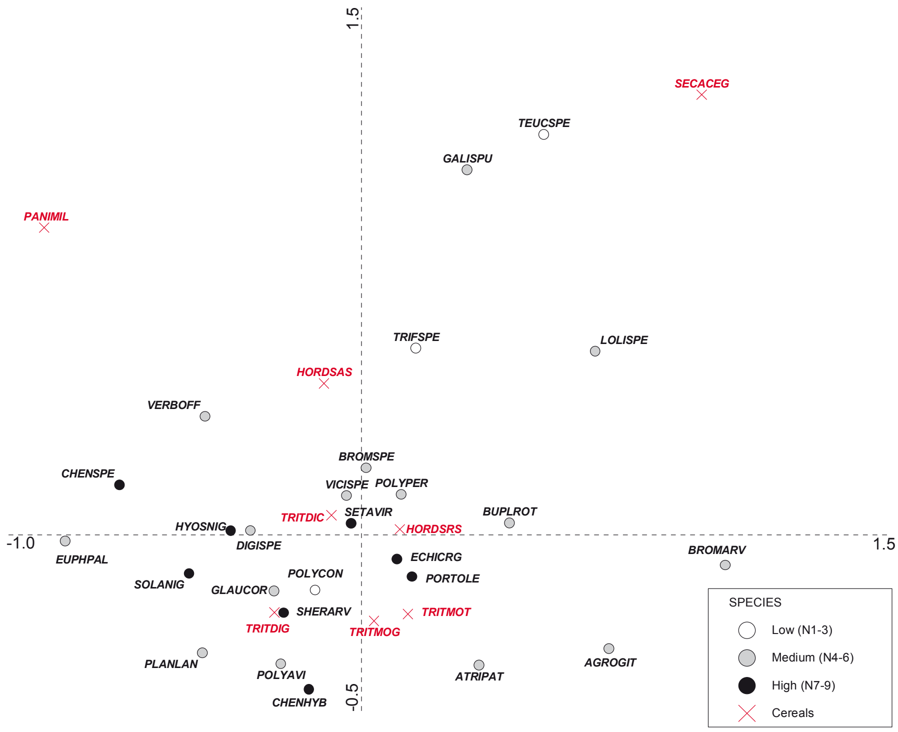


Fig. 42. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the ecological indicator values for nitrogen (after Borhidi 1995).

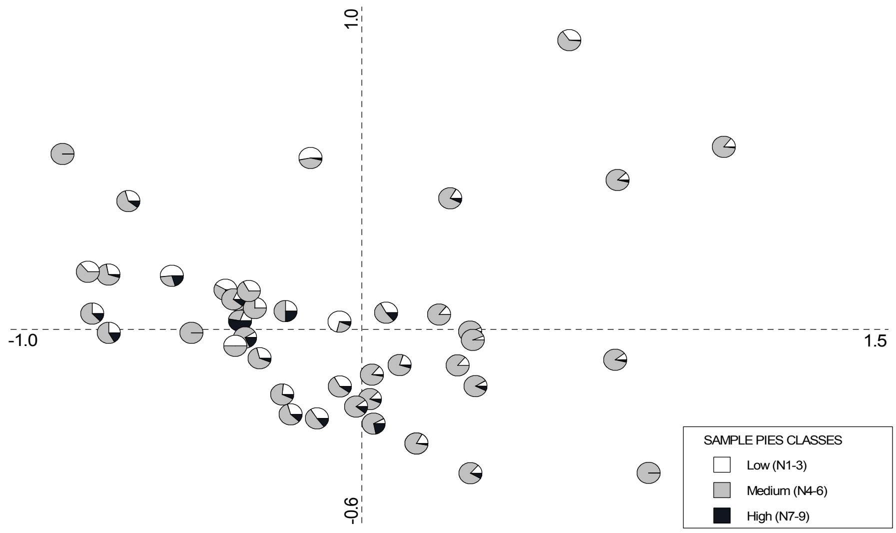


Fig. 43. Bronze Age Feudvar. Correspondence analysis of the proportions of weed species without CHENSPE according to their nitrogen indicator value for samples identified as unsieved spikelets (after Borhidi 1995).

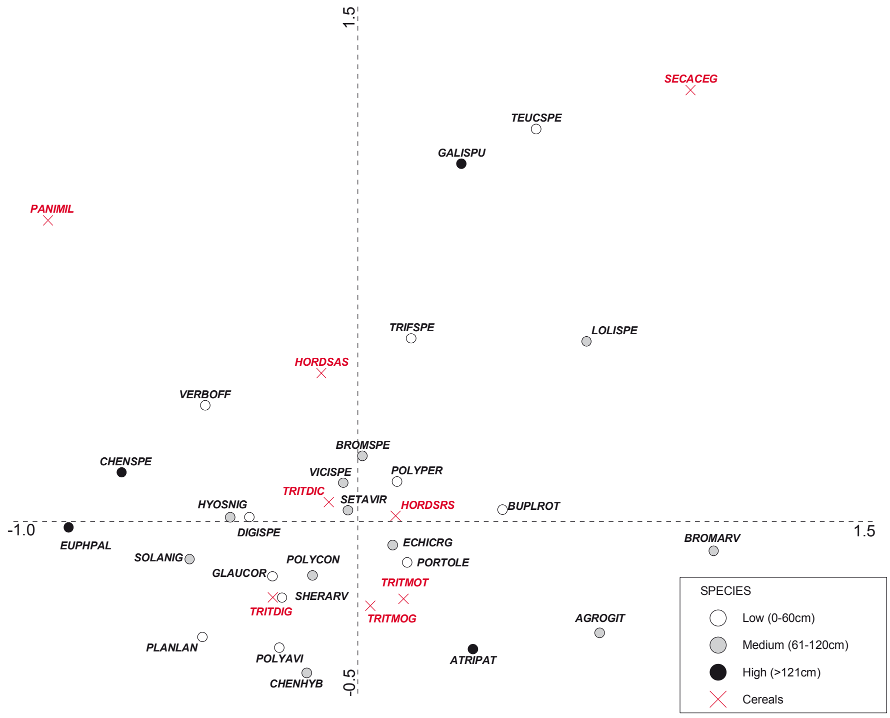


Fig. 44. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the maximum flowering height for each weed (after Bojnanský and Fargašová 2007).

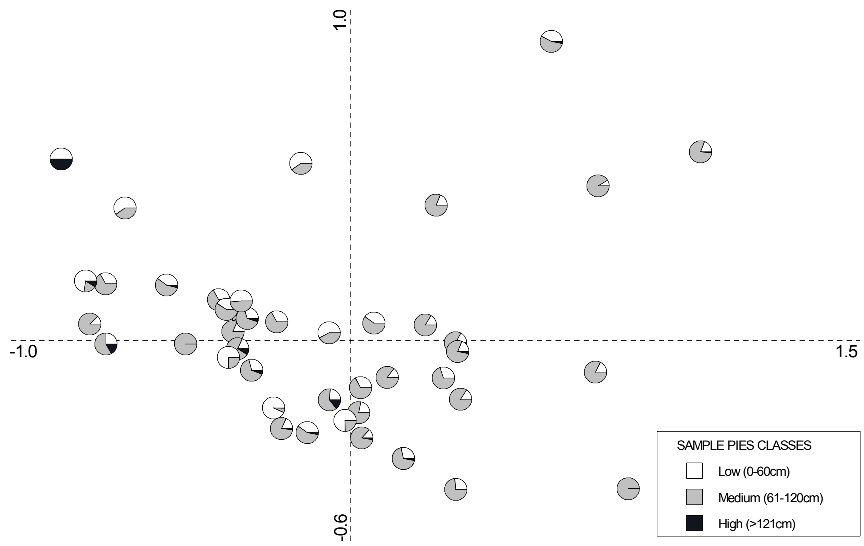


Fig. 45. Bronze Age Feudvar. Correspondence analysis showing the proportions of weed species without CHENSPE according to their maximum flowering height for samples identified as unsieved spikelets (after BOJNANSKÝ AND FARGAŠOVÁ 2007).

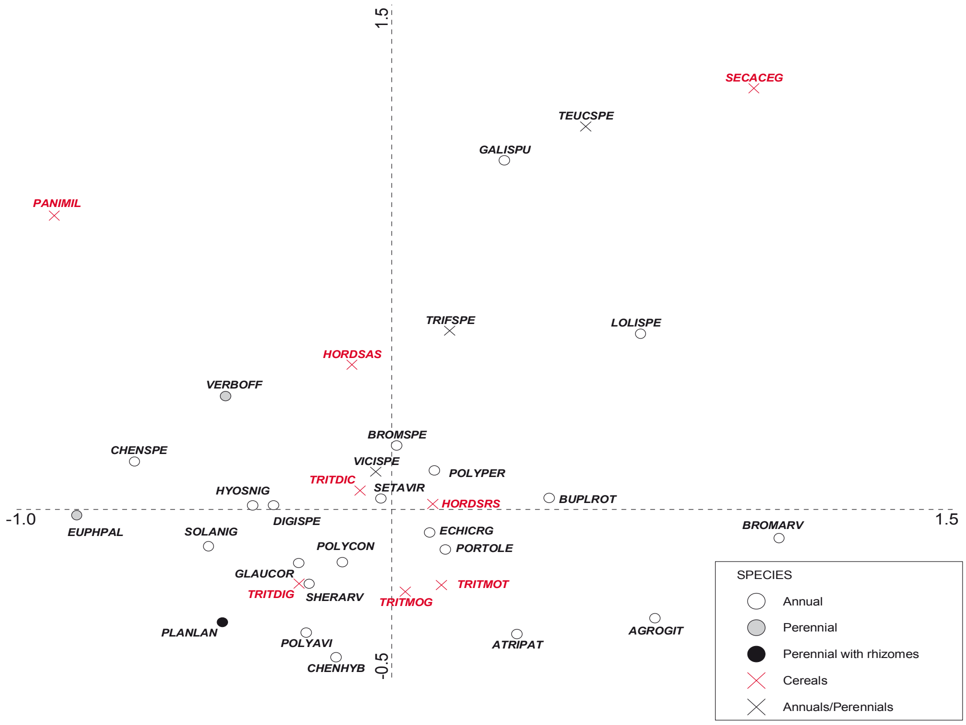


Fig. 46. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the life cycle of each weed i.e. whether they are an annual, perennial with or without rhizomes (after Bojnanský and Fargašová 2007).

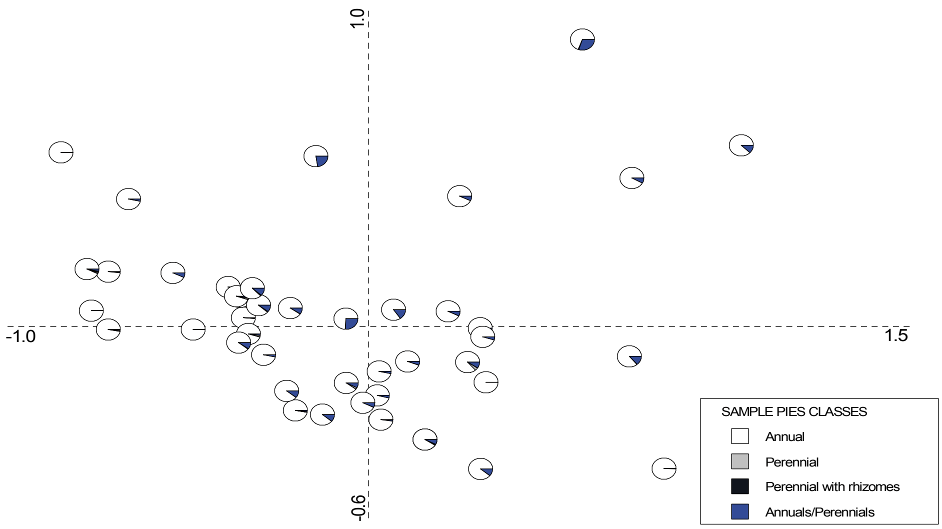


Fig. 47. Bronze Age Feudvar. Correspondence analysis showing the proportions of annuals and perennials for samples identified as unsieved spikelets (after Bojnanský and Fargašová 2007).

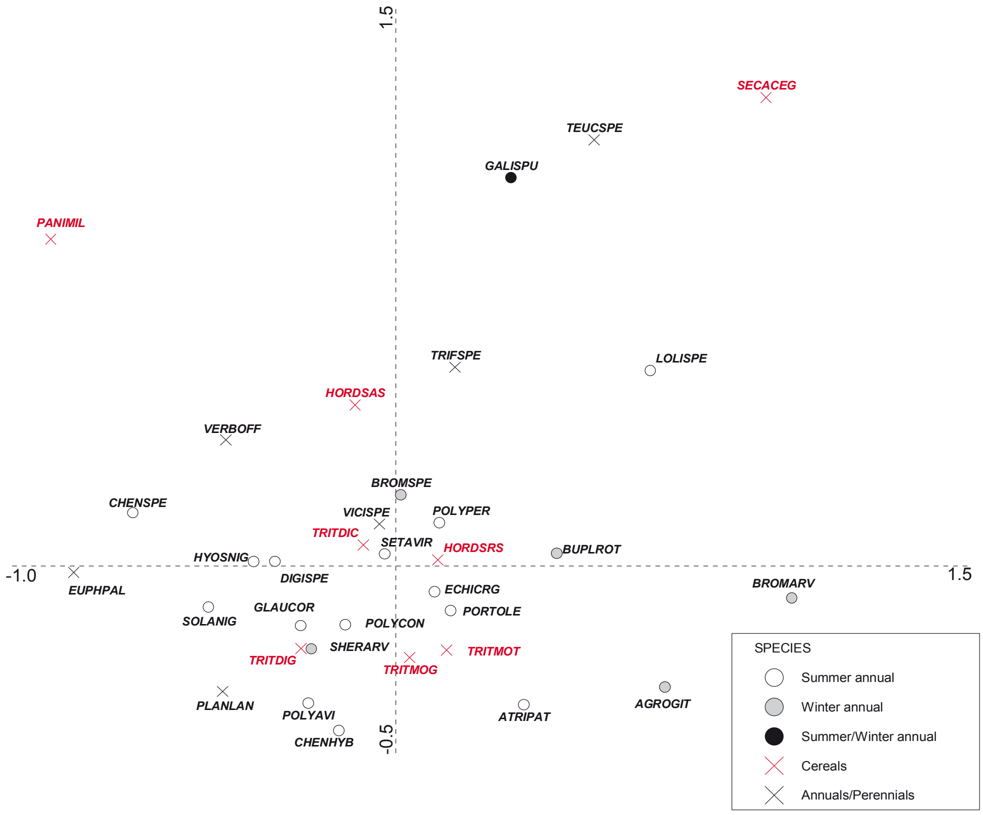


Fig. 48. Bronze Age Feudvar. Correspondence analysis of crops and weed species for samples identified as unsieved spikelets showing the germination time of each weed (after Bojnanský and Fargašová 2007).

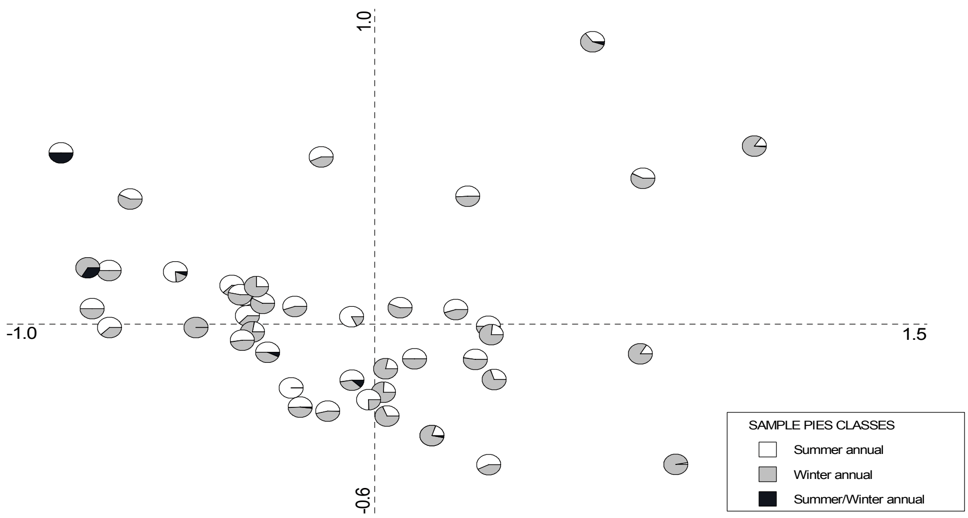


Fig. 49. Bronze Age Feudvar. Correspondence analysis showing the proportions of summer and winter annuals without CHENSPE for samples identified as unsieved spikelets (after Bojnanský and Fargašová 2007).

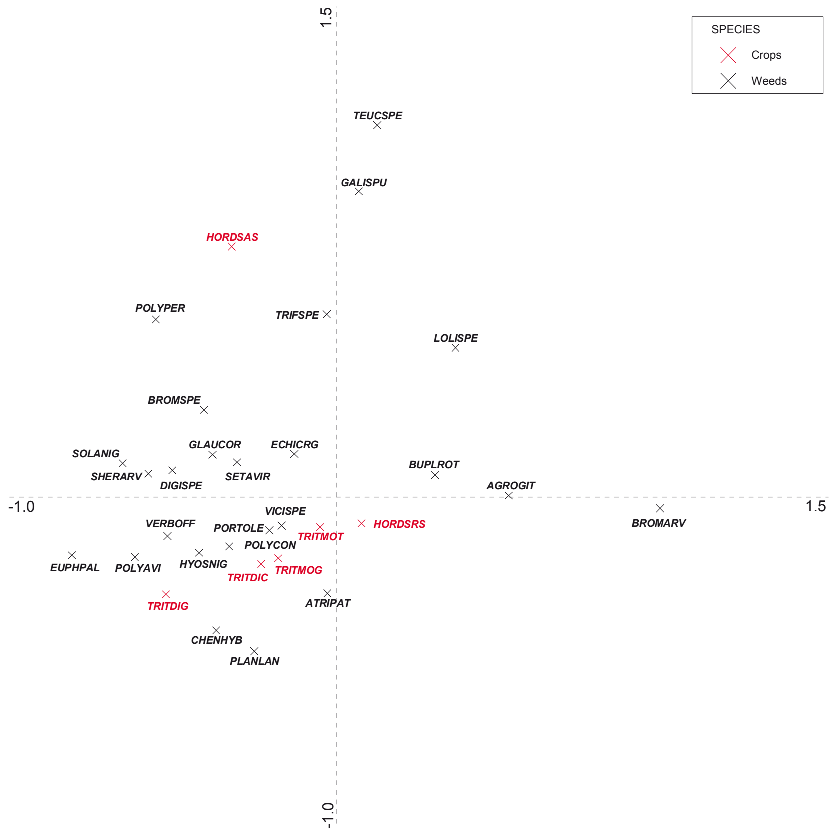


Fig. 50. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species without CHENSPE, SECACEG and PANMIL for samples identified as unsieved spikelets.

Exploring differences between barley and einkorn cultivation

Spikelets, unsieved: The results from the unsieved spikelets show a similar trend in ecological and anthropogenic factors throughout all the samples. The samples are primarily dominated by einkorn which may suggest that the spikelets are from an einkorn crop with admixtures of barley, emmer, broomcorn millet and so called rye. The divide between broomcorn millet and so called rye within the plots and the large influence of *Chenopodium* may, however, mask any patterns seen between barley and einkorn. Thus, to explore any further patterns that might emerge, a correspondence analysis was run on the dataset removing so called rye, broomcorn millet and *Chenopodium*. Samples containing >70 % of these species were also excluded as they may contain a crop deposit.

The weed and cereal associations do not change significantly from the previous correspondence analyses (Fig. 50). Barley grain is clearly separate from the other cereals at the top of the plot. However, barley rachis has a high association with einkorn in the middle of the plot. At present, it is unclear why barley rachis is closely associated with einkorn. Of the nine ecological and anthropogenic factors analysed, only the distribution of nitrogen values and summer / winter annuals produced clearer patterns (not shown).

Fine sieving by-products, unsieved: a correspondence analysis was run on the dataset removing spelt, bread / wheat, so called rye, broomcorn millet and *Chenopodium*. Samples containing >70 % of these species were also excluded as they may contain a crop deposit (Fig. 51). Sample composition shows a divide between those dominated by einkorn to the left of the plot and those with a greater proportion of barley to the right (Fig. 52). In addition, there is a clear divide between samples recovered from pits and hearths to the left of the plot and those from house levels to the right (Fig. 53). Of the nine ecological and anthropogenic factors analysed, only the distribution of nitrogen values and summer / winter annuals produced clearer patterns (Fig. 54).

Fig. 51. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species, without TRITSPL, TRITAED, CHENSPE, SECASEG and PANMIL, for samples identified as unsieved fine sieving by-products.

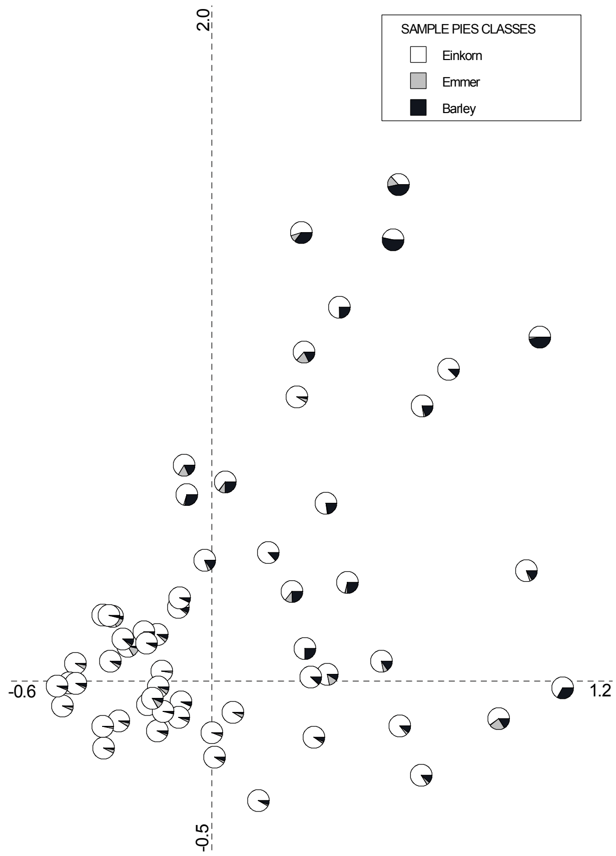


Fig. 52. Bronze Age Feudvar. Correspondence analysis of the portions of cereals per sample, without TRITSPL, TRITAED, CHENSPE, SECASEG and PANMIL, identified as unsieved fine sieving by-products.

Products, unsieved: a correspondence analysis was run on the dataset removing bread / wheat, so called rye, broomcorn millet and *Chenopodium* sp. Samples containing >70 % of these species were also excluded as they may contain a crop deposit. The weed and cereal associations do not change significantly from the previous correspondence analyses (Fig. 55). Barley grain and rachis is clearly separate from the other cereals to the right of the plot. Sample composition shows a divide between those dominated by einkorn to the right of the plot and those dominated by barley to the left (Fig. 56). In addition, there is a clear divide between samples recovered from pits to the bottom right of the plot and those from house levels to the top (Fig. 57). Of the nine ecological and anthropogenic factors analysed, only the distribution of moisture, nitrogen values and summer / winter annuals produced clearer patterns (not shown).

Nitrogen

Spikelets, unsieved: The weed species were coded to their nitrogen indicator values. Two groups of species are distinguished in the plot (Fig. 58). First, species characteristic of high nitrogen soils, einkorn and emmer to the bottom left of the plot and second, species characteristic of low and medium nitrogen soils and barley to the top and right.

Fine sieving by-products, unsieved: Similar results: First, species characteristic of high nitrogen soils, einkorn and emmer to the left of the plot, and second, species characteristic of low and medium nitrogen soils and barley to the bottom right (not shown).

Products, Unsieved: Similar results: First, species characteristic of high nitrogen soils, einkorn and emmer to the right of the plot and second, species characteristic of low and medium nitrogen soils and barley to the left (not shown).

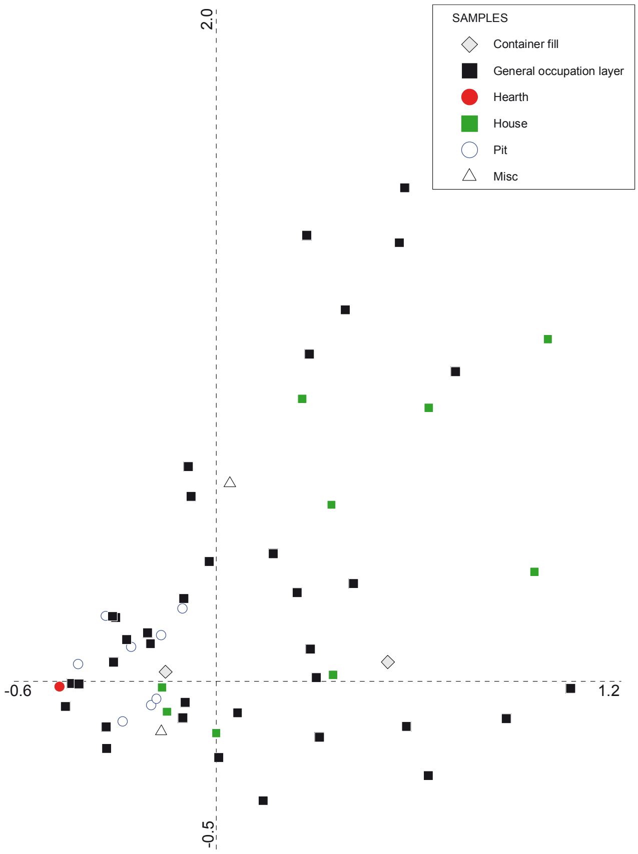


Fig. 53. Bronze Age Feudvar. Correspondence analysis of samples, without TRITSPL, TRITAED, CHENSPE, SECASEG and PANMIL, identified as unsieved fine sieving by-products per feature type.

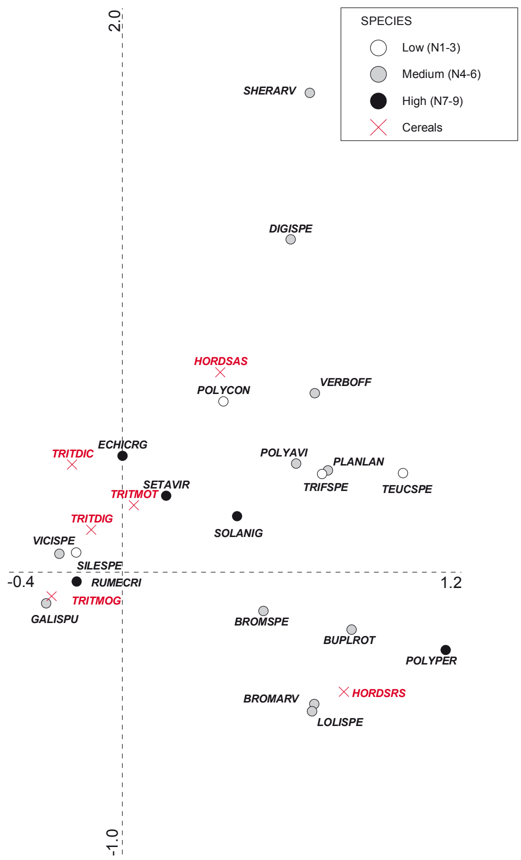


Fig. 54. Bronze Age Feudvar. Correspondence analysis of crops and weed species, without TRITSPL, TRITAED, CHENSPE, SECASEG and PANMIL, for samples identified as unsieved fine sieving by-products showing the ecological indicator values for nitrogen (after after Borhidi 1995).

Moisture

Products, Unsieved: Species characteristic of wetter soils are associated with emmer in the bottom right of the plot. Einkorn and barley are associated with species typical of dry, well drained soils (Fig. 59; 60).

Sowing time

Spikelets, unsieved: Two groups of species are distinguished in the plot (Fig. 61). First, summer annuals, einkorn and emmer to the bottom left of the plot and second, winter annuals and barley to the top and right. Fine sieving by-products, unsieved: Similar results: First, summer annuals, einkorn and emmer to the left of the plot and second, winter annuals and barley to the bottom right (not shown). Products, Unsieved: Similar results: First, summer annuals, einkorn and emmer to the right of the plot and second, winter annuals and barley to the left (not shown).

3.3.3 Conclusions

Weed species within the three groups of samples identified as unsieved spikelets, unsieved fine sieving by-products and unsieved products were examined in relation to nine ecological and anthropogenic factors. Although these three groups of samples contain three different crop processing stages, they all showed the same results. Thus, the overall picture presented by the weed species indicates that the environment within which the crops grew had plenty of light, grew in a mild climate (not too hot or cold) on well

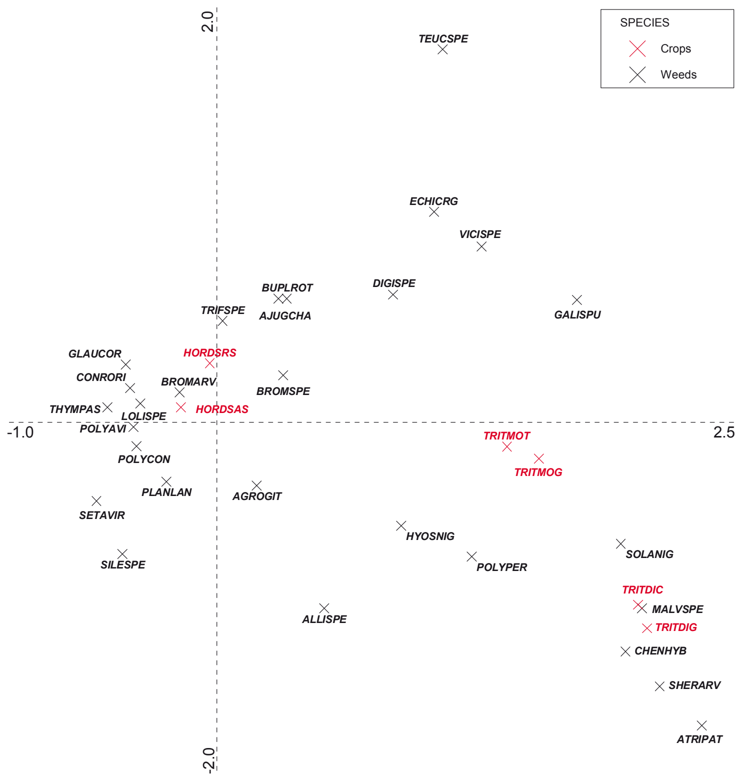


Fig. 55. Bronze Age Feudvar. Correspondence analysis of crops, possible crops and weed species, without TRITAED, CHENSPE, SECASEG and PANMIL, for samples identified as unsieved products.

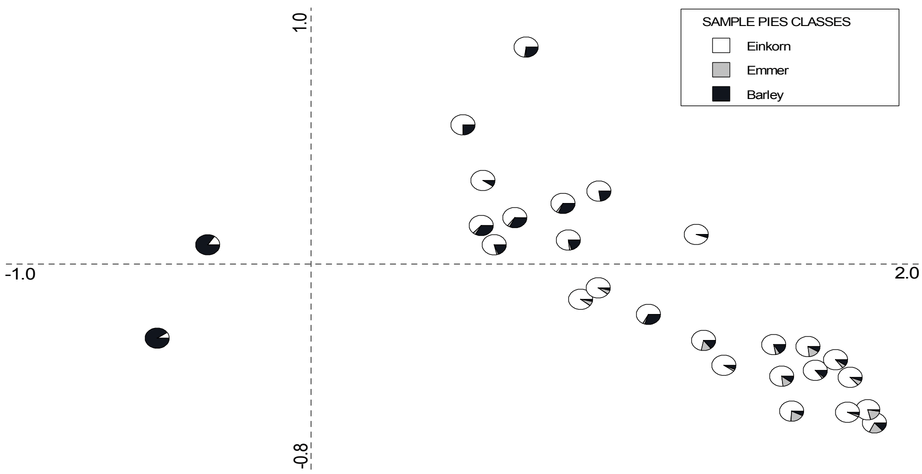


Fig. 56. Bronze Age Feudvar. Correspondence analysis of the proportions of cereals per sample, without TRITAED, CHENSPE, SECASEG and PANMIL, identified as unsieved products.

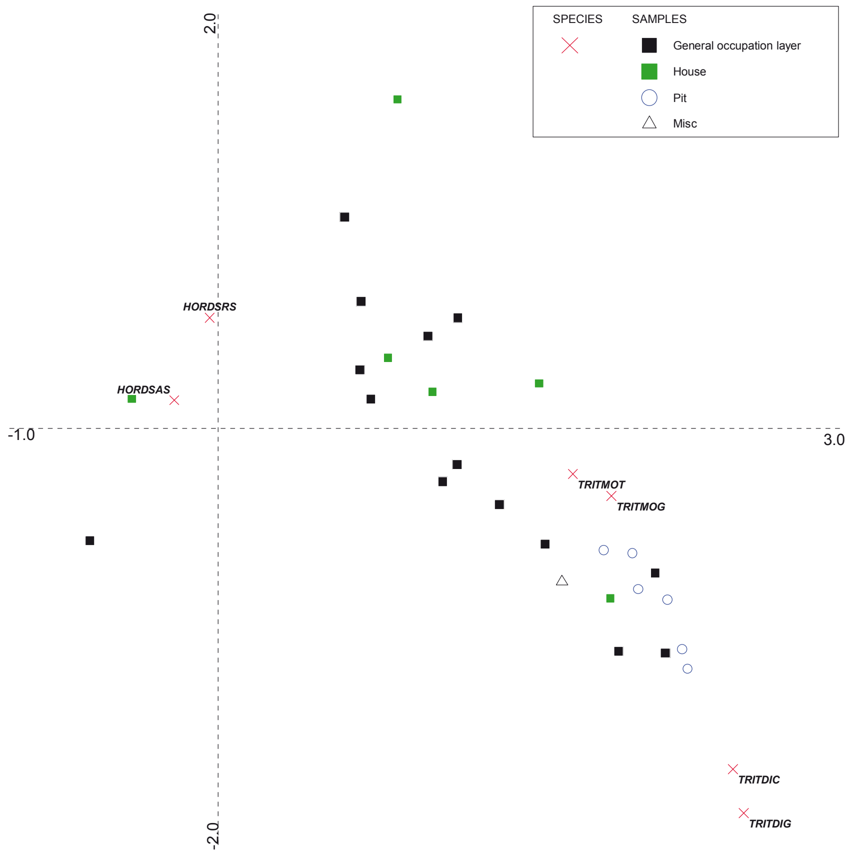


Fig. 57. Bronze Age Feudvar. Correspondence analysis of samples, without TRITAED, CHENSPE, SECASEG and PANMIL, identified as unsieved products per feature type.

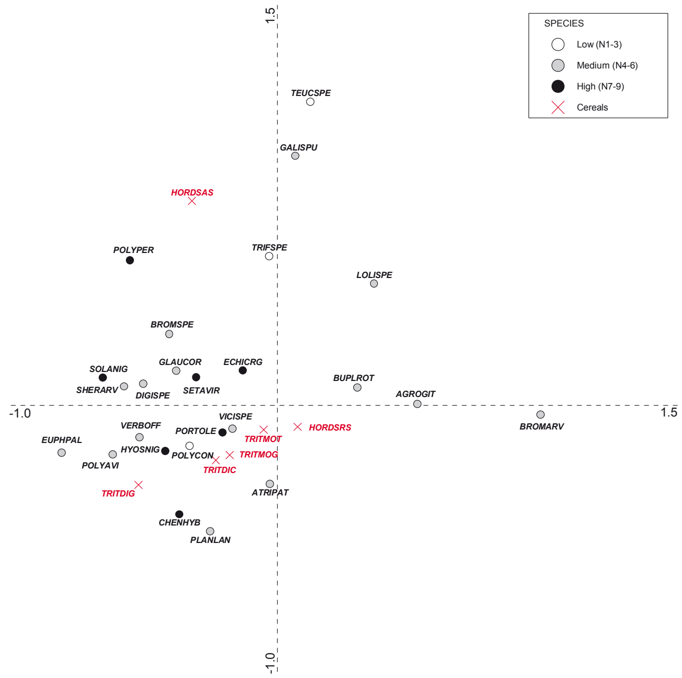


Fig. 58. Bronze Age Feudvar. Correspondence analysis of crops and weed species, without CHENSPE, SECASEG and PANMIL, for samples identified as unsieved spikelets showing the ecological indicator values for nitrogen (after Borhidi 1995).

Fig. 59. Bronze Age Feudvar. Correspondence analysis of crops and weed species, without TRITAED, CHENSPE, SECASEG and PANMIL, identified as unsieved products showing the ecological indicator values for moisture (after Borhidi 1995).

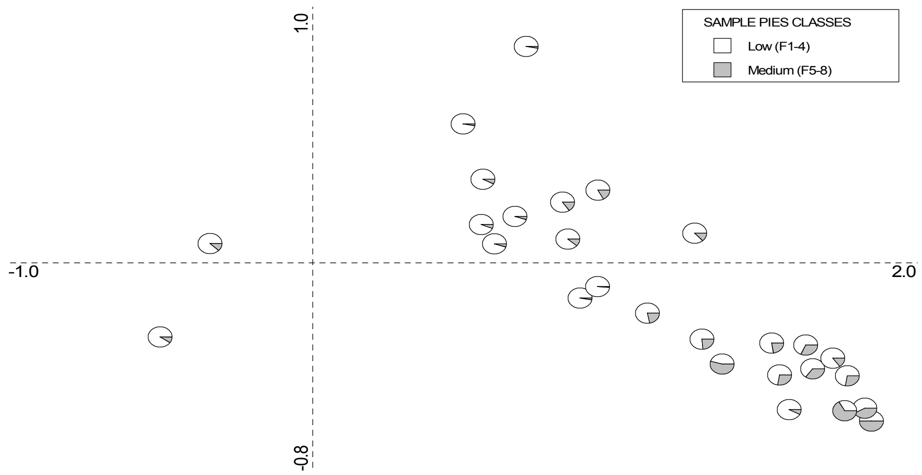


Fig. 60. Bronze Age Feudvar. Correspondence analysis of the proportions of crops and weed species, without TRITAED, CHENSPE, SECASEG and PANMIL, according to their moisture indicator value for samples identified as unsieved products (after Borhidi 1995).

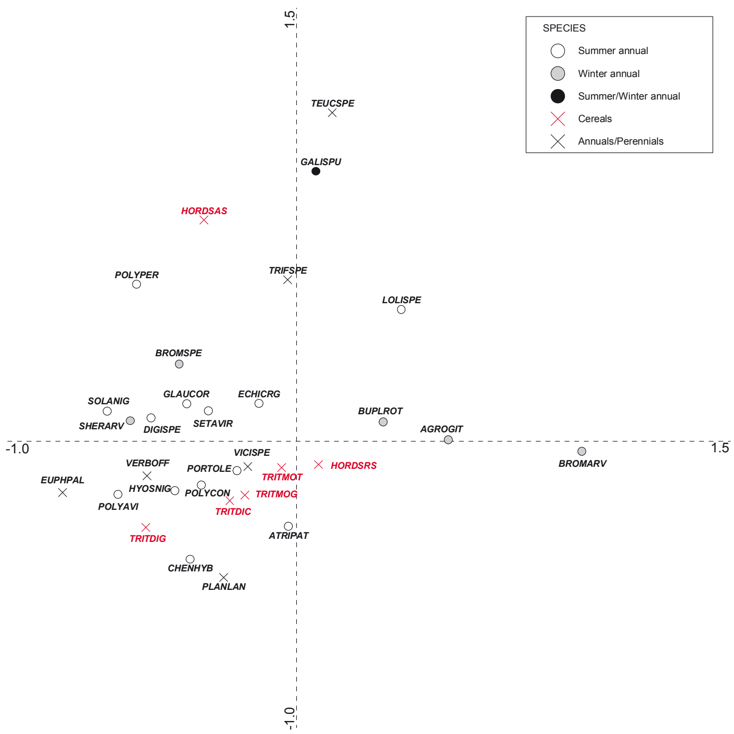


Fig. 61. Bronze Age Feudvar. Correspondence analysis of crops and weed species, without CHENSPE, SECASEG and PANMIL, for samples identified as unsieved spikelets showing the germination time of each weed (after Bojnanský and Fargašová 2007).

drained, slightly alkali soil with an overall medium nitrogen value. The anthropogenic factors analysed suggest that the crops grew on disturbed ground, sown in autumn, with possible weeding activities, and were harvested low to the ground so that both the straw and grain could be collected.

The correspondence analysis also revealed a separation between two groups of crops. Group A, which includes barley and so called rye[147], is characterised by species indicative of low levels of nitrogen and by winter annuals. Group B, on the other hand, includes einkorn, emmer, spelt, bread / durum wheat and broomcorn millet and is characterised by species indicative of high levels of nitrogen and by summer annuals. With all three groups of samples presenting the same results, it is likely that the differences seen between group A and B represent two different crop husbandry regimes at Feudvar.

3.4 Intra-site variability

From chapter 2.6, a number of patterns were identified in the distribution of certain crop processing samples throughout the western trench at Feudvar. This section will examine these trends further in order to determine whether different cultivation methods can be associated with a particular group of inhabitants or household. As already observed from the previous analyses, barley and so called rye are generally associated with house deposits, while the wheats (einkorn, emmer, spelt, bread / durum wheat) and broomcorn millet are more associated with pits. Broomcorn millet is also closely associated with pits, especially within the southern end of the trench. The association of broomcorn millet with wheat and with pits may therefore support the theory that broomcorn millet may have been added to the wheat crop to help in storage (see p. 237).

Two factors, nitrogen availability and germination time, distinguished differences in cultivation methods of group A crops (barley and so called rye) and group B crops (einkorn, emmer and broomcorn millet). In

147 This so called rye is the weed Dasypyrum villosum [Kroll].

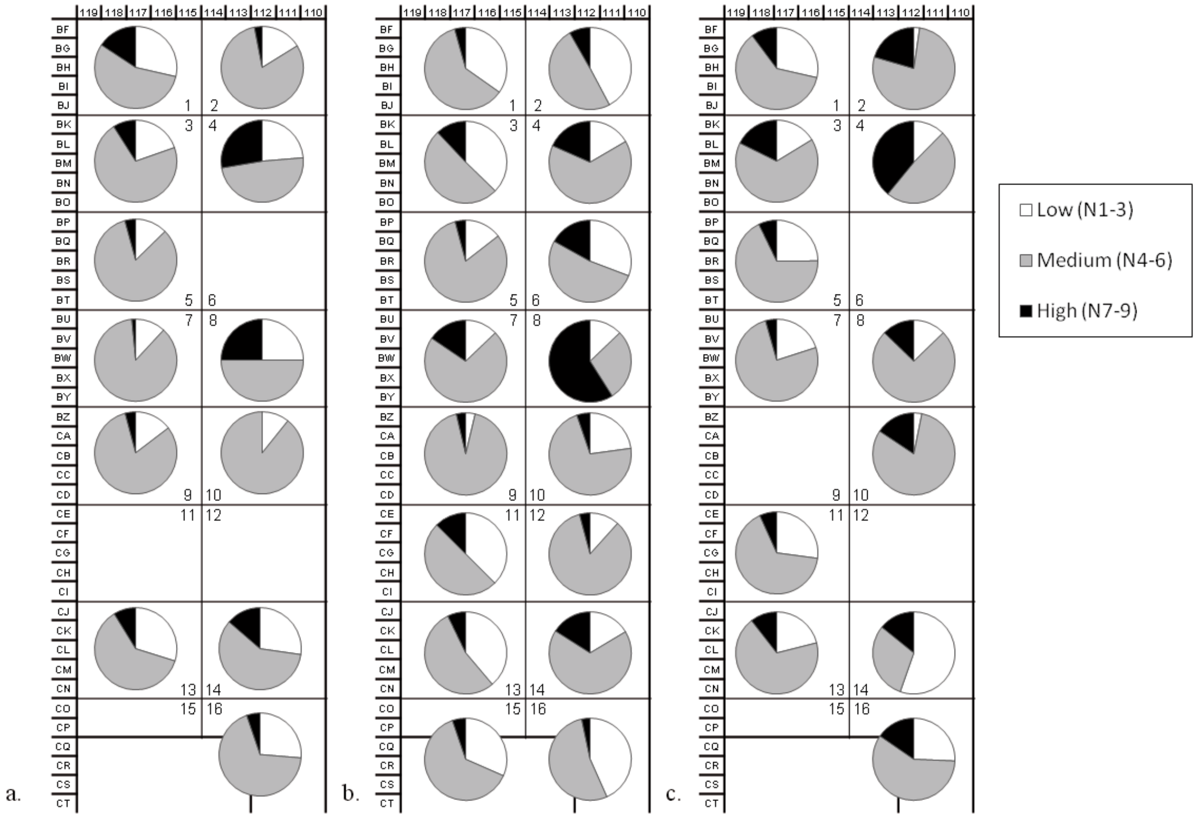


Fig. 62. Bronze Age Feudvar. Pie charts representing the percentages of low, medium and high nitrogen indicator values of weed species for samples identified a) as unsieved spikelets, b) as unsieved fine sieving by-products and c) as unsieved products per block (5x5m) .

order to explore possible differences in cultivation methods applied by different households, the distribution of species characteristic of low, medium and high nitrogen environments were plotted across the western trench for each of the three unsieved crop processing stages. Species indicative of high nitrogen availability are found predominantly in areas 4 and 8 for all three groups (Fig. 62). This corresponds with floor deposits from the Fisher House. From chapter 2.5, these areas were seen as being dominant in einkorn and emmer remains. The remaining areas are all dominant in species characteristic of medium nitrogen levels. Looking at the proportion of summer and winter annuals and perennials / annuals across the trench, some slight patterning may also be seen (Fig. 63). First, blocks 4 and 8 are higher in summer annuals. Second, blocks 5, 7 and, to a lesser extent, blocks 13 to 16 at the south end of the trench are higher in winter annuals. Nevertheless, dominance does vary depending on the crop processing stage being examined.

Thus, from the analysis of spatial distribution of samples within the trench, it may be possible to see a slight increase in species indicative of higher nitrogen levels and summer annuals within the Fisher House which may correspond with possible differences seen in the cultivation regimes of einkorn and emmer. Correspondence analyses on the datasets has been a helpful tool in making a distinction between house and pit features which provides further evidence of depositional practices at the site. Unfortunately, at present, detailed chronological and archaeological information is unavailable so it is difficult to determine whether any chronological changes occurred at the site in relation to crop processing regimes during the Bronze Age.

3.5 Identification of crop husbandry practices at Feudvar

3.5.1 The arable environment (climate, temperature, water and soil pH)

Feudvar is located within northern Serbia in the province of Vojvodina. Today the climate is mildly continental due to the warmer influences of the Adriatic (Mediterranean) climate. In Belgrade (approximately

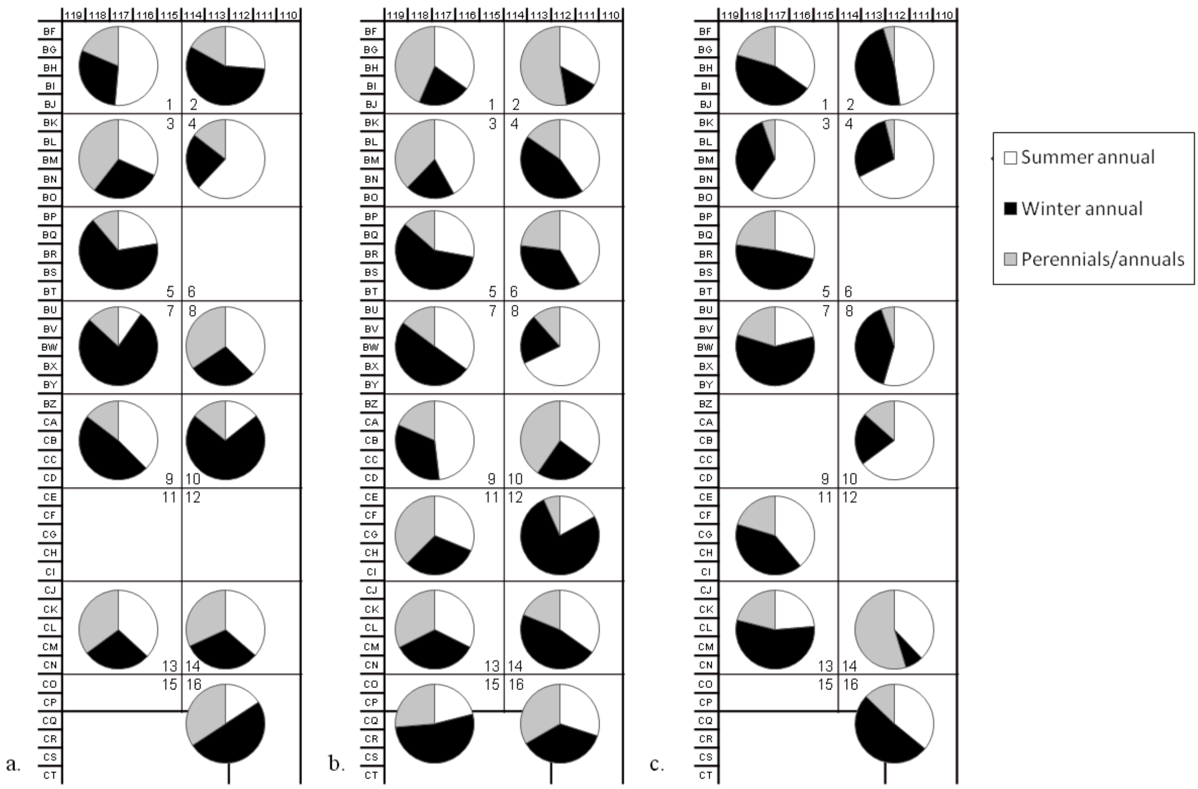


Fig. 63. Bronze Age Feudvar. Pie charts representing the percentages of summer annuals, winter annuals and perennial/annuals for samples identified a) as unsieved spikelets, b) as unsieved fine sieving by-products and c) as unsieved products per block (5x5m) .

60 km south of Feudvar) temperatures on average range from 22°C in the summer to 0°C in the winter, with an average annual rainfall of 635 mm[148]. Evaporation is particularly intensive in Vojvodina due in part to the high summer temperatures as well as strong winds[149]. Climatic conditions during the Bronze Age occupation of Feudvar were influenced by the Sub-Boreal period (*ca.* 3300–1000 BC). Although the Pre-Boreal is characterised by a cooler and wetter climate than the preceding Atlantic period, it is suggested that the climate was similar to that of today, differing by only 1 to 2°C[150].

The Titel plateau today is about 16 km long, extending in a NW-SE direction and about 8 km wide. It is located near the confluence of the Tisza (running to the east of the site) and the Danube (running along the south). The area is therefore directly influenced by fluvial erosion, flooding and waterlogging. Today the soils consist of alluvials, deposited by the two rivers, and chernozems, which is the main soil type within the region including the Plateau itself. Chernozem and the loamy alluvial soils found along the rivers are particularly well drained, although the alluvials are at a much greater risk of flooding. The chemical properties of chernozem in Vojvodina are on average slightly alkaline, with a high availability of potassium and phosphate. As a result, this type of soil is particularly well suited for obtaining high quality crops with high stable yields[151].

It is suggested that the formation of chernozem soils in Serbia developed due to the influences of the continental climate and forest steppe during the preboreal *ca.*11,500 BP[152]. The mechanism by which these

148 Bell 2003, 521.
149 Filipovski and Ćirić 1969, 271.
150 Velichko and Nechaev 2005, 65.
151 Ubavić and Bogdanović 1995.
152 Thater and Stahr 1991.

soils were formed is still debated, with some suggesting a link between the development of chernozem and human activity such as deforestation during the Neolithic[153]. However, in Central Europe this has been largely disproved within areas of Linearbandkeramik (LBK) settlement[154]. In Hungary, others suggest that the appearance of steppe vegetation in the Great Hungarian Plain during the early Holocene triggered the formation of chernozem soils[155]. Regardless of the mechanism by which chernozem developed, it is evident that these soils would have been well established in northern Serbia before the occupation of Feudvar during the Bronze Age.

The next group of soils which surround the Titel plateau are hydromorphic smoniza and black soils, which are types of alluvial soils that formed as a result of the two rivers, but contain a higher percentage of clay. These are very poorly drained soils with the occurrence of groundwater in the top 30 cm for 6 months of the year and the emergence of salinisation. Because of their abundant moisture they are unsuitable for cultivation, although today drainage systems have been implemented in Serbia to allow them to be utilised. These soils are also known as 'minute soils', as they require a short optimal period of cultivation.

From the ecological indicator values, the weed species suggest that during the Bronze Age at Feudvar the temperature was typical of a submontane broad leaved forest belt (T6). In northeast Serbia today, submontane and montane beech forests can be found[156]. In terms of continentality, the weeds typically characterised suboceanic (K4) species, with slight oceanic (K3) and subcontinental (K5) tendencies, mainly of Central Europe although extending to the east. Plant reaction indicated basifrequent plants (R7) found on slightly calcareous soils. This corresponds with the pH of chernozem soils today which are neutral to slightly alkali, although hydromorphic soils also have a neutral pH in the Balkans[157].

The moisture value for the species generally indicates a semidry habitat (F4). As the chernozem soils are well drained soils, while the surrounding hyromorphic soils are particularly waterlogged, this would suggest that the majority of the species were growing on chernozem soil. The presence of *Phragmites australis, Trapa natans* and *Schoenoplectus lacustris* from the whole Feudvar assemblage, which have high moisture values (F10–F11), indicates plants of frequently flooded soils. Along the Danube today, especially in areas of Croatia and Serbia, *Phragmites australis, Trapa natans* and to a lesser extent *Schoenoplectus lacustris* are regularly found. Therefore, during the Bronze Age these species are likely to have grown on the alluvial soils which are prone to flooding and run to the south and east of the Titel plateau.

3.5.2 Cultivation methods

The different cultivation methods employed by a farmer will ultimately determine the crops productivity, its sustainability (i.e. long term cultivation) and labour requirements. Two groups of species were identified from the correspondence analysis: group A, which includes barley and is characterised by species indicative of low levels of nitrogen and by winter annuals, and group B, which includes einkorn, emmer, spelt, bread / durum wheat and broomcorn millet and is characterised by species indicative of high levels of nitrogen and by summer annuals. It was concluded that these differences indicated two different cultivation methods. These issues will be discussed in more detail, focusing on four main cultivation activities: preparing the ground (i.e. tillage methods), sowing the seeds of the crop, tending the crop (i.e. weeding, manuring) and harvesting.

Tillage methods

Tillage refers to the preparation of soil for the growing of crops. The extent of soil disturbance will be determined by the type of method employed and the amount of energy applied to the activity. This is ultimately linked to the type of crop grown and the scale and intensity of the cultivation regime employed.

153 Gerlach et al. 2006.
154 Lorz and Saile 2011.
155 Joó et al. 2007.
156 Koprivica et al. 2008.
157 Mitkova and Mitrikeski 2005.

By examining the 33 weed species recovered from Feudvar, only five species are perennials and one, *Plantago lanceolata*, is a perennial with rhizomes (making it less susceptible to disturbance). The remaining 27 species are all annuals. Previous research suggests that annuals increase with the rise of disturbance, especially in relation to tillage activities[158]. Thus, at Feudvar, the dominance of annuals over perennials suggests that the agricultural fields were tilled before the crops were sown.

Soil organic matter availability and distribution of nutrients to crop plants are often influenced by the type and degree of soil tillage. Tillage practices have been shown to increase nitrogen availability by aerating the soil and mobilising micro organisms[159]. The loss of soil organic matter is, however, greatest within ploughed fields[160]. Soils tilled in the autumn also have a greater risk of nitrogen leaching due to high precipitation during the autumn and winter[161]. On the other hand, intensive tillage practices are typically associated with manuring and are therefore more likely to maintain soil nitrogen levels compared to extensive plough cultivation[162]. Tillage intensity also has an effect on weed density, where fields with minimal tillage have greater quantities of weeds[163]. In addition, species-rich fields have been shown to correlate with marginal environmental conditions, rather than fertile soils, as well as with extensive mixed-cropping-breeding systems that depend on both animal and crop production[164].

Although no tillage equipment (i.e. ploughs, hoes or digging sticks) has been recovered from the excavations at Feudvar, tillage practices may be inferred from the archaeobotanical remains. The high nitrogen levels associated with einkorn, emmer and broomcorn millet (group B) and the low number of weed species associated with the crops, may suggest that intensive tillage methods were practiced. Barley (group A), on the other hand, had a greater association with species indicative of low nitrogen environments, which may suggest a more extensive regime and the use of an ard plough. Autumn tilling of barley (group A), may also be inferred from the presence of winter annuals and species indicative of low nitrogen levels.

In conclusion, the cultivated fields at Feudvar were tilled before the crops were sown. Two different forms of tillage were also inferred from the archaeobotanical remains. For barley (group A), extensive ard cultivation was most likely performed. For the cultivation of einkorn, emmer and broomcorn millet (group B), a more intensive tillage method was performed, either through repeated use of an ard or the use of hoes.

Sowing strategies

Autumn versus spring sowing

The time at which a crop is sown provides information about the yearly activities at the site. The sowing time of a crop may also indicate productivity, as winter sown crops have a longer growth period they may have potentially higher yields. From the germination time of the weed species found within the crops, it is possible to infer the season the crop was sown. The basic principle suggests that if a crop contains predominantly spring germinating weeds, then the cereal was sown in spring, while a dominance in winter annuals indicate autumn sowing[165]. At Feudvar, the correspondence analyses showed that winter annuals had a greater association with barley (group A), while summer annuals had a greater association with einkorn, emmer and broomcorn millet (group B). This could suggest that barley was sown in the autumn, while einkorn, emmer and broomcorn millet were sown in the spring.

158 Ellenberg 1950; Hillman 1981; van der Veen 1992; Zimdahl 2007.
159 Doran et al. 1998.
160 Salinas-Garcia et al. 1997.
161 Stenberg et al. 1997.
162 van der Veen 1992, 139.
163 Blackshaw et al. 2001.
164 Fried et al. 2008.
165 Groenman-van Waateringe 1980; Jones 1981; Wasylikowa 1981.

However, studies have shown that summer annuals will outcompete winter annuals in nitrogen rich fields[166]. In addition, studies have shown that weeding in spring reduces the number of winter annuals and encourages the growth of short-lived summer annuals[167]. Thus, autumn sown crops that are subjected to intensive practices (i.e. weeding and manuring) have been shown to have a weed flora rich in summer annuals[168]. The high association of summer annuals with group B (einkorn, emmer and broomcorn millet) may therefore result from more intensive practices being applied to autumn sown crops.

The identification of spring sown broomcorn millet has also been traditionally identified presence of Chenopodietea within the samples[169]. More recently, this method has allowed the identification of a spring sown broomcorn millet crop at the Bronze Age site of Ganglegg[170]. Broomcorn millet (*Panicum miliaceum*) is commonly planted as a summer crop, due to its sensitivity to frost, its ability to withstand intense heat, poor soils, draught and has a relatively short growing period compared to the other cereals[171]. It may therefore be prudent to reconsider the identification of autumn sown broomcorn millet at Feudvar. Previous work by Kroll (1997), suggests that broomcorn millet was indeed sown in spring at Feudvar and may have been an effective method to reduce weed infestation in winter fields as its cultivation would prevent re-establishing weeds from growing abundant seeds. Therefore, if broomcorn millet was indeed grown as a minor crop at Feudvar then it may have been sown in spring rather than autumn.

Maslins and monocrops

Another aspect to consider is the practice of intercropping, where two or more species are sown together in a field to increase yield and / or reduce complete crop failure. In traditional farming communities in Ethiopia, intercropping of emmer and barley is commonly practiced in order to add variety to the diet and reduce risk of economic loss from pests or adverse weather conditions[172]. The inclusion of barley to a wheat crop is also believed to increase the wheat yield and protect it against fungal attack. Two methods have been commonly used to determine the presence of a maslin crop in archaeobotanical samples: first, through the presence of two or more cereals in one sample and second, from similar proportions of the crops[173].

However, the presence of two or more crop species within a sample may result from a number of activities unrelated to intercropping. For example, mixing of cereals after harvest (i.e. as a result of crop processing or depositional activities), from crop rotation or from accidental contamination[174]. The examination of proportions is also problematic as the point of a maslin crop is to allow one crop to outperform another depending on the environmental conditions. In this sense, the proportions within a sample are not a reliable indication of intercropping. A solution to these problems was proposed by van der Veen who suggested that multivariate analyses can be used to identify intercropping through the close associations seen between crops and suites of weeds[175].

At Feudvar, the correspondence analysis shows a close association with einkorn and emmer and their associated weeds. This may suggest that einkorn and emmer were grown as a maslin crop, but the environmental conditions were more suited to einkorn, resulting in the dominance of einkorn within the majority of the samples. The correspondence analyses also identified a close association between einkorn and barley rachis within samples identified as unsieved spikelets. Although the intercropping of einkorn and barley may explain this close association, the overall results of the correspondence

166 Carson and Barrett 1988; van der Veen 1992, 131–133.
167 van Elsen 2000.
168 Jones et al. 1999; Bogaard et al. 2001.
169 Kroll 1979; Wasylikowa 1978.
170 Italy: Schmidl and Oeggl 2005.
171 Nesbitt and Summers 1988; Schmidl et al. 2005.
172 D'Andrea et al. 1999; D'Andrea and Mitiku 2002; Kislev, 1989.
173 van der Veen 1995.
174 Jones and Halstead 1995; Dennell 1978; Willerding 1988.
175 van der Veen 1995.

analyses consistently showed the separation of barley and einkorn within the plots and a separation between their associated weeds. From these results, it is therefore unlikely that the intercropping of einkorn and barley occurred at Feudvar.

Sowing method

In the previous chapter it was determined that a certain proportion of the cereal remains would likely represent seed corn, especially in the case of glume wheat spikelets. A number of methods can be employed to sow the cereals including broadcasting or dribbling into channels. The area of land that needs to be sown will have an effect on the method employed, as large areas will need a more rapid method of sowing. Thus, extensive ard cultivation tends to be associated with broadcast sowing (i.e. low labour input / low area yield), while smaller scale cultivation tends to involve dribbling or planting (i.e. high labour input / high area yields[176]). Therefore, broadcasting is faster but more wasteful, while dribbling in rows is slower but less wasteful and allows weeding.

In conclusion, the high proportion of winter annuals associated with barley (group A) would suggest that this crop was sown in autumn by broadcasting, which requires less labour input per area. Einkorn, emmer and broomcorn millet (group B), were also likely sown in autumn by dribbling or planting, but due to more intensive practices (i.e. weeding and manuring) the weed flora is dominated by summer annuals. In addition, the strategy of intercropping may have also been practiced at Feudvar through the mixing of einkorn and emmer.

Intensive practices

Weeding

The application of intensive practices has already been highlighted above in relation to tillage practices and sowing strategies, but what is meant by intensive practices? Intensive agricultural activities involve the high input of resources, i.e. labour, manure, irrigation, into a given area of land, resulting in high area yields. Weeding or hoeing crops is classed as an intensive action that takes time and man power. This strategy prevents weeds from reaching maturity and outcompeting the crop plants, which ultimately affects the productivity and yield of the crop. Studies have shown that weeding encourages the growth of annuals, due to the high levels of soil disturbance (see p. 261). The level and intensity of weeding will have an impact on the weed species present in the field. For example, if autumn crops are weeded in the spring then the majority of winter annuals will be removed. The freshly hoed ground is then more susceptible to the growth of quick growing summer annuals.

However, identifying weeding in archaeobotanical material can be problematic. For example, Bogaard suggests that hand tillage using a hoe could have a similar effect on the overall weed composition as small-scale ard ploughing followed by weeding[177]. In addition, if crops are grown in spring on freshly tilled earth, then it is very difficult to distinguish between the disturbance seen from the tillage methods and any further weeding activities. At Feudvar, weed species associated with both groups are indicative of high soil disturbance, whether from tillage or tillage and weeding. However, if einkorn and emmer (group B) were sown in autumn, their strong association with summer annuals would suggest weeding of the crops in spring.

Manuring

Another intensive practice is manuring, which involves enriching the agricultural soil to increase crop productivity. As nitrogen is responsible for the protein quality within the grains, the lack of nitrogen will severely affect yield and the grains nutritional quality[178]. Manuring as part of an intensive regime would therefore allow families to produce relatively high yields from small areas of land. The only problem with

176 Halstead and Jones 1989; Halstead 1995.
177 Bogaard 2004, 142.
178 Gregg 1988, 64.

this method is the availability of manure and subsequently the number of livestock available. At Feudvar, the availability of manure is likely, as zooarchaeological remains indicate the rearing of cattle, sheep / goat and pigs at the site[179], although the quantity needed to provide enough manure is difficult to estimate. In addition, manure could have been applied directly, by allowing the livestock to graze on the land between cultivation periods, or indirectly, by collecting and spreading the manure manually. The strong association between weed species characteristic of high nitrogen environments and einkorn, emmer and broomcorn millet (group B), may suggest that these crops were manured. In contrast, the strong association between species indicative of medium to low levels of nitrogen in the soil and barley (group A) would suggest that no soil enrichment occurred for this crop.

However, the lower levels of nitrogen indicative of barley cultivation at Feudvar may not necessarily indicate poor crop yields, as nitrogen availability is also impacted by the type of soil (i.e. whether well aerated or compacted) and its ability to retain nutrients. Within the landscape of Feudvar, the main soil type is chernozem. Chernozem soil has been shown to have a naturally high fertility that has allowed cultivation of cereals without the addition of manure[180]. Chernozem soils are also particularly rich in potassium and calcium[181]. Crop rotation and fallowing are strategies that have also been implemented to increase nitrogen, prevent soil exhaustion and therefore increase crop yields. However, experimental evidence has shown that prolonged cultivation need not necessarily result in low yields[182]. In addition, Rösch suggests that non-demanding cereals like spelt, broomcorn millet and barley can reach sufficient yields without fertilisation and that soil fertility could be conserved by a rotation system[183].

The identification of crop rotation in archaeobotanical material has generally occurred from the identification of two or more species within a sample[184]. Alternatively, the identification of perennial meadow and footpath plants in crop weeds have been used to infer short fallow phases in Bronze Age contexts[185]. At Feudvar, the high number of annuals makes it unlikely that the fields were left fallow. However, it is difficult to determine whether another form of crop rotation occurred, as the majority of samples contain more than one cereal species. The intercropping of nitrogen fixing legumes or crop rotation (legume-cereal) is another method of maintaining soil fertility during cultivation. From the correspondence analysis, *Vicia* is regularly associated with einkorn and may support the use of legumes in the husbandry regime to increase soil nitrogen. In conclusion, intensive practices i.e. manuring and weeding, are likely to have been practiced for einkorn, emmer and broomcorn millet (group B) due to their strong association with summer annuals and species indicative of high nitrogen levels. Barley (group A), on the other hand, had a strong association with winter annuals and species indicative of medium-low nitrogen availability suggesting that manuring and weeding was not practiced on a regular basis on the crop.

Field location

The choice of cultivation scale and intensity will also depend on the location of the settlement in relation to the fields. For example, research has shown that the most intensively cultivated plots are usually those located closest to the village (within 500m), while extensive cultivation is performed further afield[186]. At Feudvar, the location of the settlement would have allowed both intensive and extensive regimes to be practiced on the plateau. It is likely that the more intensively cultivated crops, such as einkorn, emmer and broomcorn millet, were cultivated closer to the settlement on the plateau, while barley could have been cultivated at greater distances from the site (whether further along the plateau or to the west of the site).

179 Hänsel and Medović 1991.
180 Gerasimov and Glazovskaya 1965.
181 Dent et al. 2011.
182 Rowley-Conwy 1981; Reynolds 1992.
183 Rösch 1996.
184 e.g. Dennell 1978, 148; Willerding 1988.
185 Rösch 1996.
186 Jones et al. 1999; Bogaard et al. 2011.

Harvesting
The arable weeds also give information about harvesting methods. For example, the proportion of seeds from tall and short weeds in the harvested crop will vary according to the height at which the sickle cuts the straw or if the preferred harvesting method involves plucking the ears singly[187]. Typically, the presence of low growing species in cereals is used to infer harvesting low down on the culm, while the presence of seeds of free-standing, non-twining species indicates sickle harvesting[188]. Ethnographic work by Ibáñez et al. suggest that in areas with long dry summers harvesting was able to be conducted at a slower pace, so alternative methods of harvesting such as ear plucking or uprooting could be conducted[189]. The use of the sickle was therefore suggested as a means to allow the development of a quick system of crop collecting.

At Feudvar, low growing species such as *Sherardia arvensis*, *Trifolium* and *Bupleurum rotundifolium* were found in the majority of samples suggesting that the cereals were cut low on the culm. This would mean that the straw, as well as the cereal grains were collected at the site. Ethnographic research in Spain has identified that einkorn straw is used mainly for crafts and thatching, while emmer straw is mainly used for animal bedding. Straw could also be used for fodder but only if there was no other food source[190]. The recovery of sickles at Feudvar would also suggest that they were used for harvesting cereals at the site[191].

3.6 Conclusion

The analysis of weed ecology was conducted on three groups of samples, unsieved spikelets, unsieved fine sieving by-products and unsieved products, identified in chapter 2.5. Nine different analyses were conducted for each group analysing the ecological and anthropogenic requirements of each weed species. The correspondence analyses showed that all three assemblages presented the same results regardless of crop processing stage. Overall, the ecological indicator values suggest that the species had plenty of light and grew in a mild climate (not too hot or cold) on well drained and slightly alkali soil. The anthropogenic factors suggest that the crops were grown on disturbed ground, were sown in autumn and were harvested low to the ground, so that both the straw and grain could be collected. In addition, two distinct groups of species, with different ecological requirements, were identified:

- Group A, which includes barley and is characterised by species indicative of low levels of nitrogen and by winter annuals.
- Group B, which includes einkorn, emmer, spelt, bread / durum wheat and broomcorn millet and is characterised by species indicative of higher levels of nitrogen and by summer annuals.

The differences between these two groups of species are likely the result of two different crop processing regimes practiced (i.e. differences in intensity and scale) at the site, where barley (group A) was cultivated under a more extensive regime, while einkorn, emmer and broomcorn millet (group B) was cultivated more intensively. These results support Kroll, who initially suggested that an increase in the presence of summer annuals within einkorn samples in the course of time at Feudvar, resulted not from a change in sowing time, but a change in cultivation methods from large scale extensive to small scale intensive cultivation[192]. These results will be discussed further in chapter 9, in relation to the archaeobotanical evidence from the whole of the Carpathian Basin.

187 Hillman 1981.
188 Stevens 2003.
189 Ibáñez et al. 2009.
190 Peña-Chocarro 1999, 44.
191 Hänsel und Medović 1998.
192 Kroll 1979.

4. Summery and conclusion: Crop husbandry strategies at Bronze Age Feudvar

The dataset from Feudvar, collected by Helmut Kroll, Kiel, consisted of 524 samples collected from the 1986 western trench excavations. From this, 593,315 carbonised plant remains were identified, including 263,780 *Chenopodium polyspermum* seeds recovered from one context. A total of thirteen different crop plants were found at Feudvar: both one grained and two grained einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*)[193], spelt (*Triticum spelta*), bread / durum wheat (*Triticum aestivum / durum*), barley (*Hordeum vulgare*), broomcorn millet (*Panicum miliaceum*), broad bean (*Vicia broad*), bitter vetch (*Vicia ervilia*), grass pea (*Lathyrus sativus*), lentil (*Lens culinaris*), pea (*Pisum sativum*), flax (*Linum usitatissimum*), and gold-of-pleasure (*Camelina sativa*). Rye was also tentatively identified at the site (so called rye, cf. *Secale*[194]). In addition, a range of wild fruits and other wild / weed species were identified. The identification of a number of species, such as the large deposit of *Chenopodium polyspermum*, indicates the deliberate collection of wild species for food, medicines and building materials alongside the cultivation of crops.

The high seed densities per litre (average 20 seeds per litre) as well as the large quantities of grain, chaff and wild / weed seeds also facilitated further statistical analyses. To explore crop processing at the site, ratio analysis was conducted on the dataset and correspondence analysis was used to further corroborated and clarify the identifications. From this, six different processing stages were identified: sieved and unsieved spikelets, sieved and unsieved fine sieving residue and sieved and unsieved products. The identification of crop processing at Feudvar provides evidence of human behaviour in relation to post harvesting activities as well as formation processes at the settlement. The distinction between sieved and unsieved crop remains shows a clear choice by farmers to either process everything before storage or only partially process the crops with the intention of later processing them piecemeal within the household. These choices would have been based on a number of factors, such as time, labour availability and weather conditions, as well as the intended purpose of the crop.

Spatial analysis within the trench also suggested possible differences in activity areas associated with different households. Of particular note was the high incidence of unsieved remains within the centre of two of the northern houses, a high association of millet grains within pit features and the high presence of barley remains at the southern end of the trench. The significance of these patterns are at present unclear and will need to be examined further when the distribution patterns of other archaeological data becomes available for the site.

The presence of such rich samples allowed the detailed analysis of conditions in the fields and the reconstruction of how the crops were grown and treated. Samples identified as unsieved, spikelets, fine sieving by-products and products were therefore examined using the autecological approach to analyse the ecological characteristics of the weed species present within the samples. From the weed species recovered from Feudvar, the overall picture shows that the environment within which the crops grew had plenty of light, grew in a mild climate (not too hot or cold) on well drained, slightly alkali soil with an overall medium nitrogen value. The anthropogenic factors analysed suggest that the crops were harvested low to the ground and grew on heavily disturbed soil.

The correspondence analysis also highlighted differences between the crops. Barley generally plotting separately and had a higher number of associated weeds compared to einkorn, emmer, spelt, bread / durum wheat and millet. A number of patterns were also observed. First, a slight increase in moisture content of samples near emmer was observed from the unsieved products. Second, einkorn and emmer showed a greater association with high nitrogen weed species in all three groups of samples. Third, barley had a greater association with winter annuals. The differences between the two groups may therefore suggest differences in crop husbandry regimes and thus differences in labour investment (i.e. intensity) and scale. Barley had a more extensive regime (large scale and low labour input), while einkorn and emmer may have been more intensively gardened (small scale and high labour input regime), where additional practices of manuring and weeding occurred.

193 The presence of sanduri (*Triticum timopheevii*) is a later discovery, not mentioned in the sample papers [Kroll].

194 This so called rye is the weed Dasypyrum villosum [Kroll].

5. Appendix

FEU no. [Reed]	Planum	Abstich - Cut	W no. [Kroll]	BP	Tiefe - depth	Koor
FEU005	7		1179		123,19-123,09	CP110
FEU006	7		1182	112	123,19-123,09	CN114
FEU009	7		1185	122	123,26-123,16	CM117
FEU013	7		1190	160	123,26-123,16	CK112
FEU017	7		1195	146	123,14-123,04	CL111
FEU018	7		1196	148	123,22-123,12	CH 116
FEU019	7		1196	147	123,14-123,04	CJ110
FEU021	7		1199	109	123,22-123,12	CH114
FEU023	7		1201	162	123,42-123,27	CH119
FEU029	7		1265	182	123,27-123,17	CB-CC112-113
FEU030	7		1266	193	123,25-123,15	CB-CC
FEU034	7		1273	192	123,32-123,22	BZ-CA118-119
FEU035	7		1274	194	123,32-123,22	CA118-119
FEU037	7		1284	210	123,38-123,28	BX-BY114-115
FEU041	7		1406	264	123,52-123,42	BN-BO114-115
FEU042	7		1408	270	123,69-123,59	BN-BO112-113
FEU043	7		1409	258	123,72-123,62	BN-BO110-111
FEU046	7		1414	272	123,55-123,45	BL118
FEU047	7		1914	251	123,55-123,45	BM118
FEU049	7		1421/A	260	123,49-123,39	BF-BJ110-113
FEU050	7	2	1421/B	262	123,39-125,29	BF-BJ110-113
FEU053	8		1336	267	122,99-122,89	CK-CL117-118
FEU056	8		1377	250	123,15-123,05	CF-CG112-113
FEU057	8		1378	249	123,08-122,98	CF-CG110-111
FEU065	8		3626	755	123,36	CT113
FEU068	8		1339/14	243		CL113
FEU070	8		1339/6	237	123,19-123,09	CO113
FEU074	8		1401/14	293	123,58-123,48	BU116-117
FEU079	8		1401/39	294	123,49-123,39	BN118
FEU083	8		1403	284	123,64-123,54	BS112
FEU084	8		1403/1	306	123,51-123,41	BY114
FEU085	8		1403/1	298	123,47-123,37	BV-BW114
FEU086	8		1403/2	299	123,46-123,3?	BY112
FEU091	8		1403/43	285	123,60-123,50	BR111
FEU092	8		1403/51	295	123,64-123,54	BP112
FEU094	8		1403/8	303	123,51-123,41	BX113
FEU095	8		1403/9	296	123,31-123,21	BX112
FEU128	9	2	2051		123,44	BQ112
FEU133	9	2	2054	402	123,52-123,39	BM112
FEU135	9	2	2075	402/a	123,27-123,12	BL117
FEU136	9	2	2076	400	123,36-123,26	BK-BL116-117
FEU138	9	2	2078	408	123,27-123,15	BL119
FEU164	9	3	2233	501	123,30-123,20	BL-BM116-117
FEU165	9		2234	515	123,19-123,13	BJ-BK116
FEU182	9		2010/2	367	123,41	BM117 25/80
FEU184	9		2010/8		123,50	BO117
FEU190	9		2015/3	365	123,46	BP-BQ112
FEU199	9	2	2052/7	446	123,37	BX-BY112-115
FEU203	9		2056/2	397	123,48-123,33	BL111
FEU205	9	2	2056/6	411	123,37	BO112
FEU206	9	2	2056/6	410	123,37	BO112
FEU207	9	2	2056/7	419	123,35-123,32	BN-BO111-112
FEU208	9	2	2073/1	412	123,35	BN-BM115
FEU209	9	2	2073/2	409	123,23	BL116
FEU210	9	2	2073/2	404	123,37	BL116/10/90
FEU211	9	2	2074/1	405	123,16	BK118 20/30
FEU217	9	2	2096/13	431	123,20-123,18	BY117
FEU219	9	2	2096/14		123,30-123,36	BY116-117
FEU220	9	2	2096/2	416	123,44-123,30	BP115
FEU233	10		2040	375	122,95-122,78	CM-CO114-115

Bronze Age Feudvar. FEU numbers [Reed] and their corresponding sample details [Kroll].

Unique sample no. FEU numbers [Reed]	Planum	Abstich - Cut	NR Sample details [Kroll]	BP	Tiefe - depth	Koor
FEU237	10		2045	373	122,94-122,86	CF-CG
FEU244	10	1	2062	458	123,03-122,95	BZ119
FEU257	10	2	2197	488		
FEU262	10	2	2198	481	122,95-122,88	CL-CM111
FEU279	10		2004/2	519	122,65	CL-CM119
FEU296	11		3015	529	122,82	CN113
FEU316	11		3066			CE-CG114-115
FEU324	11	2	3110	578	122,59	CJ-CL111-113
FEU327	11		3117	574	123,09	BW-BX118-119
FEU328	11		3118	577	123,27	BV118-119
FEU329	11		3118		123,29	BV-BX118-119
FEU330	11		3118	581	123,29	BV-BX118-119
FEU342	11		3143		123,19	BN-BO115-116
FEU346	11		3148	603	123,12	BJ-BK114-117
FEU350	11		3152	595	123,18	BW-BX117-118
FEU353	11		3171	627	123,21	BN-BO113-115
FEU373	11	2	3226	615	123,19	BQ119
FEU385	11	2	3266	640		BT-BU112-113
FEU395	11	2	3287	671	123,64	BS116
FEU396	11	2	3287			BS117
FEU402	11	2	3298	649	123,79	CP-CS113-114
FEU403	11	2	3311	650	123,12	BP-BQ110-112
FEU407	11	2	3320	660	123,11	BO-BP118-119
FEU408	11	2	3322	659	123,12	BK-BM118-119
FEU409	11	2	3340	667	122,96	BK-BM110-111
FEU425	11	2	3604	760	122,66	CL-CD111-113
FEU435	11	2	3590/2	763	122,58	CA-CB110-112
FEU439	12		3039	539	122,76	CM112
FEU441	12		3360	671	123,09	BY116-118
FEU446	12		3365	715	122,81	BX-BY112-113
FEU461	12		3393	679	122,93	BS116-117
FEU468	12		3412	710	123,87	BG-BH117-118
FEU477	12		3486	719	122,88	BT-BU116-117
FEU478	12		3487	718	123,01	BT-BU118-119
FEU483	12		3513	730	122,?	BS-BT15-116
FEU485	12		3537	737		BO111-113
FEU487	12		3574	745	122,90	BR-BS114-115
FEU497	12		3446/2	698	123,00	BQ-BR118-119

Bronze Age Feudvar. FEU numbers [Reed] and their corresponding sample details [Kroll].

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Würzburger Studien zur Vor- und Frühgeschichtlichen Archäologie

Die Editionsreihe Feudvar – Ausgrabungen und Forschungen in einer Mikroregion am Zusammenfluss von Donau und Theiß ist der Bearbeitung und Auswertung eines archäologischen Feldforschungsprojektes gewidmet, das von 1986 bis 1993 im heutigen Serbien durchgeführt wurde. Im Mittelpunkt der Forschungen steht die bronze- und eisenzeitliche Burgsiedlung Feudvar auf dem Titeler Lössplateau. Die Ausgrabungen lieferten den bis heute umfangreichsten Pool an metallzeitlichen Pflanzenfunden in Südosteuropa. Der vorliegende Band III umfasst zwei unabhängig durchgeführte Studien zur Archäobotanik von Helmut Kroll und Kelly Reed. Die Analysen liefern vielfältige Informationen zu Anbautechniken, Ernährung und Pflanzennutzung im Donau-Theiß-Gebiet mit einem Schwerpunkt im zweiten Jahrtausend vor Christus.

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