Correspondence analyses of archaeobotanical data:

An investigation of seasonal sowing patterns

Mark McKerracher

Introduction and Methodology

The FeedSax monograph (Hamerow *et al.* forthcoming) includes a lengthy discussion about seasonal sowing, which cites a series of correspondence analyses of archaeobotanical data, aimed at identifying relationships between particular cereals and arable weeds advantaged by different sowing seasons. The purpose of this document is to provide fuller details about each of these correspondence analyses on a site-by-site basis, and thereby help the reader to understand how the results were attained and, if desired, to reproduce the analyses.

The rationale for the analyses presented here is detailed in the monograph. In brief, correspondence analysis is a multivariate statistical technique which can be used to explore associations between archaeobotanical samples and the cereal and weed species which occur in them, based upon the presence and abundance of grains/seeds in a selected set of samples. The results are illustrated as two complementary scatterplots, showing samples and species respectively; samples which are closer together are more similar in composition, while species which are closer together are more likely to co-occur in the same samples, and *vice versa*. The closer a sample/species is to the origin (centre) of the plot, the more average their composition/distribution; distance from the origin increases as a sample/species deviates from the norm. We can thus explore seasonal associations between crops and weeds, by taking the scatterplots for species and coding them by cereal type (wheat, barley, oat or rye) and, for the weeds, association with sowing seasons (if any). An idealised example of how to interpret these results is provided in the monograph.

Weed species classifications were based upon the methodology of Bogaard *et al.* (2001), who found – from modern field surveys in Germany – that seasonality corresponded best with functional attributes relating to flowering onset and duration. In brief, weed species with early or short flowering periods enjoyed a competitive advantage in autumn-sown fields, while those with late or long flowering periods had an advantage in spring-sown fields (but could also occur in autumn-sown fields) (Bogaard *et al.* 2001). Species with an intermediate flowering period were equally associated with both sowing seasons.

For the species included in the FeedSax correspondence analyses, flowering onset and duration data were obtained from the *Ecoflora* database (Fitter and Peat 1994) and the Botanical Society of Britain and Ireland's *Online Atlas of the British and Irish Flora*.[1] Species for which data were ambiguous, or could not be obtained, have been classified along with the intermediate taxa as 'other'. Those with early/short flowering periods have been dubbed 'autumn-associated', and those with late or long flowering periods have been collectively dubbed 'spring-associated', in the correspondence analyses.

[1] http://ecoflora.org.uk; https://plantatlas.brc.ac.uk (accessed July 2022).

A key difference between the analyses presented in this report and those previously published by McKerracher (2019) and Hamerow *et al.* (2020) is that perennials have here been treated in the same way as annuals (i.e. classified according to their flowering onset and duration), whereas in the earlier studies they were classified as 'other' – unless they are capable of regenerating from vegetative fragments, in which case they were classed as 'spring-associated'. The decision to treat them in the same way as annuals, with classifications according to flowering habit, was based on a reconsideration of the methodology of Bogaard *et al.* (2001). The case study of Stafford has been subject to both approaches, and the inclusion of perennials in this way (as below) has not changed the overall picture previously discerned (Hamerow *et al.* 2020); indeed, the impression of seasonal sowing associations has been reinforced.

Sites were selected for inclusion in this study if their overall assemblage of charred plant remains (i.e. including all Anglo-Saxon and medieval phases) contained at least ten samples and at least ten weed seeds. In addition, some sites with fewer than ten qualifying samples (such as Coton Park, Houghton and Ottery St Mary) were included because they were FeedSax case study sites or to improve the geographical spread of the study.

The sites thus selected are mapped in Figure 1 and listed in Table 1. The map numbers in this report (and in the corresponding passages of the monograph) have been assigned to the sites simply based on alphabetical order, as a convenient reference device. Table 1 also displays each site's unique site ID in the Haystack database (`site.ID`). This unique identification number can be used to query the database and so retrieve additional information such as: a site's full name(s), its coordinates, and bibliographical references for the excavation and archaeobotanical analyses.[2]

In two cases, different sites in relatively close proximity (and with similar surrounding environments) have been combined for the purposes of this study, to produce larger datasets better suited to quantitative analysis: thus Holmer with Wellington Quarry, and Ingleborough with Walpole St Andrew. In other cases, some individual 'sites' are effectively composites of closely adjacent excavations, within a single settlement or parish: thus Stafford, Ely, Ottery St Mary, Ipswich, Shapwick and Wharram Percy. Lydford granary (Devon) is included in this report despite the fact that its archaeobotanical dataset is unsuitable for correspondence analysis, because of a lack of fully quantified data. Lydford has nonetheless been included as a rare and important assemblage in the south-west – providing, in particular, a comparison for Ottery St Mary.

Correspondence analyses were performed, and scatterplots created, using Canoco 5.0 (ter Braak and Šmilauer 2012). Data were imported from Microsoft Excel spreadsheets, noting that species are arranged in rows and samples in columns, and a Unimodal CA (DCA) was run with *no* transformation applied to species data (i.e. removing the default log transform). These input data are included in Digital Archive Document B11, an Excel workbook with a worksheet for each site. The discussions below specify which worksheet is being used. The column names represent the unique sample IDs from Haystack (`sample.ID`), and can be used to query the database to retrieve additional information

[2] For example, for Bishopstone (site ID 28): `SELECT site.ID, site.name, site.longName, site.eastings, site.northings, site.referenceMain FROM site WHERE site.ID = 28;`

And to find details of the archaeobotanical work done on the assemblage: `SELECT worker.name AS 'worker', event.reference AS 'assemblage reference' FROM event INNER JOIN worker ON event.workerID = worker.ID WHERE event.eventTypeID = 1 AND event.siteID = 28;`

such as the original sample name, parent context, phase, feature type, etc. The row names are arbitrary, abbreviated codes for the taxa present in each dataset, for instance `avegra` for *Avena* grain, or `antcot` for *Anthemis cotula*. The first worksheet in Archive Document B11 provides a glossary of these abbreviations.

The values in each worksheet represent the numbers of grains, seeds, achenes, or equivalent propagules belonging to a given taxon in a given sample. No other plant parts, such as rachis segments or glume bases (i.e. chaff), have been included, because in the majority of cases these parts are comparatively rare and ultimately likely to be filtered out as unrepresentative 'noise'. Restricting the analyses to grains and seeds also ensures a certain comparability between analyses, as these parts are predominant in all assemblages. An inclusive approach was taken when selecting taxa, meaning that qualifiers like 'cf.' and 'type' were overlooked; for instance, *Anthemis cotula* identifications were combined with *Anthemis* cf. *cotula* identifications. This is a compromise approach, reducing critical rigour but maximising usable data; removing such 'qualified' identifications would be an equally valid approach, but it is not pursued in this report.

Wild taxa were excluded if considered implausible as arable weeds: for instance, aquatic species, or woody perennials unlikely to set seed under arable conditions; such classifications are detailed in the plant taxon metadata (Digital Archive Document B12). Of the remaining taxa, family- and genus-level identifications were excluded (unless amalgamated with a species-level identification: see Digital Archive Document B07 for discussion of amalgamations) because little meaningful ecological data can be attached to them. Ambiguous species identifications – such as *Alchemilla vulgaris/Aphanes arvensis* – have similarly been excluded unless the constituent species can be assigned the same 'seasonality' classification: thus, for instance, *Bromus hordeaceus/secalinus*.

All crops except free-threshing cereals were excluded because this study aims only to investigate the cultivation of free-threshing cereals. Hence, only five cereal taxa were included: barley (*Hordeum* L.), oats (*Avena* L.), rye (*Secale cereale* L.), free-threshing wheat (*Triticum* L. free-threshing type), and indeterminate wheat (*Triticum* L. indet.) – these latter two included individually, not combined, unless otherwise stated. It is here deemed most likely that indeterminate wheat grains in fact represent a free-threshing variety, since free-threshing wheats are more likely than hulled wheats to be rendered indeterminate by charring distortion, and because free-threshing types are overwhelmingly dominant in Anglo-Saxon and medieval English archaeobotany (Boardman and Jones 1990, 4–5; McKerracher 2019, 30). Ambiguous cereal classifications, such as '*Hordeum/Secale cereale*', were excluded even if they represented free-threshing types, because they can offer no insights into *specific* crop-weed associations, which is the purpose of this study.

Samples were included in these analyses only if they could be classified as 'charred' and 'dominated by free-threshing cereals', in the senses defined by McKerracher (2019), and with the same parameter values employed in that study: see Digital Archive Document B07 for full discussion of this subject. In addition, samples were only included if they contained at least ten items (cereal grains and weed seeds), and plant taxa were only included if present in at least three samples: these quora were applied to remove (1) samples so sparse as to prohibit meaningful quantitative study, and (2) species so rare as to skew the analyses (McKerracher 2019, 132: Parameters 10 and 11). These two criteria have been applied recursively, i.e. after removing samples with fewer than ten weed seeds, weed species were checked to ensure that they still occurred in at least three samples, and so on.

Unless otherwise stated, the results presented in this report include all qualifying samples, regardless of their phase or crop processing classification (e.g. fine-sieved product or by-product). Additional correspondence analyses restricted by phase or crop processing classification were explored, but are too numerous to present in full, and in most cases did not produce substantially different results. Such variations are only presented where they display patterns significantly different to those exhibited by the whole-assemblage analyses, e.g. the chronologically-restricted analysis at Higham Ferrers. Similarly, so as to reduce excessive clutter in this long report, not all sample scatterplots have been reproduced with coding by phase or crop processing classification, unless such coding provided interpretative insights.

Figure 1 - Distribution of sites selected for analysis. Regions are from (Rippon, Smart and Pears 2015).

Table 1 - Sites included in this study.

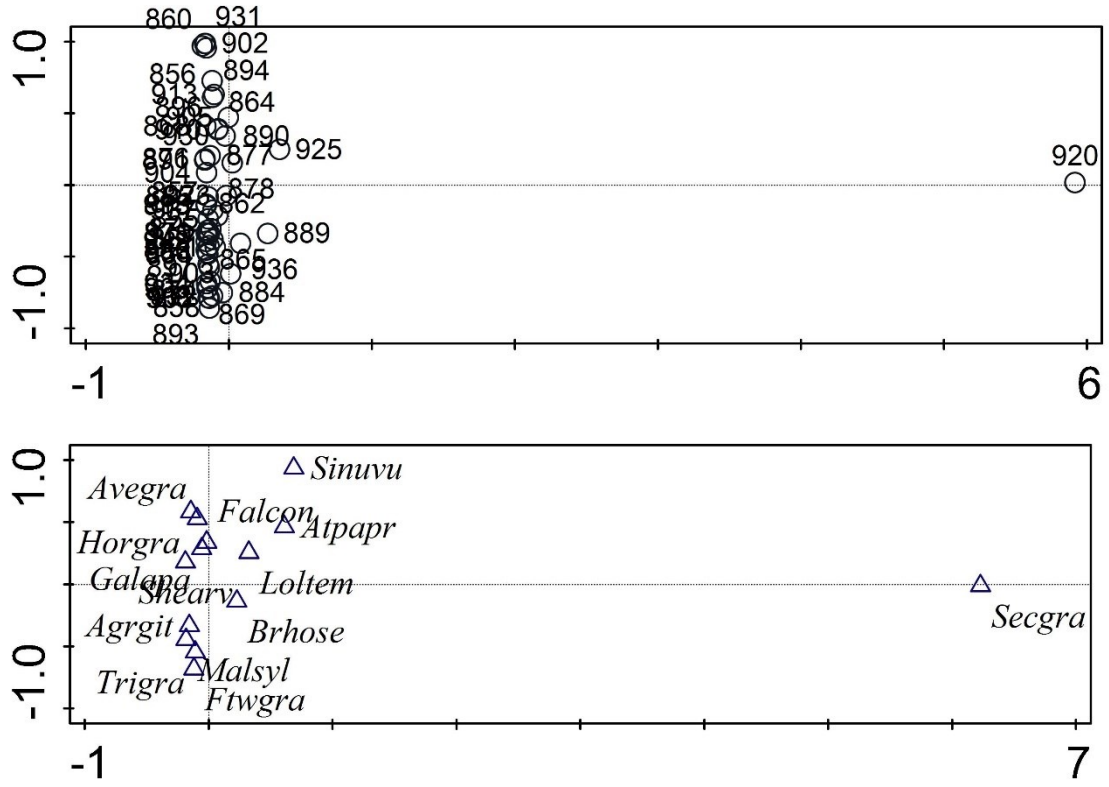
no.	site	haystack site ID
1	Bishopstone	28
2	Boreham	5
3	Botolph Bridge	10
4	Coton Park	734
5	Cottington Hill	671
6	Dorney	101, 172
7	Eckweek	11
8	Ely	3, 43, 656
9	Exwell Barton	556
10	Fishtoft	674
11	Gosberton	484, 485
12	Higham Ferrers	522
13	Holmer	735
14	Houghton	523
15	Ingleborough	482
16	Ipswich	46–67
17	Longstanton	34, 531
18	Lydd Quarry	186
19	Lydford	690
20	Lyminge	519
21	Mildenhall	727
22	Norwich Castle	681
23	Ottery St Mary	521, 555
24	Pudding Lane	520
25	Raunds	15–19
26	Rocester	700
27	Royal Opera House	678
28	Shapwick	23
29	Shorts Gardens	707
30	Springfield Lyons	8
31	Stafford	12, 14, 481
32	Stotfold	733
33	Stratton	502
34	Thanet Earth	742
35	Walpole St Andrew	464
36	Wellington Quarry	524
37	West of Kempston	662
38	Wharram Percy	125, 363
39	Yarnton	9

1. Bishopstone (East Sussex)

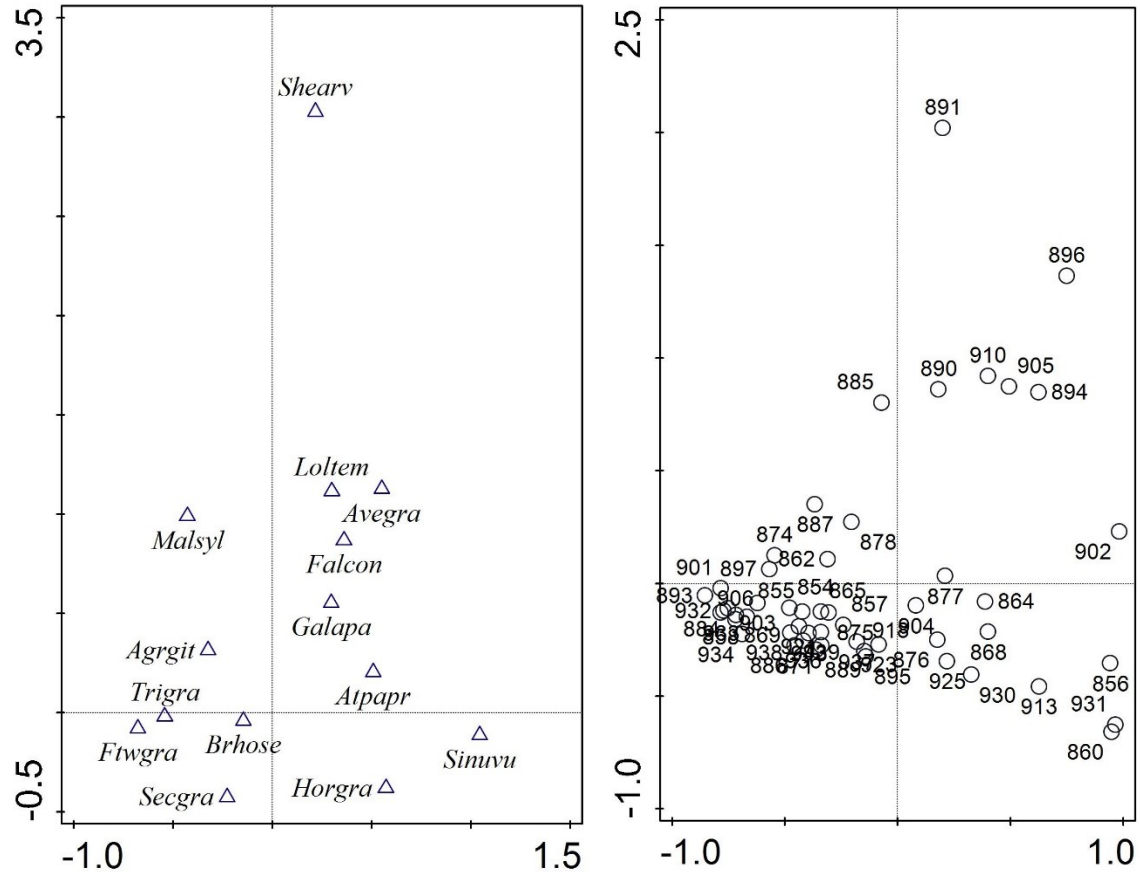
Worksheet: **01_bis**

Begin with 14 species in 52 samples.

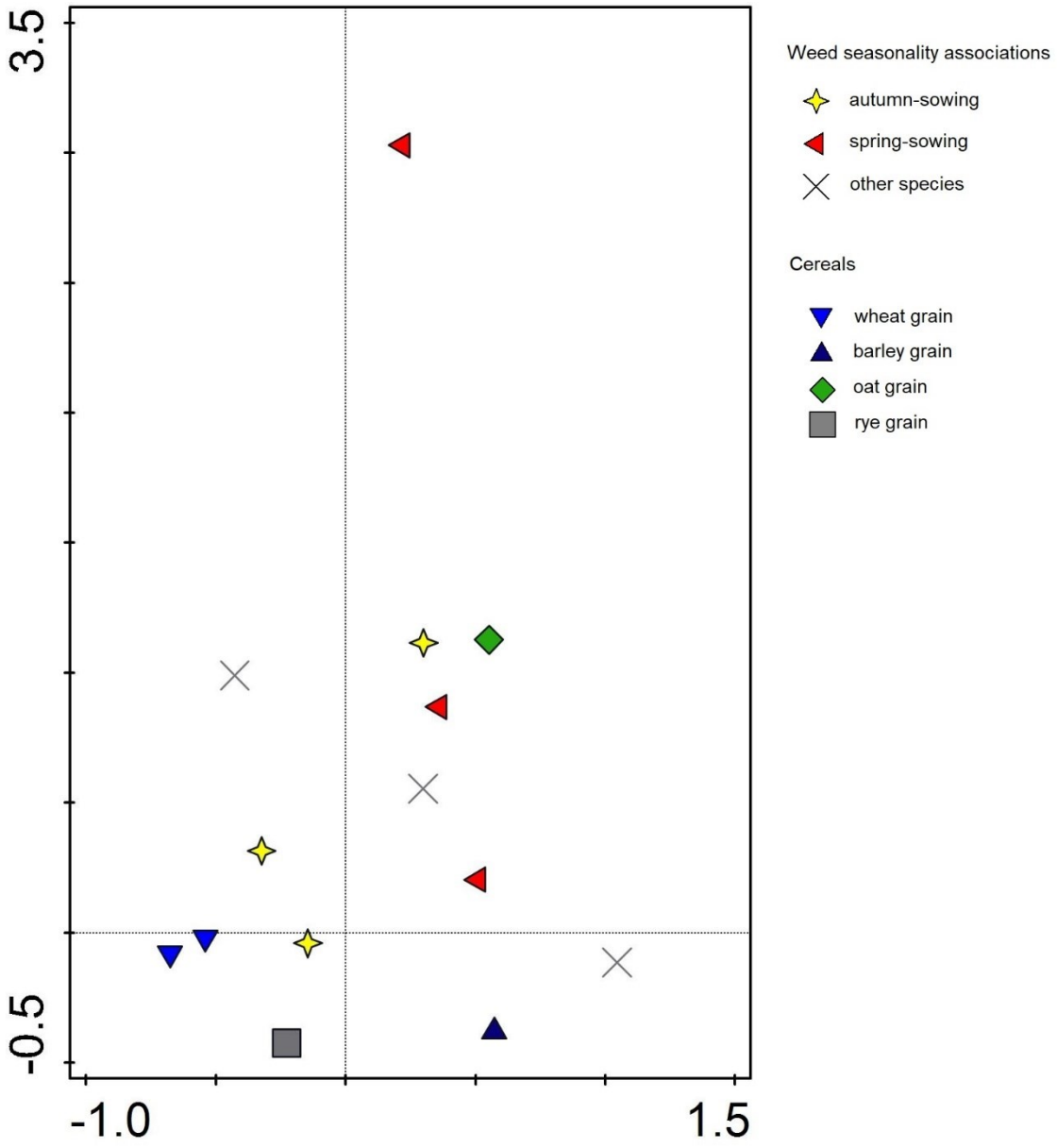
920 is an outlying sample, *Secgra* is an outlying species:



Delete 920 and re-run, to produce a clearer distribution:

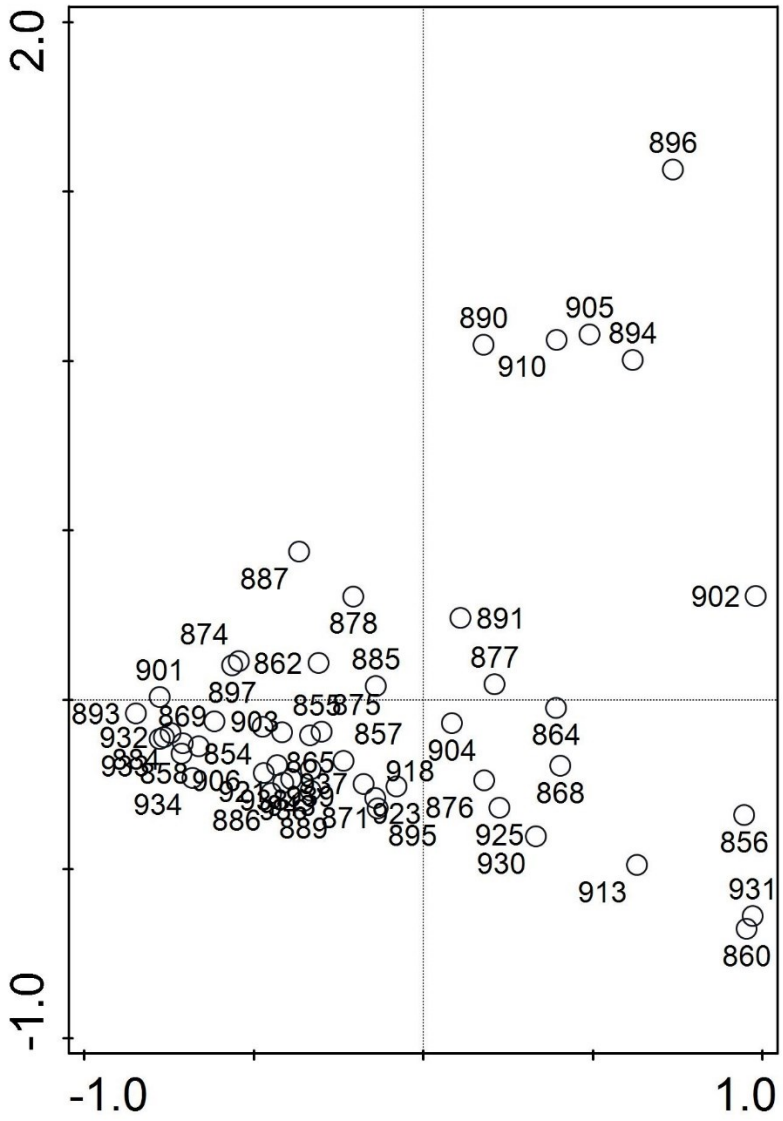


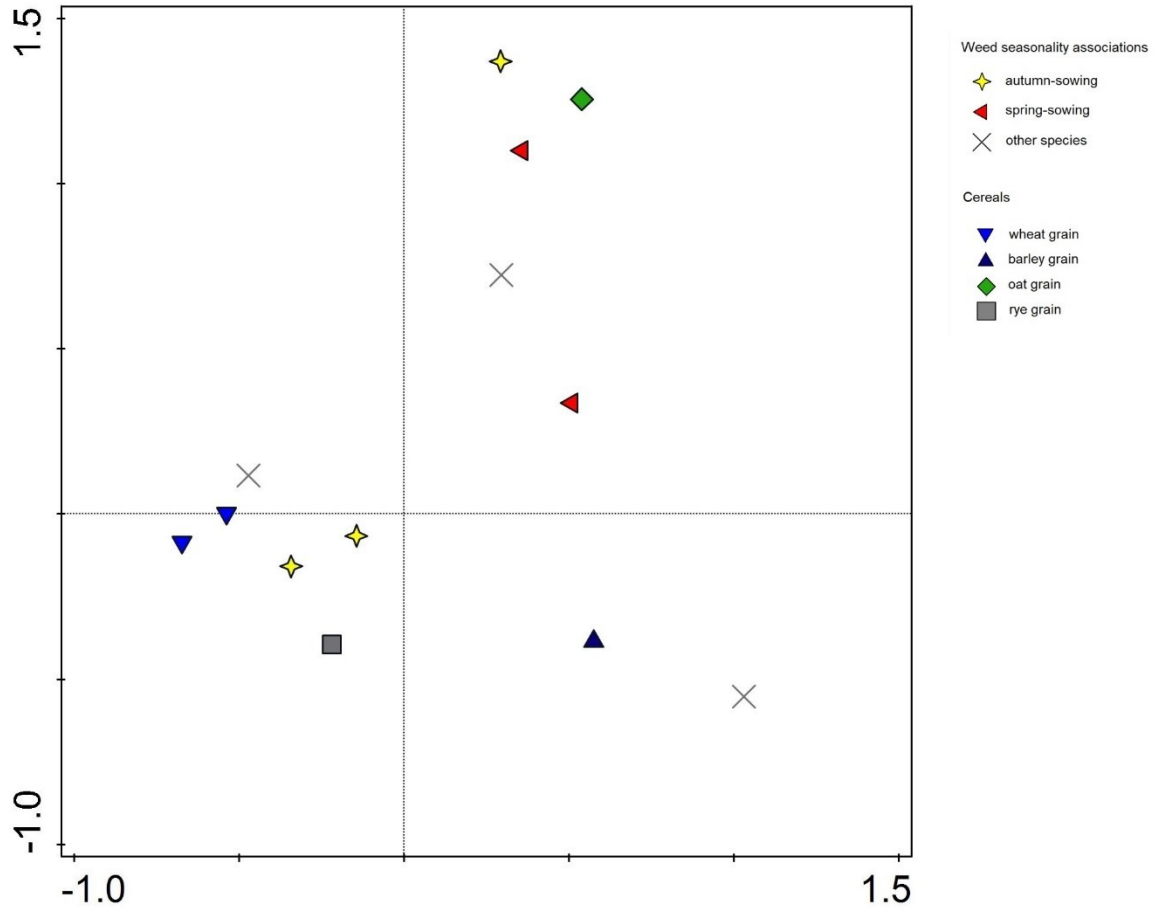
Code species by cereal type and seasonality to see an emergent trend, with wheat and rye more closely associated with ‘autumn’ weeds (to the left), and barley and oat more closely associated with ‘spring’ weeds (to the right):



Shearv remains something of an outlier.

Delete *Shearv* and re-run, to produce a similar distribution, still suggesting a correspondence between wheat, rye and autumn-associated weeds to the left, and barley, oats and spring-associated weeds to the right:



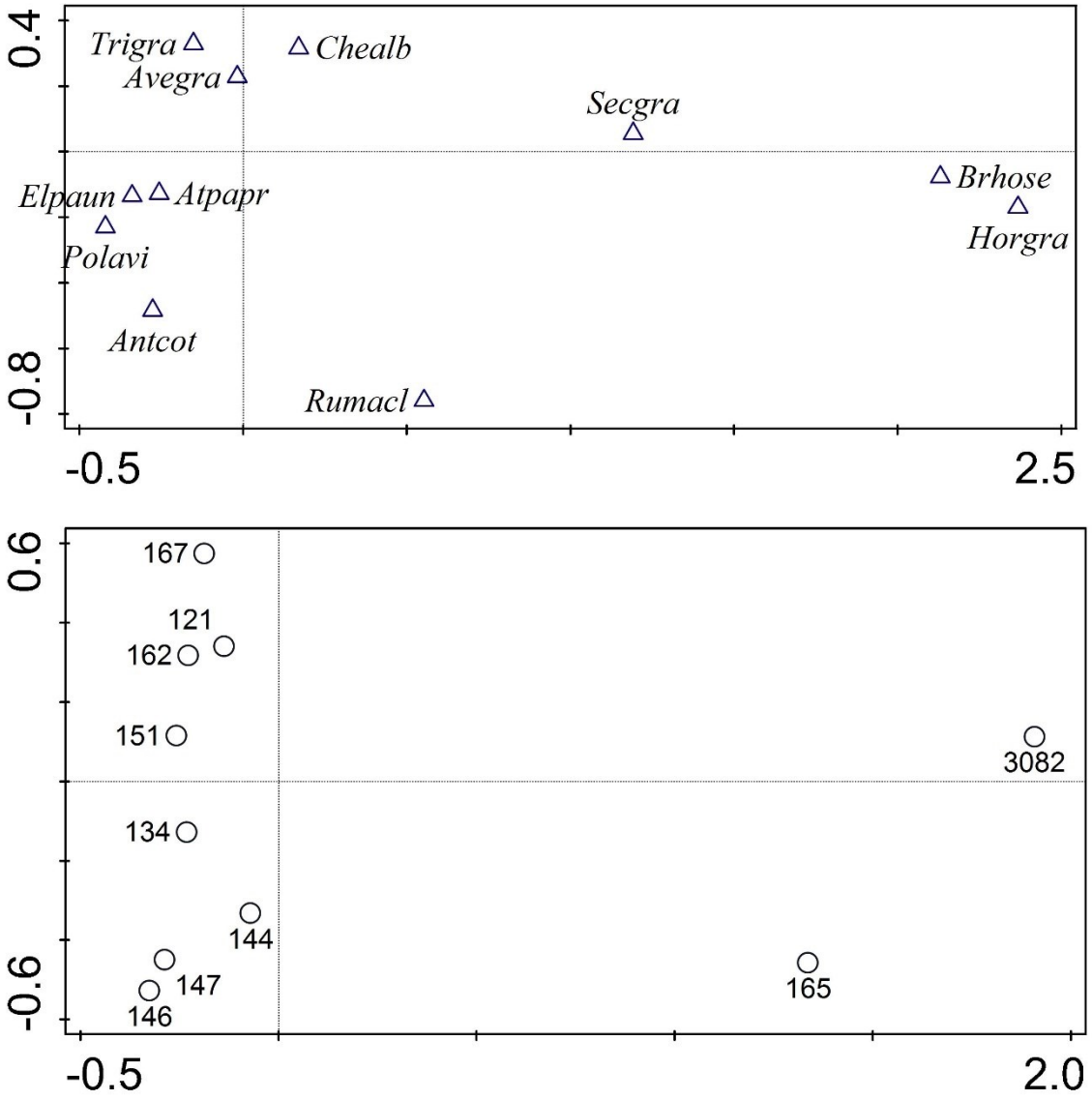

1.5
-1.0
-1.0
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

2. Boreham (Essex)

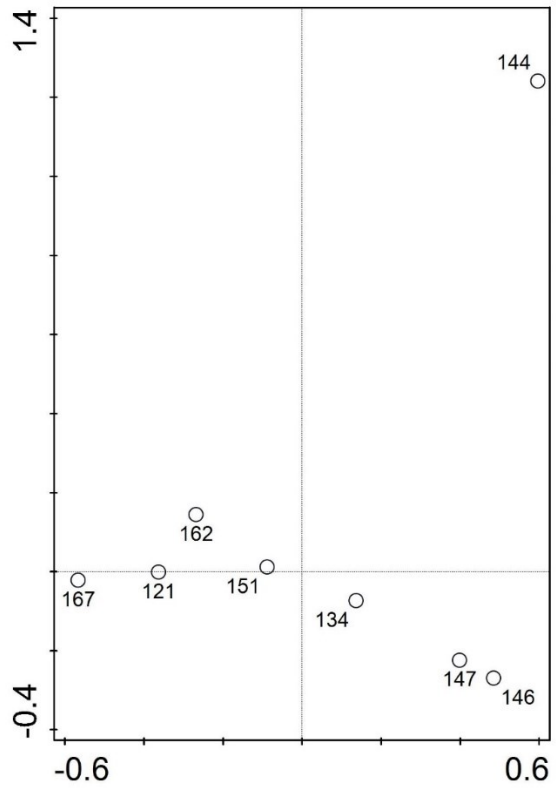
Worksheet: **02_bor**

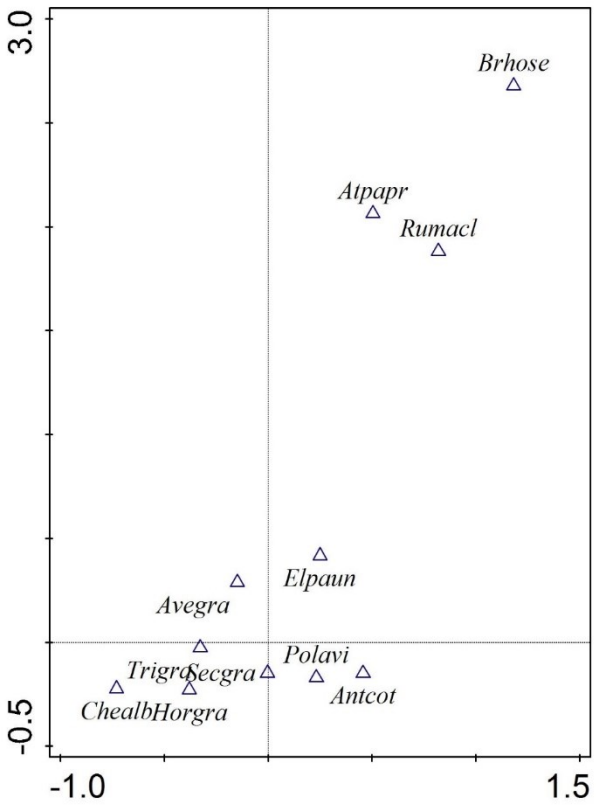
Begin with 11 species in ten samples.

The only autumn-associated weed is *Brhose*, which appears somewhat associated with *Horgra*, but that is mainly because of two outlying samples (165 and 3082):

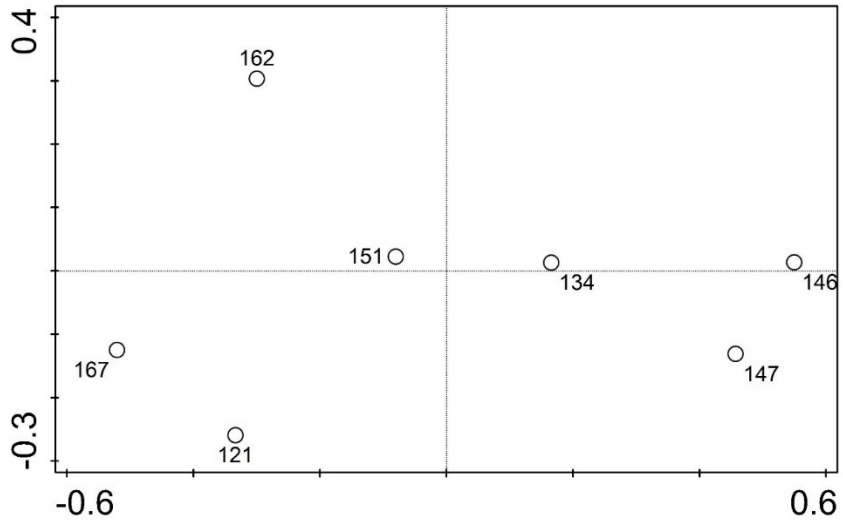


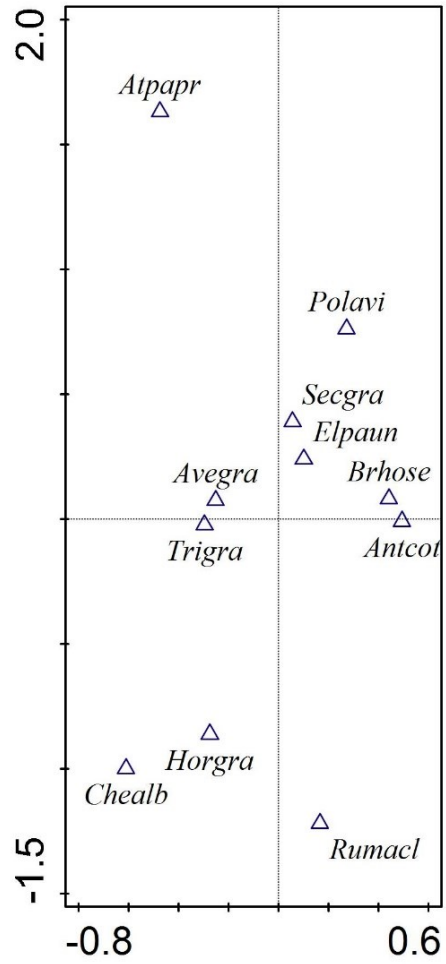
Now 144 is an outlier:

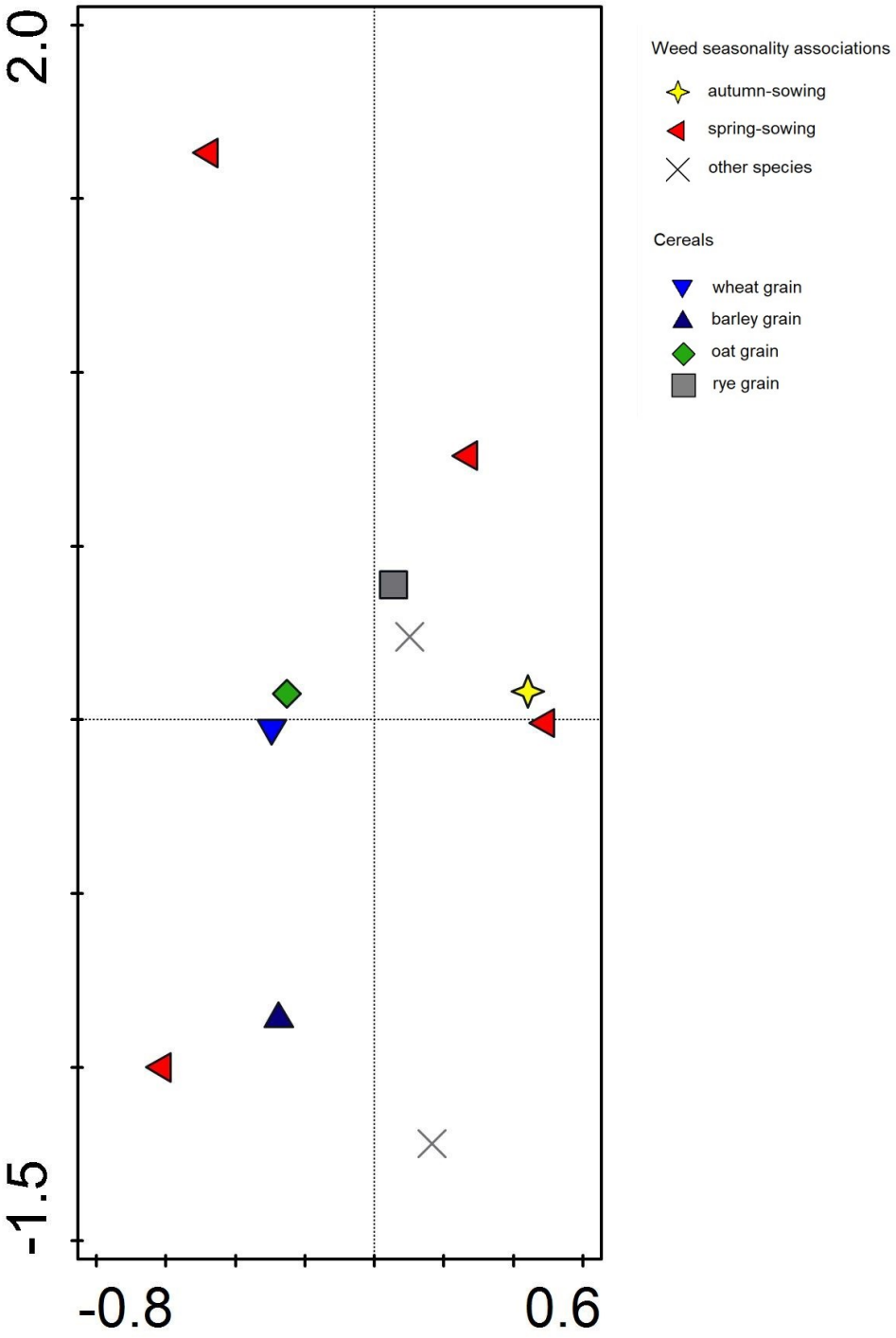




Delete 144. *Brhose* is now the only autumn-associated weed species and is present in only one sample. Hence there are no seasonal associations to be found, and the assemblage can be considered 'spring-dominated', as discussed in the monograph.



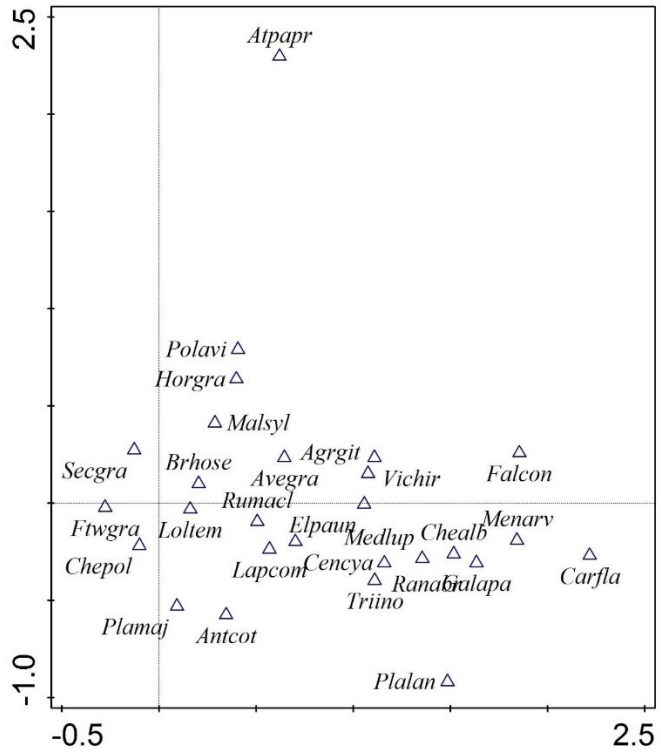


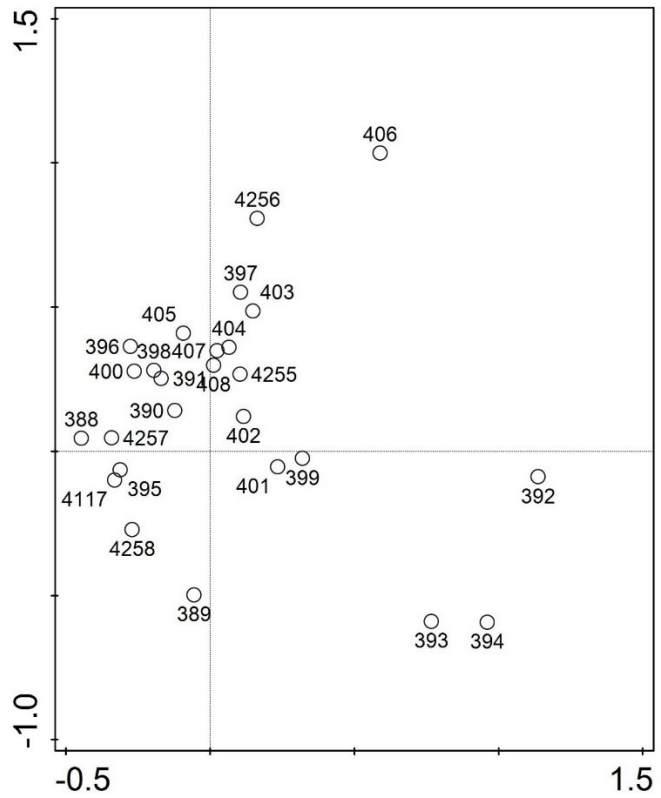

2.0
-1.5
-0.8
0.6
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

3. Botolph Bridge (Peterborough)

Worksheet: **03_bot**

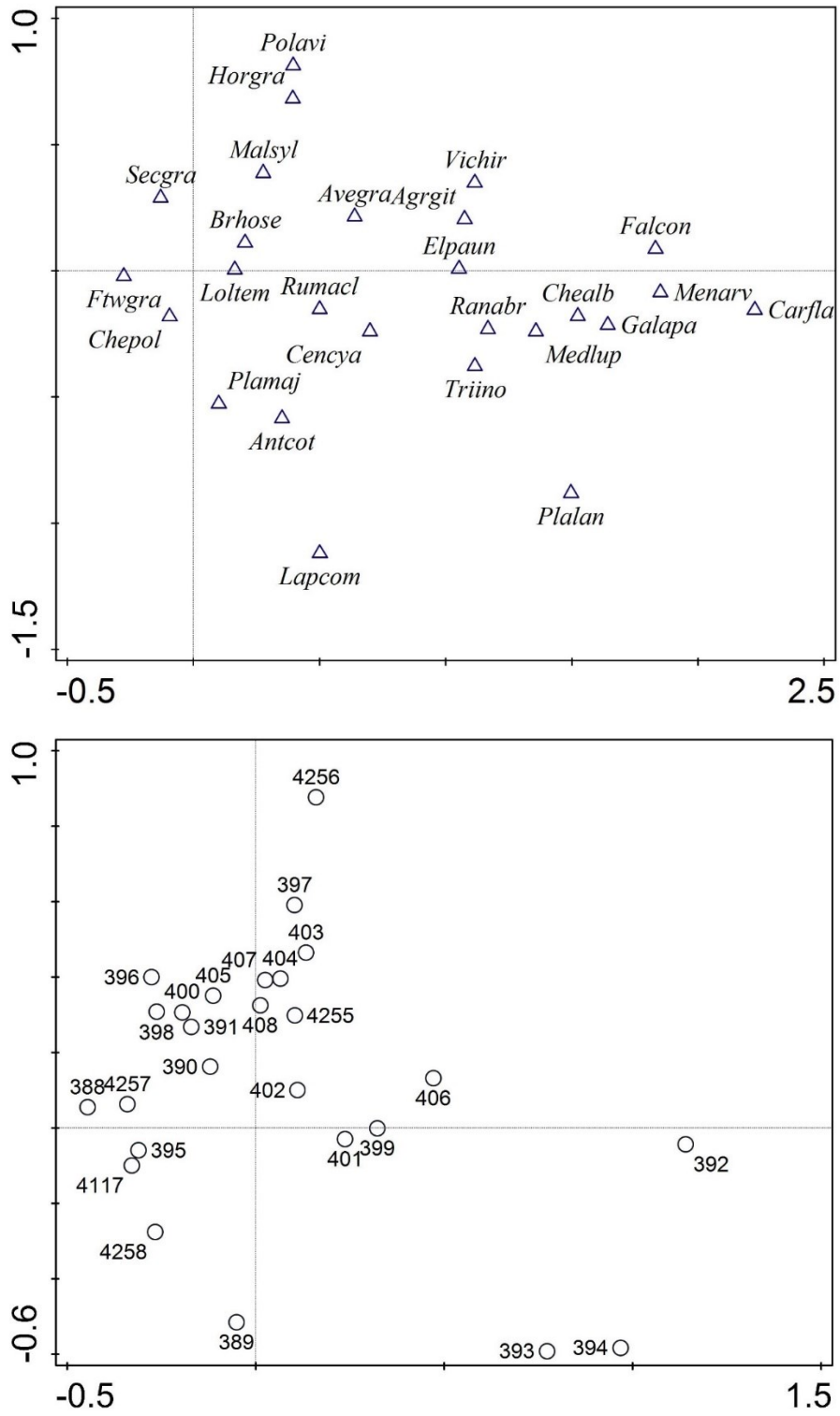
Begin with 27 species in 26 samples.

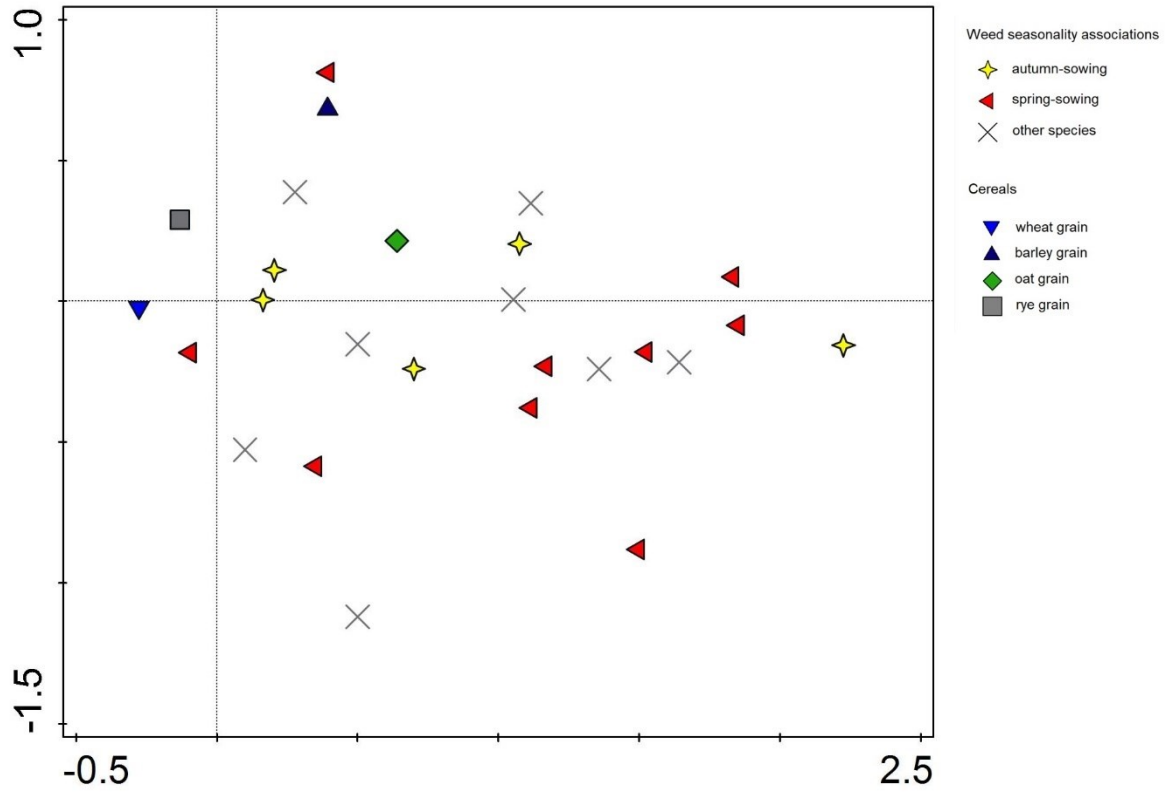




Delete outlier species *Atapapr* and re-run, to produce a clearer distribution.

No clear seasonal associations emerge. Both spring- and autumn-associated weeds are present, and intermingled in the correspondence analysis plot.

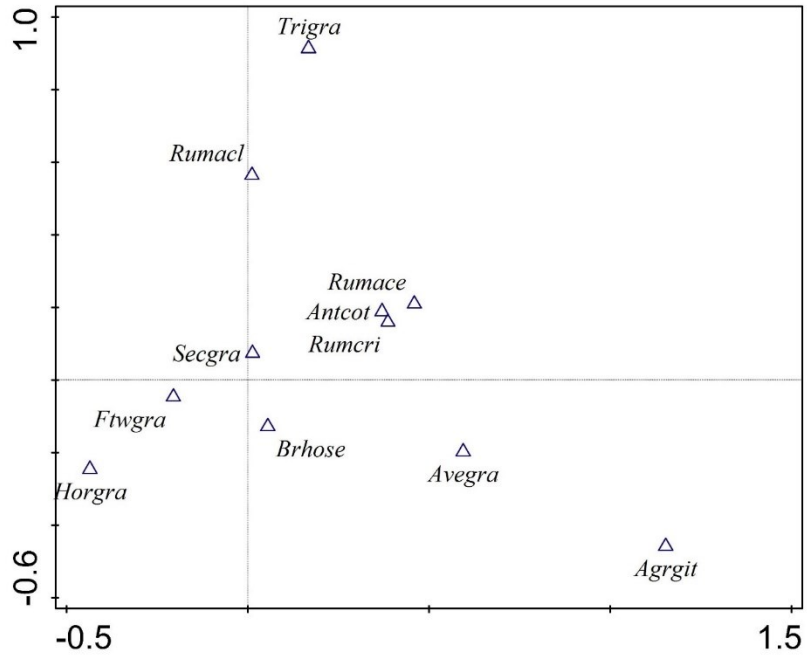


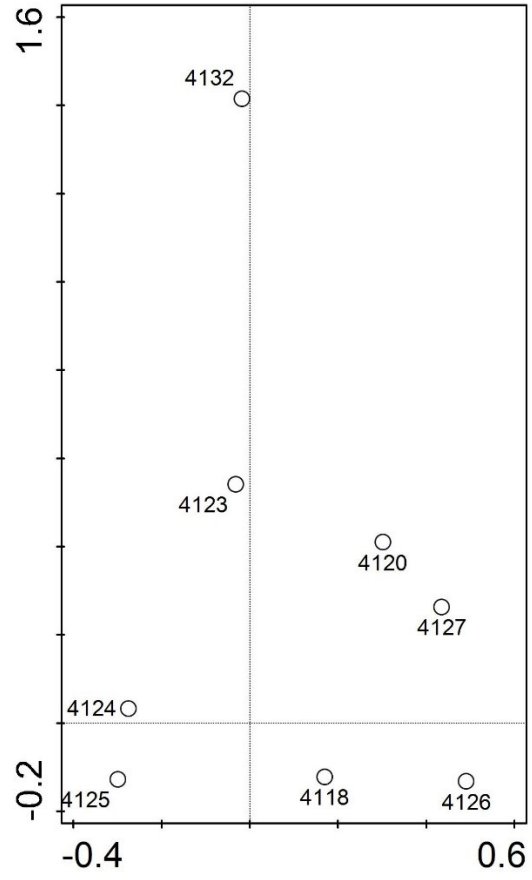

1.0
-1.5
-0.5
2.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

4. Coton Park, Rugby (Warwickshire)

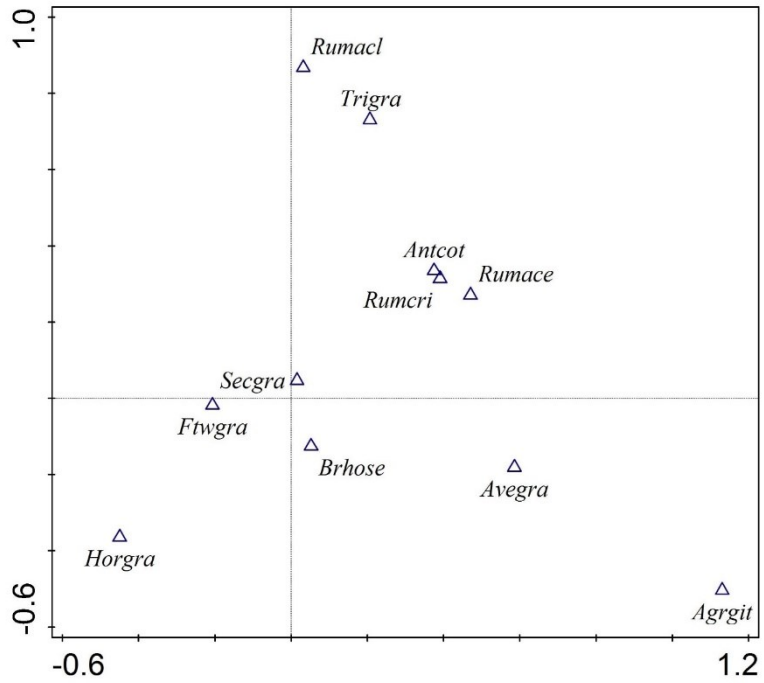
Worksheet: **04_coto**

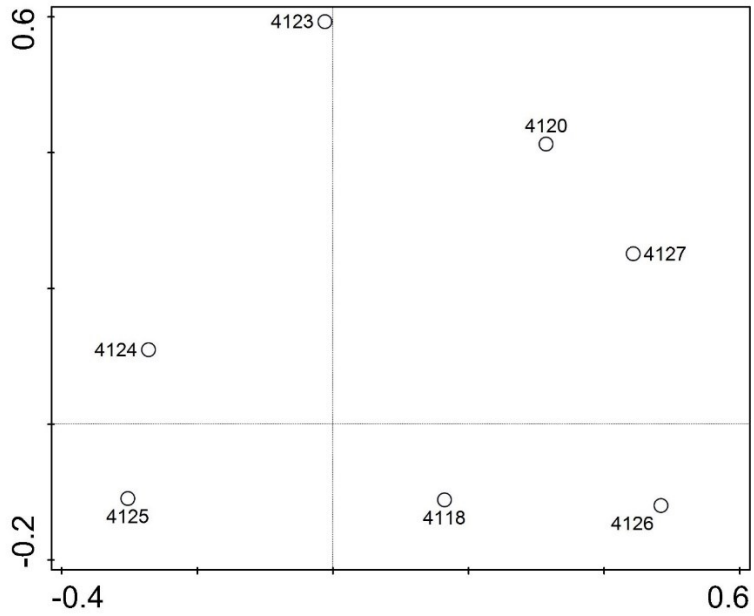
Begin with 11 species in eight samples.

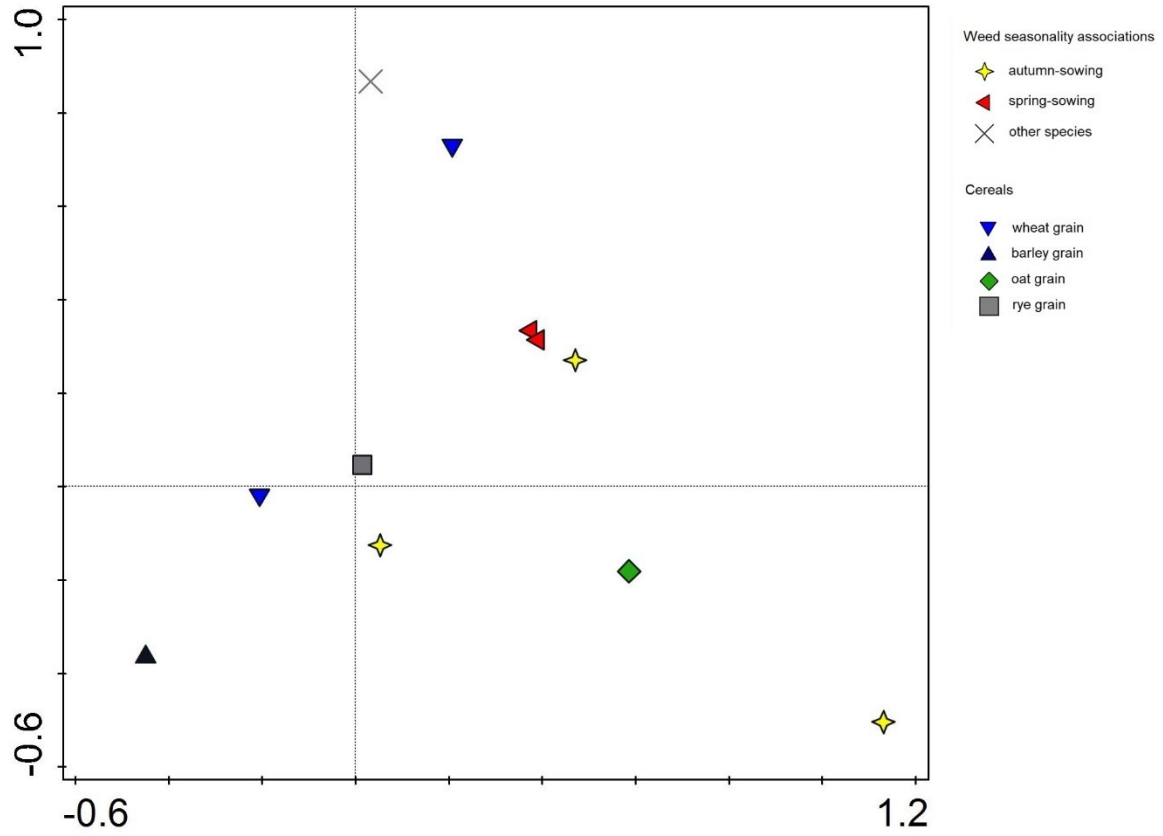




Delete outlier sample 4132 and re-run to produce a clearer distribution, but with no systematic seasonal associations between cereals and seasons.



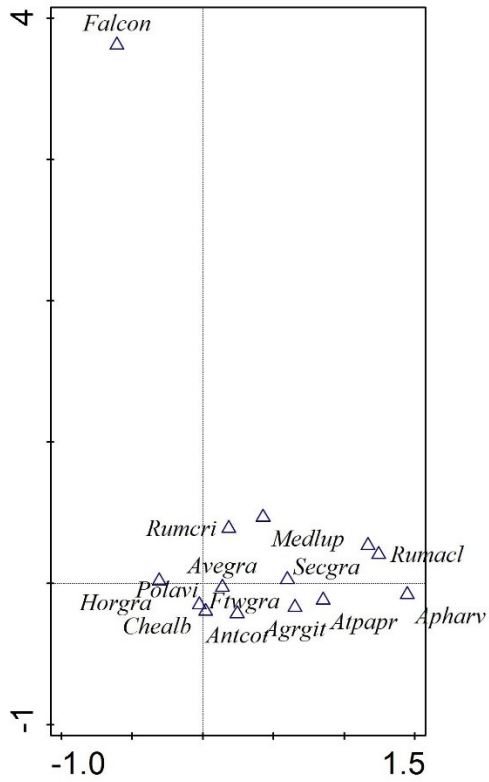


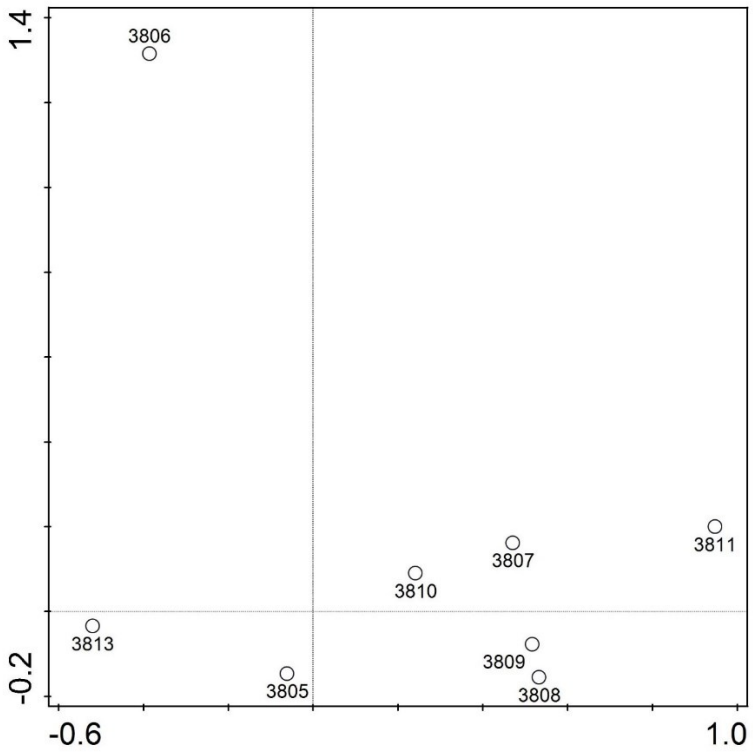

1.0
-0.6
-0.6
1.2
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

5. Cottington Hill (Kent)

Worksheet: **05_cott**

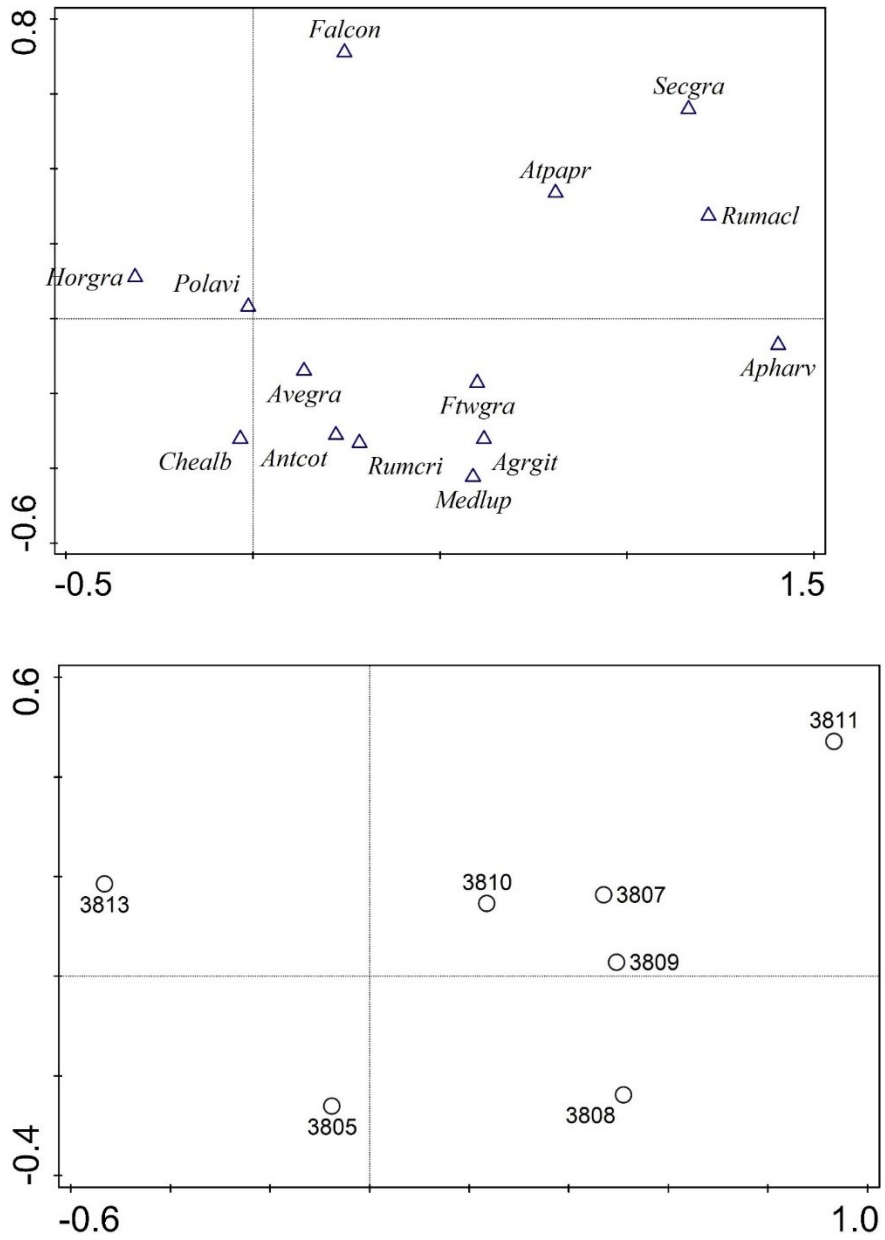
Begin with 14 species in eight samples.

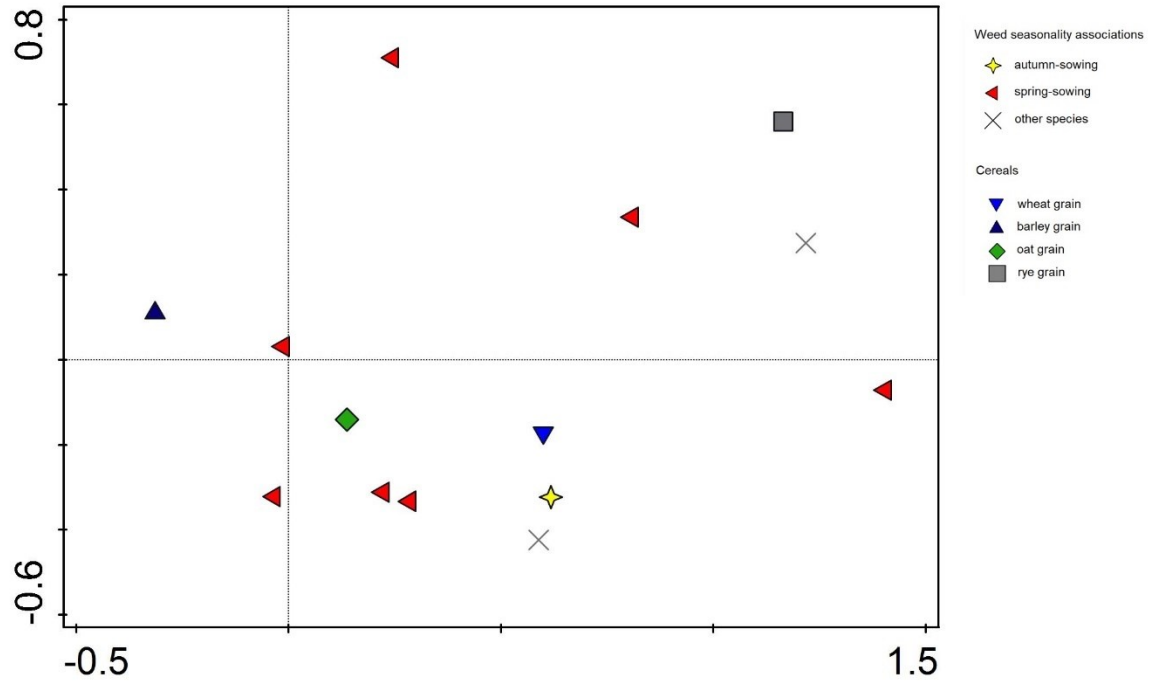




Delete outlier sample 3806 and re-run, to produce a clearer distribution.

No systematic seasonal associations emerge, and indeed there is only one autumn-associated weed: *Agrgit*. Hence, this assemblage can be classed as ‘spring-dominated’ (see monograph).



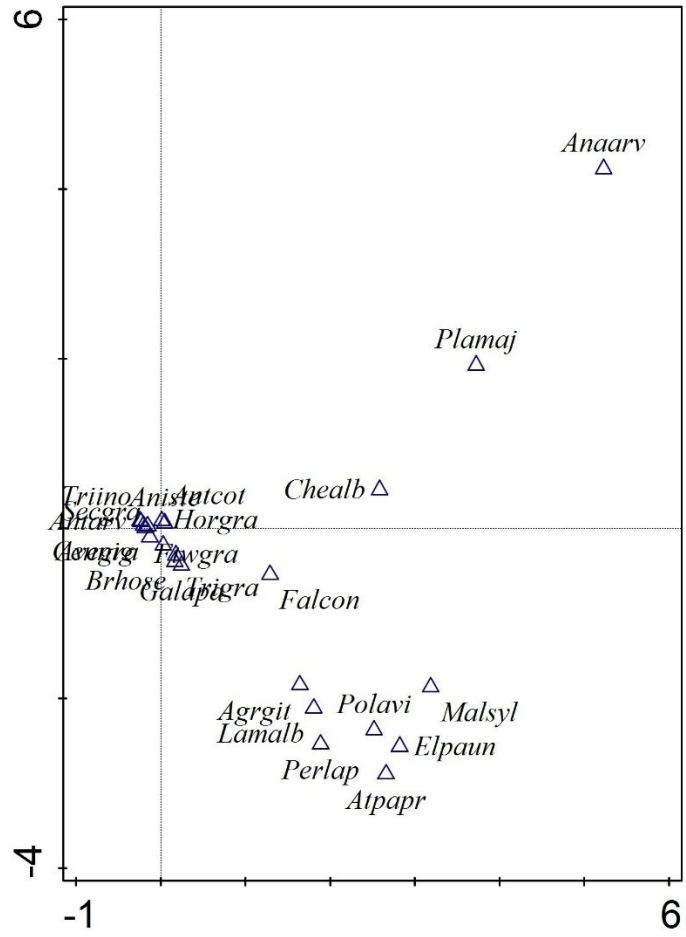

0.8
-0.6
-0.5
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

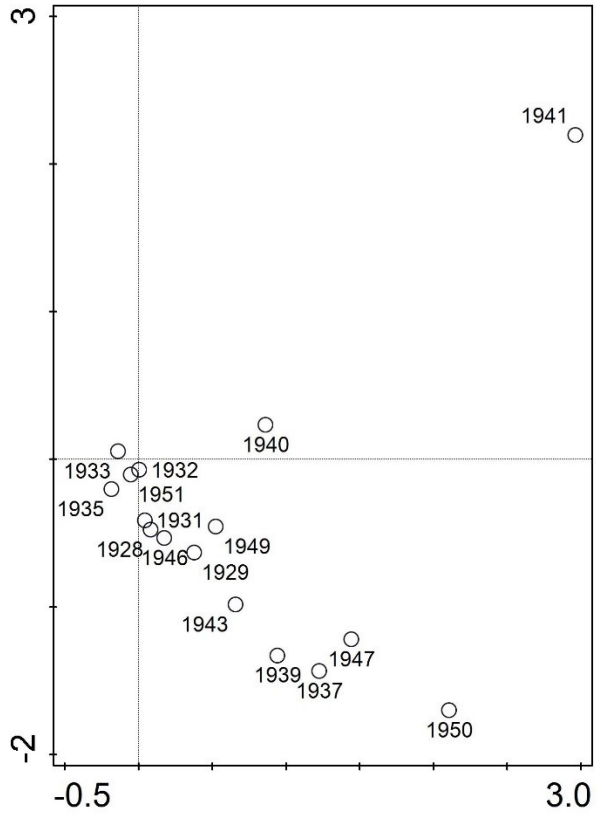
6. Dorney (Buckinghamshire)

Worksheet: **06_dor**

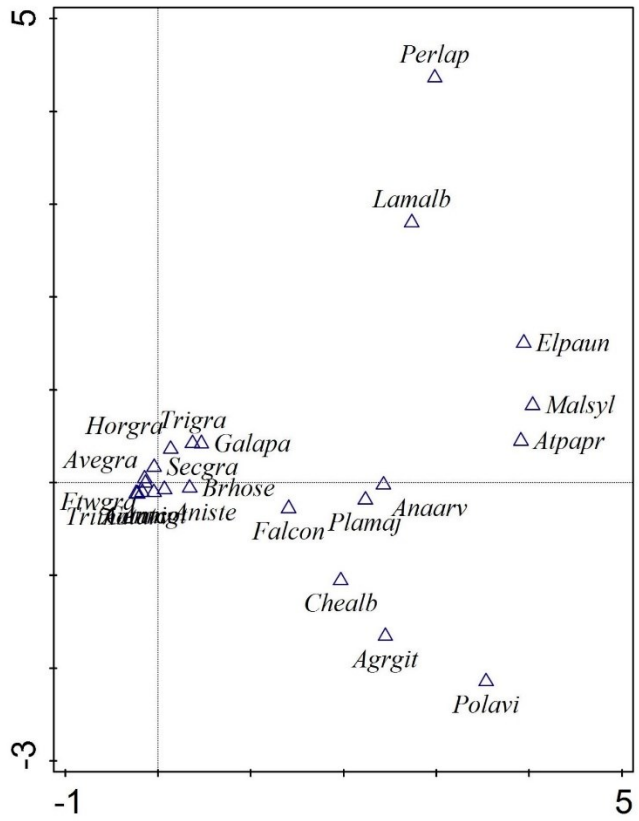
Comprising Lot's Hole, Lake End Road East, and Lake End Road West.

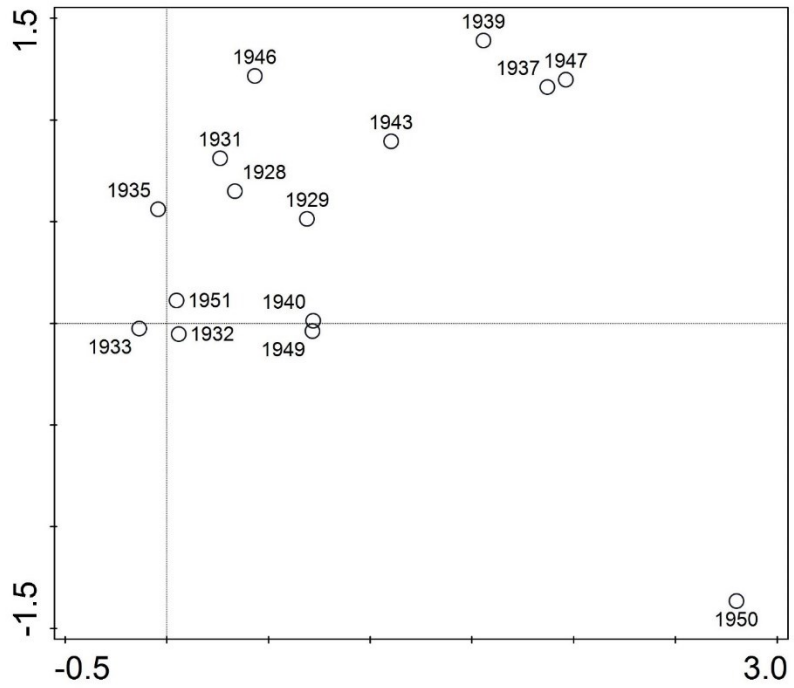
Begin with 23 species in 16 samples.



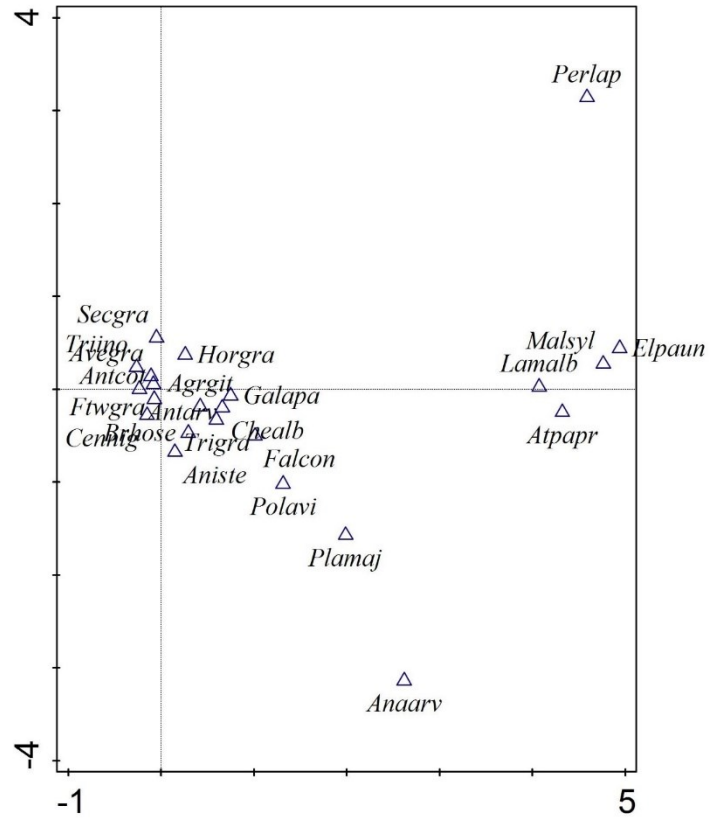


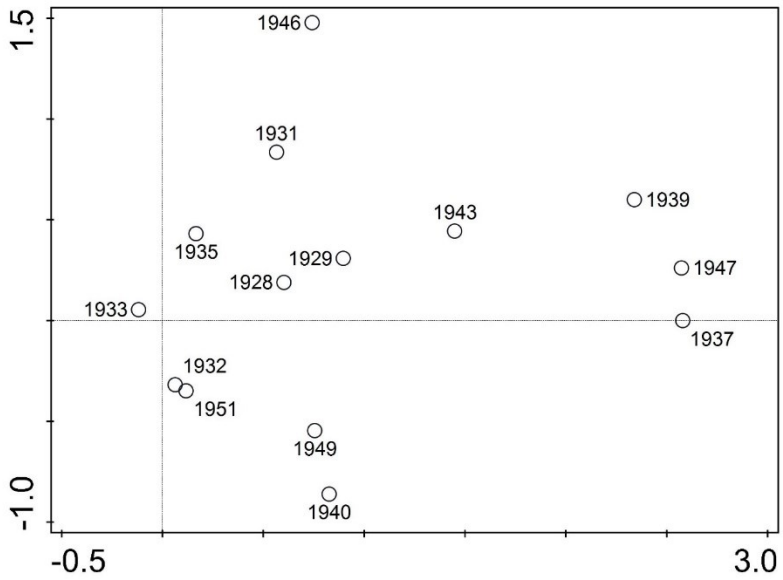
Delete outlier sample 1941 and re-run.

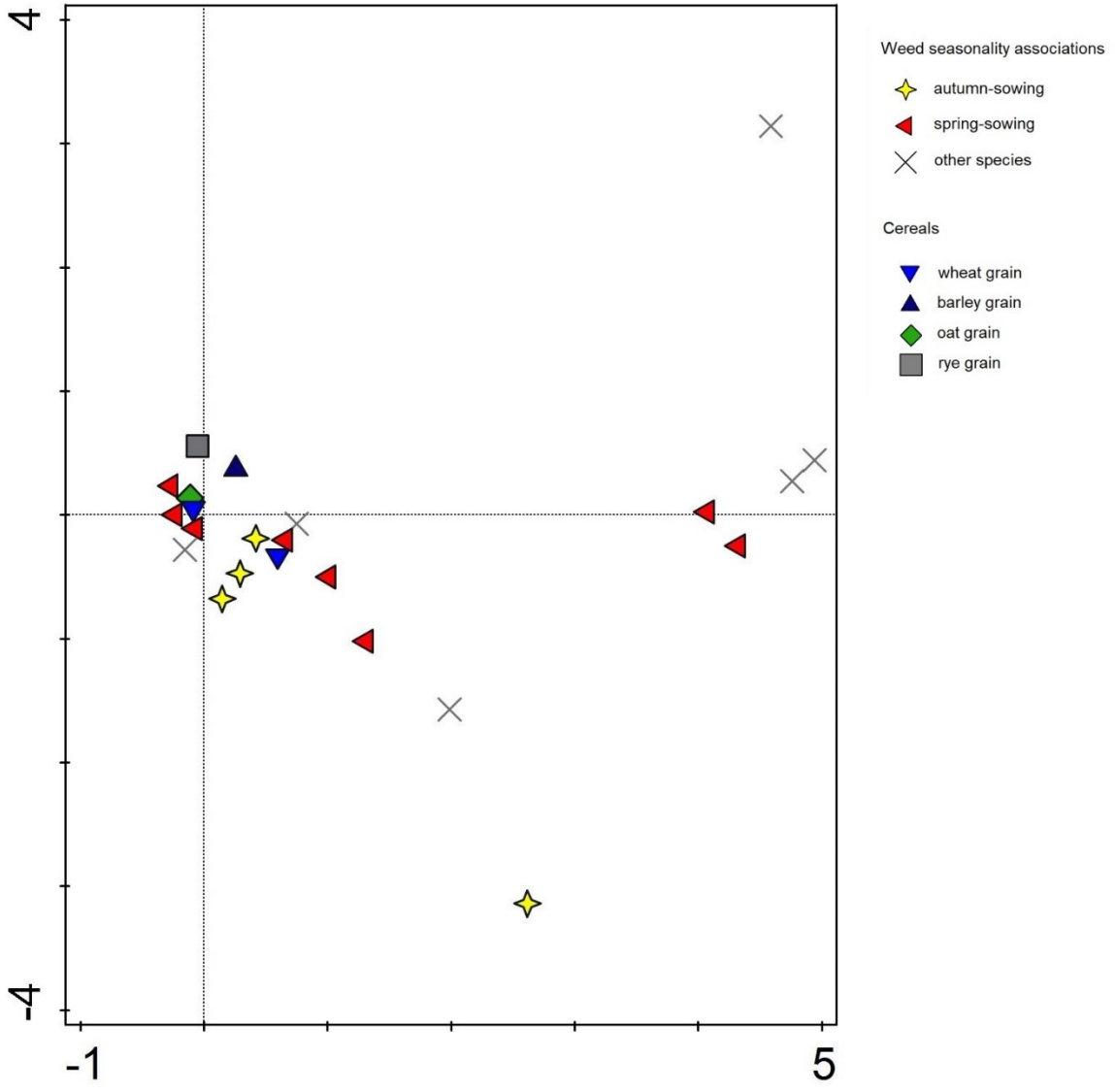




Delete outlier sample 1950 and re-run, to produce a clearer distribution. There are no apparent systematic associations between cereals and seasons.



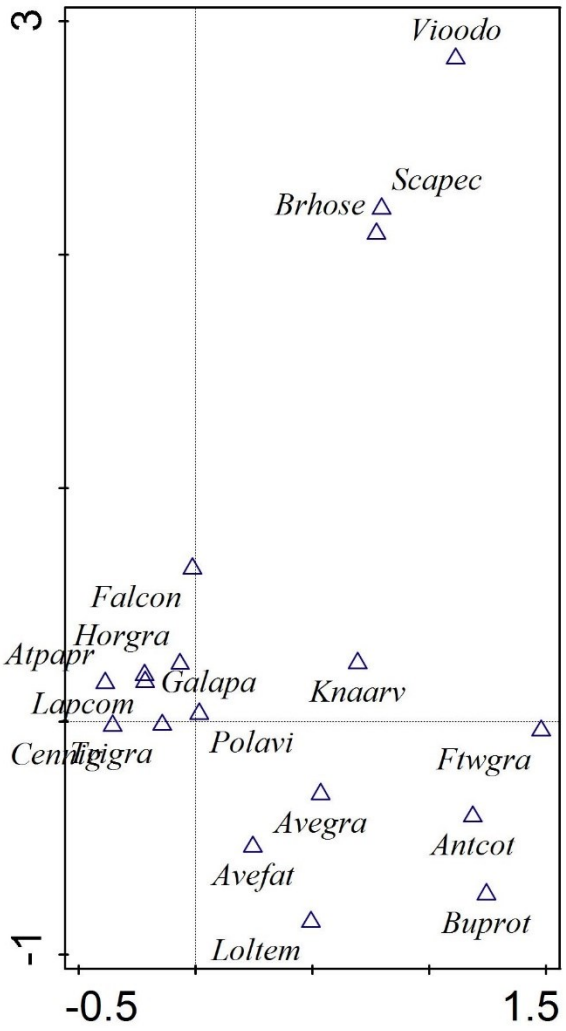

1.5
-1.0
-0.5
3.0
1946
1931
1939
1943
1935
1929
1947
1928
1933
1937
1932
1951
1949
1940

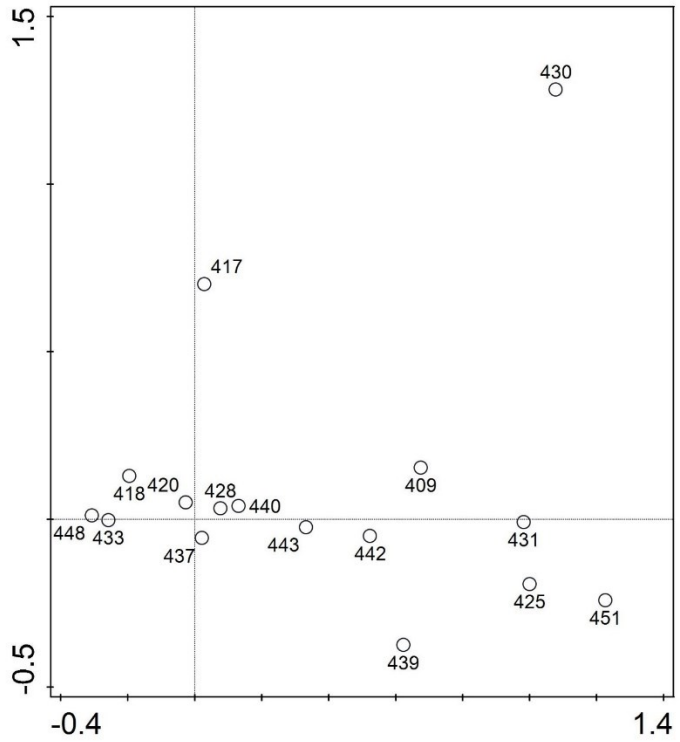

4
-4
-1
5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

7. Eckweek (Avon)

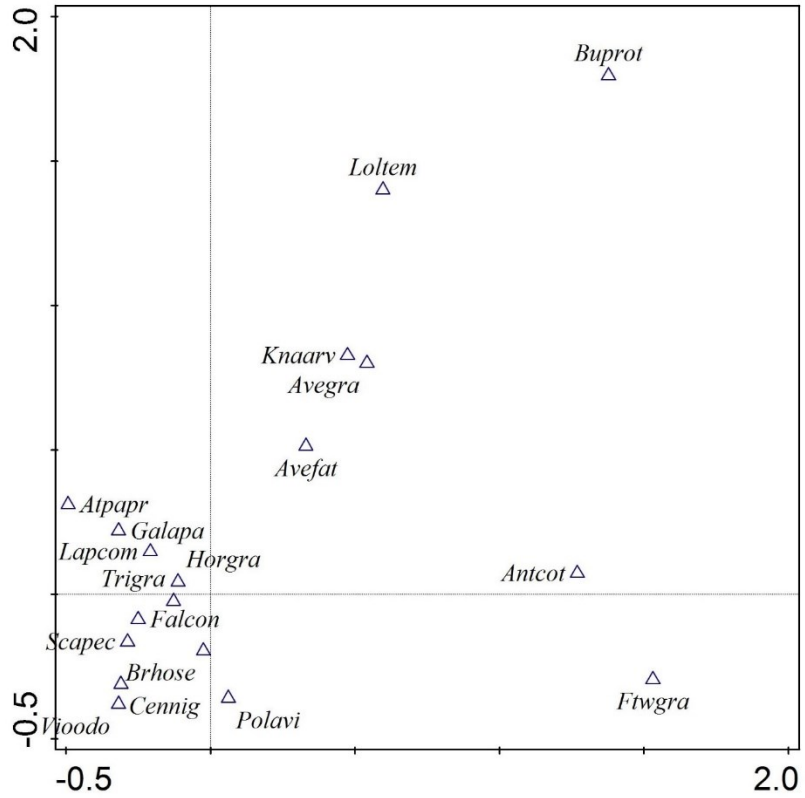
Worksheet: **07_eck**

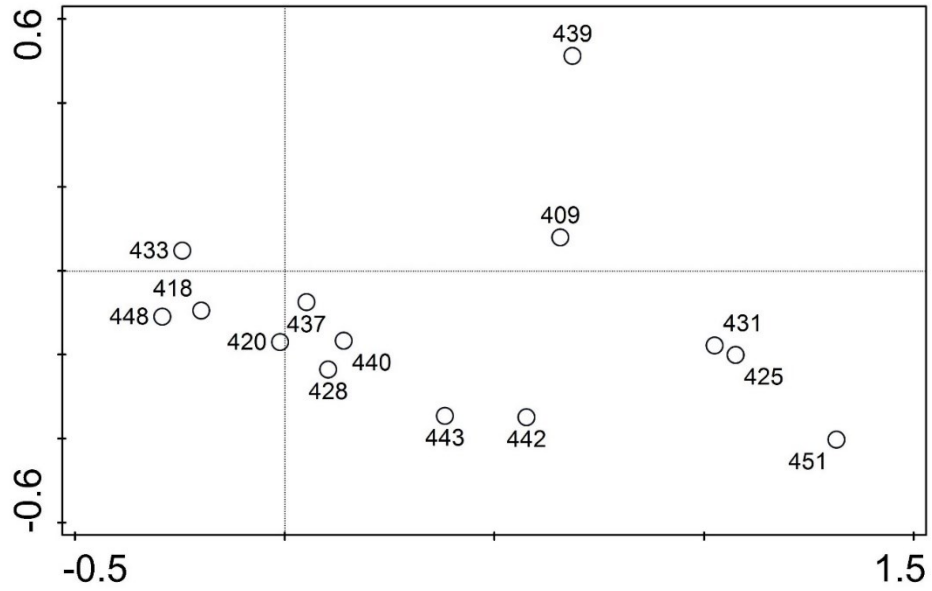
Begin with 18 species in 16 samples.

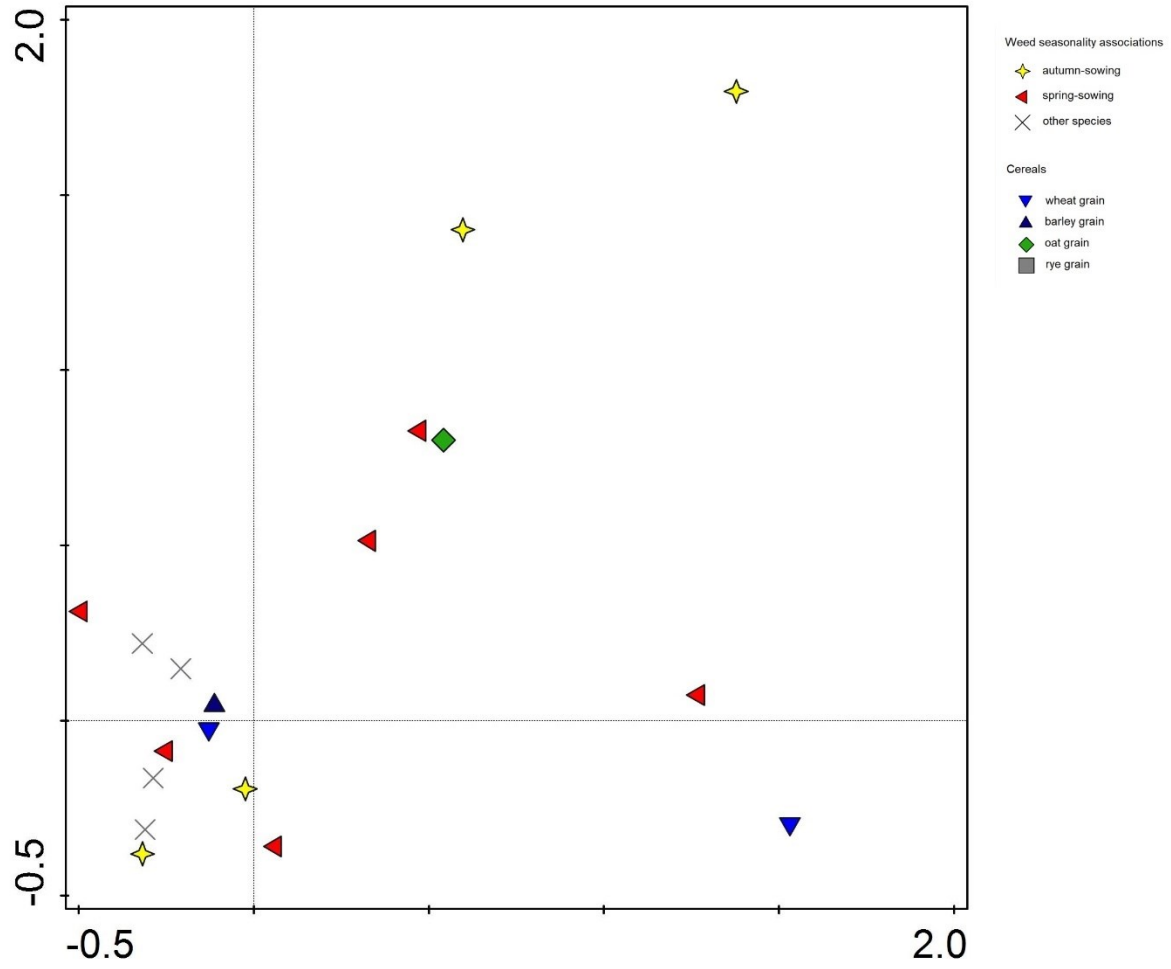




Delete outlier samples 417 and 430 and re-run, to produce a clearer distribution. No systematic associations between cereals and seasons emerge. This is a heavily wheat-dominated assemblage containing both autumn- and spring-associated weed species.




0.6
-0.6
-0.5
1.5
439
409
433
418
448
437
420
440
428
431
425
443
442
451

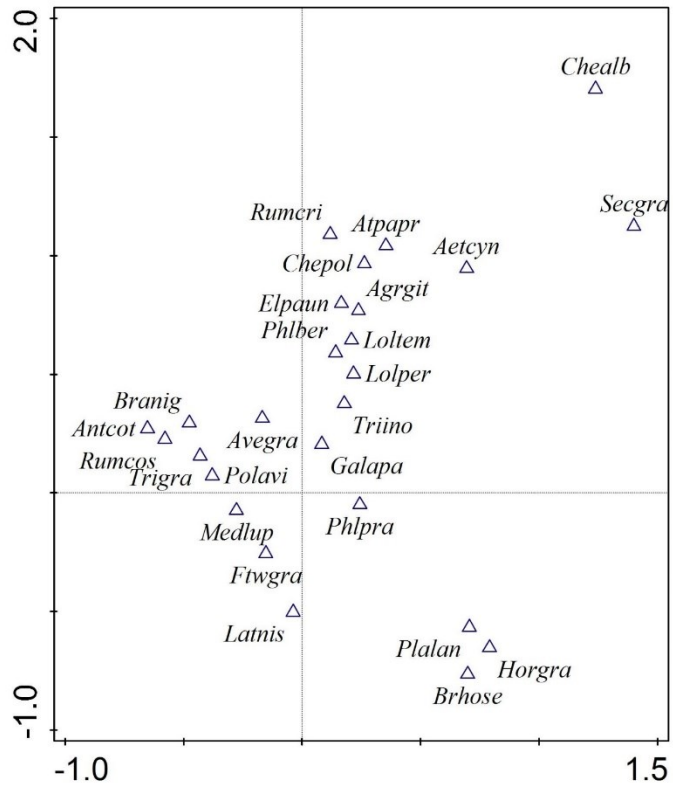

2.0
-0.5
-0.5
2.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

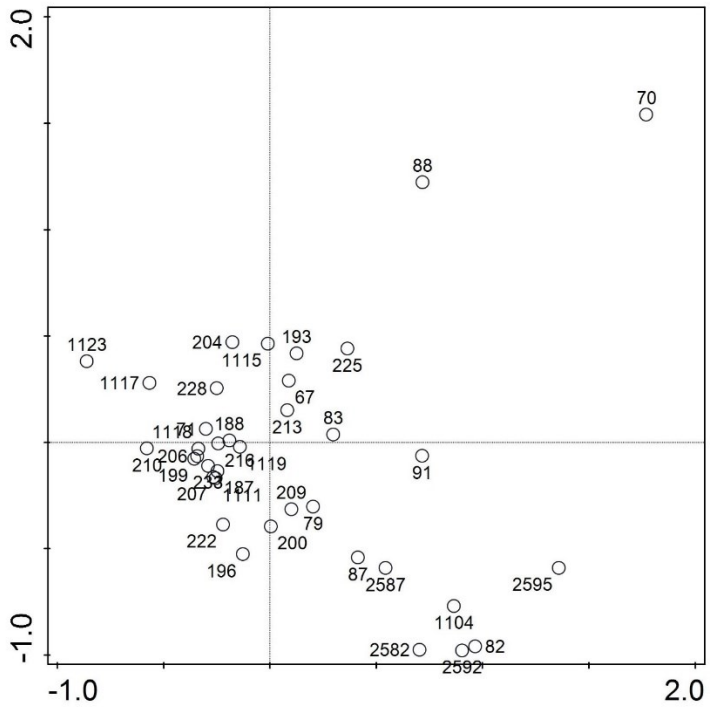
8. Ely (Cambridgeshire)

Worksheet: **08_ely**

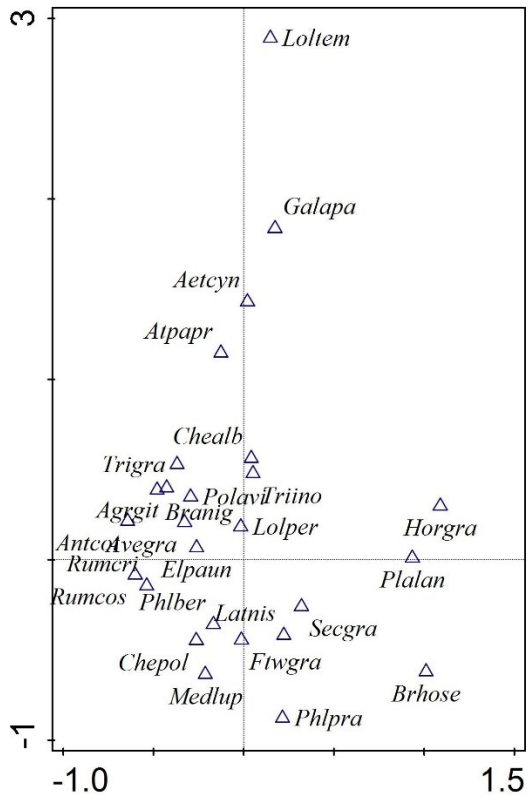
Comprising Walsingham Way and West Fen Road excavations (Ashwell and Consortium sites)

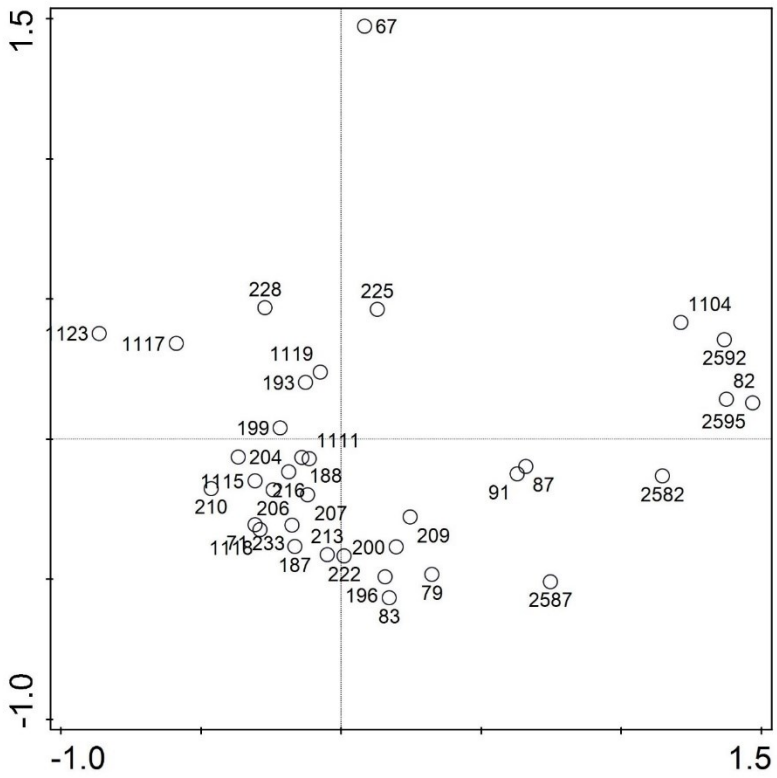
Begin with 26 species in 37 samples.



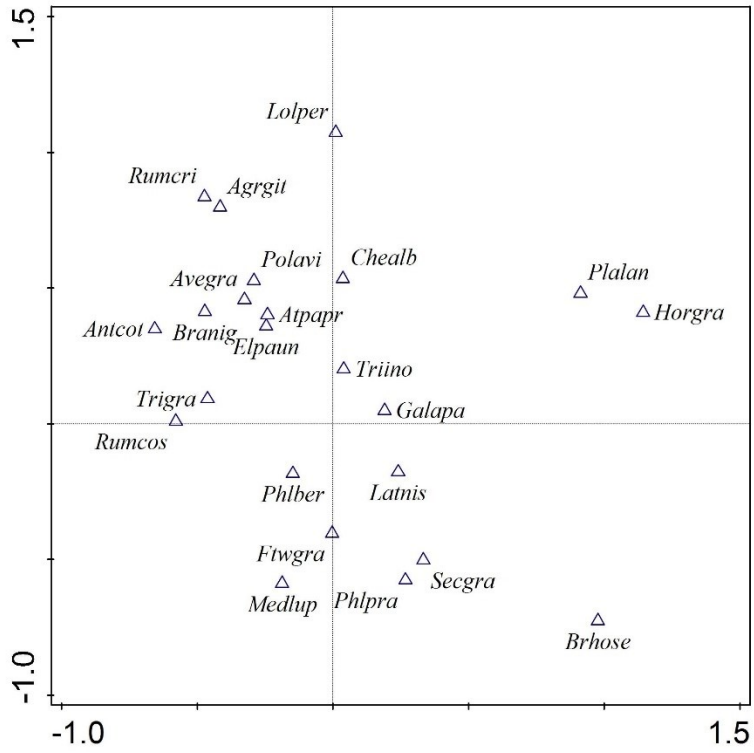


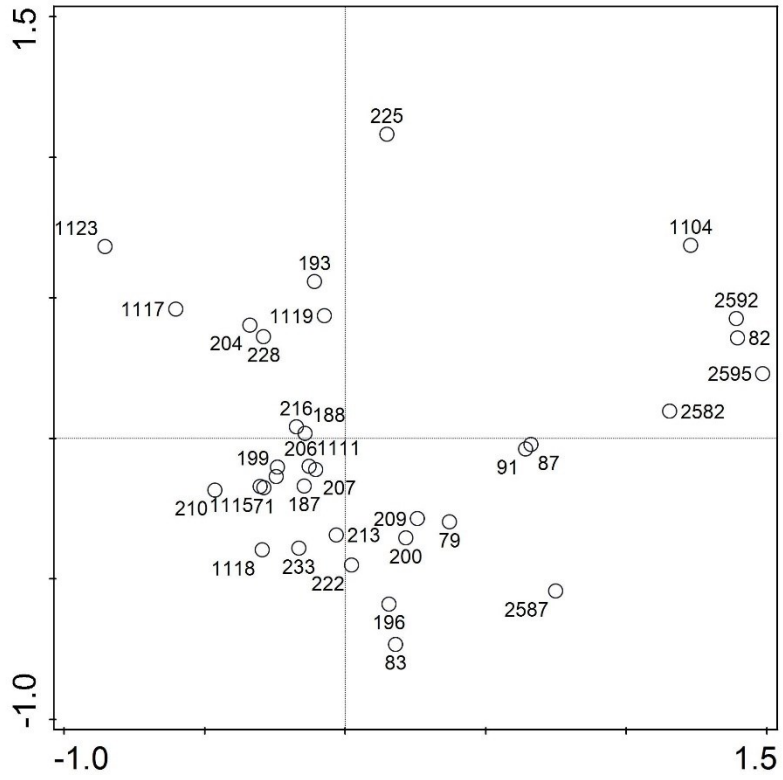
Delete outlier samples 70 and 88 and re-run.



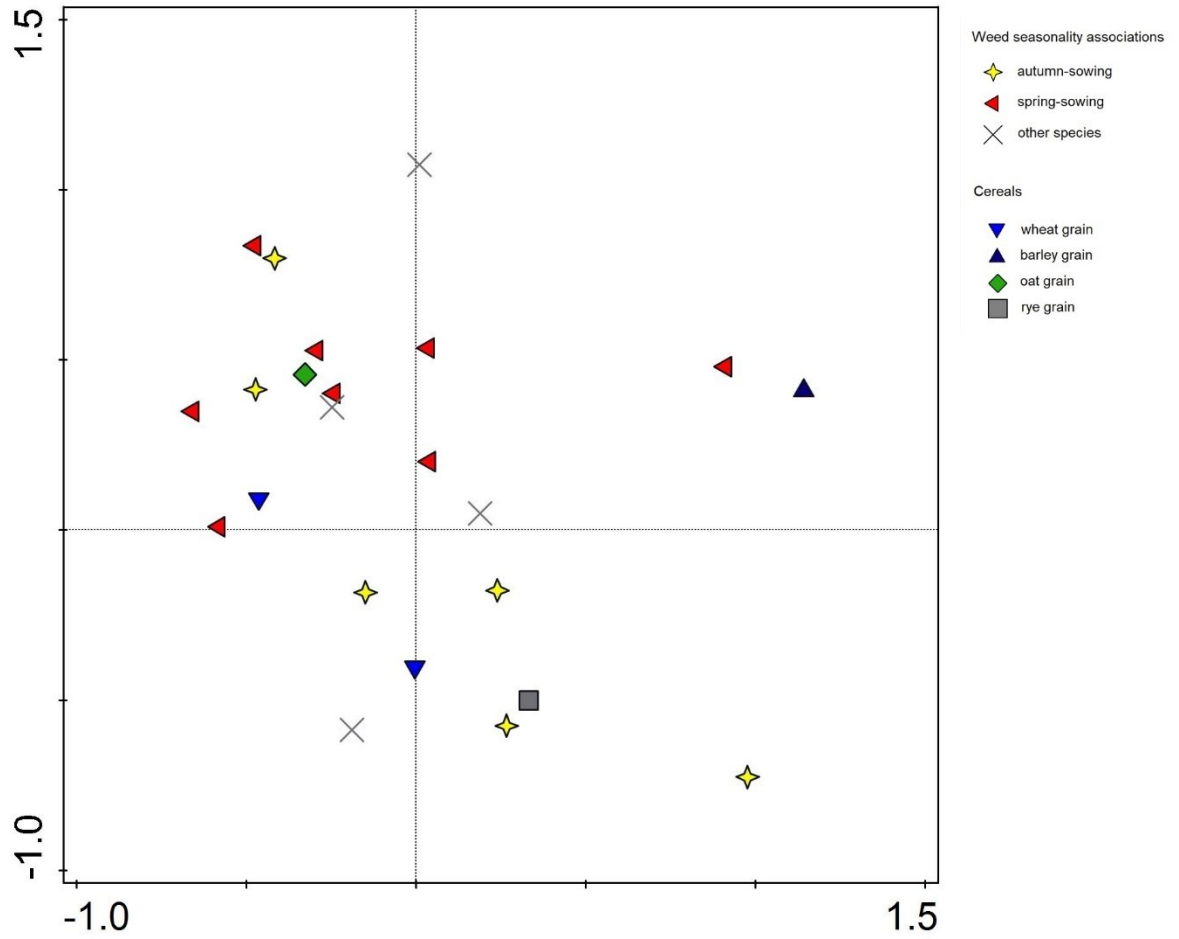


Delete outlier sample 67 and re-run, to produce a clearer distribution.

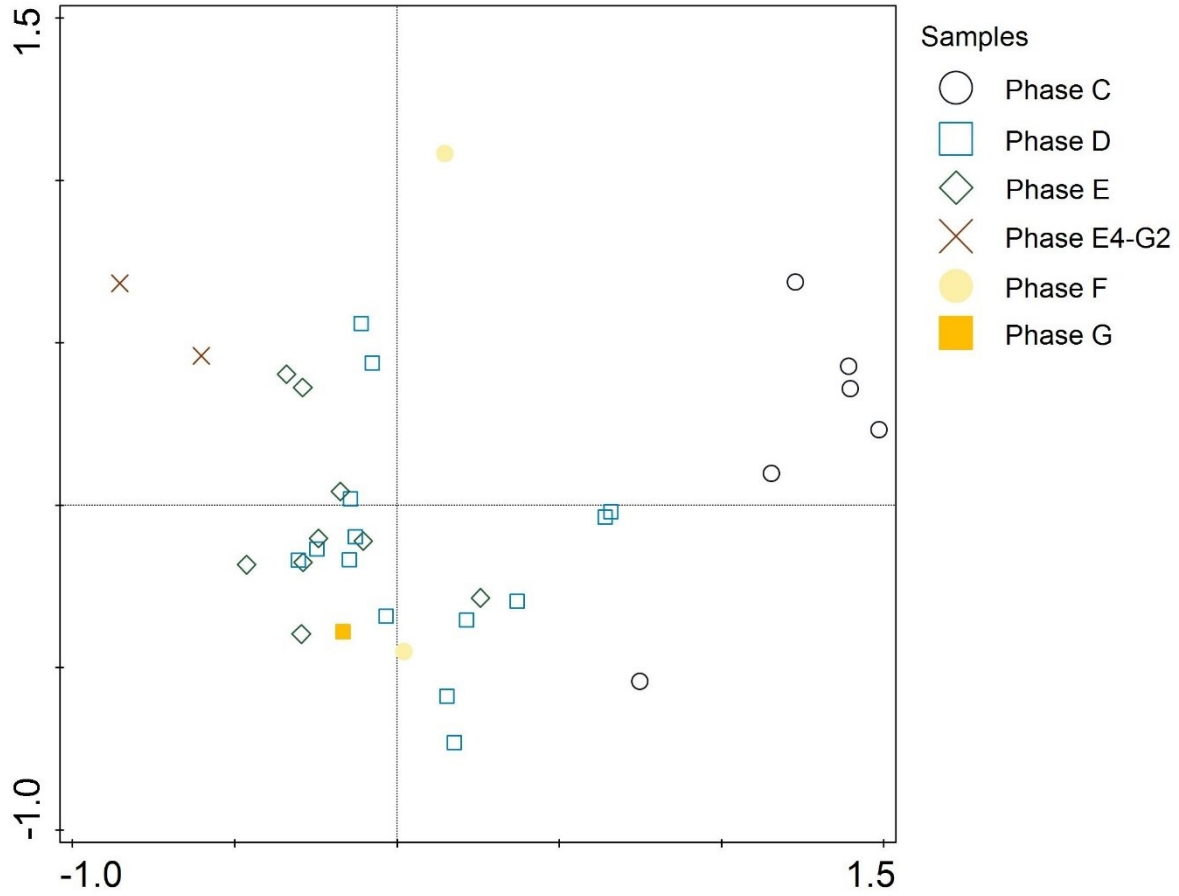




Some seasonal associations appear along the y-axis: wheat, rye and autumn-associated weeds tend towards the negative end, while barley, oats and spring-associated weeds tend towards the positive end. There is no clear-cut, exclusive division between these two groups, so we cannot say that systematic seasonal sowing patterns were rigidly adhered to at Ely, or perfectly represented in the archaeobotanical record.



There were likely many variations among the farms supplying the monastic centre at Ely through the Anglo-Saxon and medieval periods, but it is worth noting that the y-axis distribution does not correspond to any chronological patterns among the samples. Some chronological gradient is apparent on the x-axis – with Phase C samples to the right, and Phase E–G samples on the left – but this does not correspond to the seasonal patterns along the y-axis. Hence, these results would be consistent with systematic seasonal sowing having been practised from as early as Phase C (*c.* AD 670–880).

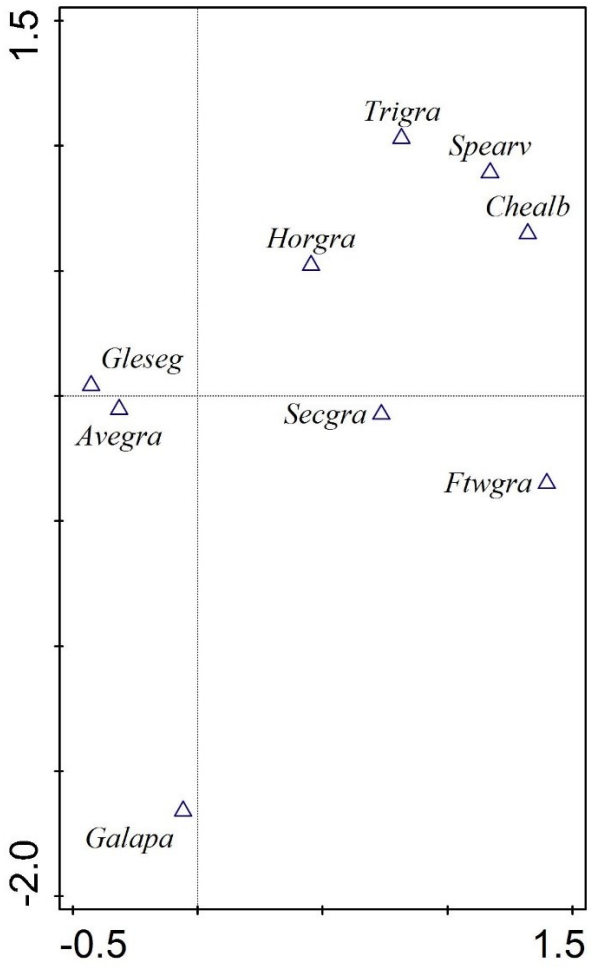

1.5
-1.0
-1.0
1.5
Samples
Phase C
Phase D
Phase E
Phase E4-G2
Phase F
Phase G

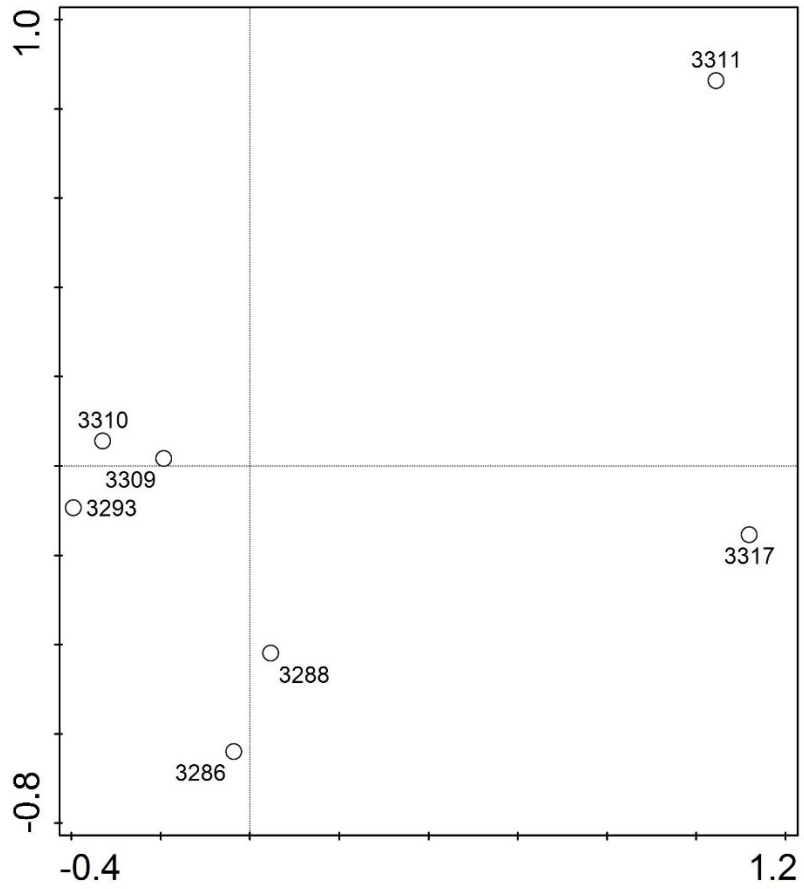
9. Exwell Barton (Devon)

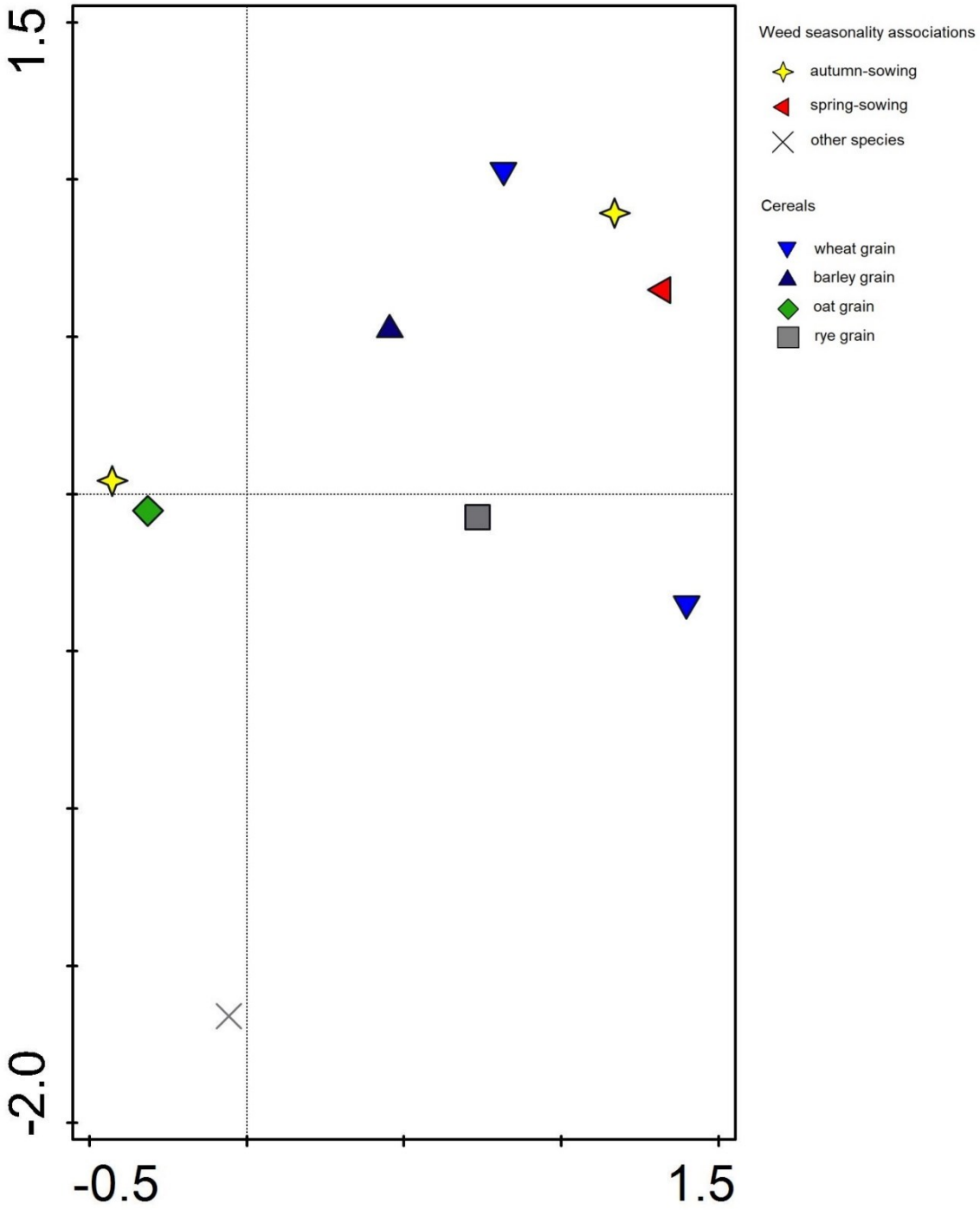
Worksheet: **09_exw**

Begin with nine species in seven samples.

The assemblage has an extremely low diversity of weeds, including only one spring-associated species (*Chealb*). The autumn-associated *Gleseg* is overwhelmingly dominant among the weed seeds, hence this assemblage's classification as 'autumn-dominated' in the monograph.




1.0
-0.8
-0.4
1.2
3311
3310
3309
3293
3317
3288
3286


1.5
-2.0
-0.5
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

10. Fishtoft (Lincolnshire)

Worksheet: **10_fis**

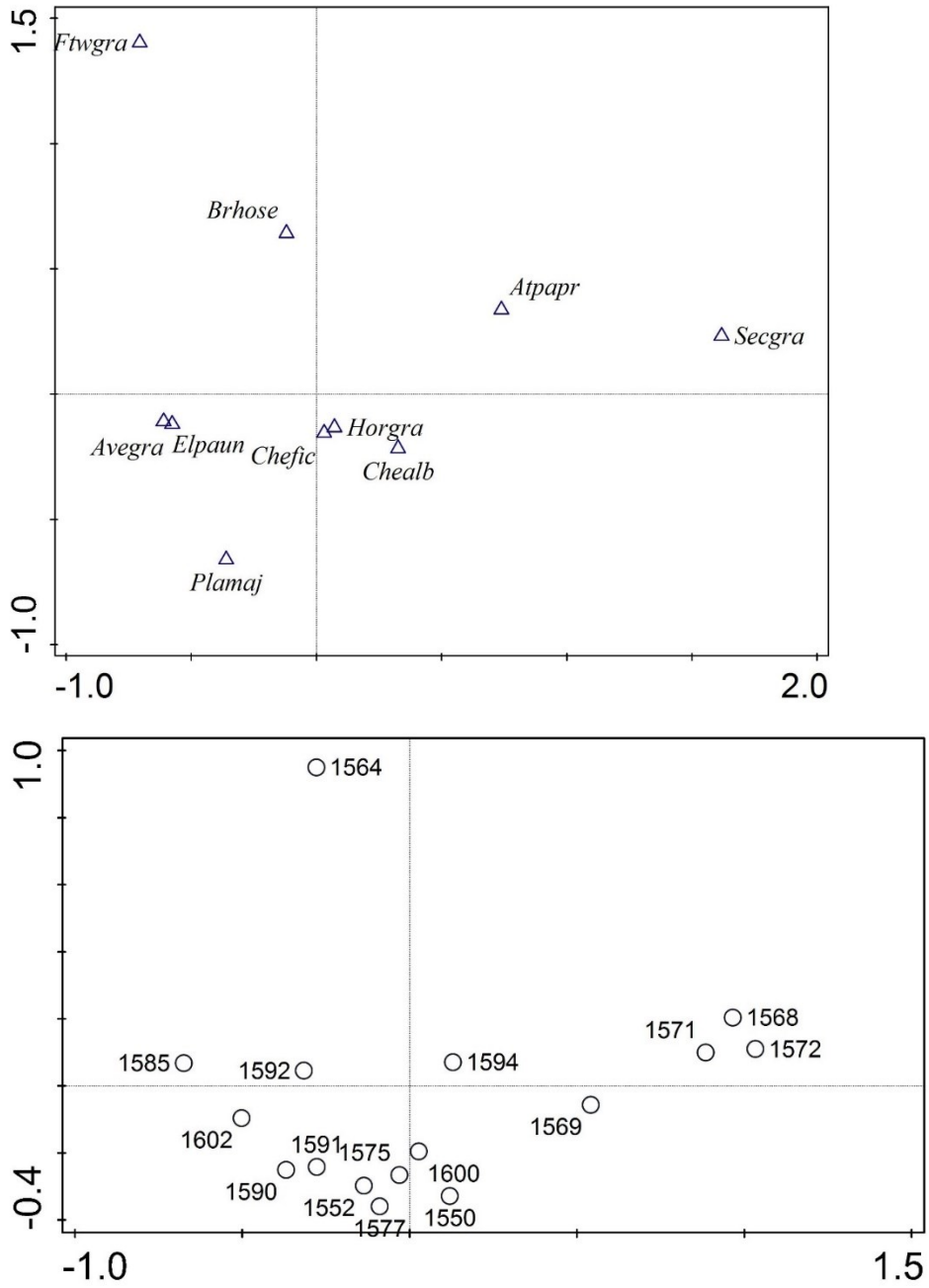
Begin with 12 species in 26 samples – but, after data preparation, none of the weed species are associated with autumn sowing. In fact, even before the data cleaning protocols have been applied, there was only one autumn-associated weed in the assemblage (*Anaarv*), and it was so rare as to be removed by the data cleaning protocols outlined at the start of this document. Hence, it appears likely that (almost) all crops at Fishtoft were sown in the spring during this period: B2–D (*c.* AD 630-1030). In addition, all but one of these samples were dominated by barley grains (≥70% of free-threshing cereal grains) – hence the 'barley/spring-dominated' classification of this assemblage in the monograph.

11. Gosberton (Lincolnshire)

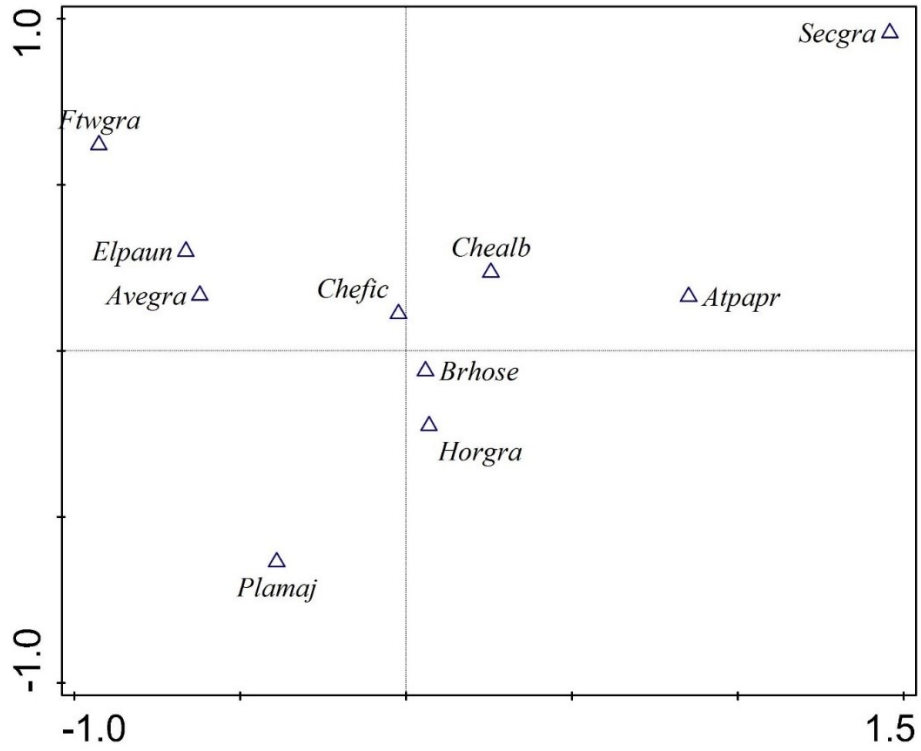
Worksheet: **11_gos**

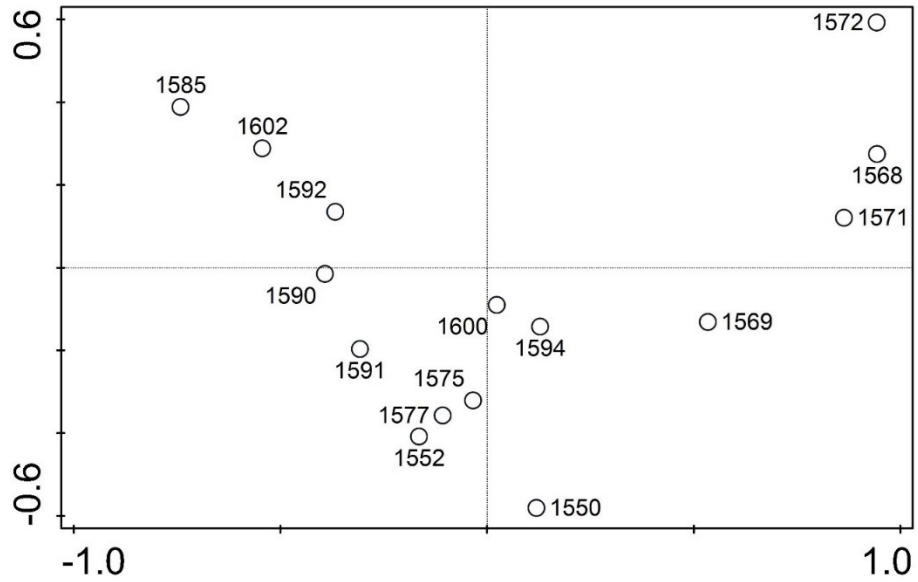
Comprising samples from the Mornington House and Chopdike Grove excavations.

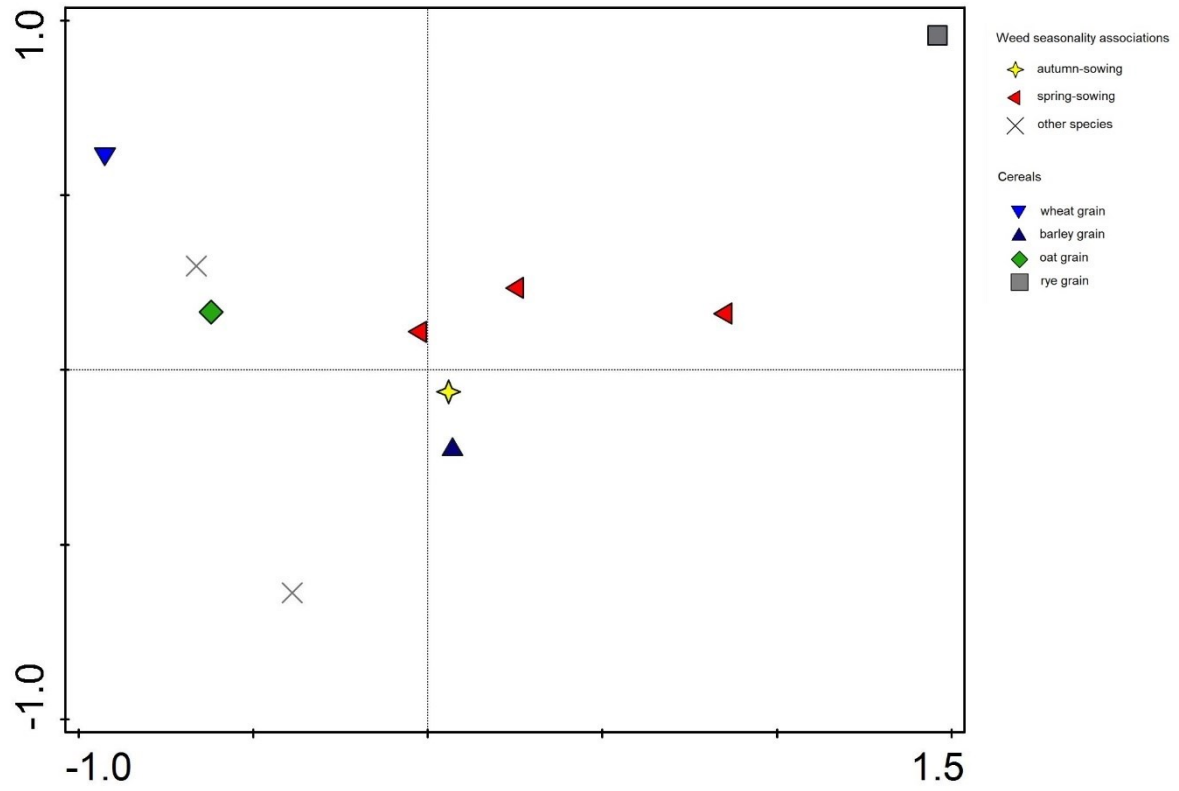
Begin with ten species in 16 samples.



Delete outlier sample 1564 and re-run, to produce a clearer distribution. There is only one autumn-associated weed species (*Brhose*), and it displays no particular association with any of the cereal(s). Moreover, as with the Fishtoft assemblage, the majority of samples are dominated by barley grains (≥70% of free-threshing cereal grains), and this assemblage is therefore also classified as 'barley/spring-dominated'.



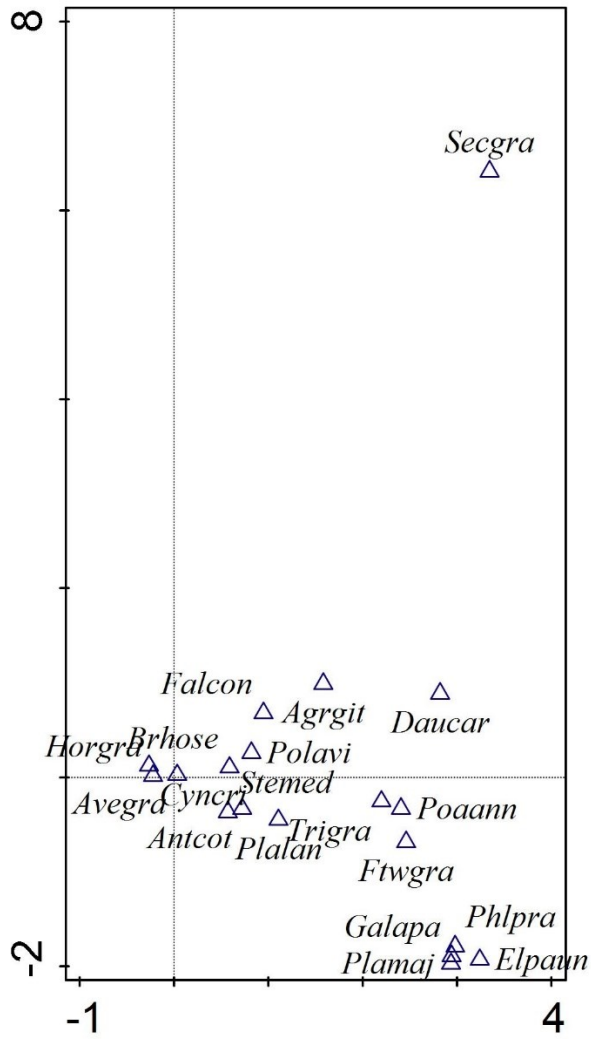


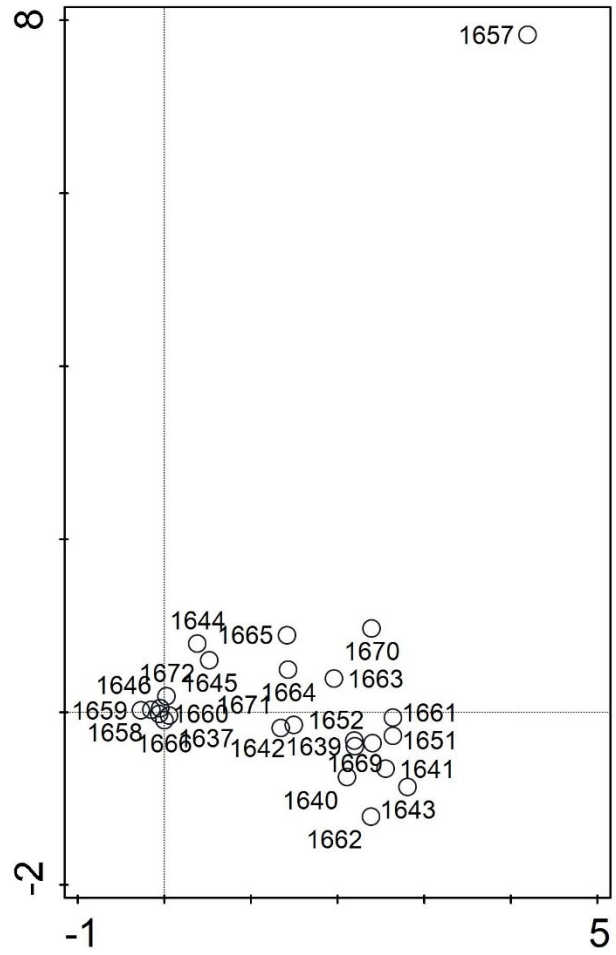

1.0
-1.0
-1.0
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

12. Higham Ferrers (Northamptonshire)

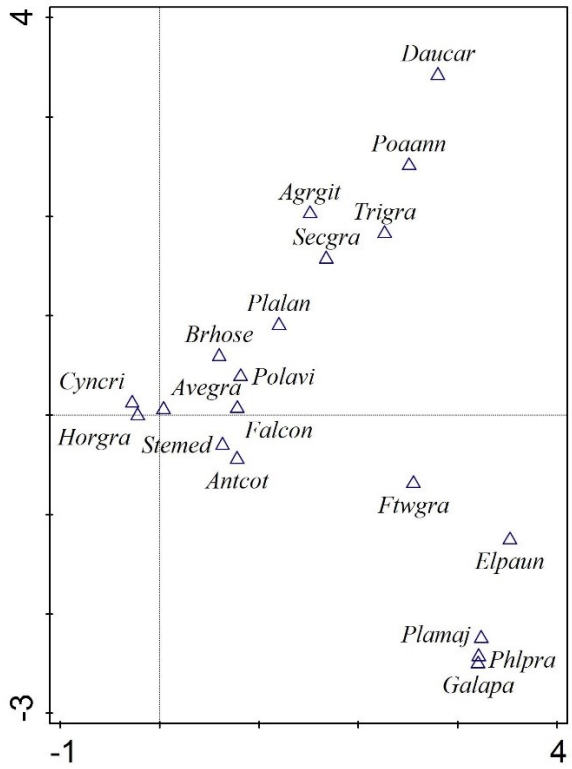
Worksheet: **12_hig**

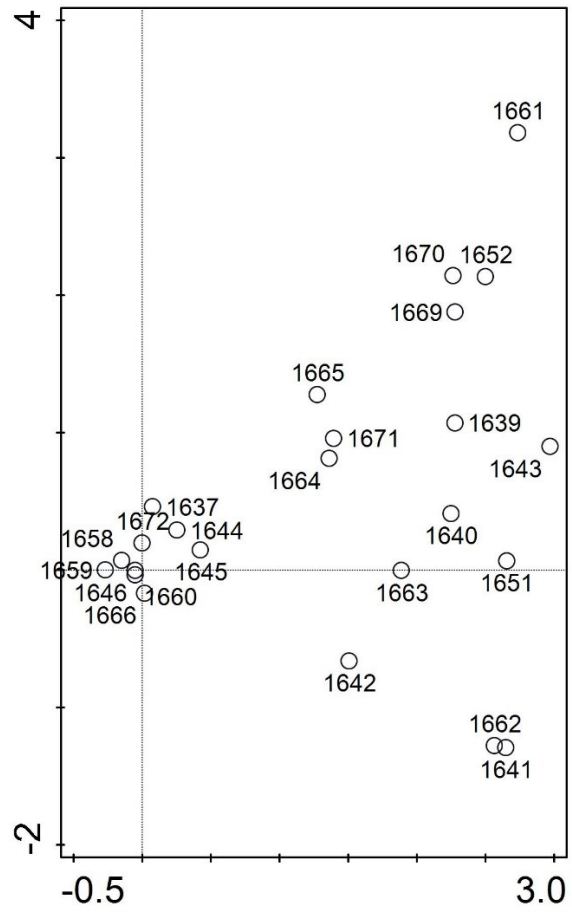
Begin with 19 species in 25 samples.

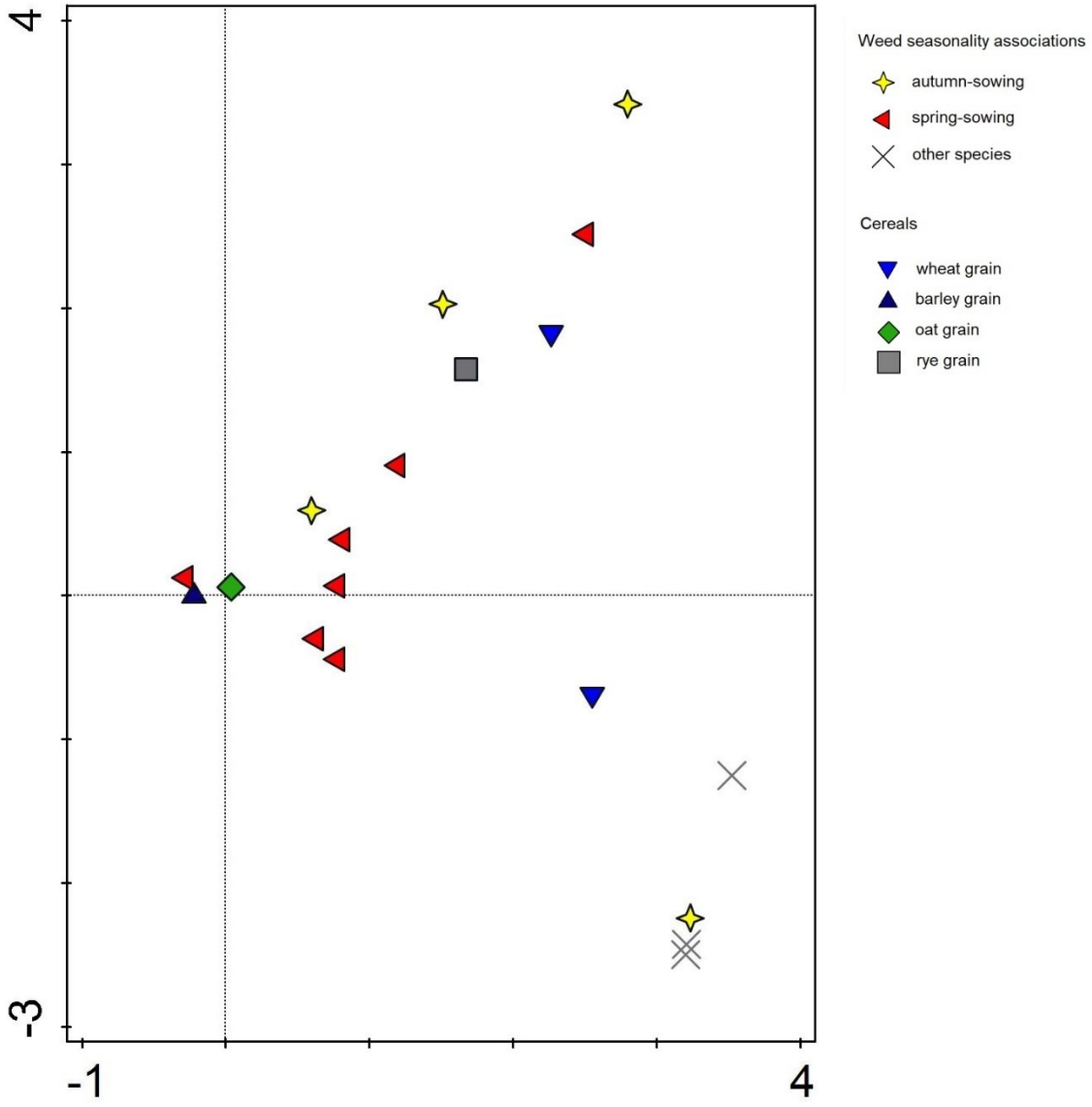




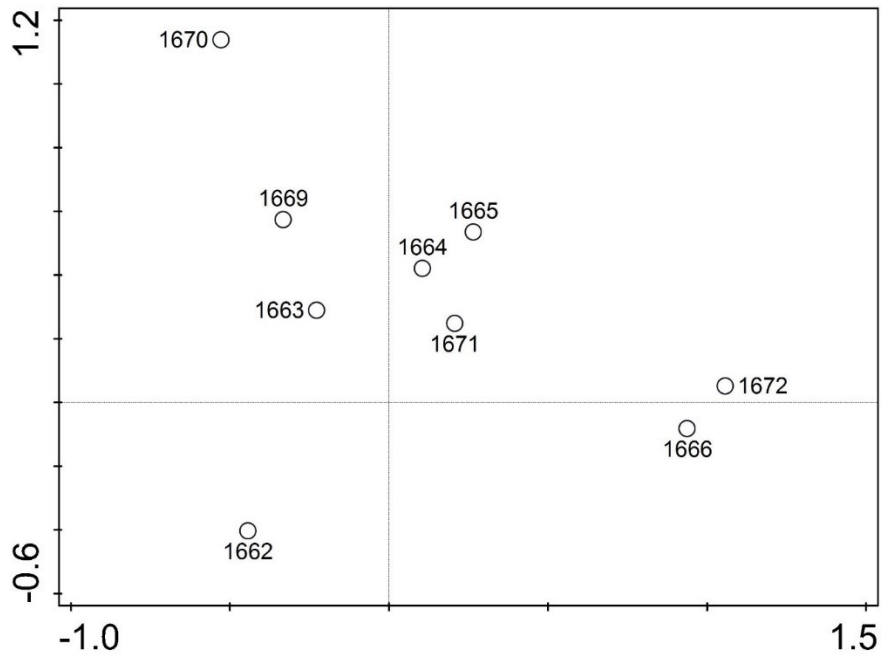
Delete outlier sample 1657 and re-run, to produce a clearer distribution. There is some separation between cereals along the x-axis, with wheat and rye to the right, barley and oats to the left, but no corresponding separation of weeds according to the seasonal association. Could there be a seasonal association obscured by the long timespan represented by these assembled samples (phases A–G1: *c.* AD 420–1360)?

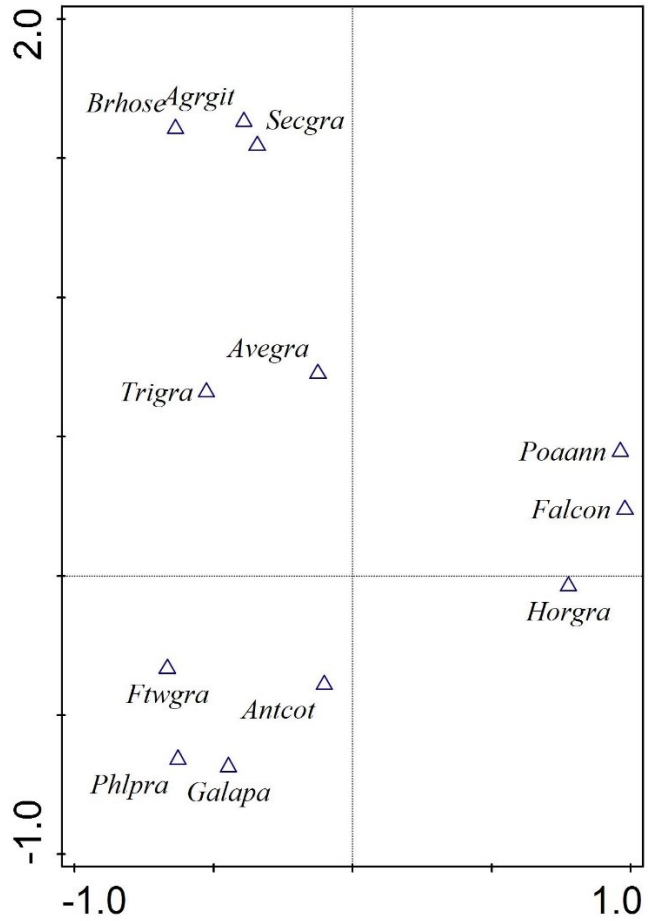

4
-3
-1
4
Daucar
Poaann
Agrgit
Trigra
Secgra
Plalan
Brhose
Cyncri
Avegra
Polavi
Horgra
Stemed
Falcon
Antcot
Ftwgra
Elpaun
Plamaj
Phlpra
Galapa


4
-2
-0.5
3.0
1661
1670
1652
1669
1665
1639
1671
1643
1664
1637
1672
1644
1658
1640
1659
1645
1651
1646
1660
1663
1666
1642
1662
1641

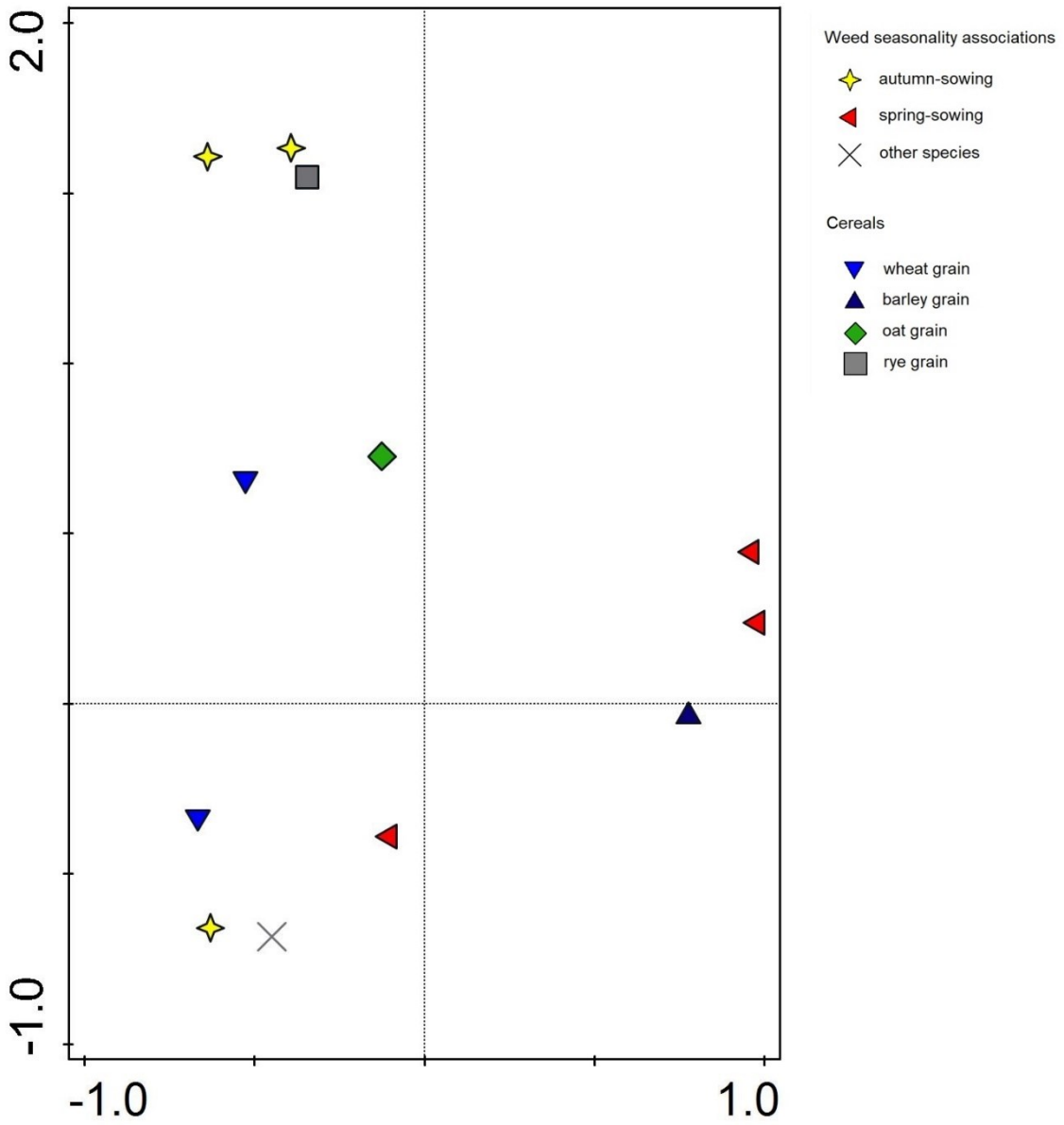

4
-3
-1
4
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

Restrict the analysis to samples from the later phases, D1–E3 (880–1120) and E3–G1 (1080–1360), and begin with 12 species in nine samples.





Now there appears to be a seasonality gradient along the x-axis, with wheat, rye and autumn-associated weeds to the left, and barley, oats and spring-associated weeds to the right. Hence, if 'champion-style' seasonal sowing was practised at Higham Ferrers, it was restricted to its later phases of occupation, *c.* AD 880–1360.

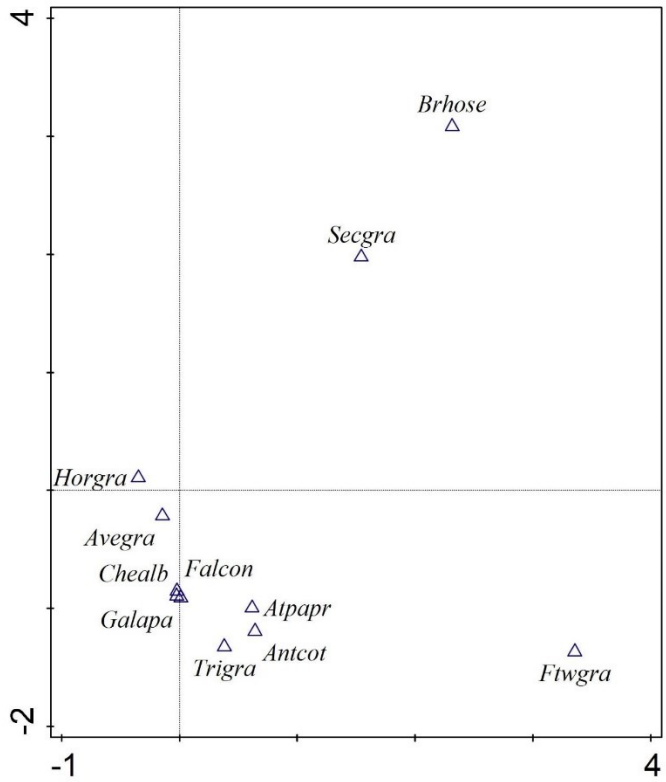


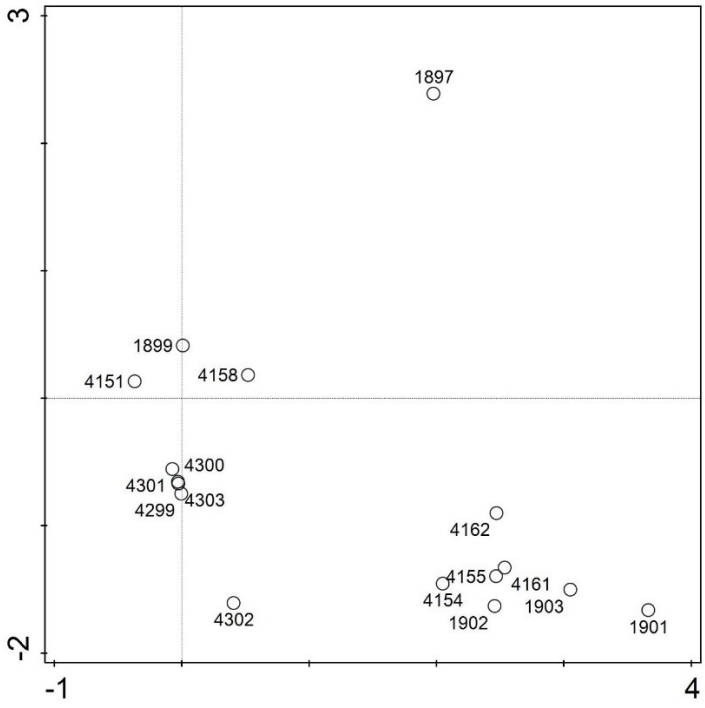
13. Holmer and Wellington Quarry (Herefordshire)

Worksheet: **13_hol**

Comprising samples from Holmer and two separate excavations at Wellington Quarry.

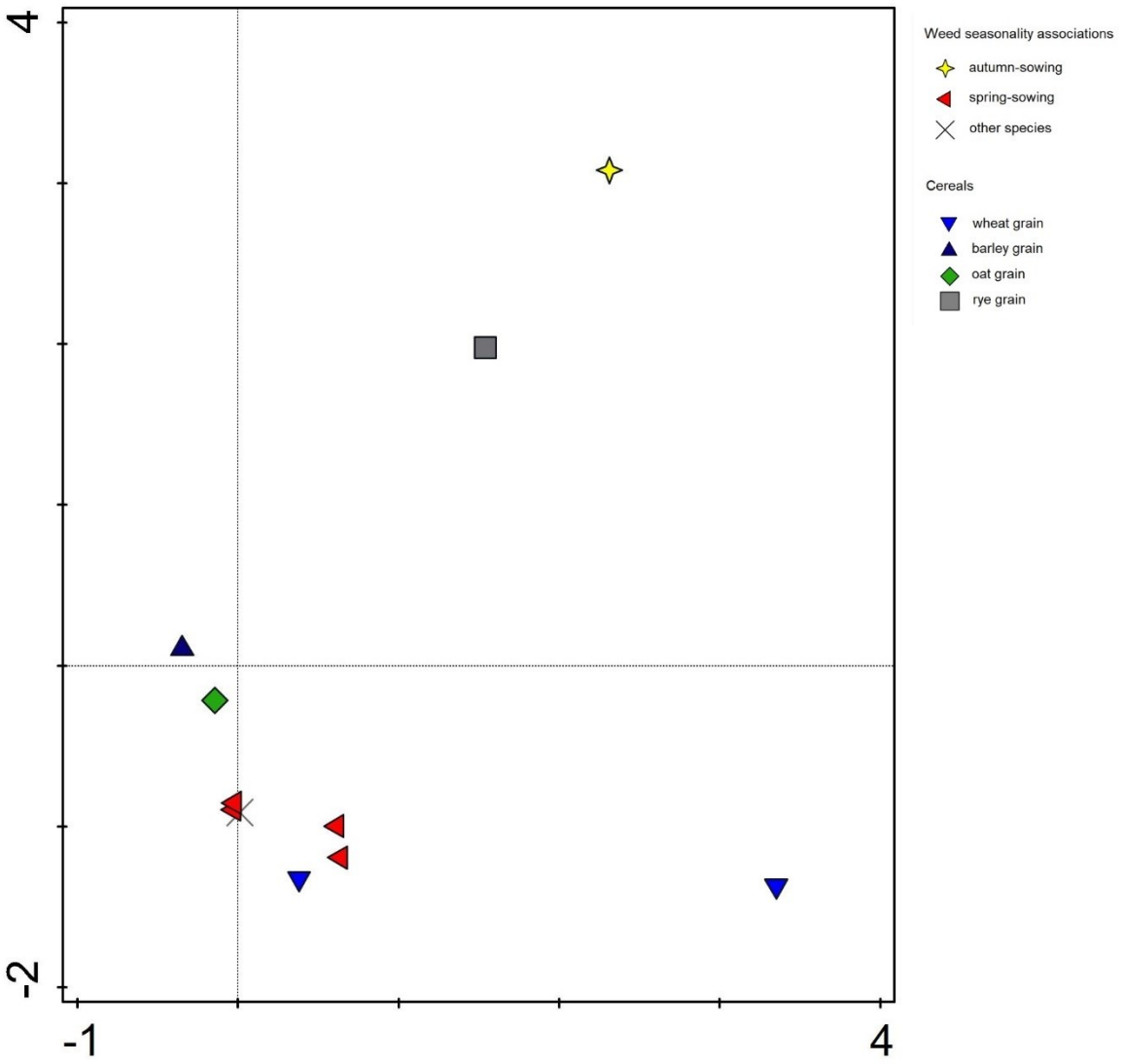
Begin with 11 species in 16 samples.



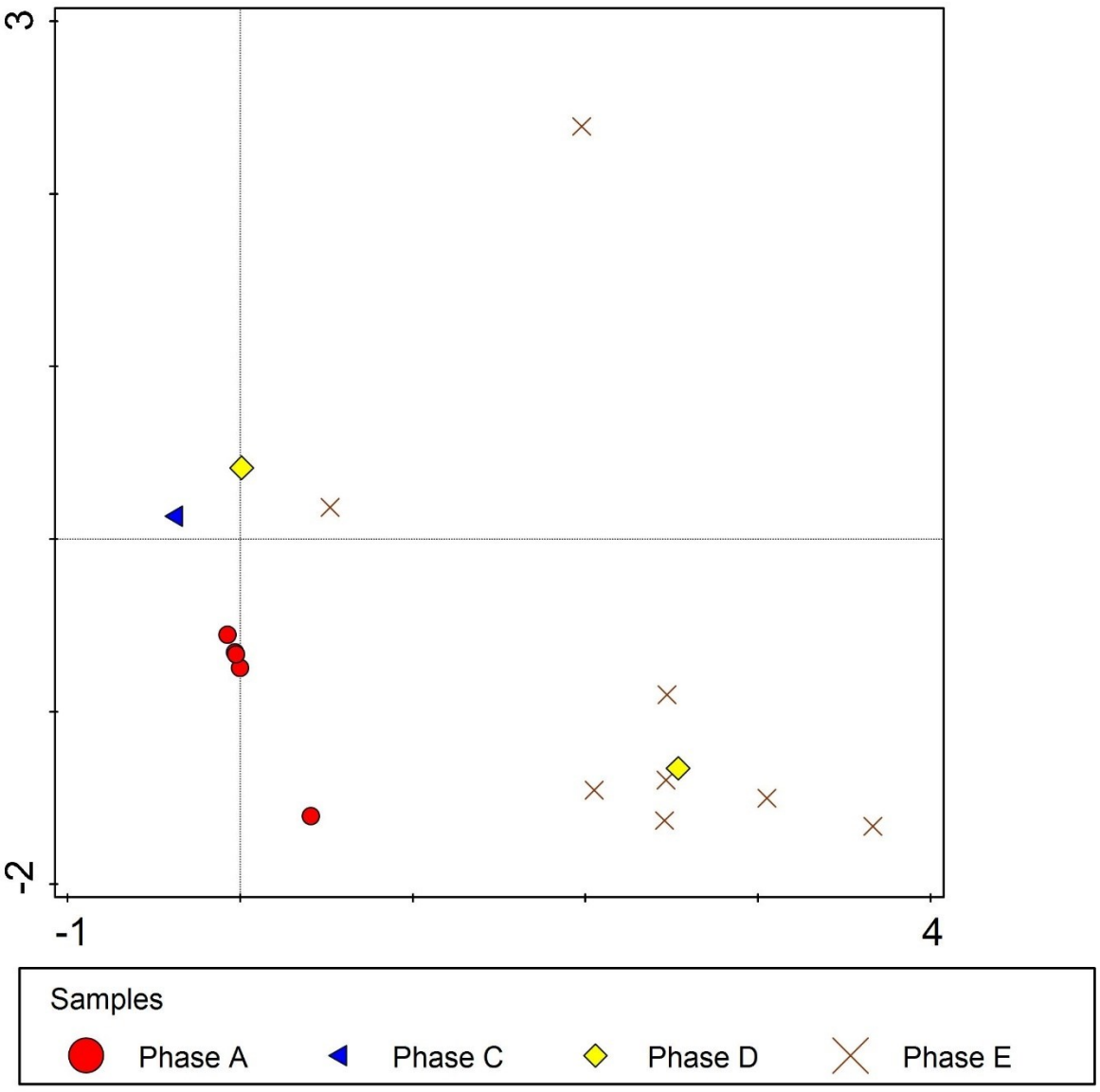


There is only one weed species associated with autumn-sowing (*Brhose*), and therefore this assemblage is classified as 'spring-dominated' in the monograph.

Is it significant that this solitary autumn-associated species lies to the right of the x-axis along with *Secgra* (rye grain) and *Ftwgra* (free-threshing wheat grain)?



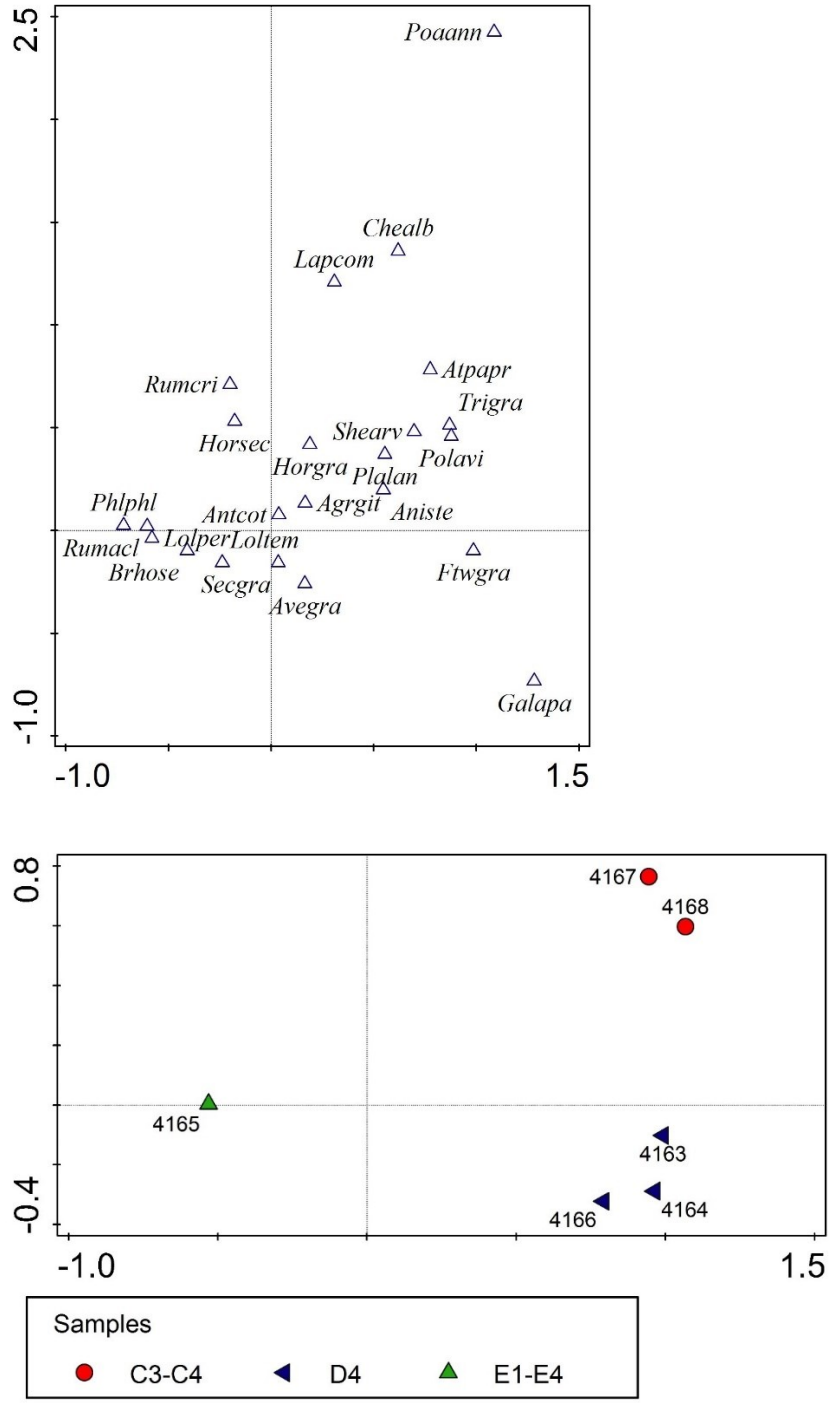
In fact, this is something of an artificial distinction related to the chronological gradient of samples along the x-axis, due to the fact that *Trigra* (*Triticum* indet. grain) is a more common identification in Wellington Quarry's Phase A samples, to the left, where *Ftwgra* is more commonly identified in the Phase E samples to the right. Discounting this pattern (which is thus an artefact of wheat-identifiability), there remains just the isolation of sample 1897 towards the top of the y-axis: the only sample rich in both rye grains and *Bromus hordeaceus/secalinus* seeds. This single sample is not deemed to be a sufficient basis for inferring rye as a regular autumn crop in a systematic seasonal sowing regime.


3
-2
-1
4
Samples
Phase A
Phase C
Phase D
Phase E

14. Houghton (Cambridgeshire)

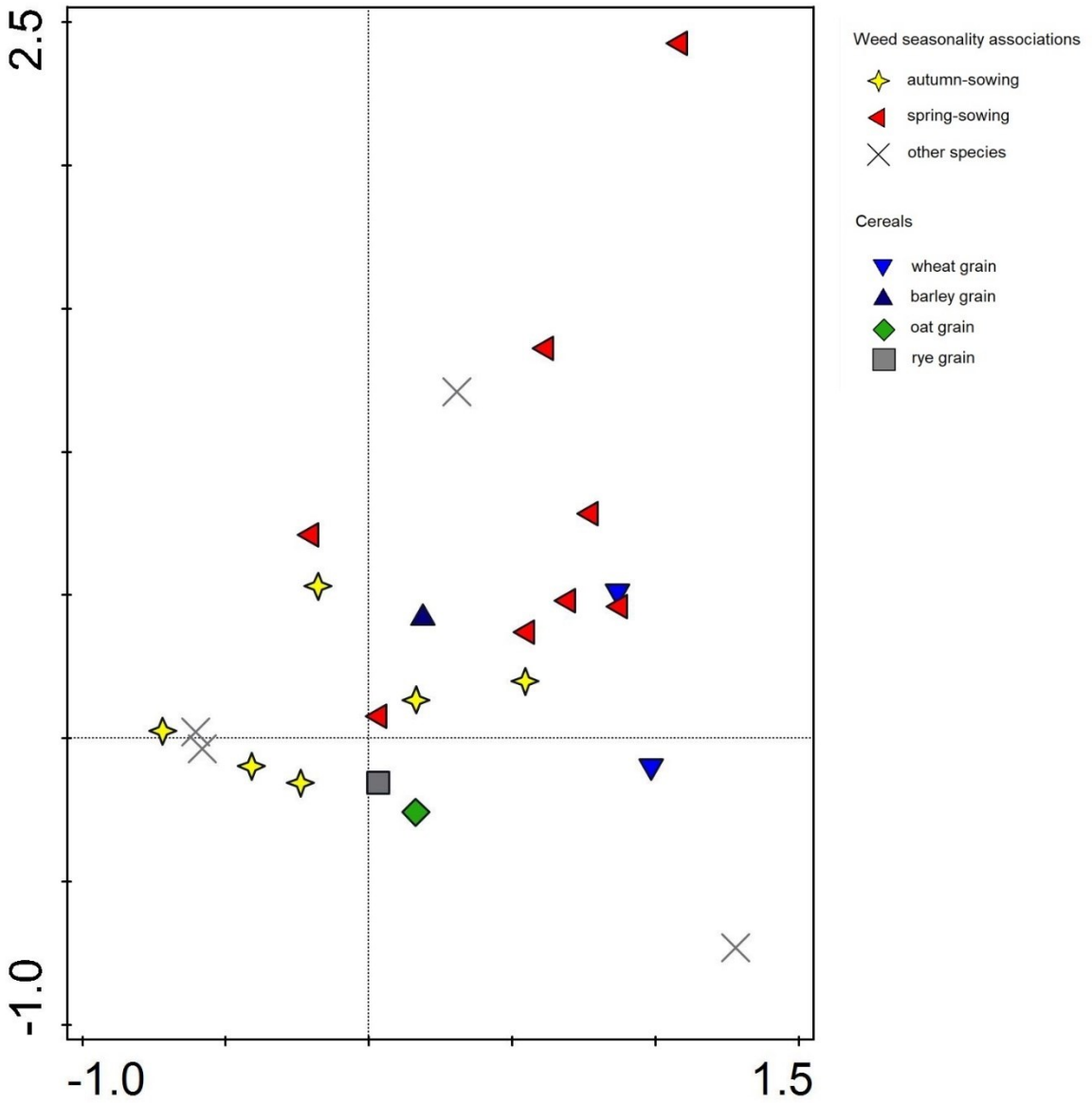
Worksheet: **14_hou**

Begin with 23 species in six samples.



The x-axis displays a chronological gradient (phases C3-D4 to the right, E1-E4 to the left) which has no corresponding with cereals or seasons. Phases C3-C4 and D4 separate along the y-axis, and there is some indication of seasonal separation along this axis too, with barley, indeterminate wheat and spring-associated weeds towards the positive end, and oats, rye, free-threshing wheat and autumn-

associated weeds towards the negative end. One possible interpretation, therefore, is that there were two kinds of wheat cultivated at Houghton, one of which was a spring-sown crop along with barley in phases C3–C4 (*c.* 770–880). Our ability to extrapolate from these nascent patterns is limited, however, by the very small size of this assemblage.

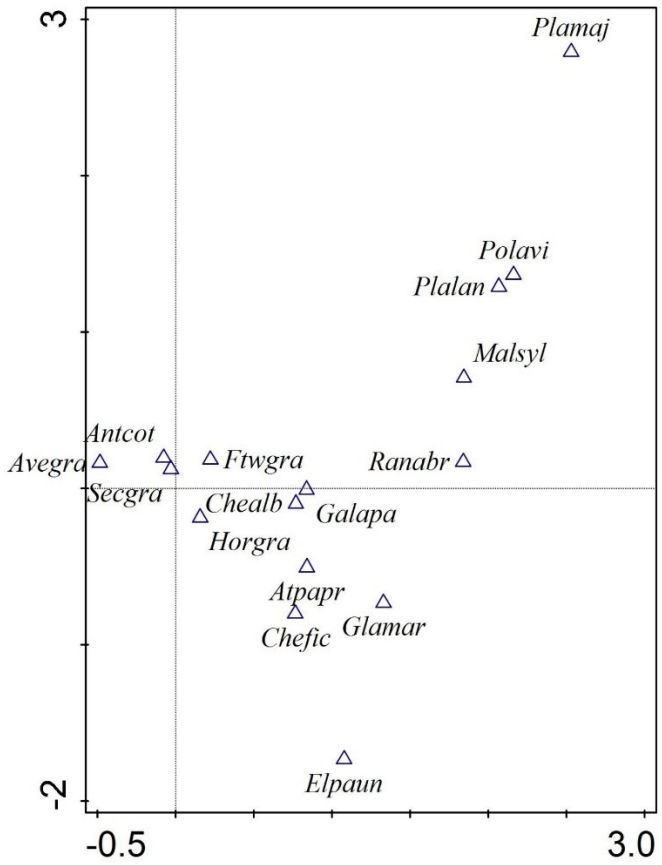


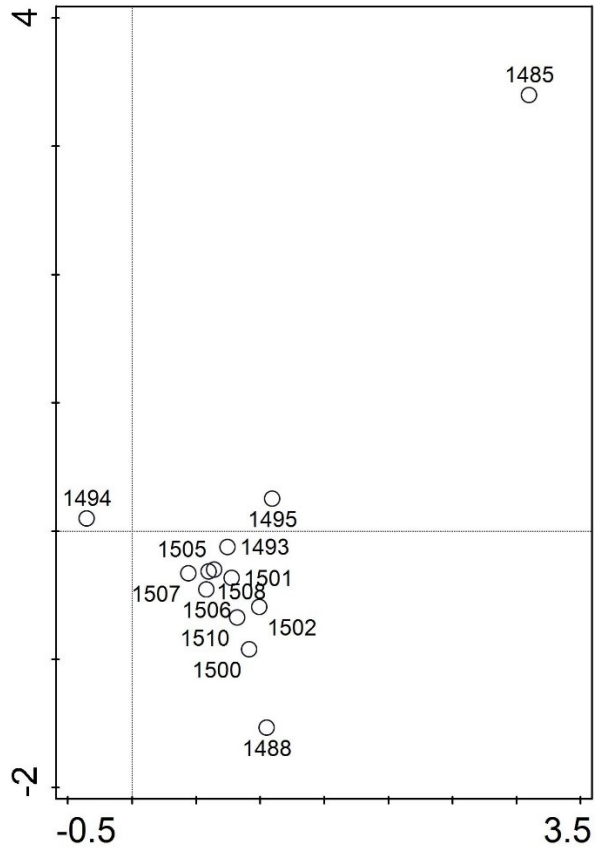
15. Ingleborough and Walpole St Andrew (Norfolk)

Worksheet: **15_ing**

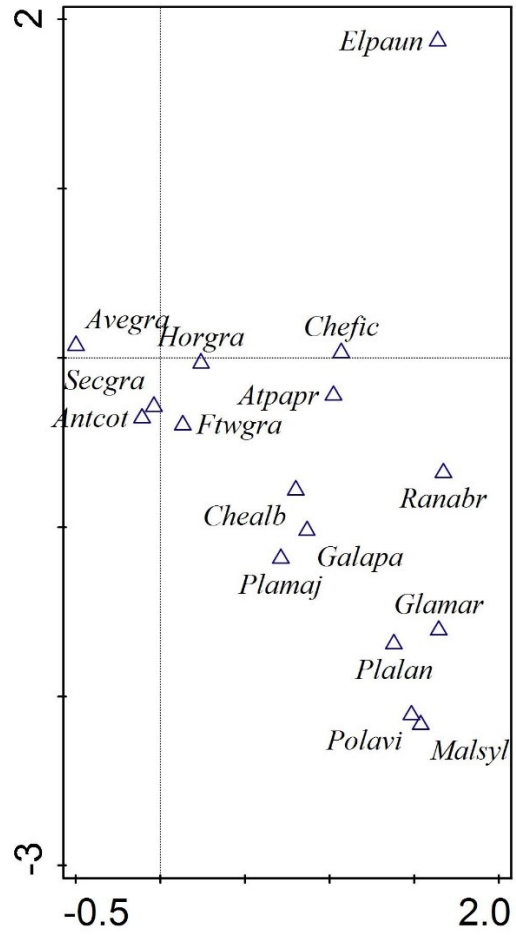
Comprising samples from excavations at Ingleborough (West Walton) and Walpole St Andrew (Rose Hall Farm).

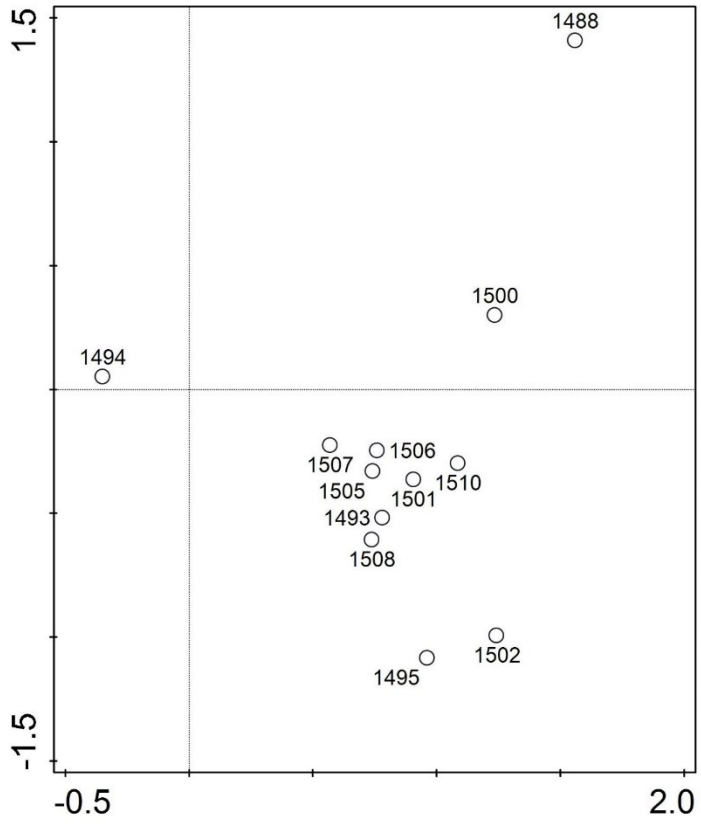
Begin with 16 species in 13 samples.

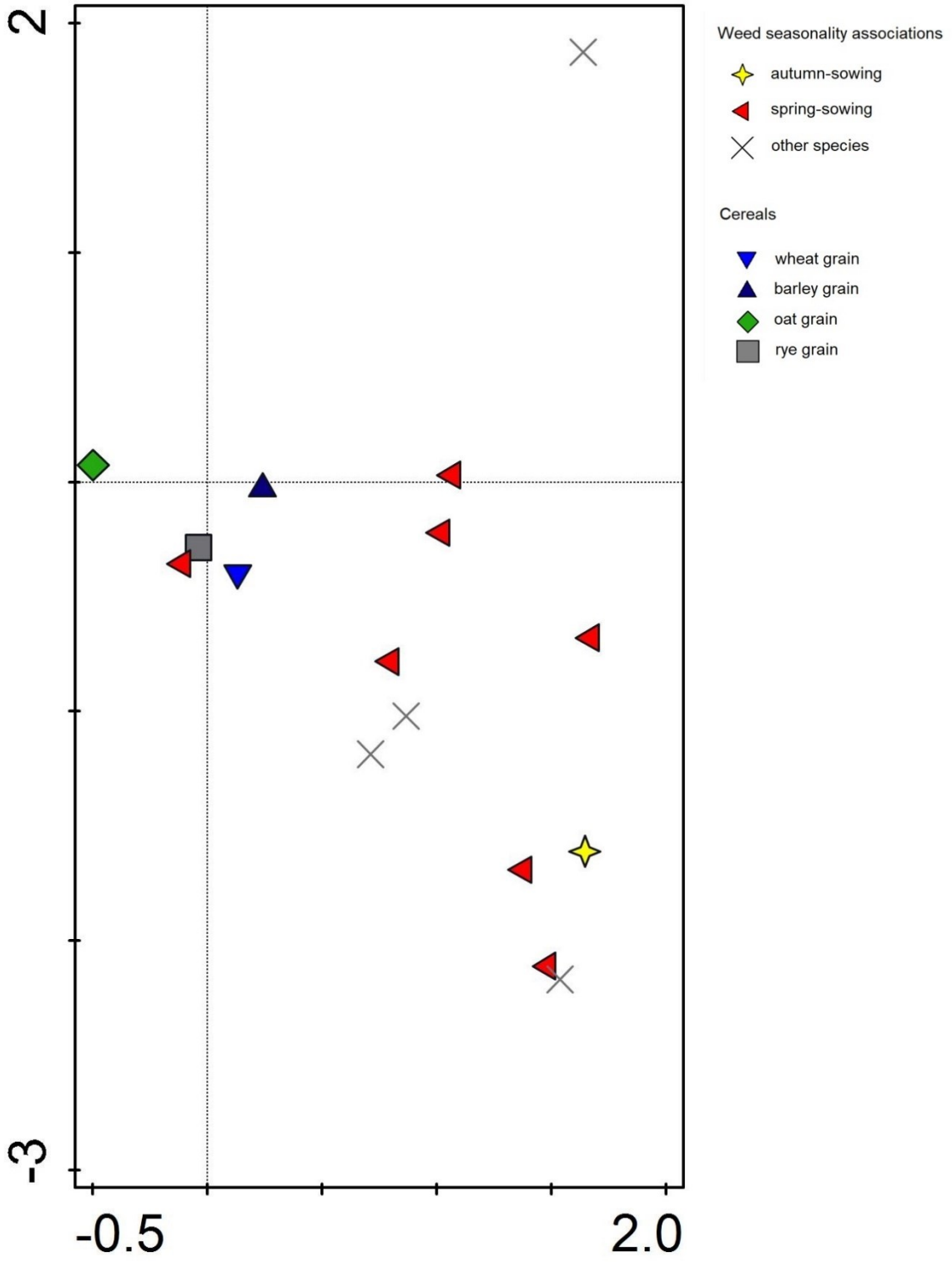




Delete outlier sample 1485 and re-run the analysis, to produce a clearer distribution. There is only one autumn-associated weed species (*Glamar*), and it is not particularly associated with any cereal. Indeed, barley is the most abundant sample in all but one of the samples, and this assemblage is therefore designed 'barley/spring-dominated' in the monograph.


2
-3
-0.5
2.0
Elpaun
Avegra
Horgra
Chefic
Secgra
Atpapr
Antcot
Ftwgra
Ranabr
Chealb
Galapa
Plamaj
Glamar
Plalan
Polavi
Malsyl

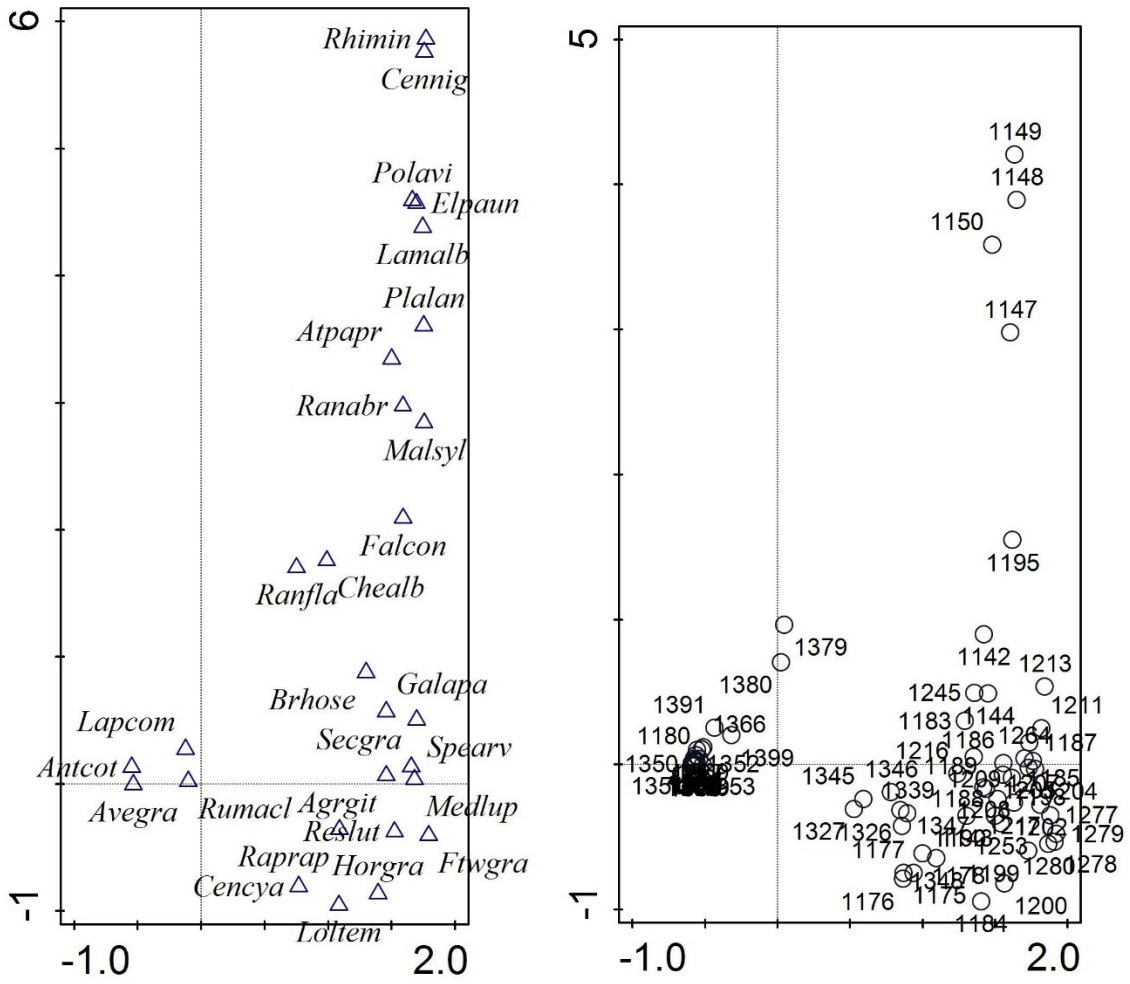

1.5
-1.5
-0.5
2.0
1488
1500
1494
1507
1506
1510
1505
1501
1493
1508
1502
1495


2
-3
-0.5
2.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

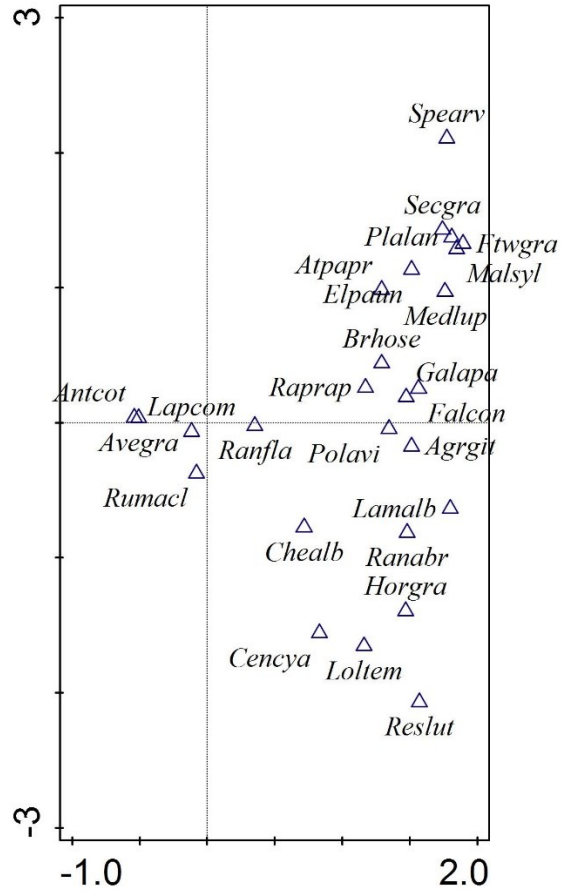
16. Ipswich (Suffolk)

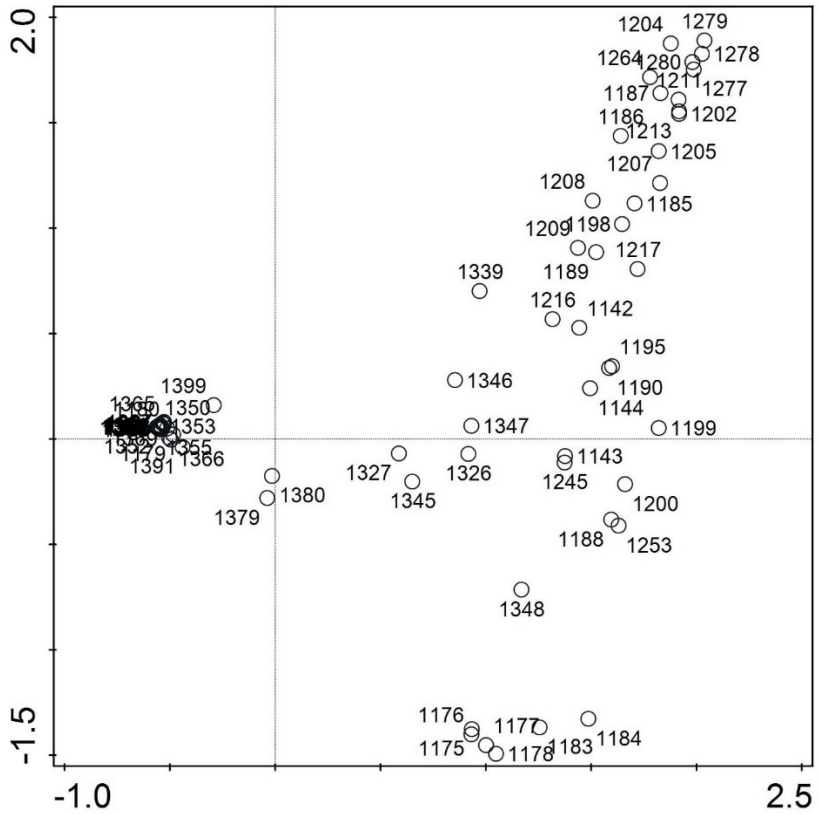
Worksheet: **16_ips**

Begin with 28 species in 76 samples.



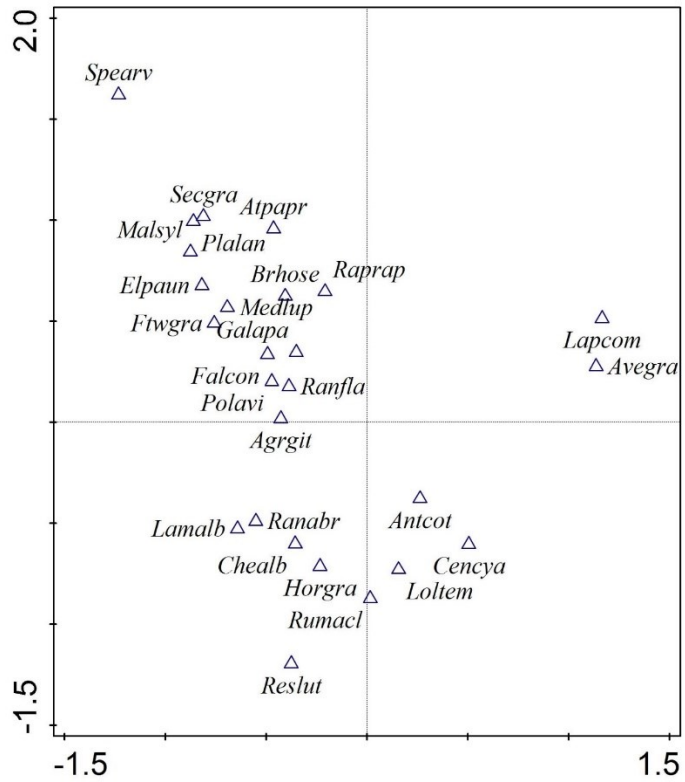
Delete outlier samples 1147, 1148, 1149 and 1150 and re-run.

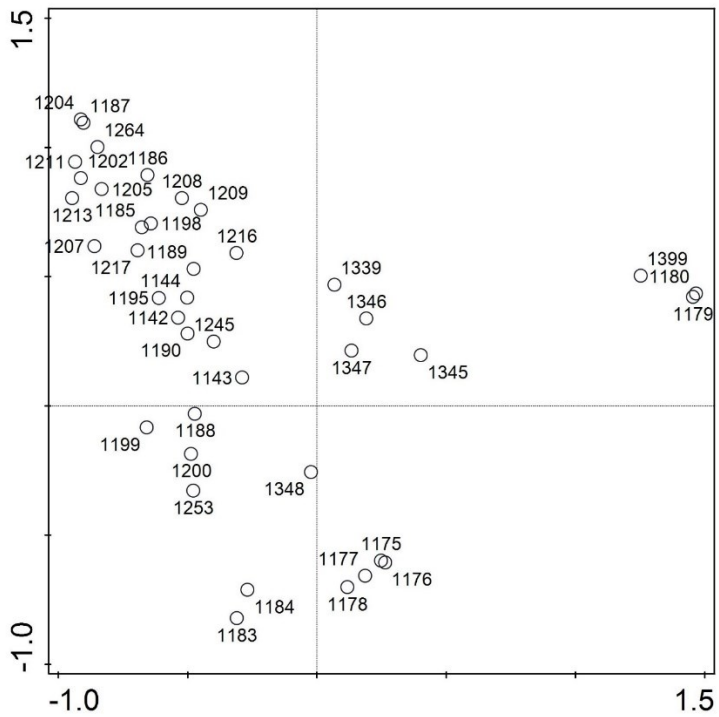

3
-3
-1.0
2.0
Spearv
Secgra
Plalan
Ftwgra
Atpapr
Malsyl
Elpalm
Medlup
Brhose
Galapa
Antcot
Raprap
Lapcom
Falcon
Avegra
Ranfla
Polavi
Agrgit
Rumacl
Lamalb
Chealb
Ranabr
Horgra
Cencya
Loltem
Reslut


2.0
-1.5
-1.0
2.5
1204
1279
1264
1280
1278
1211
1187
1277
1186
1202
1213
1205
1207
1208
1185
1209
1198
1217
1339
1189
1216
1142
1195
1346
1190
1144
1399
1350
1353
1347
1199
1355
1366
1391
1143
1327
1326
1245
1380
1345
1200
1379
1188
1253
1348
1176
1177
1175
1178
1183
1184

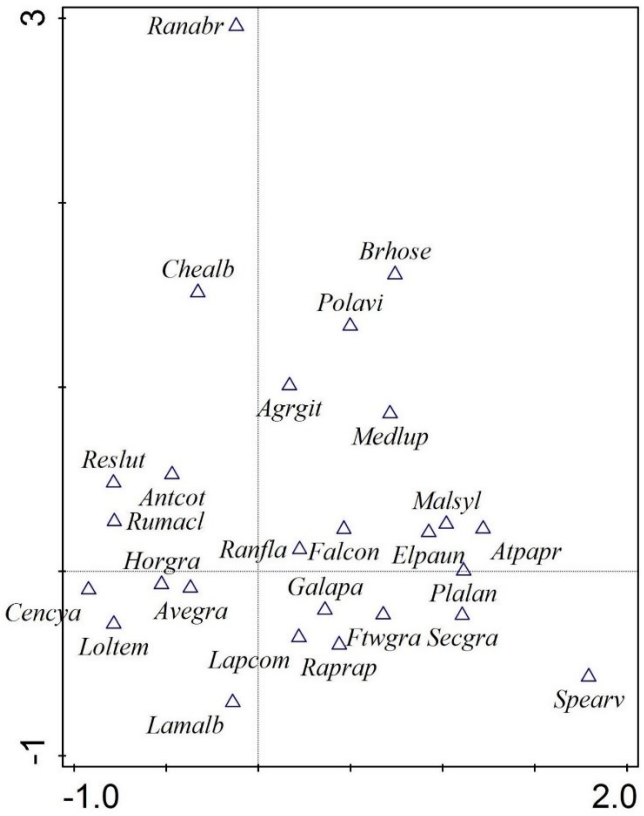
A tight cluster of samples to the left of the x-axis may be distorting other patterns in the rest of the assemblage. It appears to be predominantly associated with samples from the Wingfield Street excavation, a sub-assemblage dated to phase E (*c.* AD 1030-1220) and distinguished by its high proportions of oat grains.

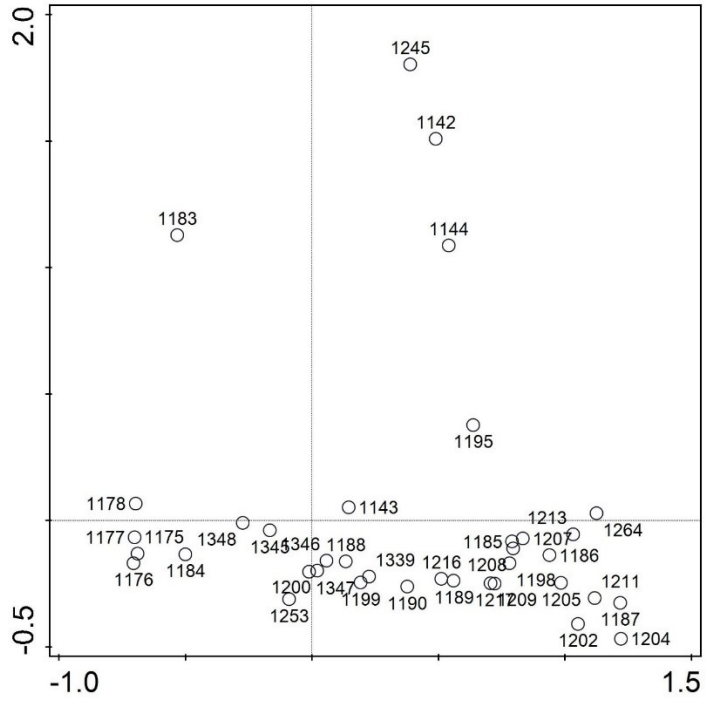
Delete the Wingfield Street phase E samples (ID 1277–1280, and 1326–1391) and re-run.

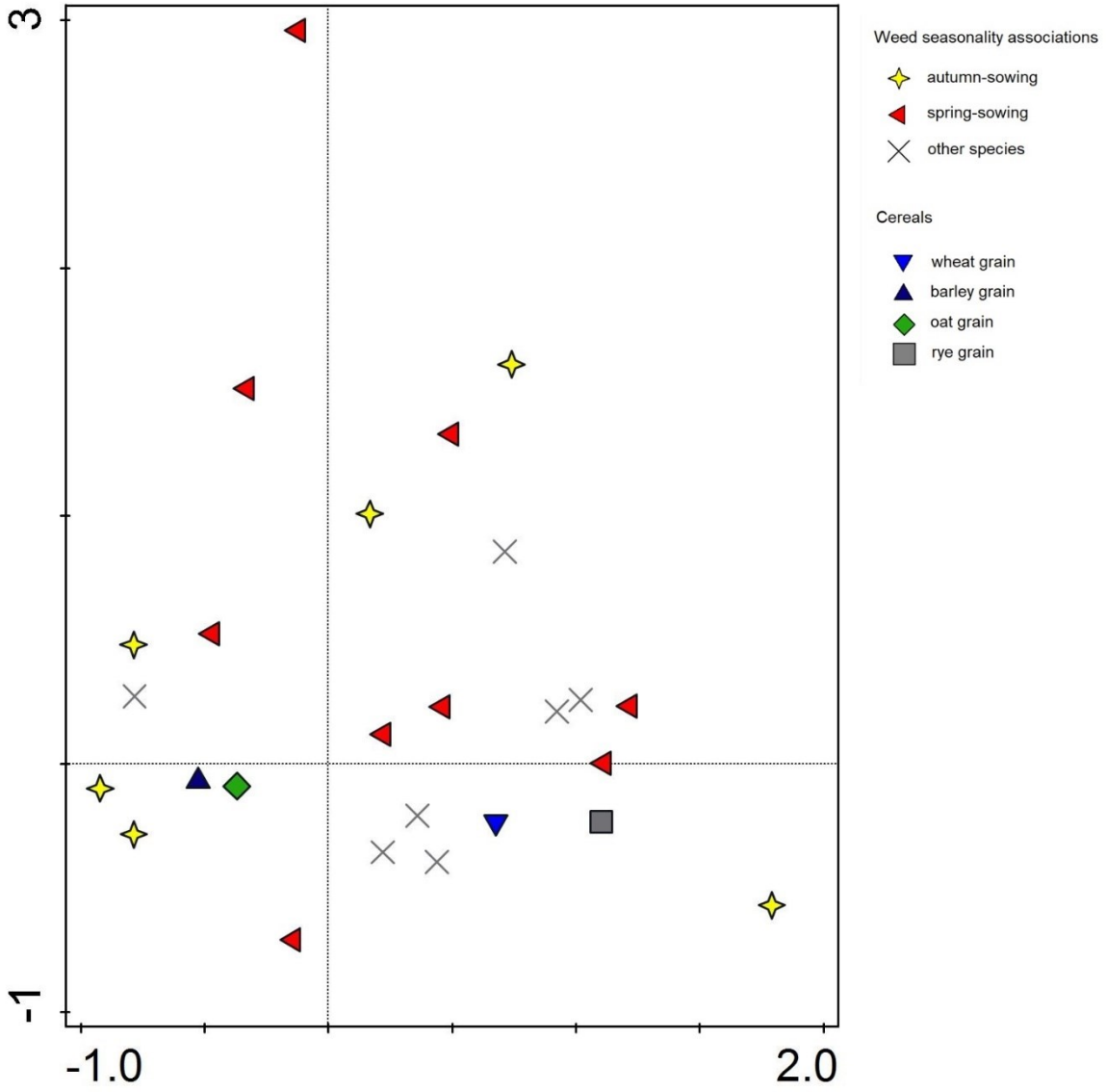




Delete outlier samples 1179, 1180 and 1399 and re-run, to produce a clearer distribution. Cereals now separate along the x-axis – oats and barley to the left, wheat and rye to the right – but there is no corresponding seasonal gradient among the weed species.





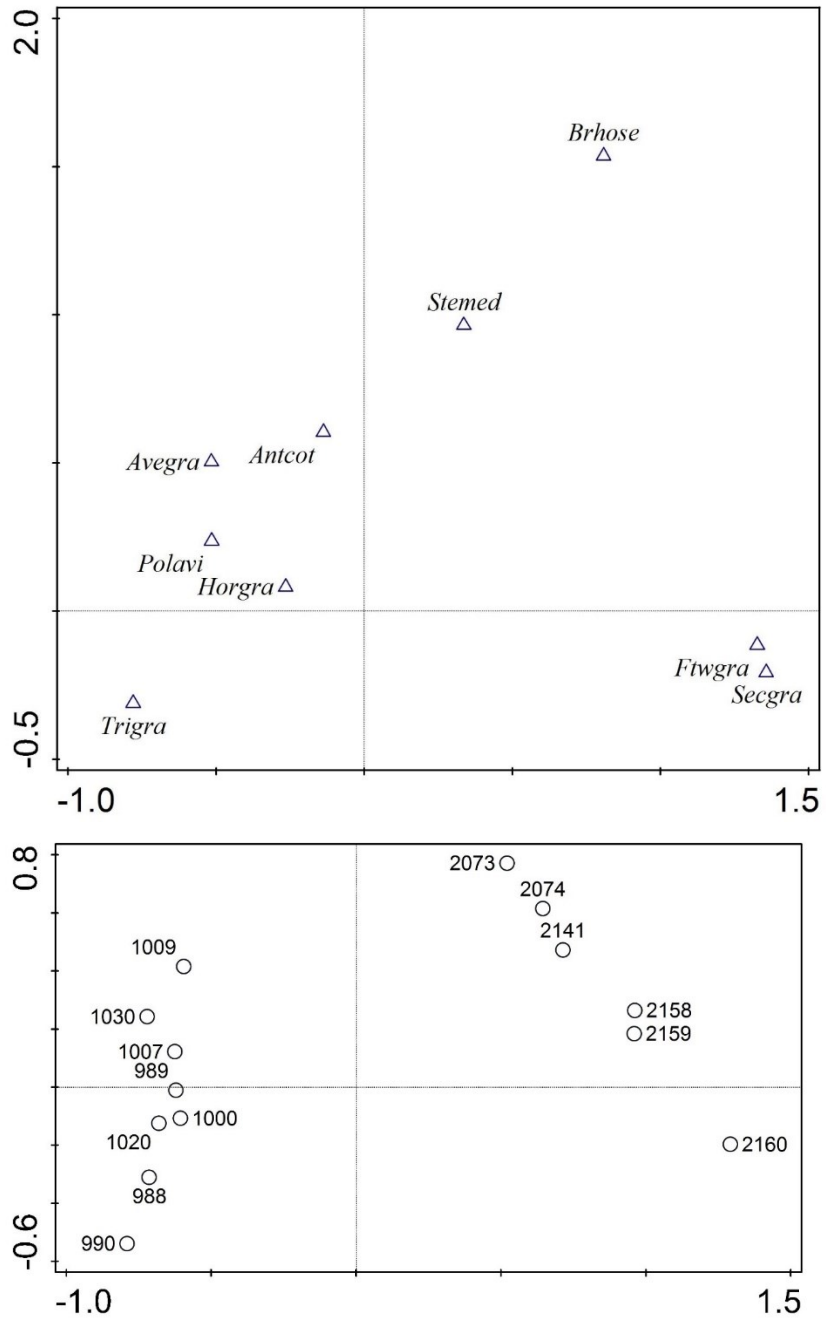

3
-1
-1.0
2.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

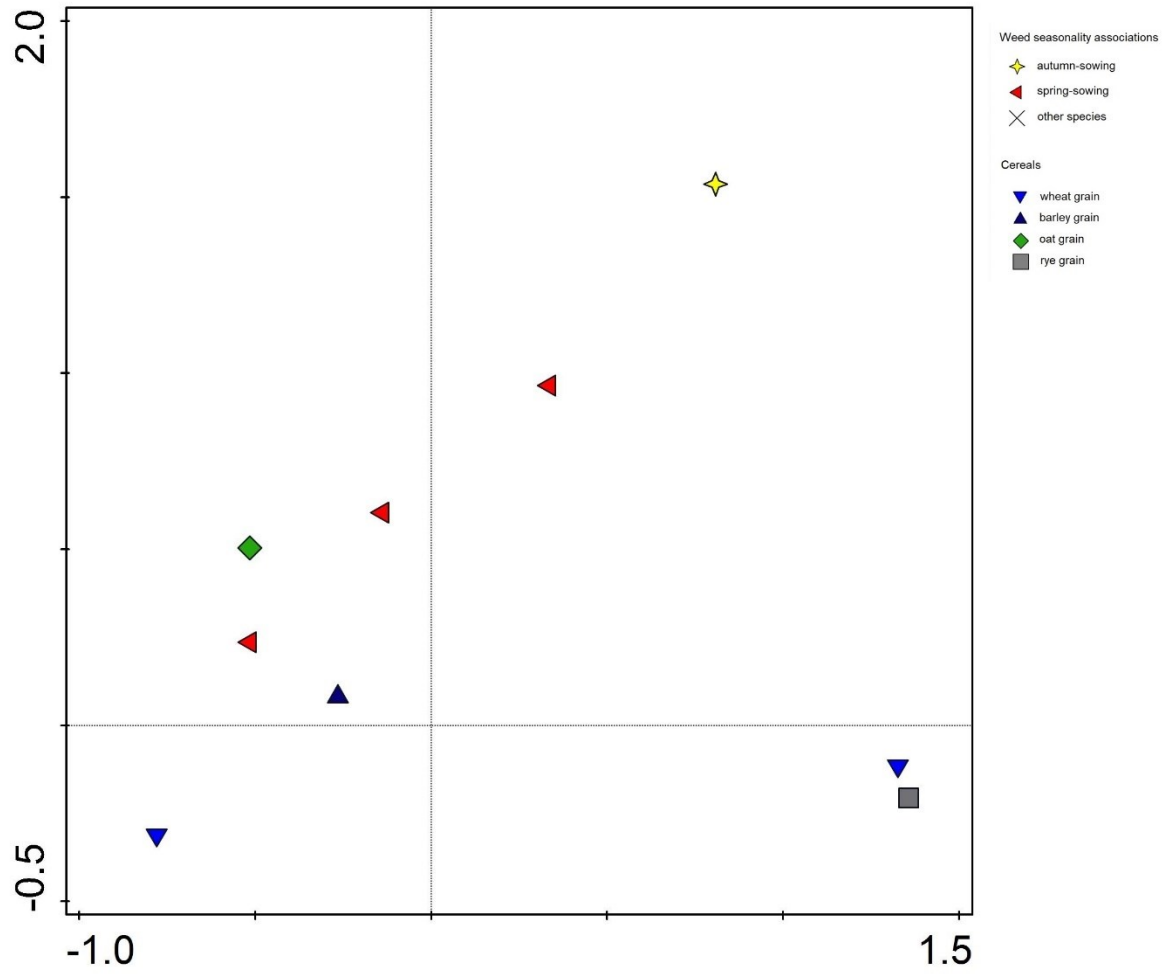
17. Longstanton (Cambridgeshire)

Worksheet: **17_lon**

Comprising samples from excavations at Longstanton West and Home Farm, Longstanton.

Begin with 9 species in 14 samples. There is only one autumn-associated weed species (*Brhose*), and it is not particularly associated with any cereal. This assemblage is therefore classified as 'spring-dominated' in the monograph.

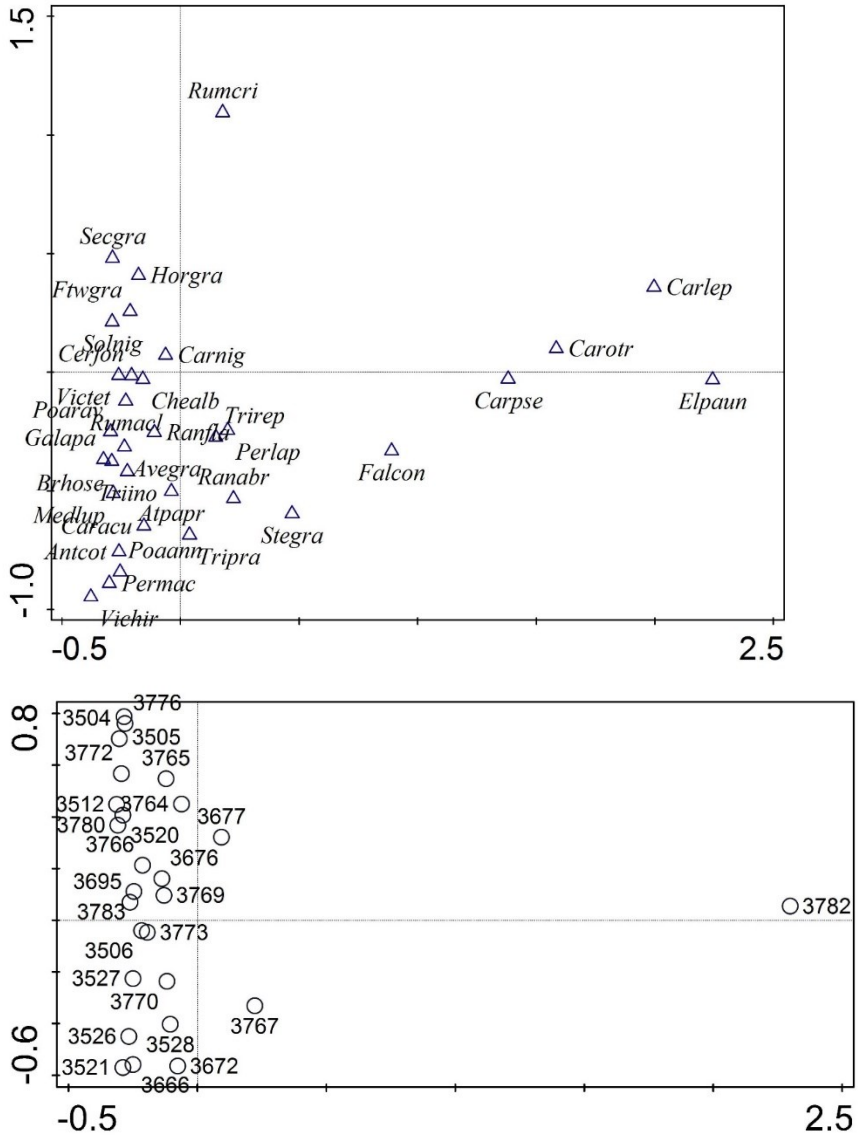



2.0
-0.5
-1.0
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

18. Lydd Quarry (Kent)

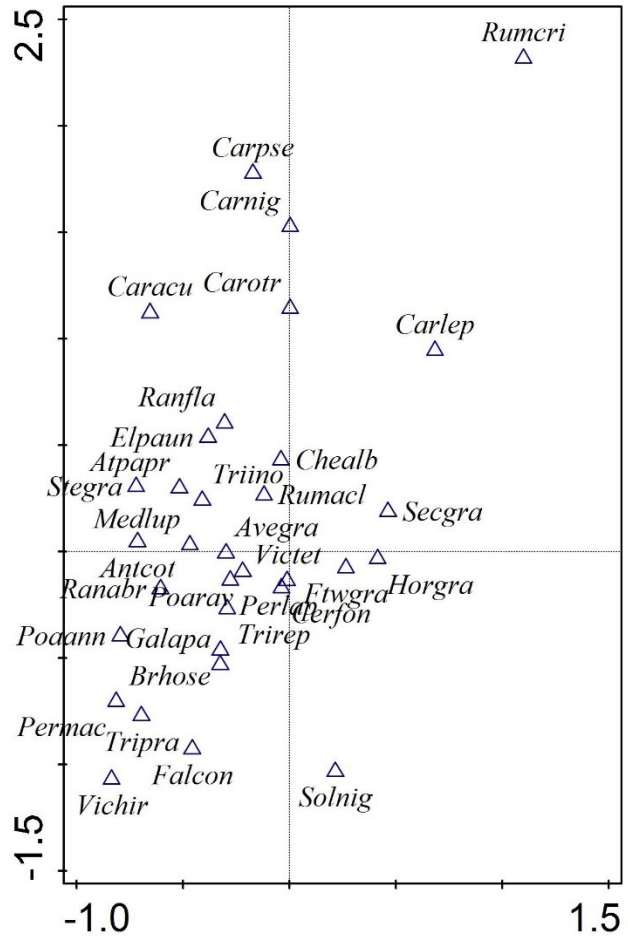
Worksheet: **18_lyd**

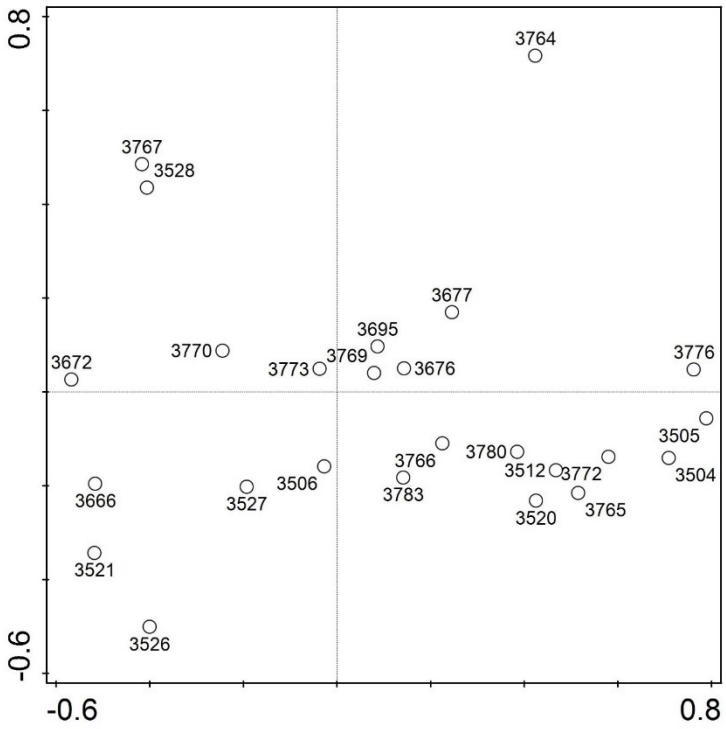
Begin with 33 species in 26 samples.

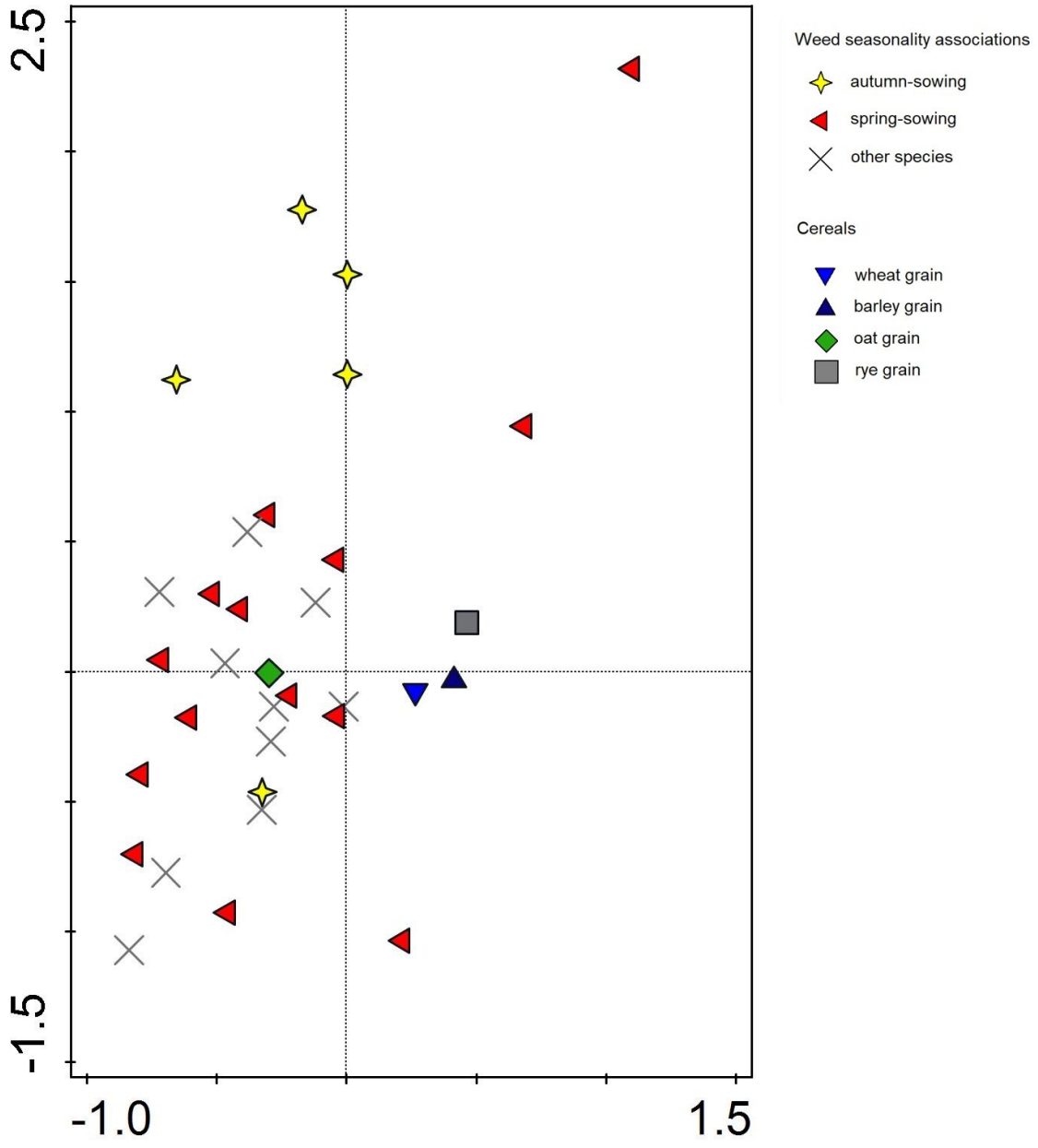


Delete outlier sample 3782 and re-run analysis, to produce a clearer distribution.

Among the weeds, there is some seasonal separation along the y-axis, with autumn-associated species tending towards the positive end and spring-associated species tending towards the negative end. There is no corresponding separation, however, among the cereals. Hence, while distinct autumn and springtime sowing seasons may have been observed at this site, there were no systematic associations between these seasons and particular cereals.


2.5
-1.5
-1.0
1.5
Rumcri
Carpse
Carnig
Caracu
Carotr
Carlep
Ranfla
Elpaun
Atpapr
Triino
Chealb
Stegra
Rumacl
Secgra
Medlup
Avegra
Victet
Antcot
Ranabr
Poarav
Perlan
Horgra
Etwgra
Alerfon
Poaann
Galapa
Trirep
Brhose
Permac
Tripra
Falcon
Vichir
Solnig


0.8
-0.6
-0.6
0.8
3764
3767
3528
3677
3695
3770
3769
3773
3676
3672
3776
3505
3780
3766
3512
3772
3504
3506
3783
3666
3527
3520
3765
3521
3526


2.5
-1.5
-1.0
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

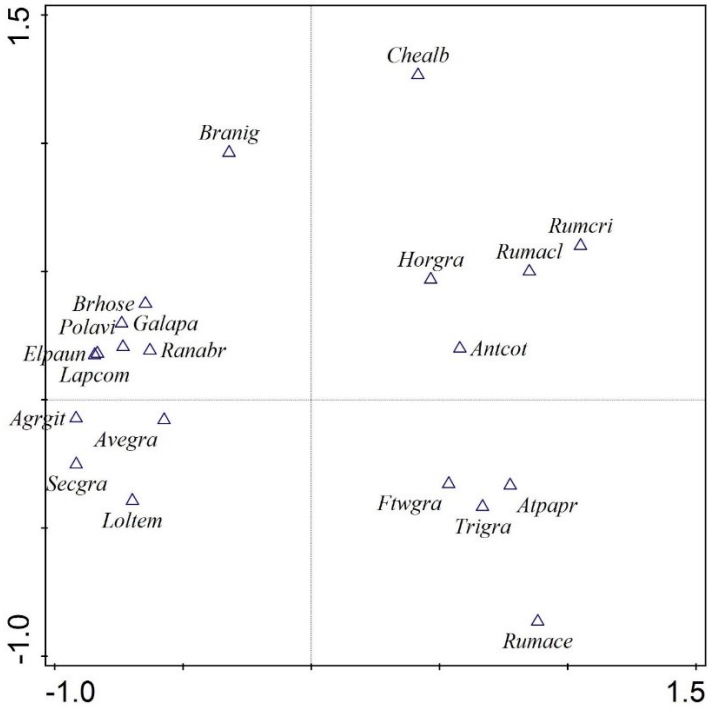
19. Lydford (Devon)

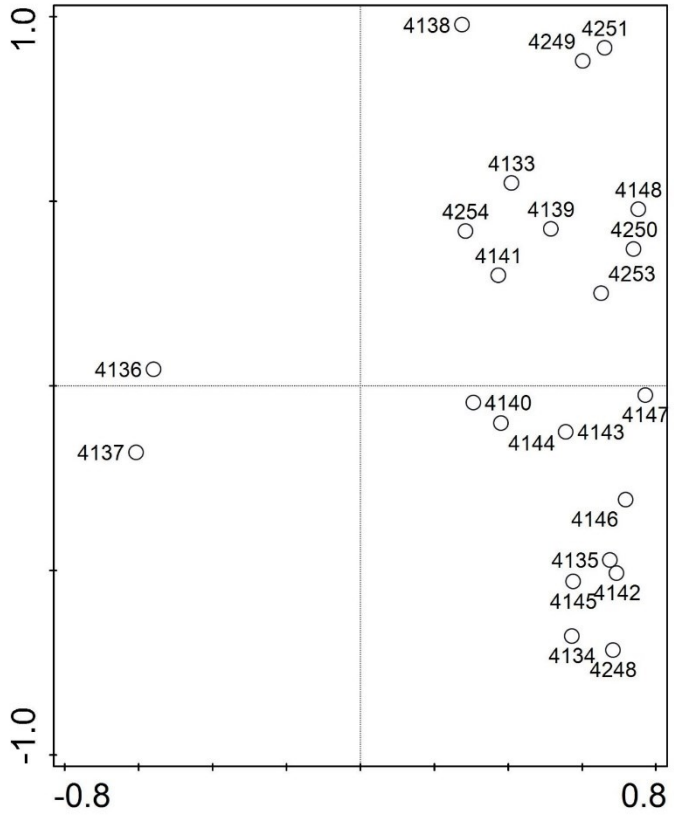
Fully quantified weed seed data are not available for this site, but it can be noted that seeds of corn marigold (*Glebionis segetum* (L.) Fourr.) and corncockle (*Agrostemma githago* L.) – both here classed as autumn-associated weed species – were found as contaminants of the rye crop in the granaries.

20. Lyminge (Kent)

Worksheet: **20_lym**

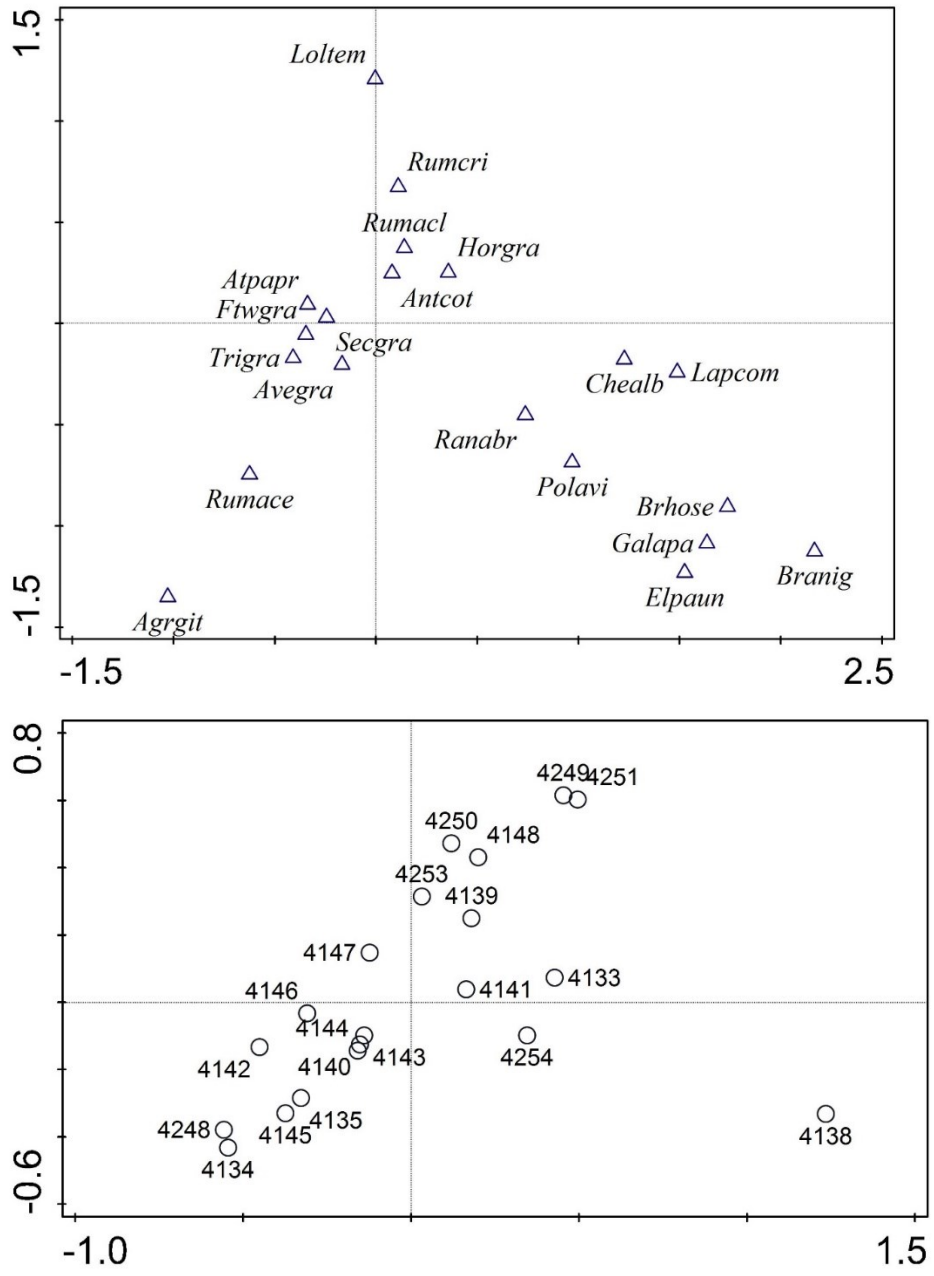
Begin with 20 species in 22 samples.

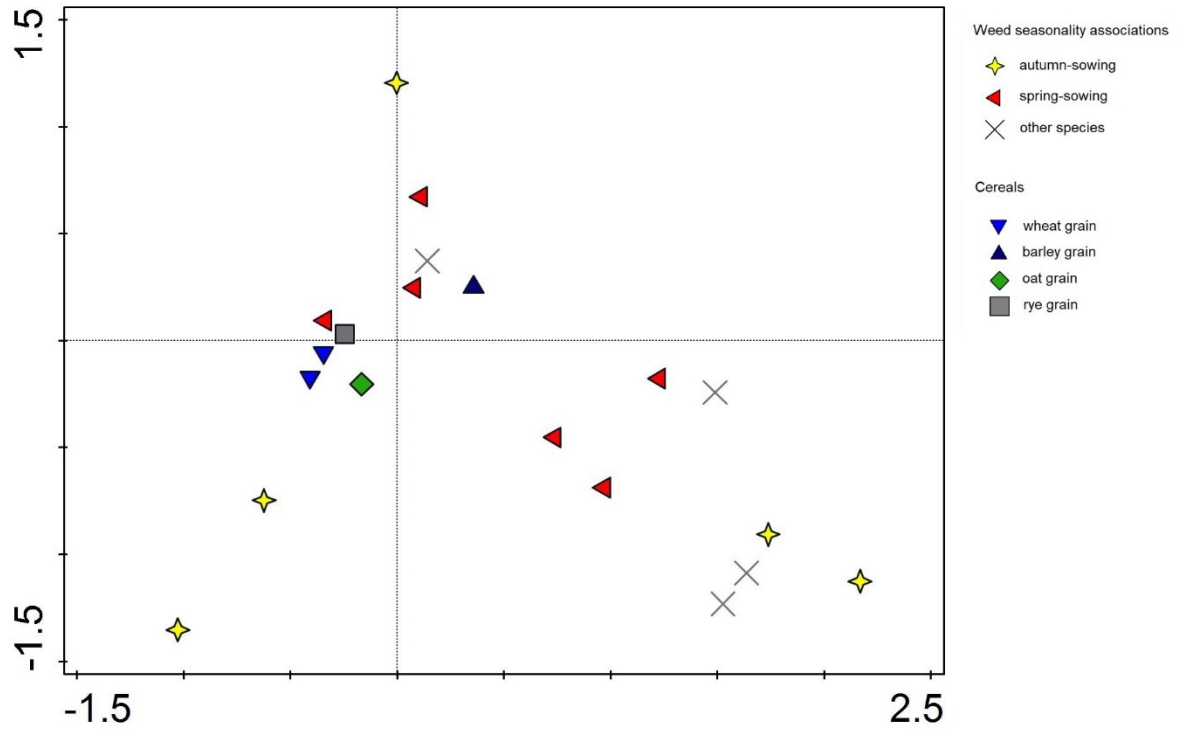




Delete outlier samples 4136 and 4137 and re-run, to produce a clearer distribution.

Both autumn- and spring-associated weed species are present, but there are no indications of systematic seasonal sowing of particular cereals.

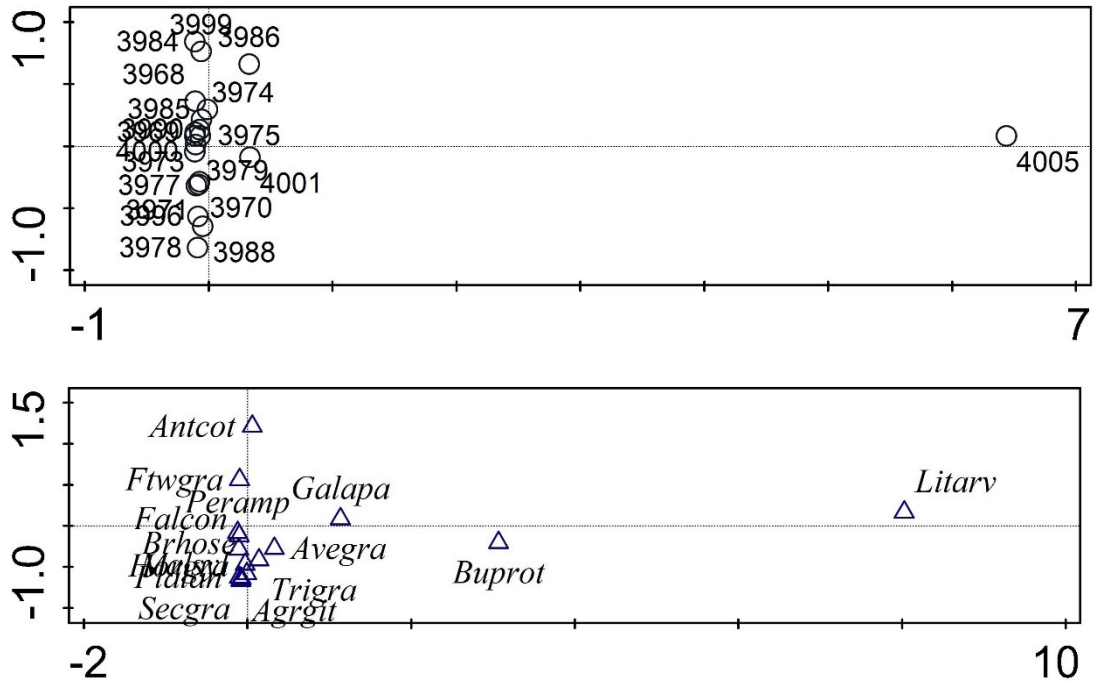



1.5
-1.5
-1.5
2.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

21. Mildenhall (Suffolk)

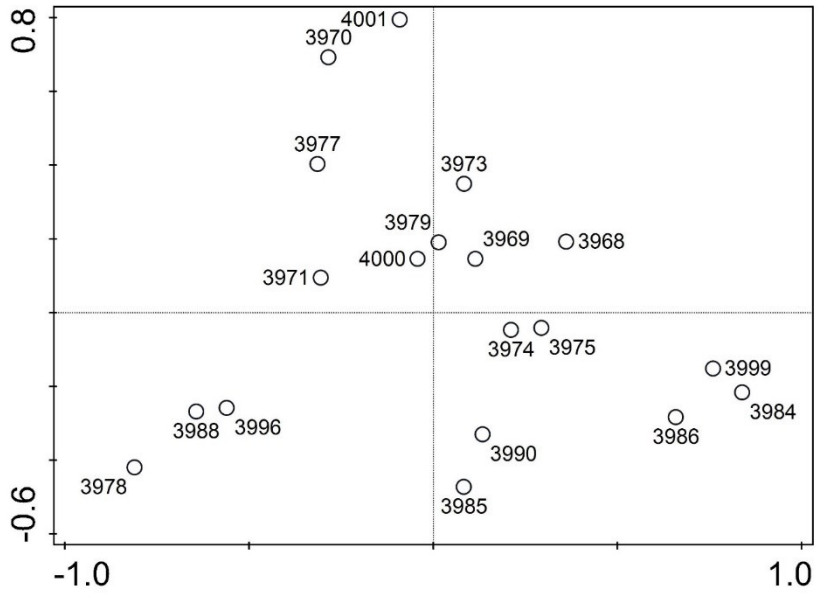
Worksheet: **21_mil**

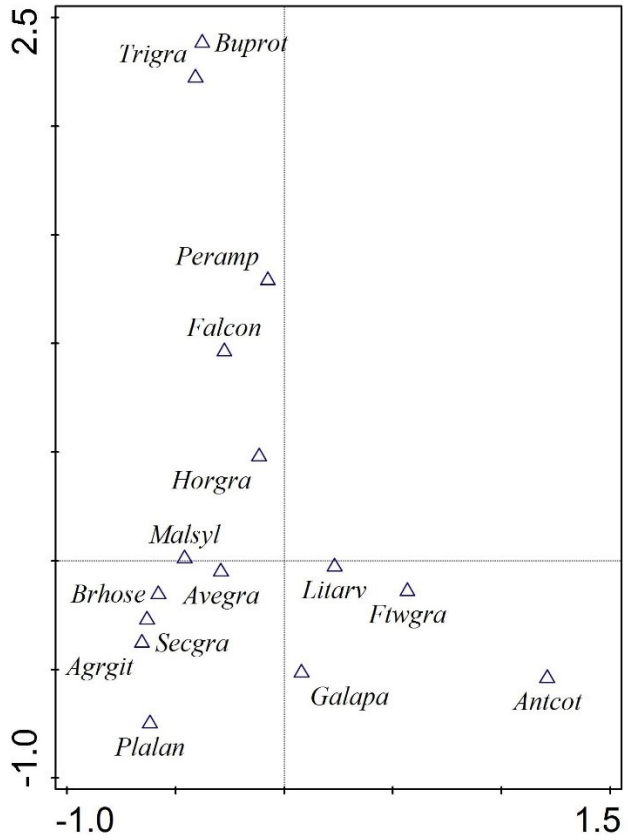
Begin with 15 species in 20 samples.

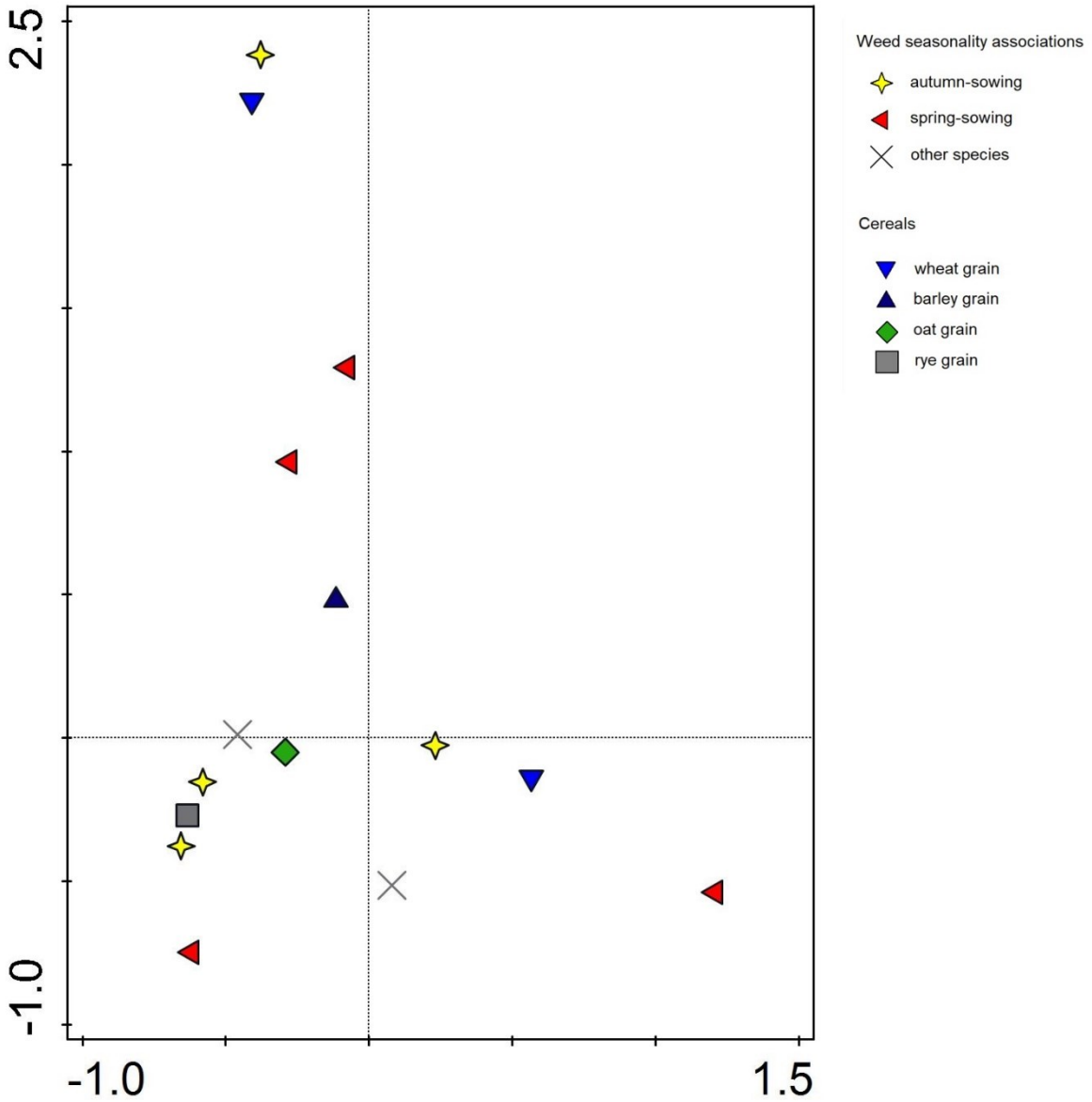


Delete outlier sample 4005 and re-run, to produce a clearer distribution.

Both spring- and autumn-associated weeds are present, but there is no indication of systematic seasonal sowing for any of the cereals.

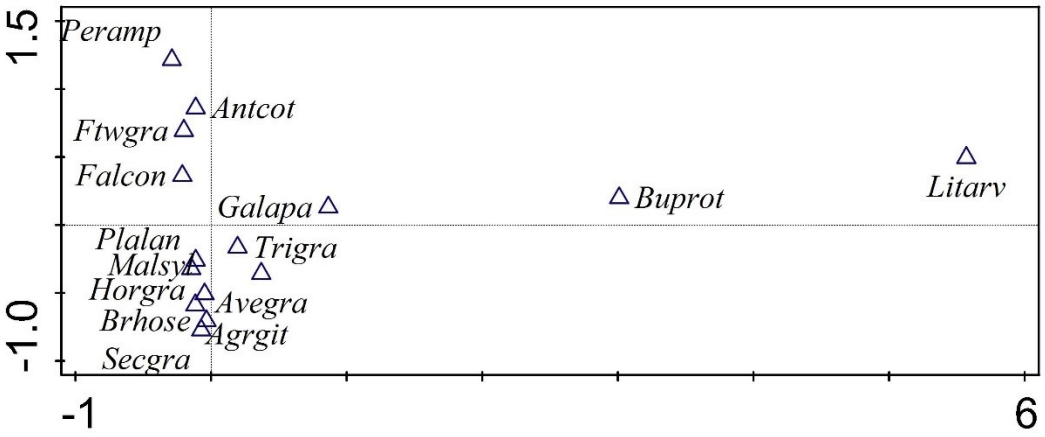


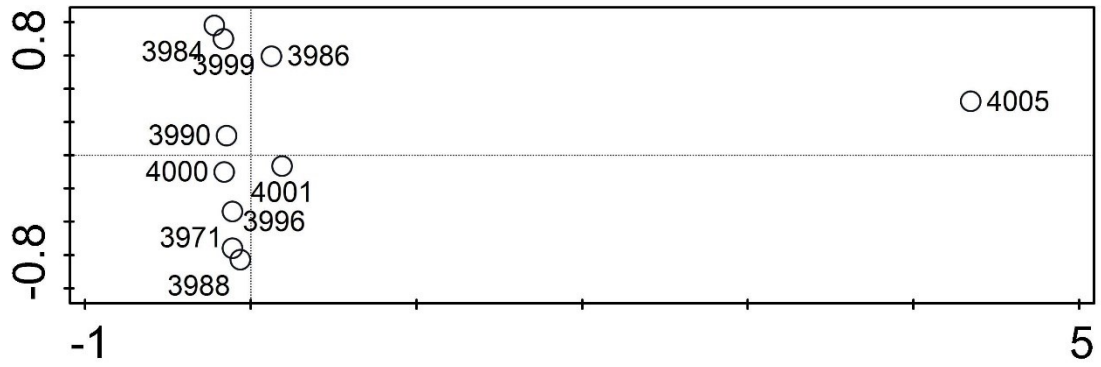

2.5
-1.0
-1.0
1.5
Trigra
Buprot
Peramp
Falcon
Horgra
Malsyl
Brhose
Avegra
Secgra
Agrgit
Plalan
Litarv
Ftwgra
Galapa
Antcot



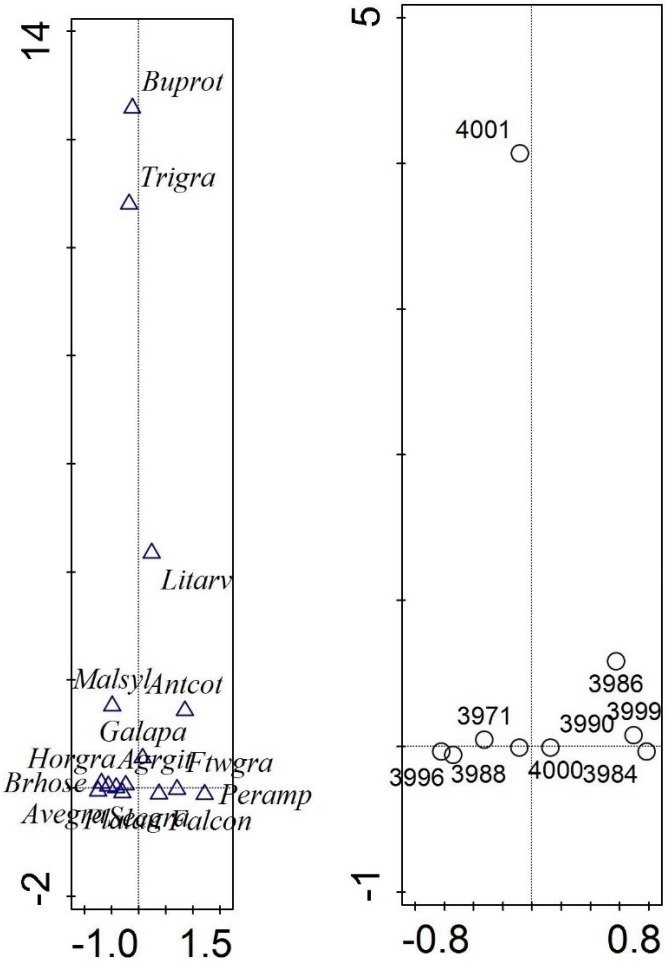
There is, however, some indication of seasonal sowing if we focus on the later phases (D1–E5).

Delete the phase C (*c.* 670–880) samples, and begin again with 15 species in ten samples.



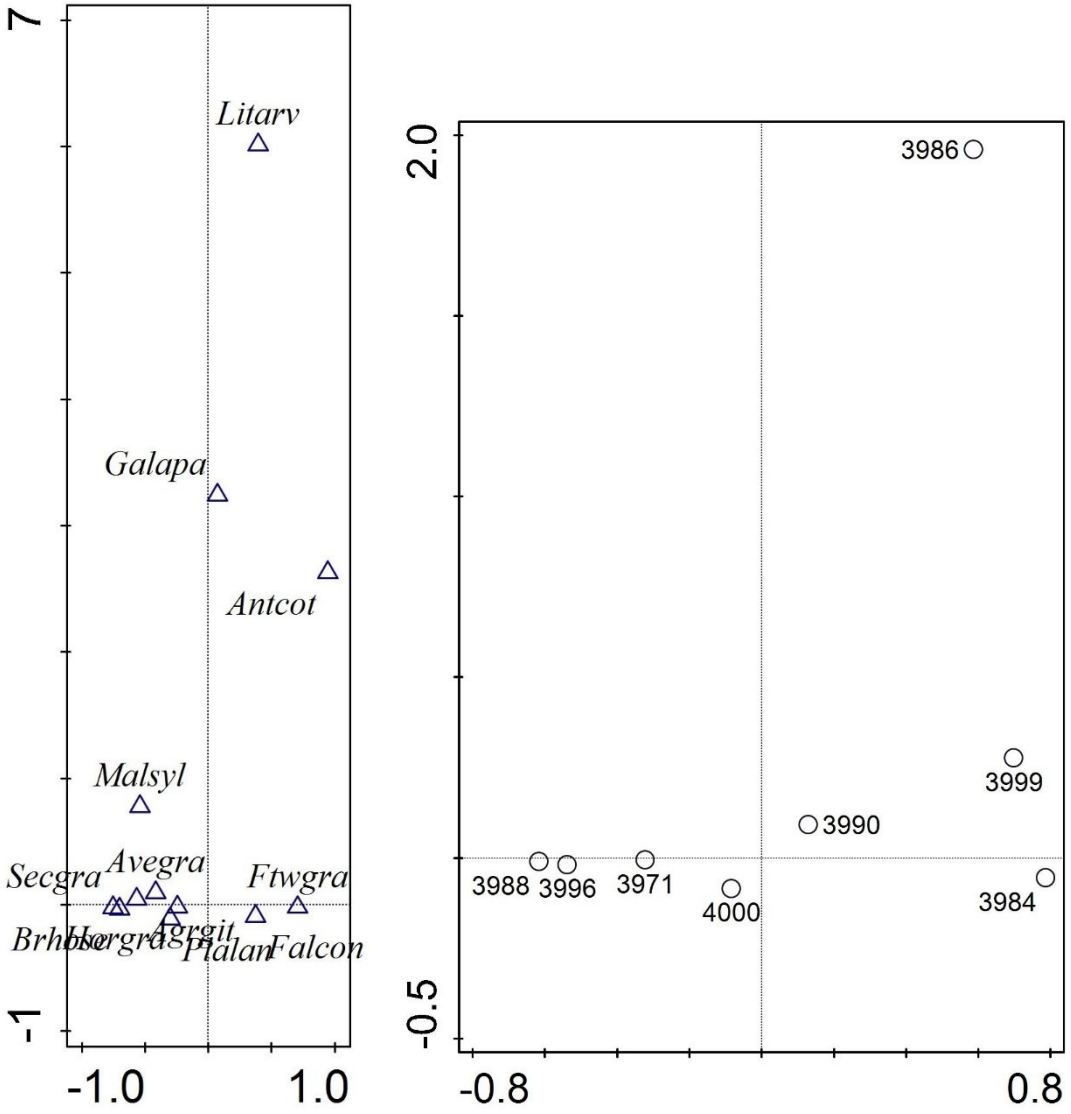


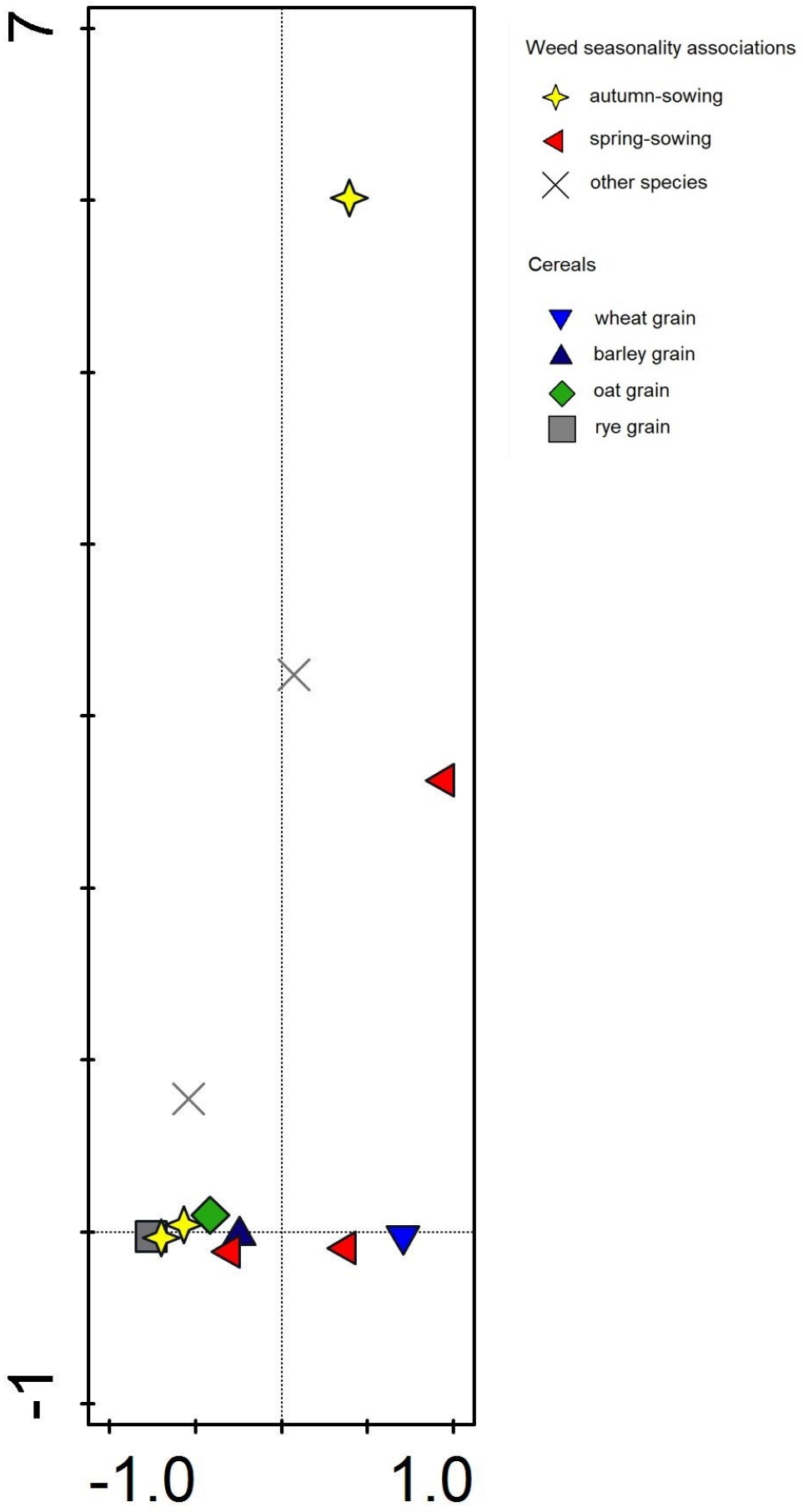
Delete outlier 4005 and re-run analysis.



Delete outlier sample 4001. Also delete species *Buprot* (no longer present in the assemblage) and *Peramp* (only one seed in one sample remains), and amalgamate *Trigra* (just one grain in one sample) with *Ftwgra*. Re-run analysis to produce a clearer distribution.

Now there is some slight indication (along the x-axis) of an association between wheat and springtime sowing, at least for these later phases (D1–E5: *c.* AD 880–1220).

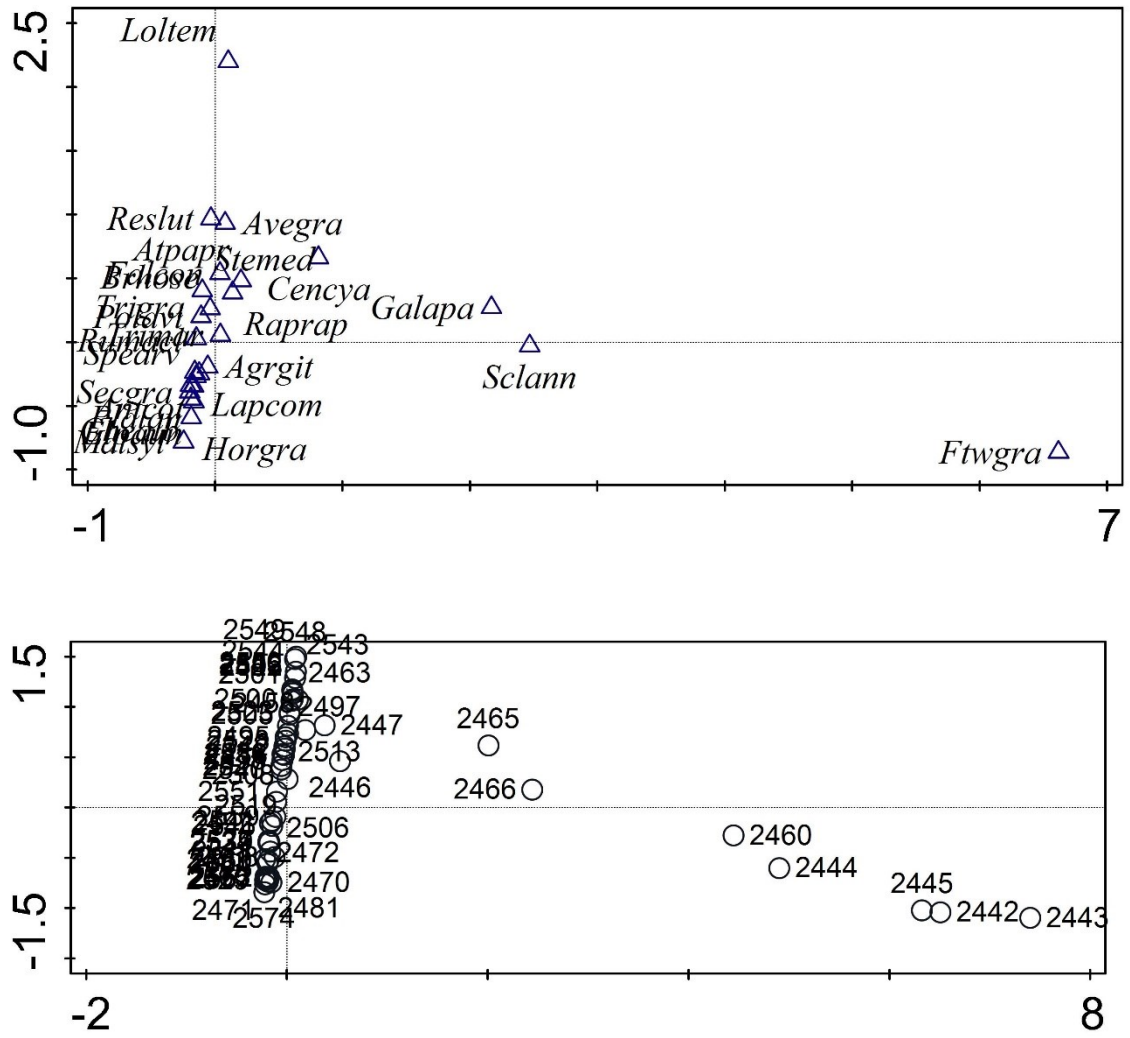

7
-1
-1.0
1.0
Litarv
Galapa
Antcot
Malsyl
Secgra
Avegra
Ftwgra
Brhhor
Hordra
Agrgit
Phalan
Falcon
2.0
-0.5
-0.8
0.8
3986
3999
3990
3988
3996
3971
4000
3984


7
-1
-1.0
1.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

22. Norwich Castle (Norfolk)

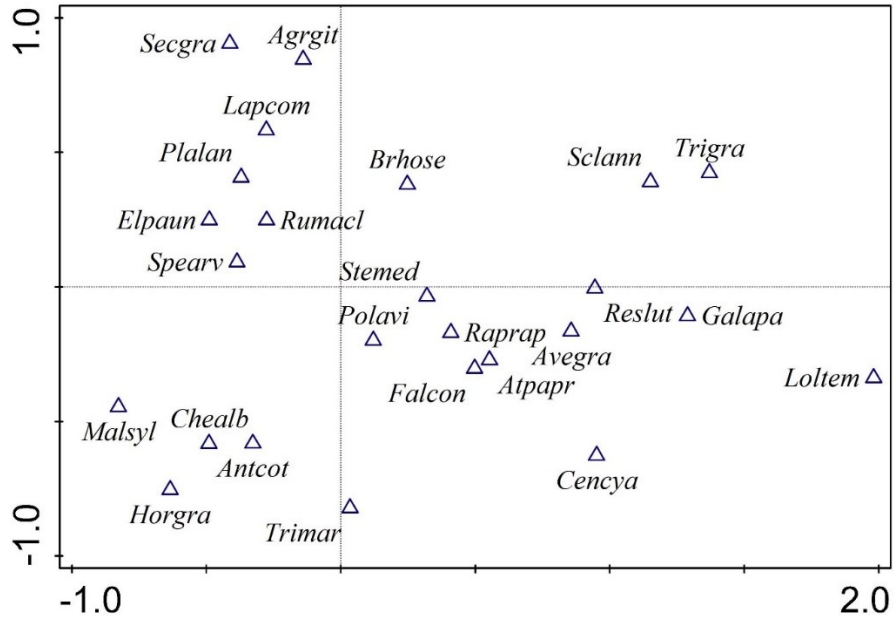
Worksheet: **22_nor**

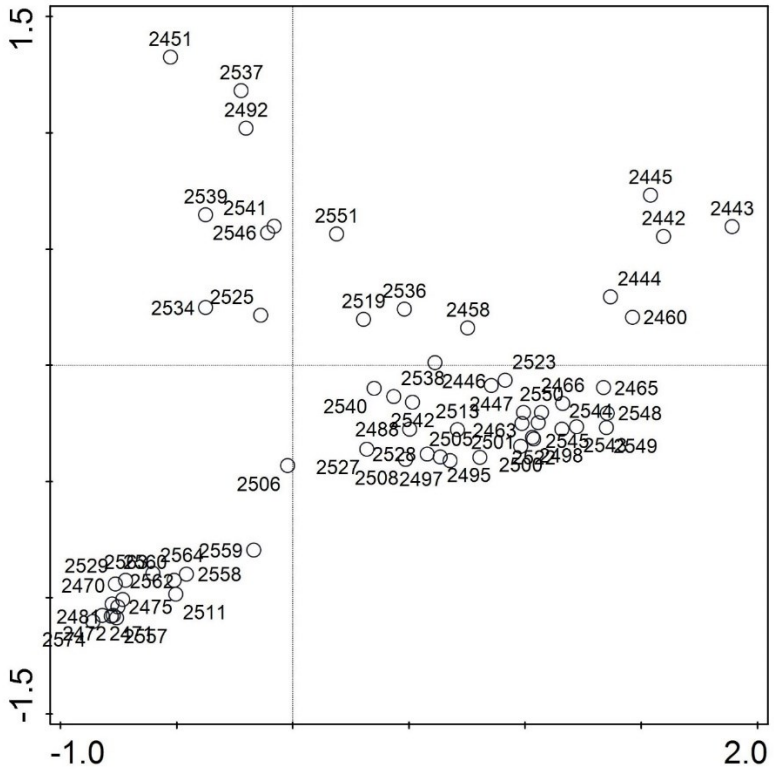
Begin with 26 species in 60 samples.



Ftwgra is conspicuous as an outlying species. Amalgamate this with *Trigra* and re-run analysis, to produce a clearer distribution.

Both autumn- and spring-associated weed species are present, but there are no indications of systematic seasonal sowing for any of the crops. Variations in crop content seem to be a strong influence on the results (as demonstrated by the distance of the cereal species from the origin – greater than that of most weed species), but there is no corresponding pattern among the weeds, at least in terms of seasonal sowing.


1.0
-1.0
-1.0
2.0
Secgra
Agrgit
Lapcom
Plalan
Brhose
Sclann
Trigra
Elpaun
Rumacl
Spearv
Stemed
Polavi
Reslut
Galapa
Raprap
Avegra
Loltem
Falcon
Atpapr
Malsyl
Chealb
Antcot
Cencya
Horgra
Trimar


1.5
-1.5
-1.0
2.0
2451
2537
2492
2539
2541
2546
2551
2445
2442
2443
2534
2525
2519
2536
2458
2444
2460
2523
2538
2446
2466
2465
2540
2447
2550
2513
2544
2548
2488
2542
2463
2505
2501
2545
2549
2528
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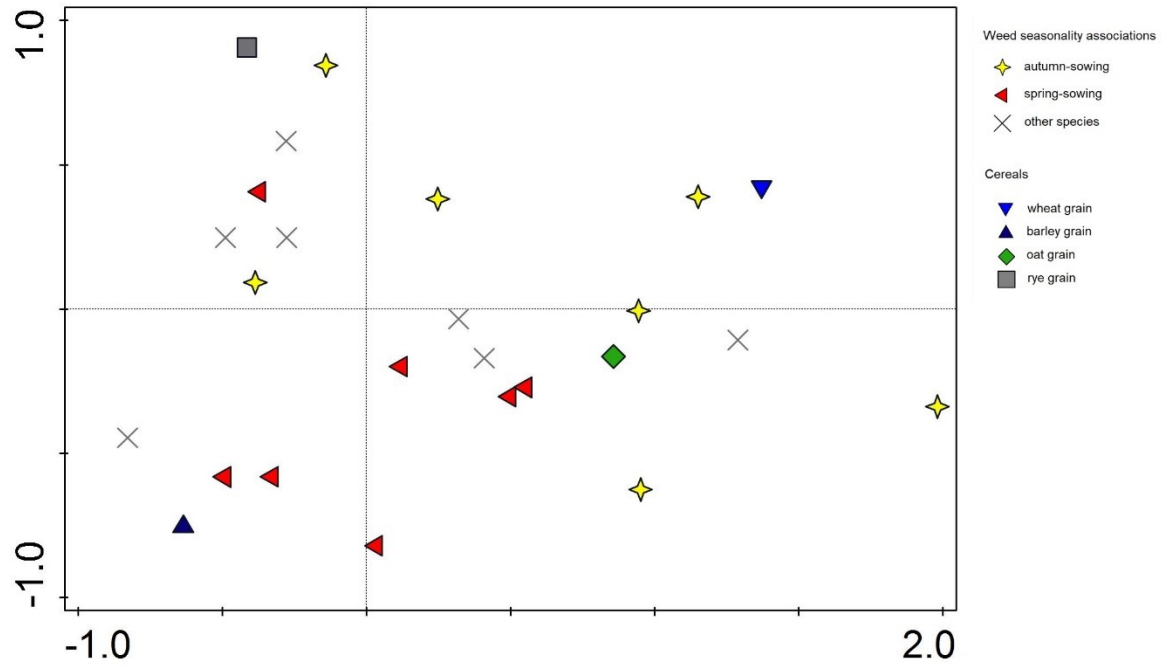
2506
2559
2564
2558
2562
2470
2475
2511
2557


1.0
-1.0
-1.0
2.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

23. Ottery St Mary (Devon)

Worksheet: **23_ott**

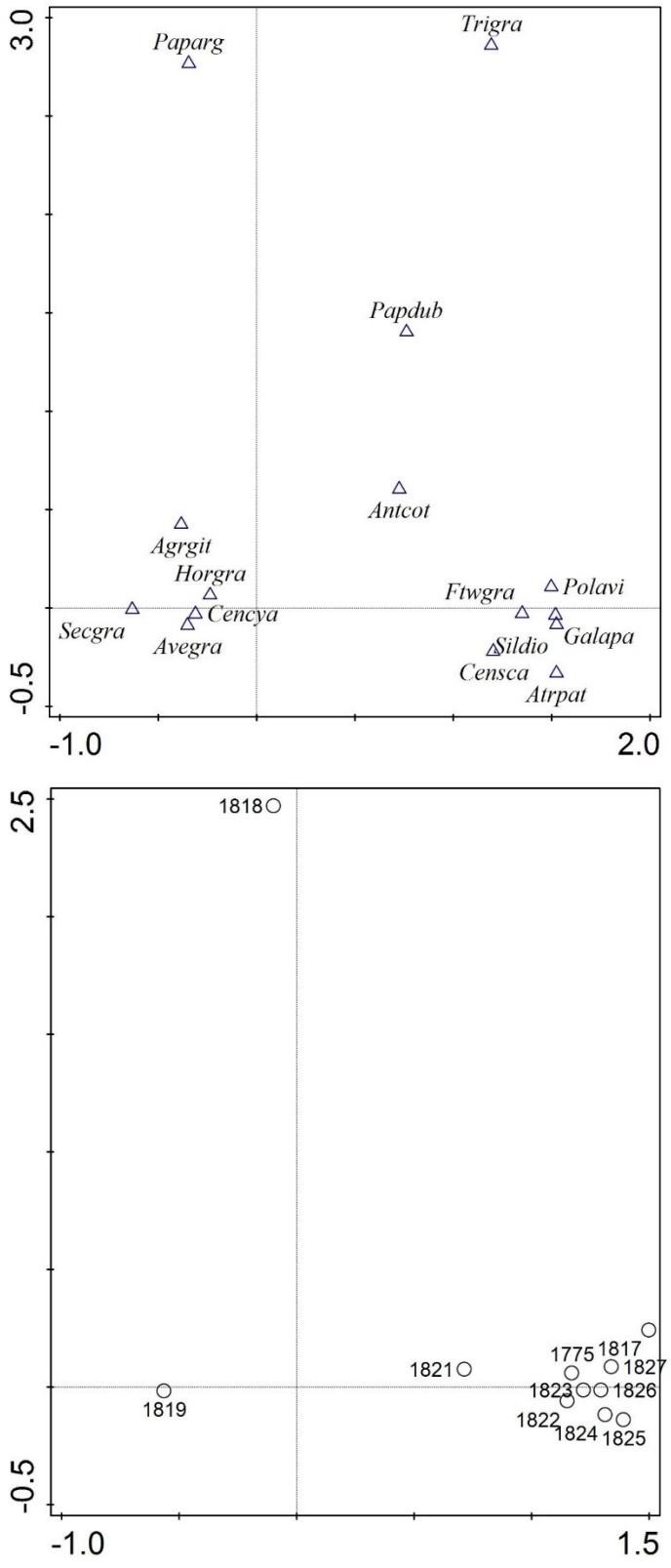
Comprising samples from Island Farm and Coldharbour excavations.

Begin with seven species in six samples. Here, data cleaning protocols have removed all spring-associated weed species, leaving only two intermediate species (*Medlup* and *Perlap*) and two autumn-associated species (*Agrgit* and *Gleseg*). The latter of these, corn marigold, is by far the most abundant weed in this assemblage. Hence, there is little to be gained by running a correspondence analysis, and this assemblage is classified as 'autumn-dominated' in the monograph.

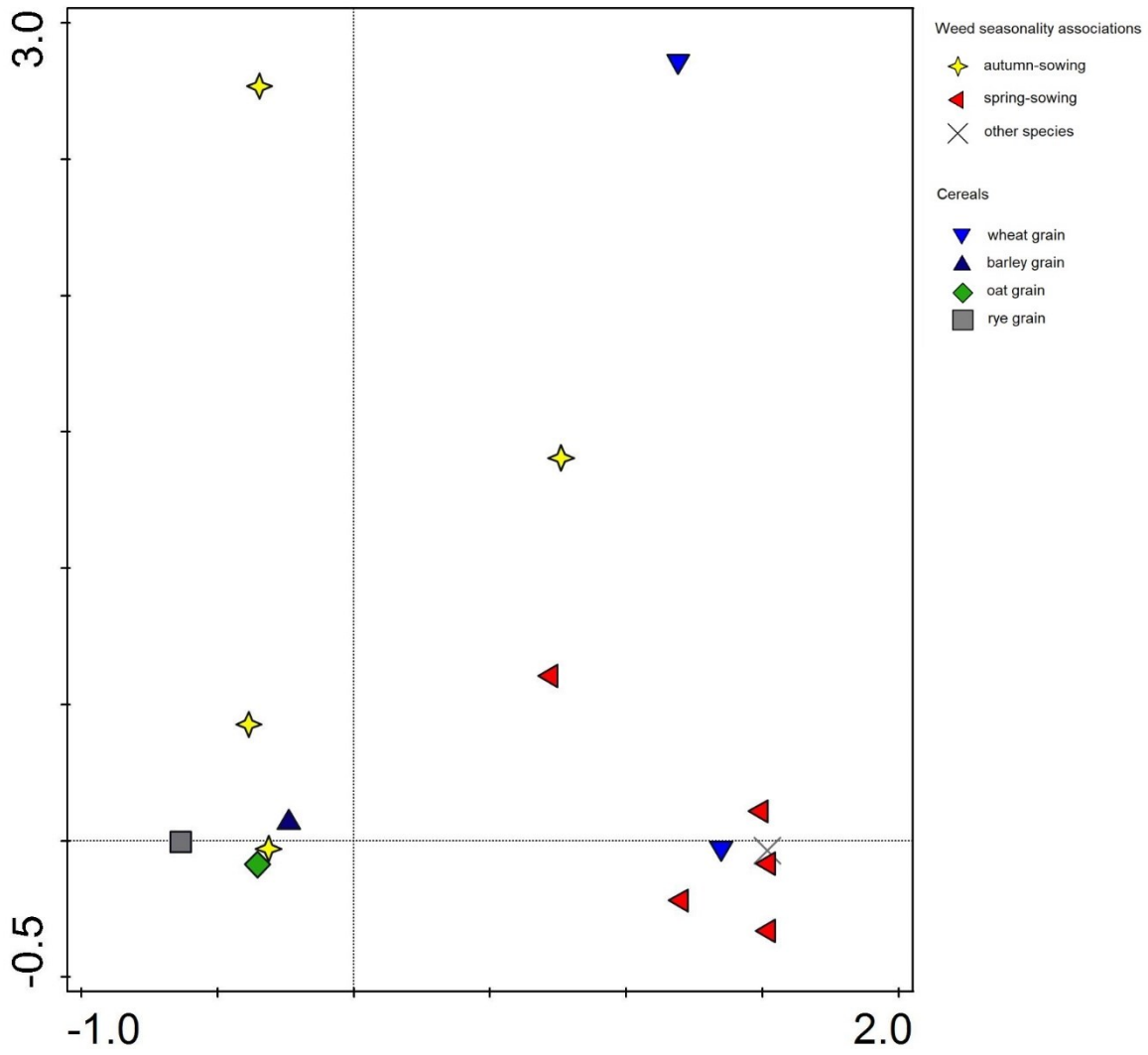
24. Pudding Lane, Barley (Hertfordshire)

Worksheet: **24_pud**

Begin with 15 species in 11 samples.



This is some separation along the x-axis between wheat and spring-associated weeds (to the right) and rye, barley, oats and autumn-associated weeds (to the left). Although all four cereals are present in this assemblage, the grain component of most samples is in fact dominated by wheat, while in two other samples (1818 and 1819, to the negative end of the x-axis) rye is the most abundant grain. Barley and oats are very minor crops (or contaminants) throughout the assemblage, so the apparent contrast here is between rye with autumn weeds on the one hand, and wheat with spring weeds on the other – although the spring/wheat correspondence is less compelling than that for autumn/rye, such that wheat might have yet been sown in either season or both.

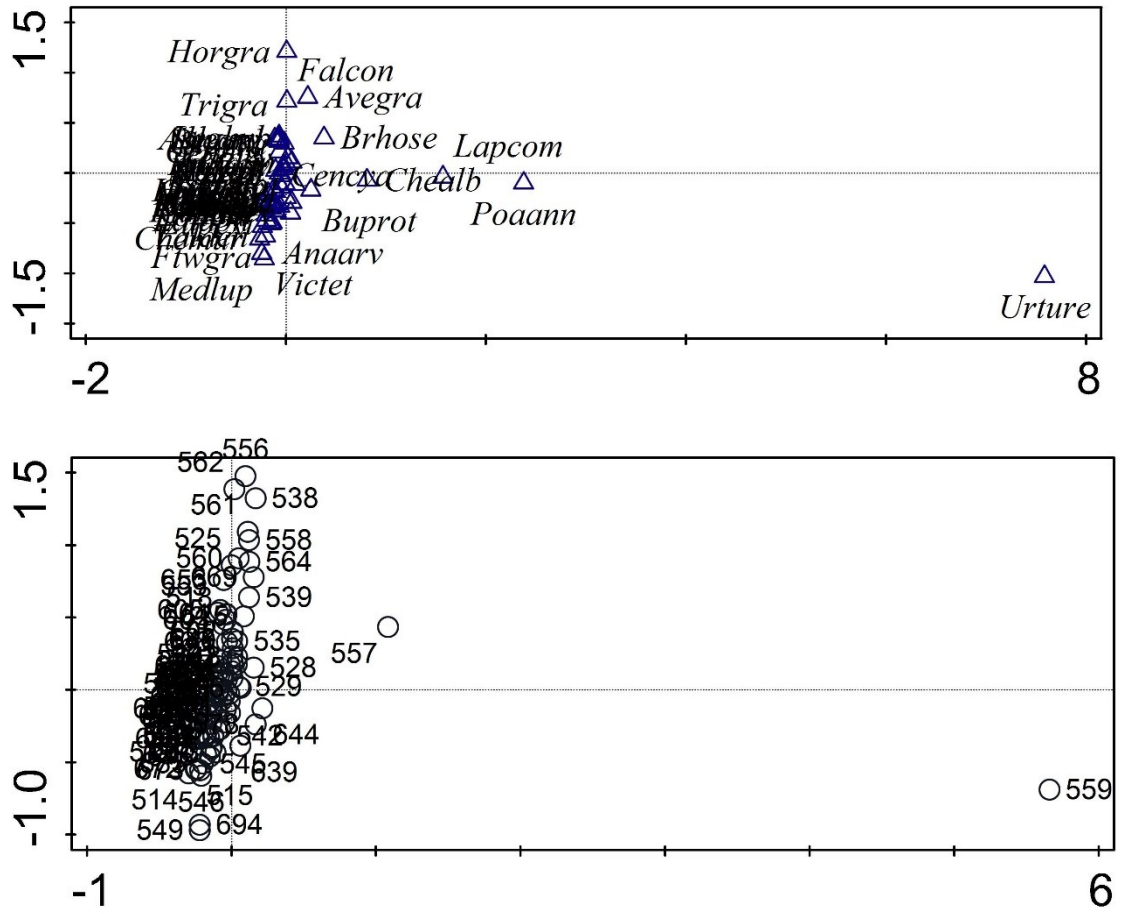


25. Raunds (Northamptonshire)

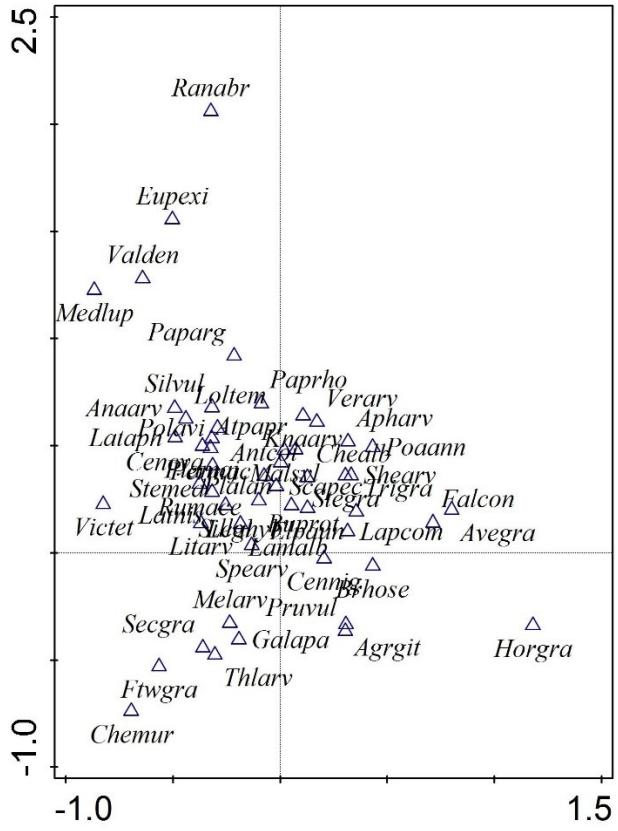
Worksheet: **25_rau**

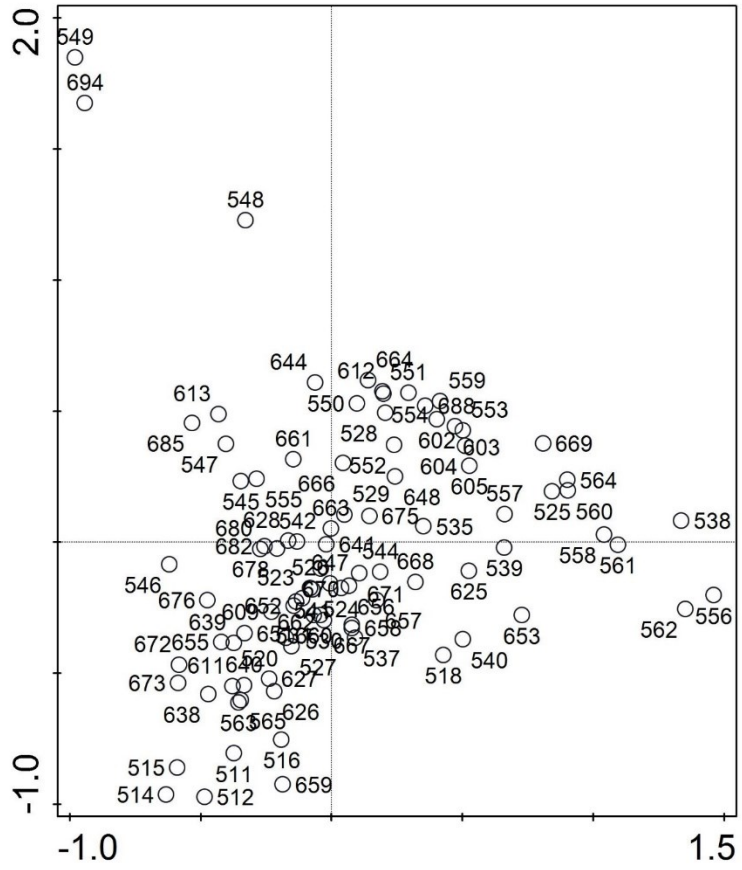
Comprising samples from the Burystead (6 samples), Furnells (6), Gells Garage (1), Langham Road (3), and West Cotton (77) sites.

Begin with 53 species in 93 samples.



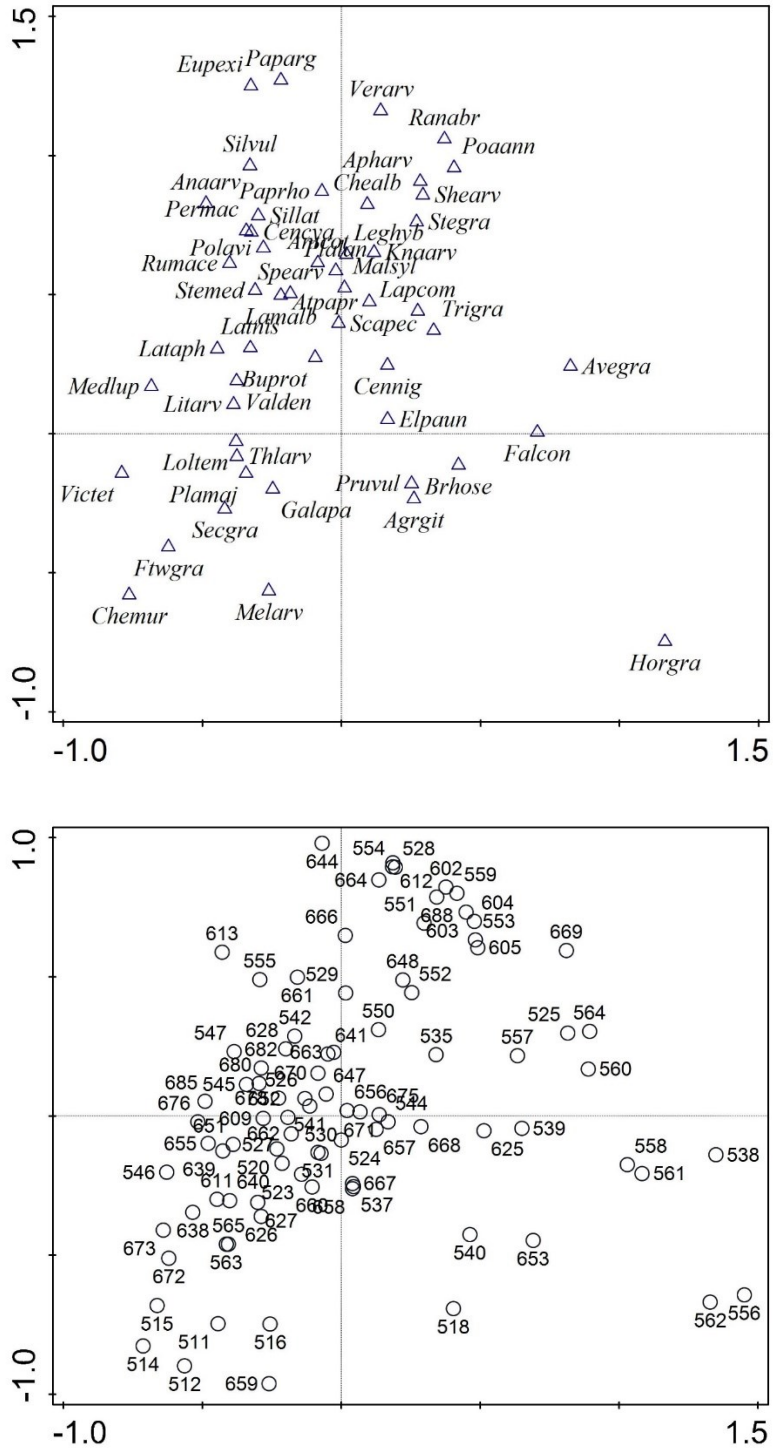
559 and *Urture* are outliers. Delete *Urture* as an outlier species (not 559, as this sample is characterised by other species too, whereas *Urture* isn't a big component of any other sample), and re-run.

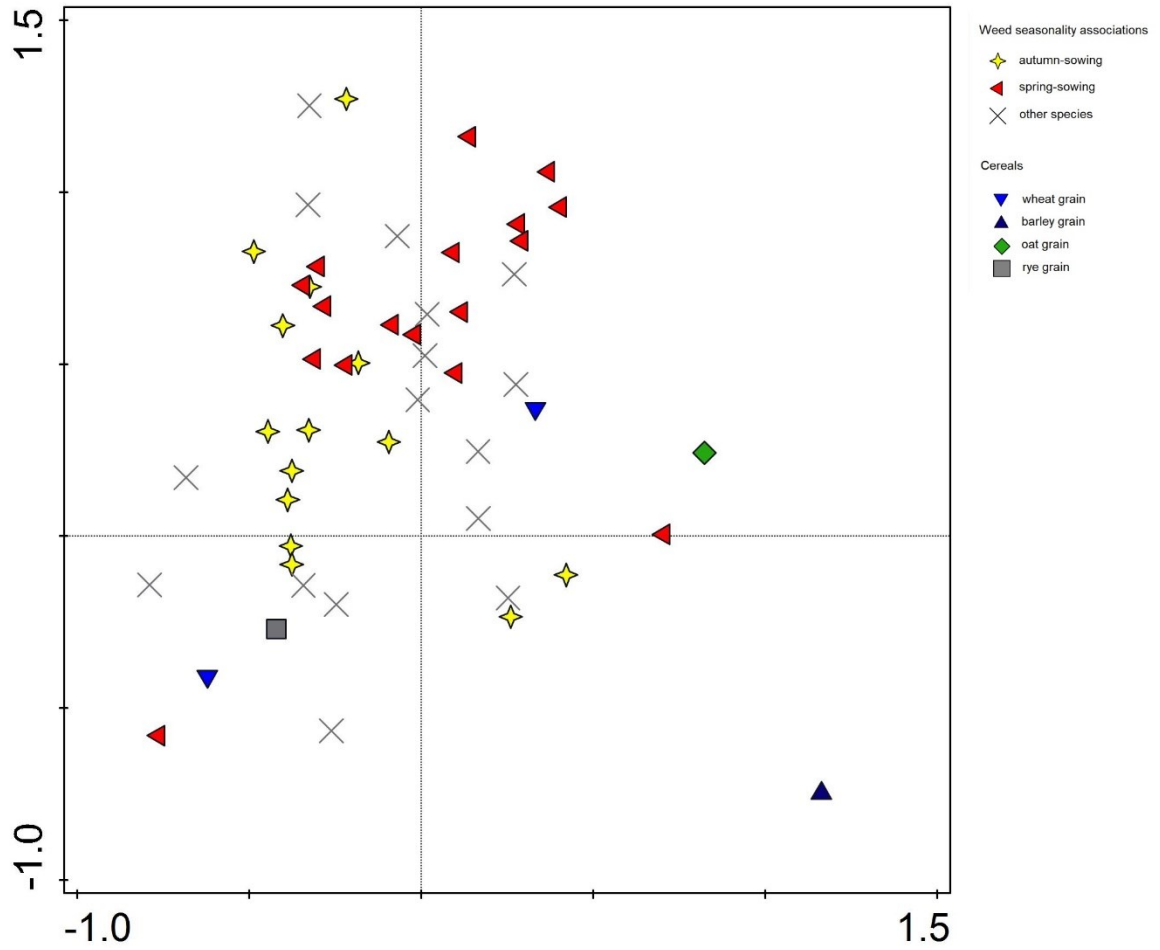

2.5
-1.0
-1.0
1.5
Ranabr
Eupexi
Valden
Medlup
Paparg
Silvul
Paprho
Loltem
Verary
Anaary
Apharv
Lataph
Knoary
Poaann
Cheath
Sheary
Falcon
Victet
Lapcom
Avegra
Litarv
Spearv
Melarv
Pruvul
Secgra
Galapa
Agrgit
Horgra
Thlarv
Ftwgra
Chemur


2.0
-1.0
-1.0
1.5
549
694
548
644
612
664
551
559
613
550
554
688
553
685
661
528
602
603
669
547
552
604
564
666
605
557
545
555
529
648
663
675
525
560
538
628
542
535
682
644
544
668
558
561
678
539
546
676
625
671
639
672
655
653
562
556
611
640
520
527
537
540
518
673
627
638
626
565
515
516
511
659
514
512

Delete outlier samples 549, 694 and 548, and re-run analysis to produce a clearer distribution.

Although there is no overriding pattern of systematic seasonality, there is some tendency towards a separation – albeit a muddy one – between autumn-associated weeds further to the left of the x-axis and the spring-associated weeds further to the right.

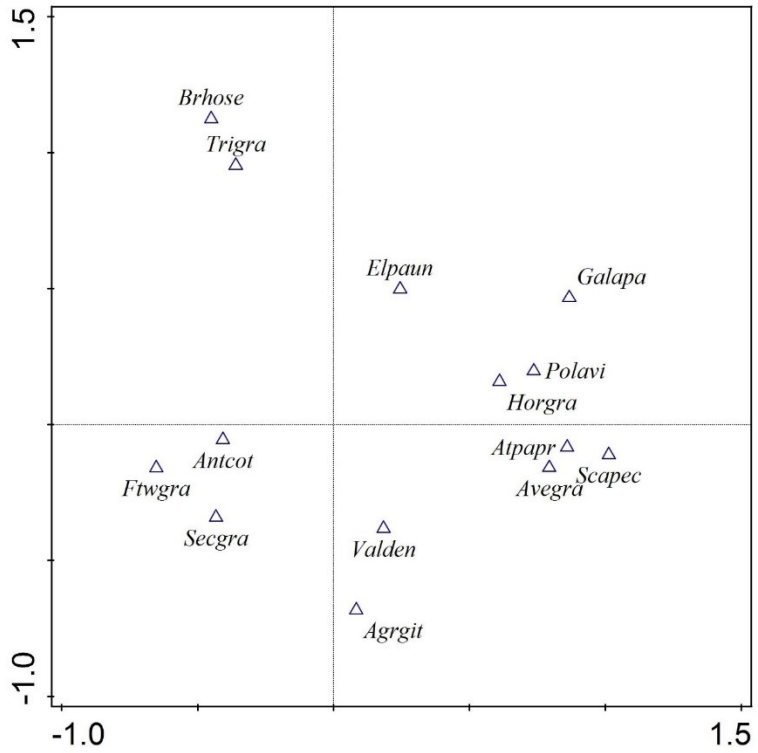


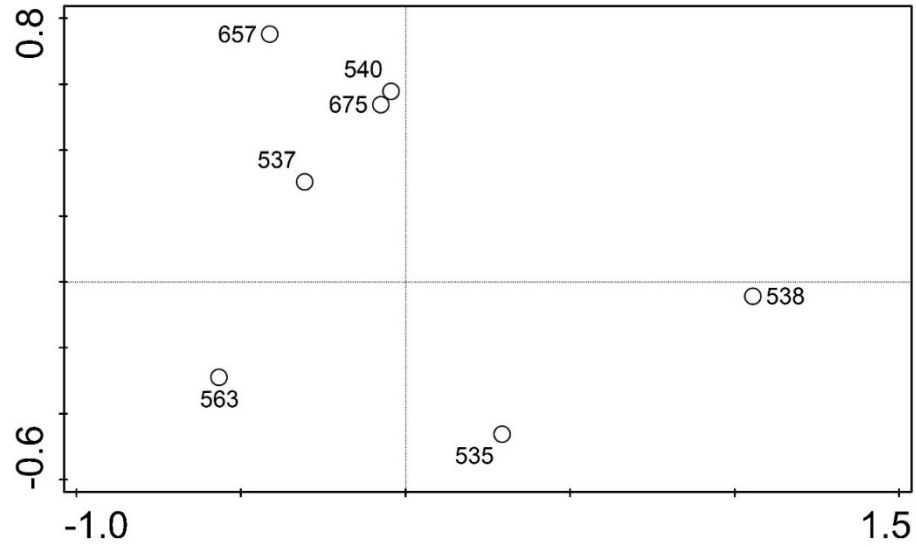


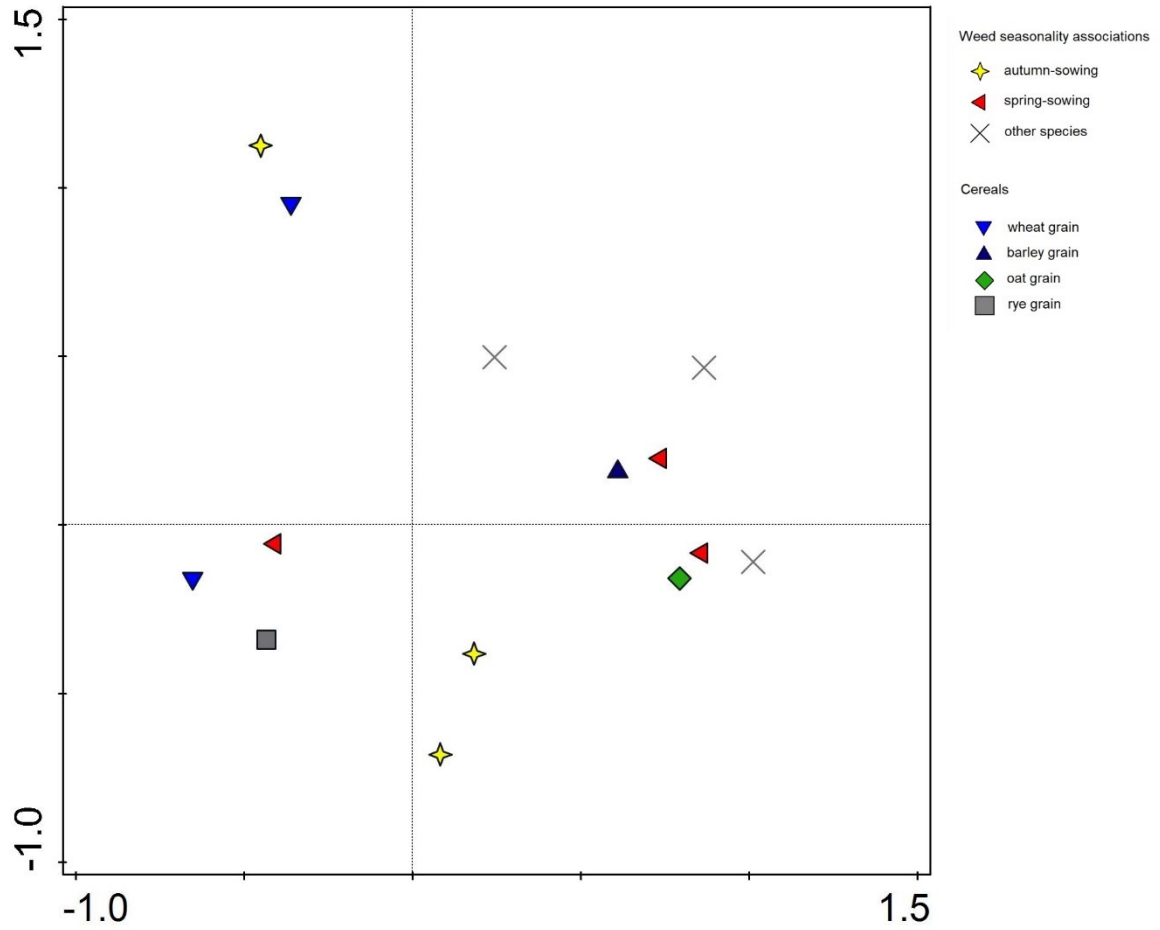
To clarify the picture, delete all samples which have not been classed as 'products' in the crop processing analysis (see Digital Archive Documents B07 and B09). This criterion retains just seven sample - one FSP and six USG – which all come from West Cotton. These sample collectively span phases D3–E5 (950–1220).

Begin again with 14 species in seven samples.

Now we see a slightly clearer separation between (to the right) barley, oats and spring weeds, and (to the left) wheat, rye and autumn weeds.


1.5
-1.0
-1.0
1.5
Brhose
Trigra
Elpaun
Galapa
Polavi
Horgra
Antcot
Ftwgra
Secgra
Atpapr
Scapec
Avegra
Valden
Agrgit

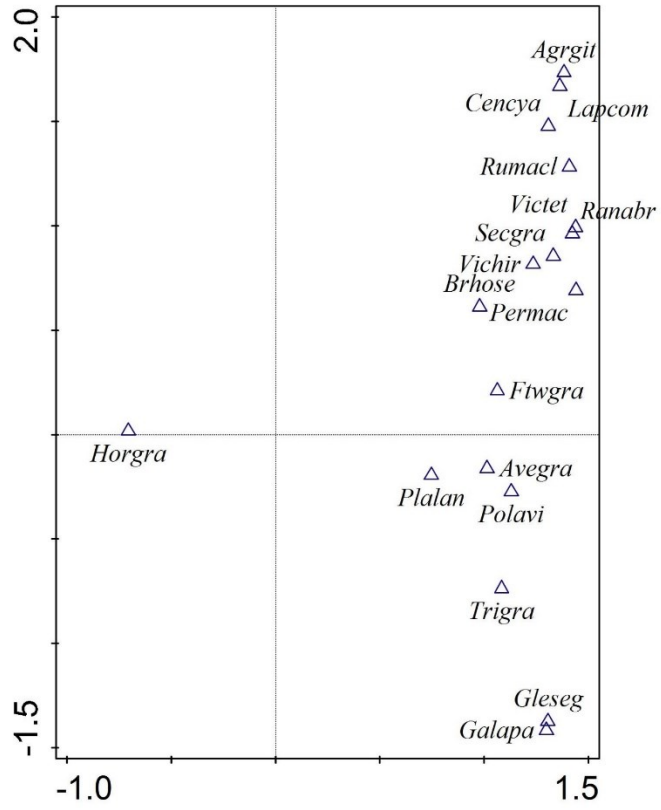

0.8
-0.6
-1.0
1.5
657
540
675
537
538
563
535

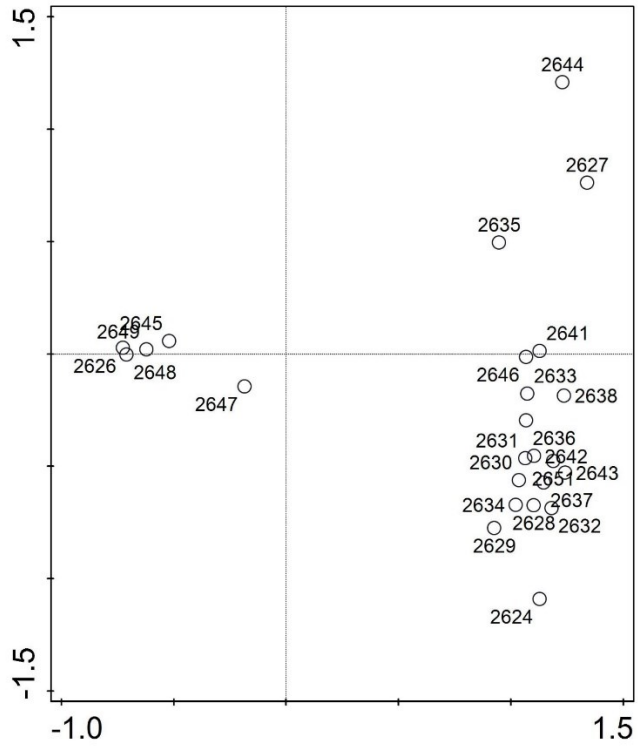

1.5
-1.0
-1.0
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

26. Rocester (Staffordshire)

Worksheet: **26_roc**

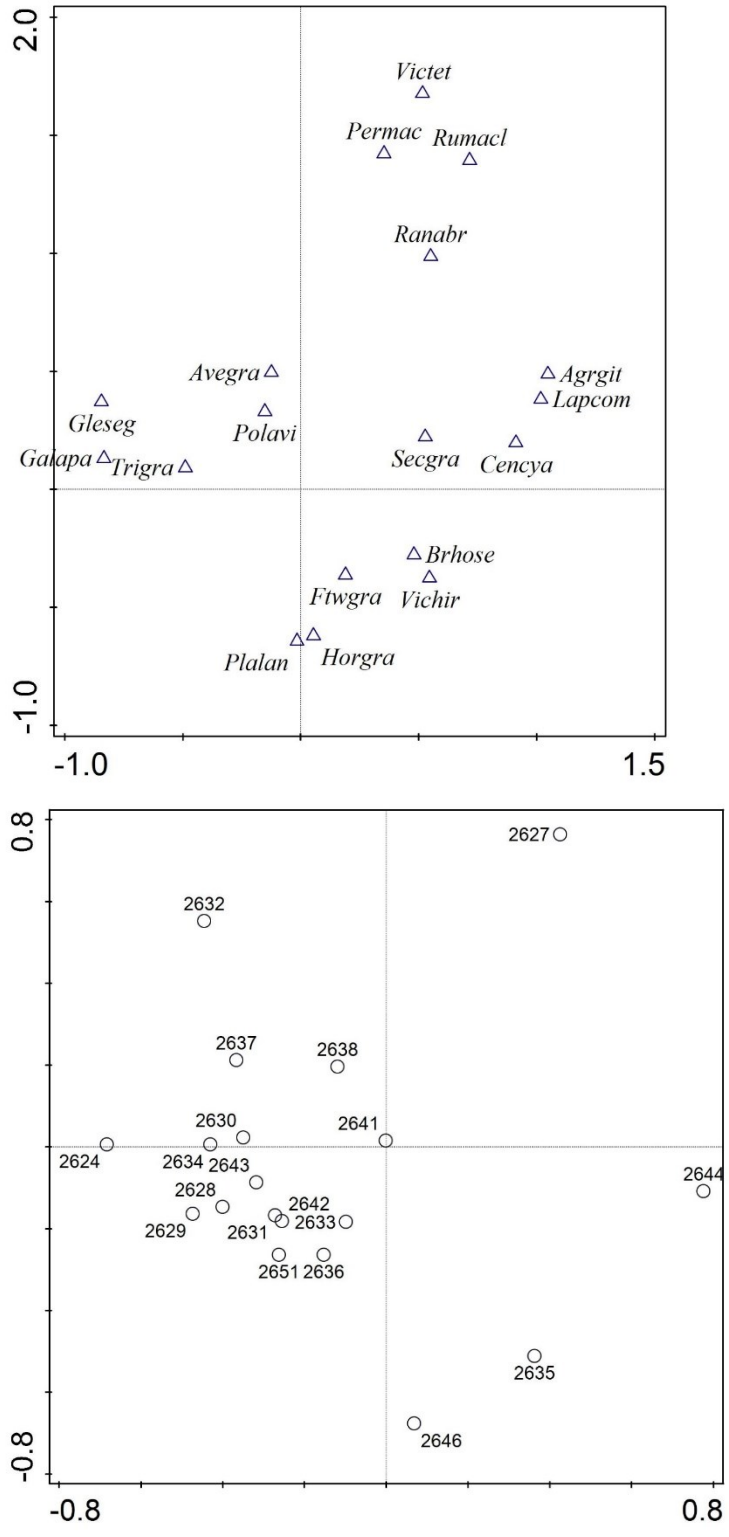
Begin with 18 species in 24 samples.

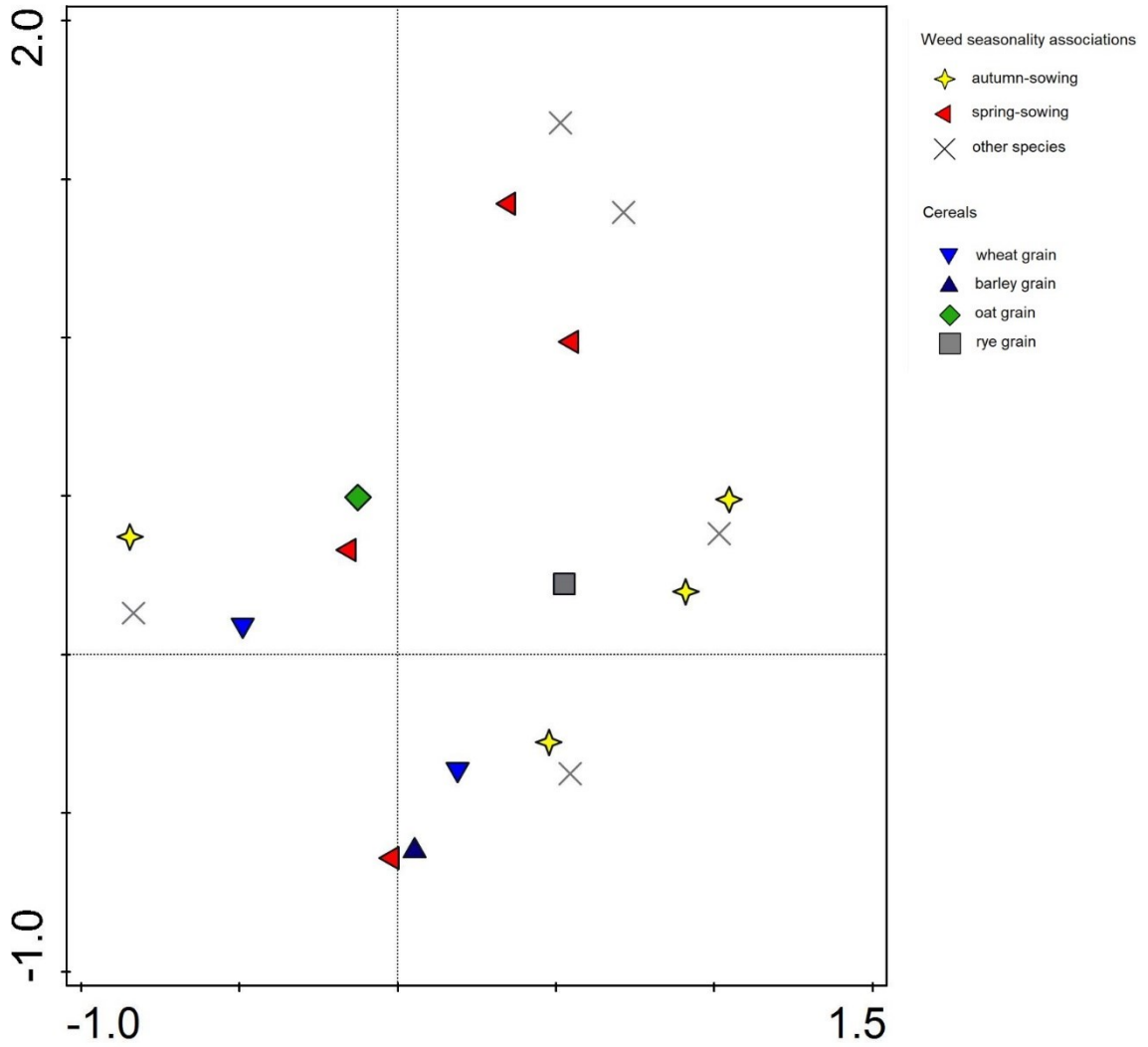




Delete a cluster of outlier samples (2626, 2645, 2647, 2648 and 2649) and re-run analysis, to produce a clearer distribution.

Both autumn- and spring-associated weed species are present, but there are no indications of systematic seasonal sowing.

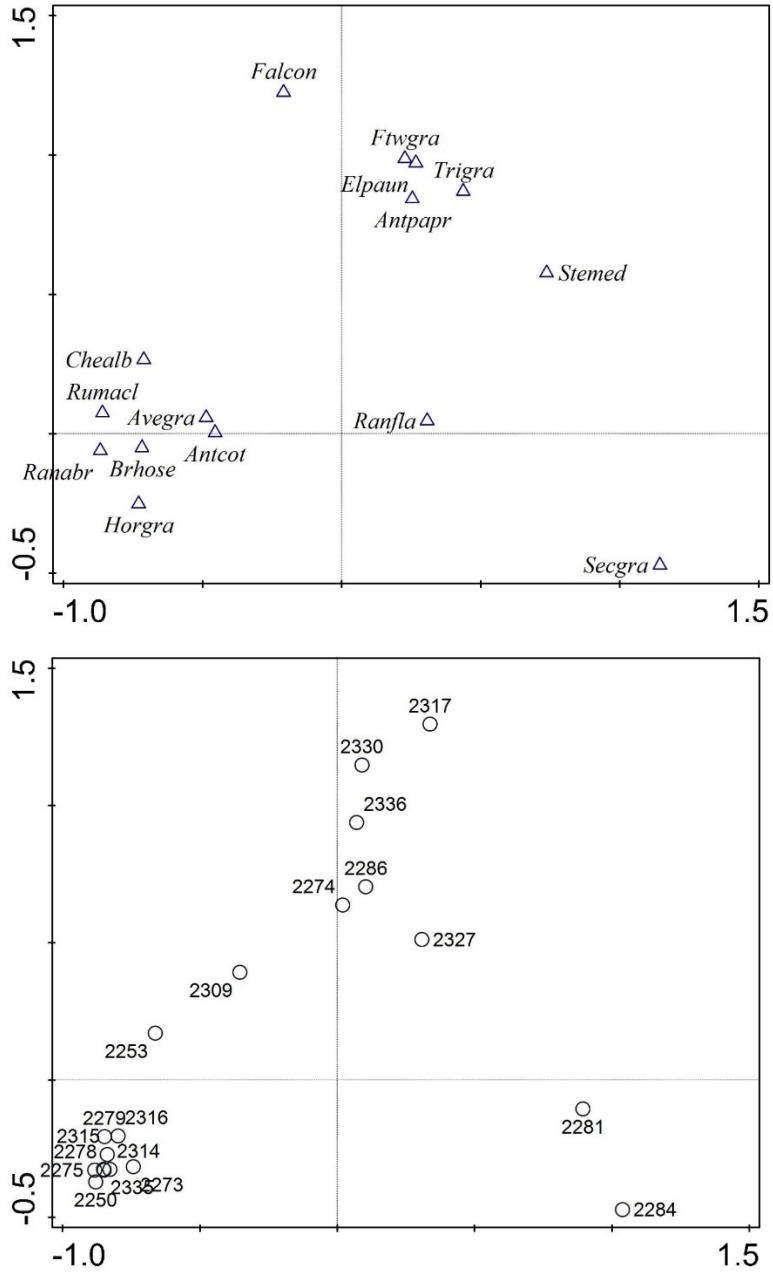


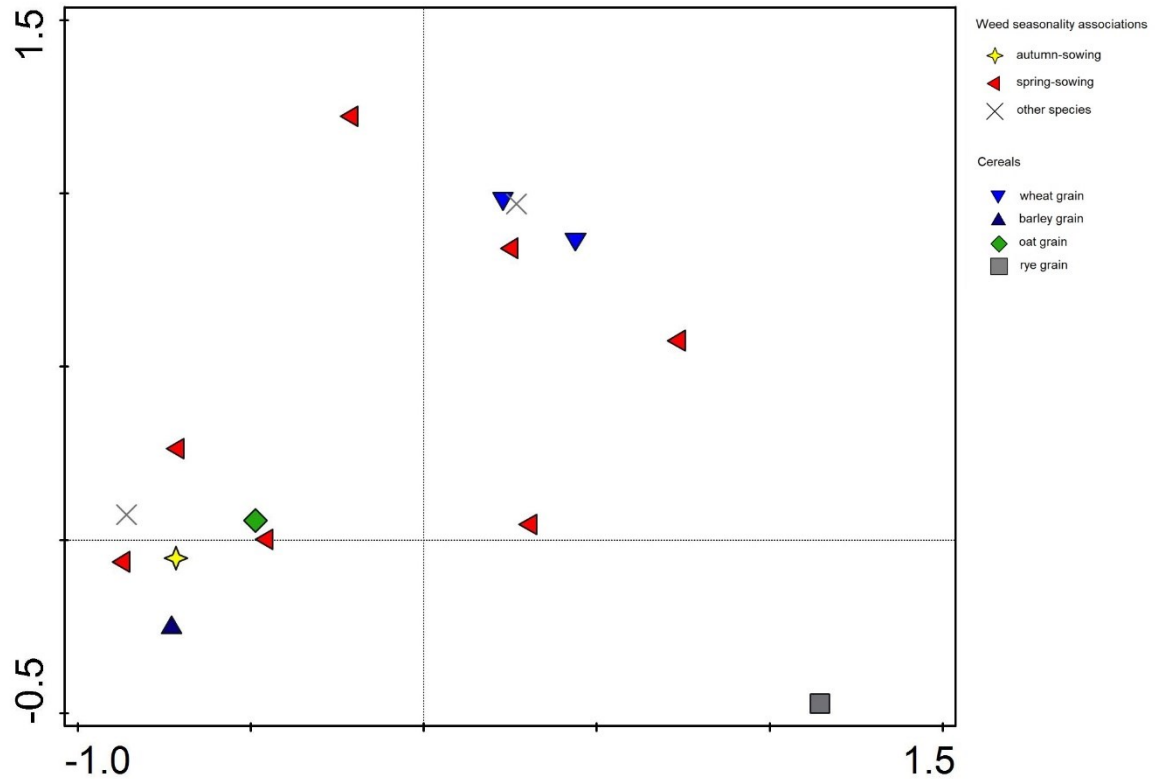

2.0
-1.0
-1.0
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

27. Royal Opera House (London)

Worksheet: **27_roy**

Begin with 15 species in 19 sample, but there is only one autumn-associated weed species present (*Brhose*), and it is not exclusively associated with any particular cereal. Hence, this assemblage is classed as 'spring-dominated' in the monograph.

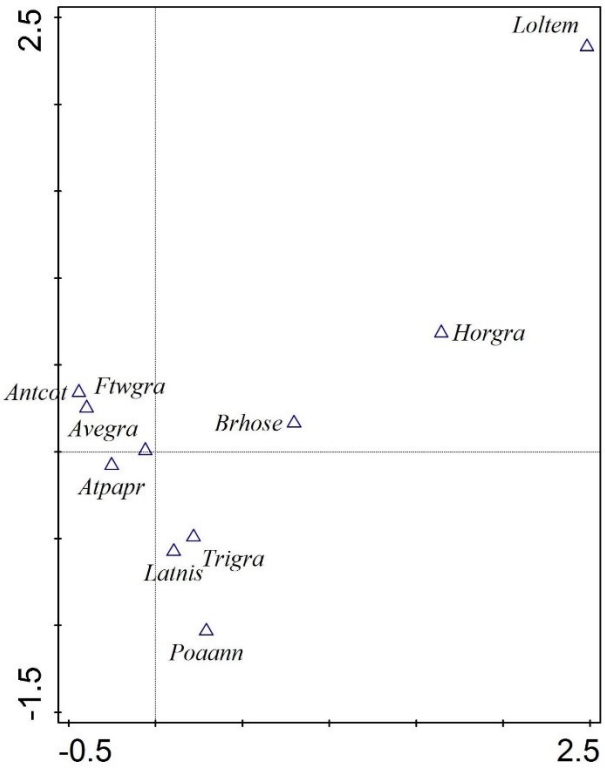


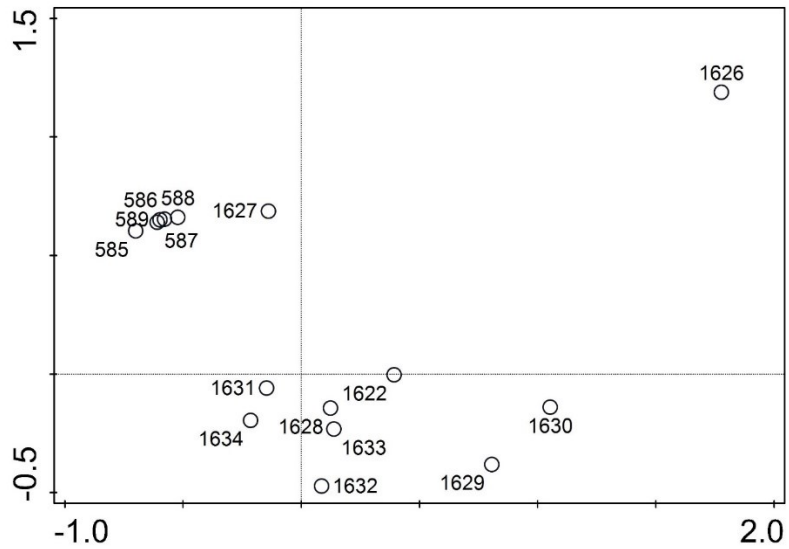

1.5
-0.5
-1.0
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

28. Shapwick (Somerset)

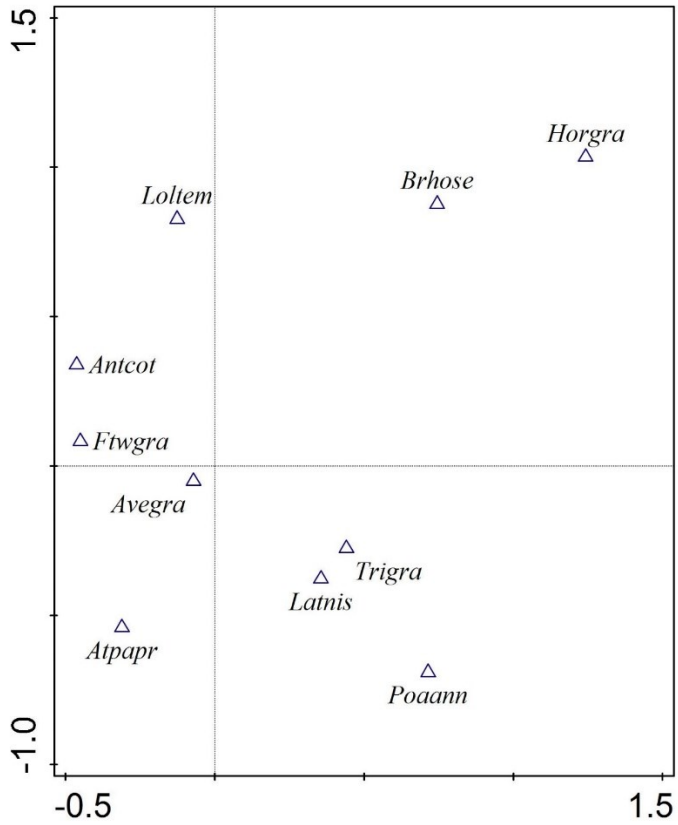
Worksheet: **28_sha**

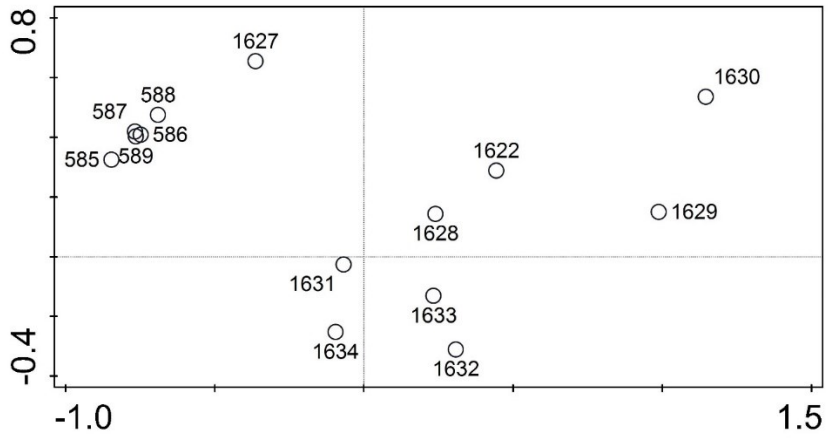
Begin with ten species in 15 samples.

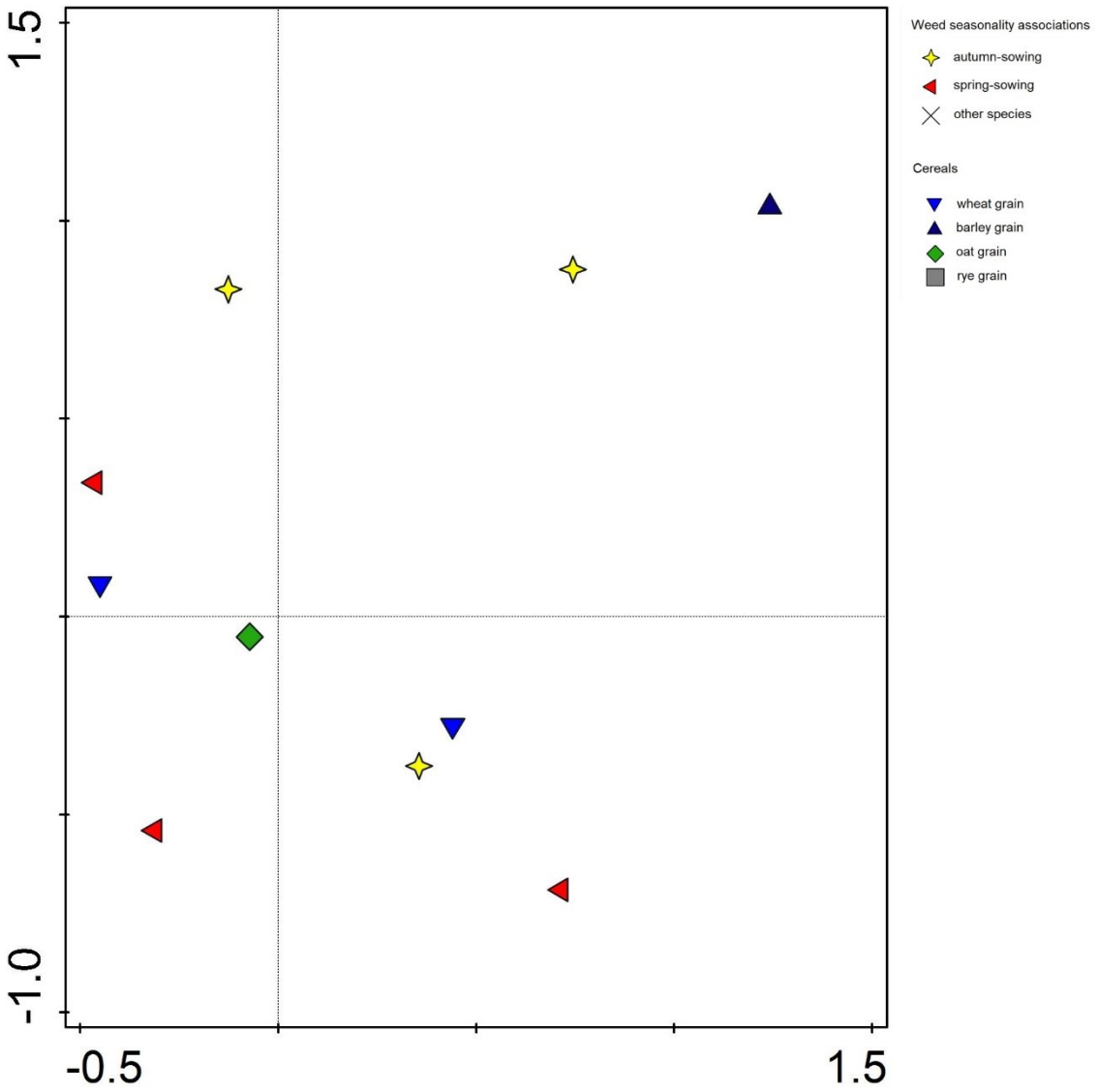




Delete outlier sample 1626 and re-run, to produce a clearer distribution. Both autumn- and spring-associated weed species are present, but there is no indication of systematic seasonal sowing. Moreover, as with Eckweek, the cereal component of most samples is dominated by wheat, so there is in any case limited scope for identifying seasonal sowing differences between crops.


1.5
-1.0
-0.5
1.5
Horgra
Brhose
Loltem
Antcot
Ftwgra
Avegra
Trigra
Latnis
Atpapr
Poaann

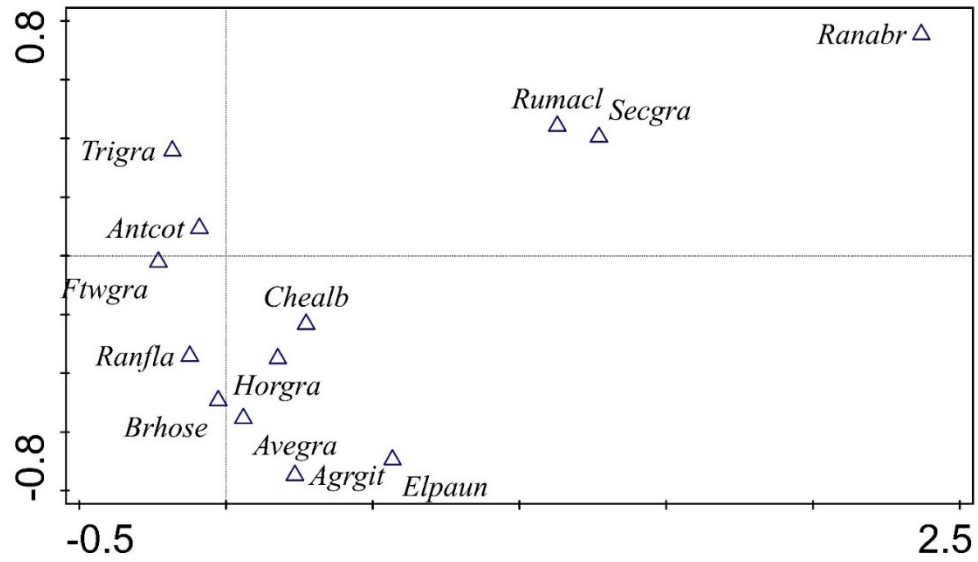

0.8
-0.4
-1.0
1.5
1627
1630
588
587
586
585
589
1622
1629
1628
1631
1633
1634
1632

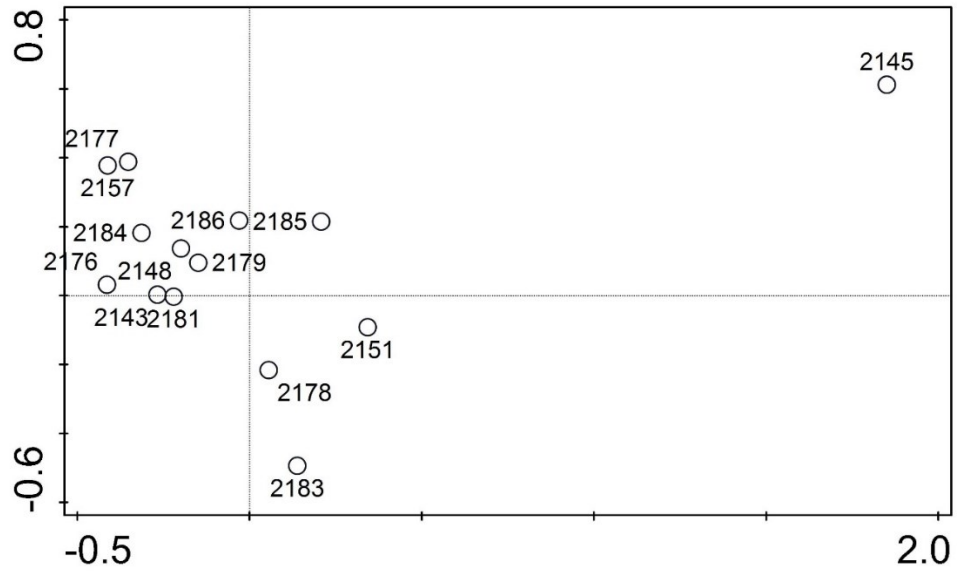

1.5
-1.0
-0.5
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

29. Shorts Gardens (London)

Worksheet: **29_sho**

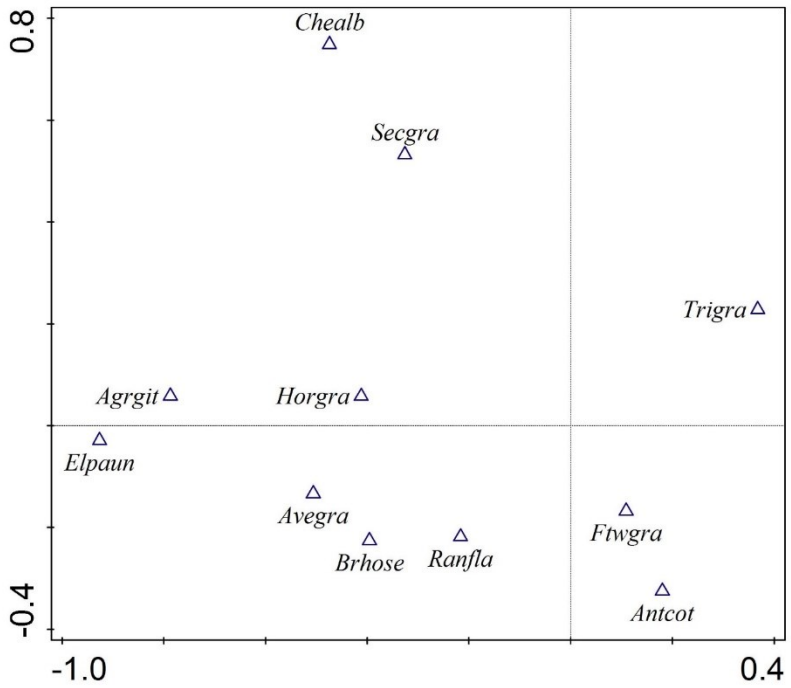
Begin with 13 species in 14 samples.

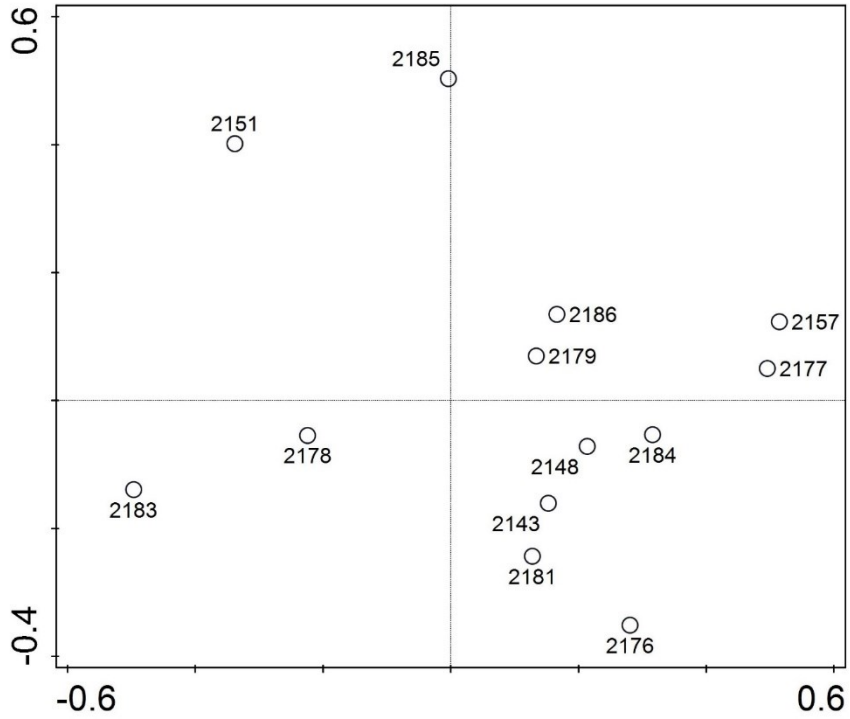


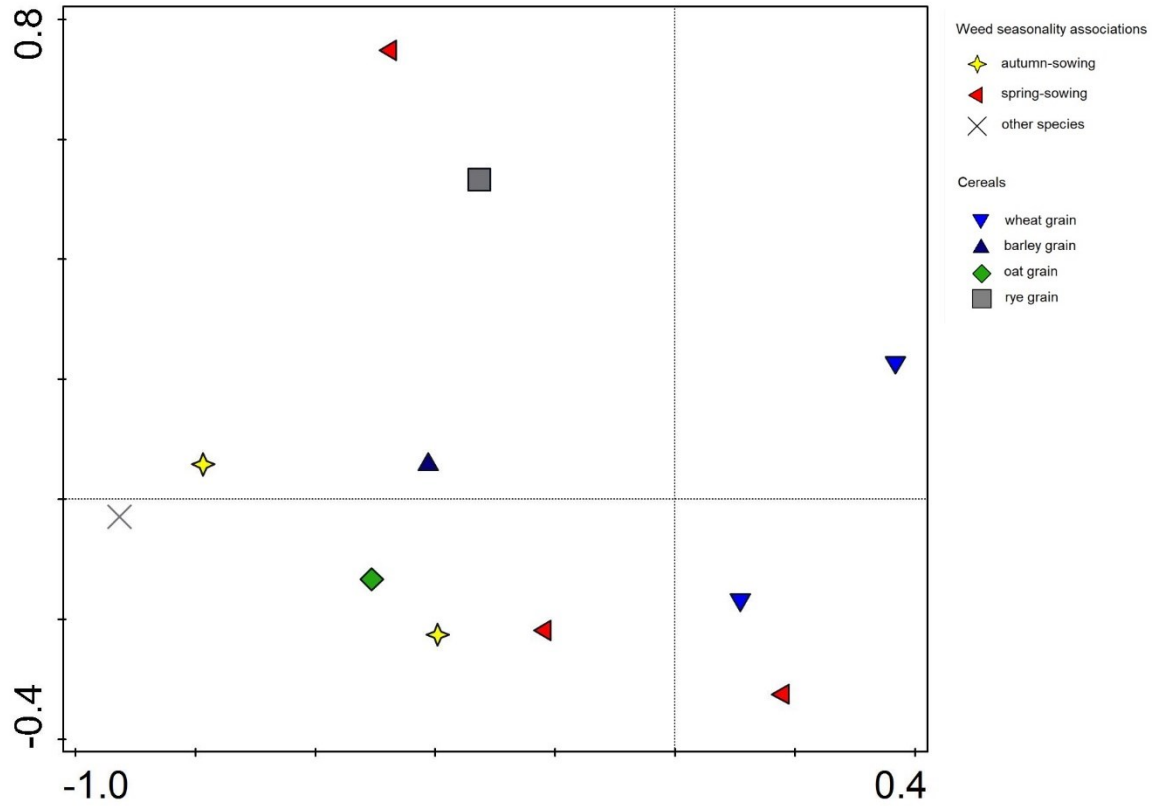


Delete outlier sample 2145. Species *Ranabr* and *Rumacl* are now both present in fewer than three samples, and should be deleted. Now re-run the analysis, to produce a clearer distribution.

There is now a (relatively weak) association between wheat and spring weeds, towards the positive end of the x-axis.


Chealb
Secgra
Trigra
Agrgit
Horgra
Elpaun
Avegra
Brhose
Ranfla
Ftwgra
Antcot
0.8
-0.4
-1.0
0.4

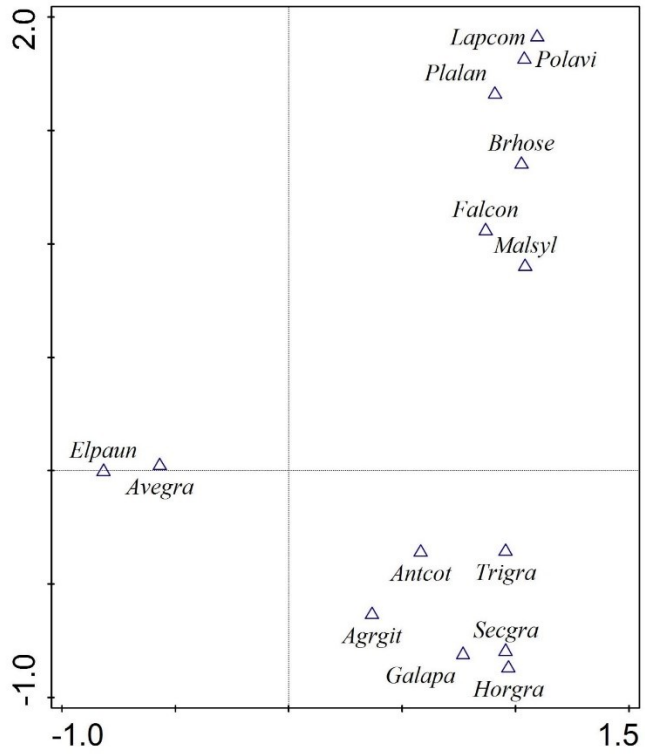

2185
2151
2186
2157
2179
2177
2178
2148
2184
2183
2143
2181
2176
0.6
-0.4
-0.6
0.6

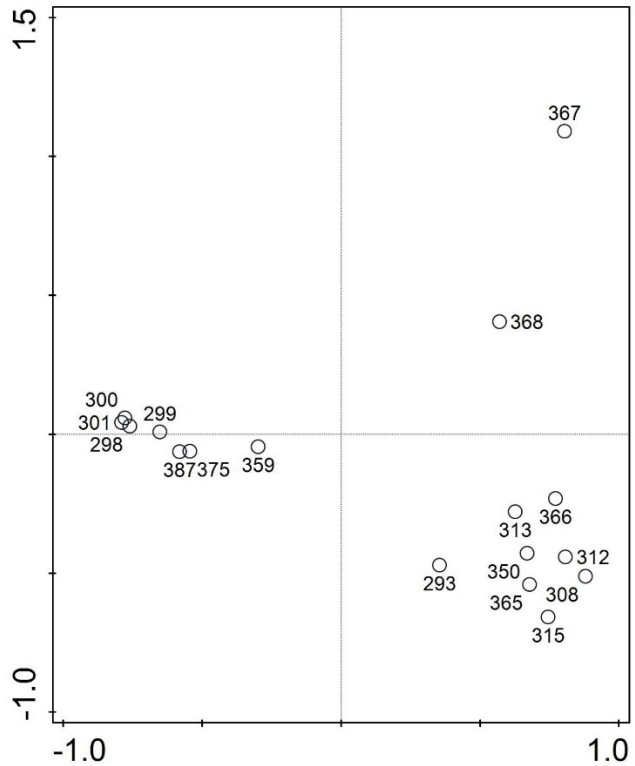

0.8
-0.4
-1.0
0.4
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

30. Springfield Lyons (Essex)

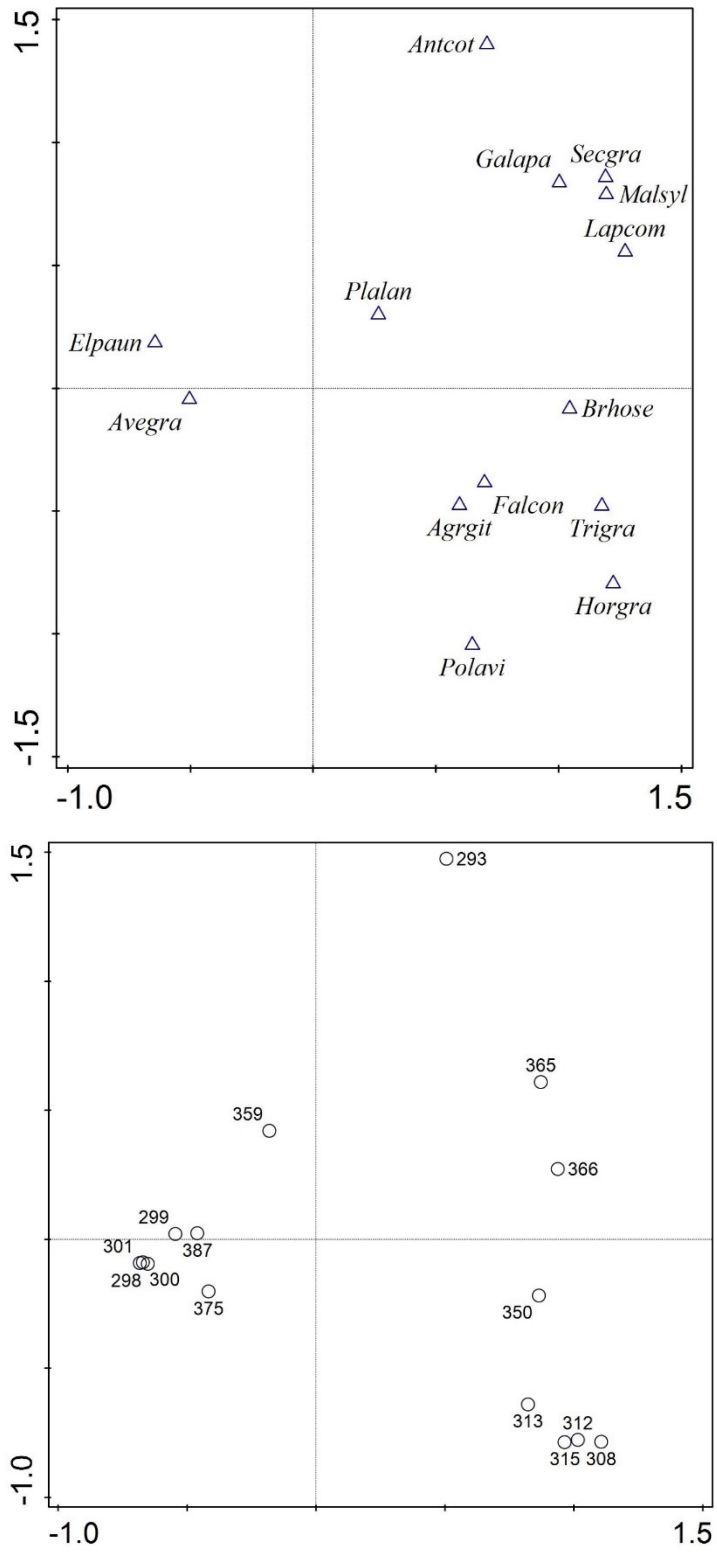
Worksheet: **30_spr**

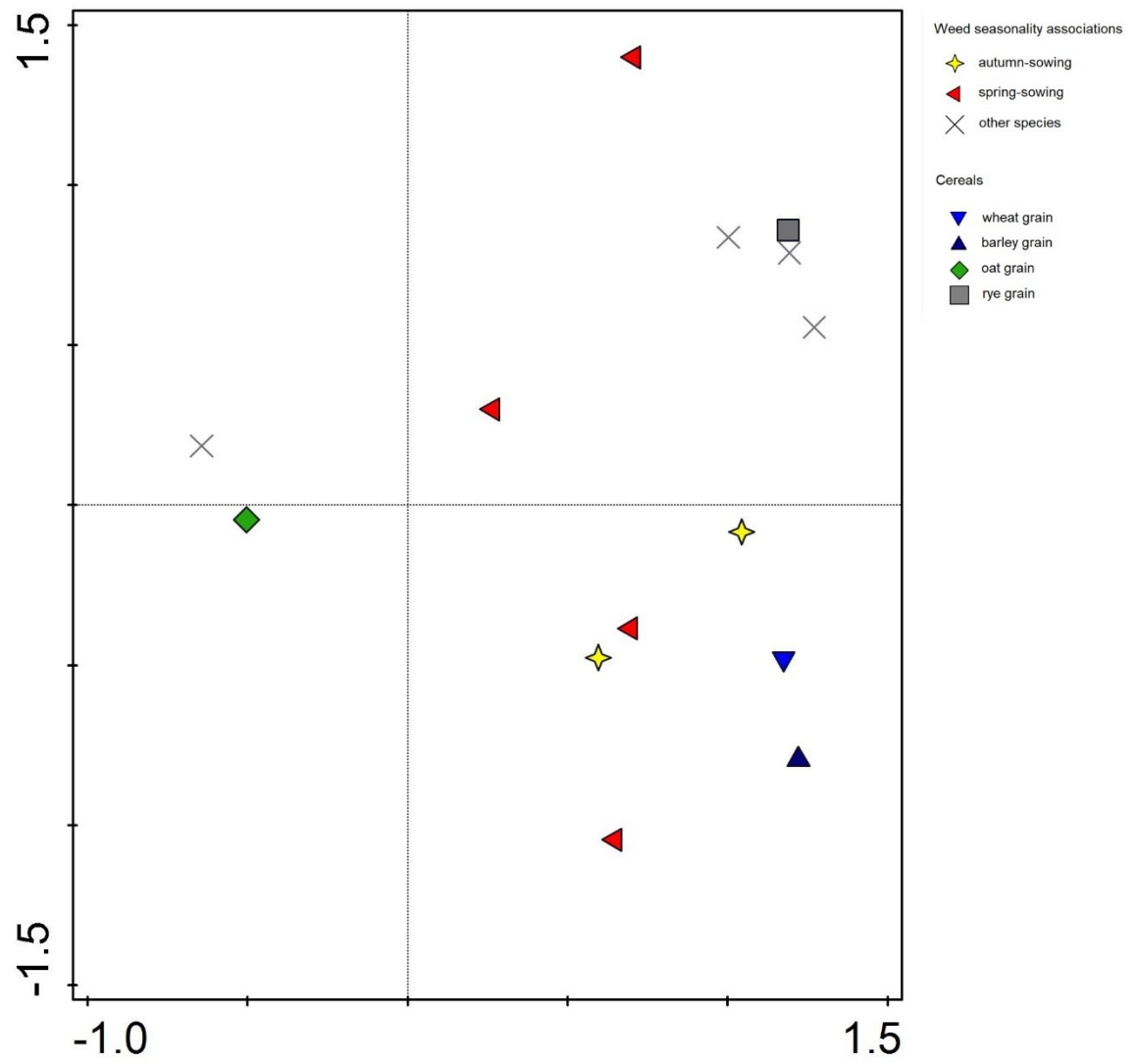
Begin with 14 species in 17 samples.





Delete outlier samples 367 and 368 and re-run, to produce a clearer distribution.



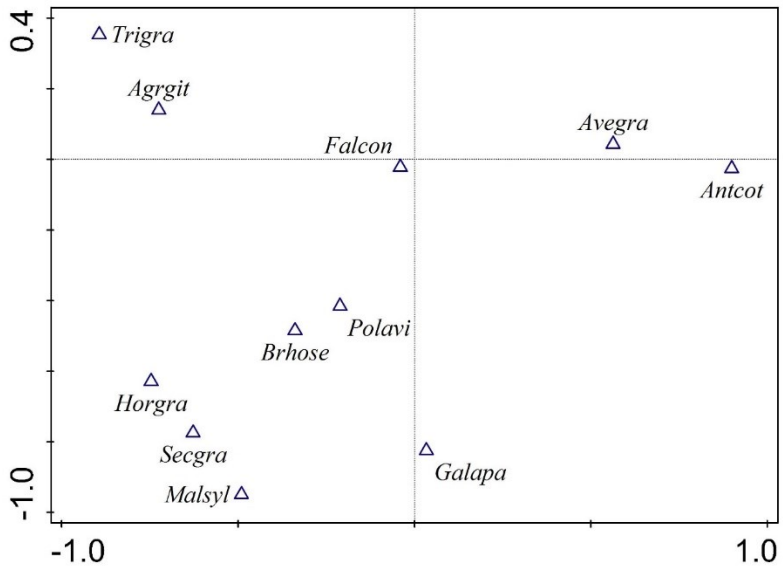


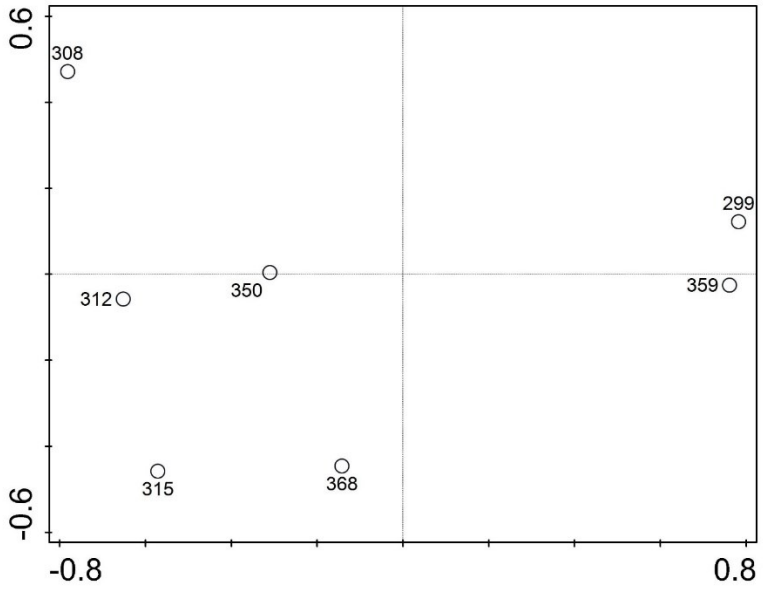
There is no indication here of systematic seasonal sowing of any of the cereals.

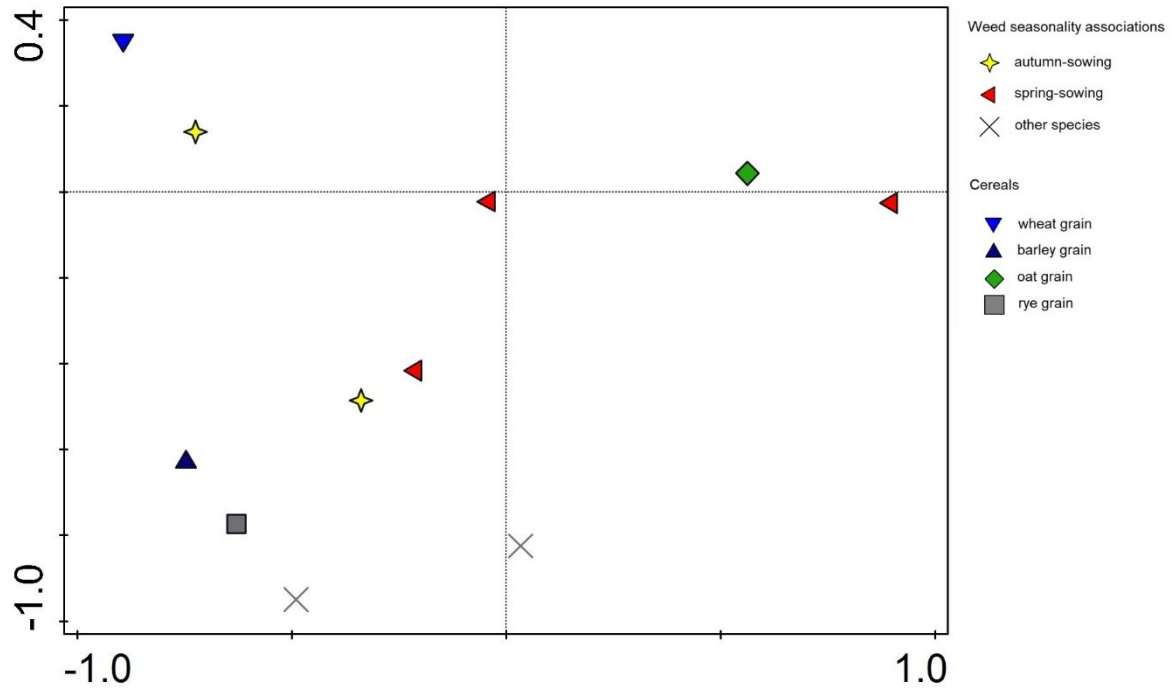
To clarify the picture, delete all samples which are not classified as 'products' in crop processing terms (i.e. those not classified FSP or USG – see Digital Archive Documents B07 and B09).

Begin again with 11 species in seven samples.

There now appears to be a contrast between oats and spring weeds (to the right) and wheat, barley, rye and autumn weeds (to the left).


Trigra
Agrgit
Falcon
Avegra
Antcot
Polavi
Brhose
Horgra
Secgra
Galapa
Malsyl
0.4
-1.0
-1.0
1.0


308
299
312
350
359
315
368
0.6
-0.6
-0.8
0.8

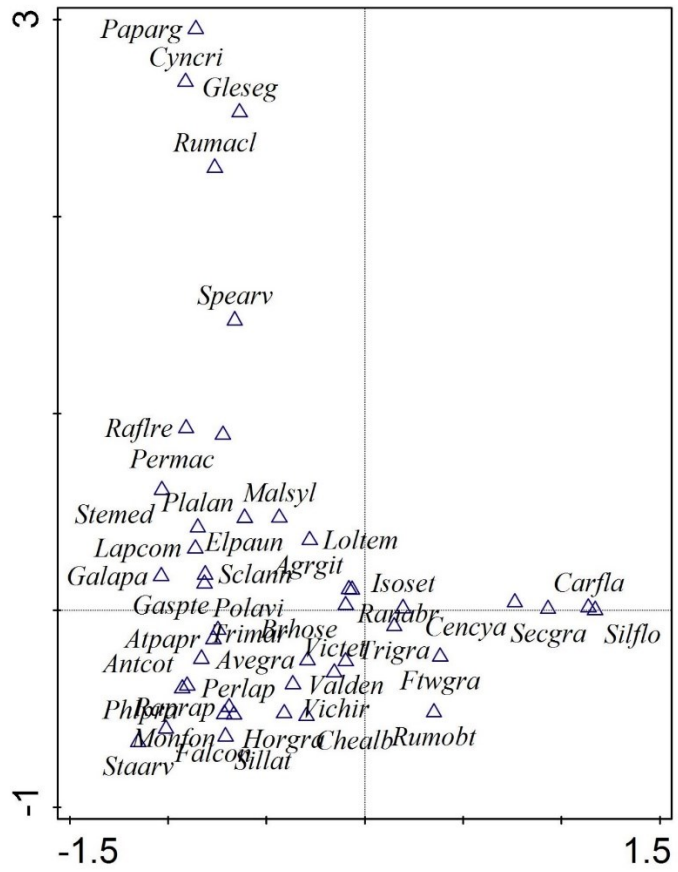

0.4
-1.0
-1.0
1.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

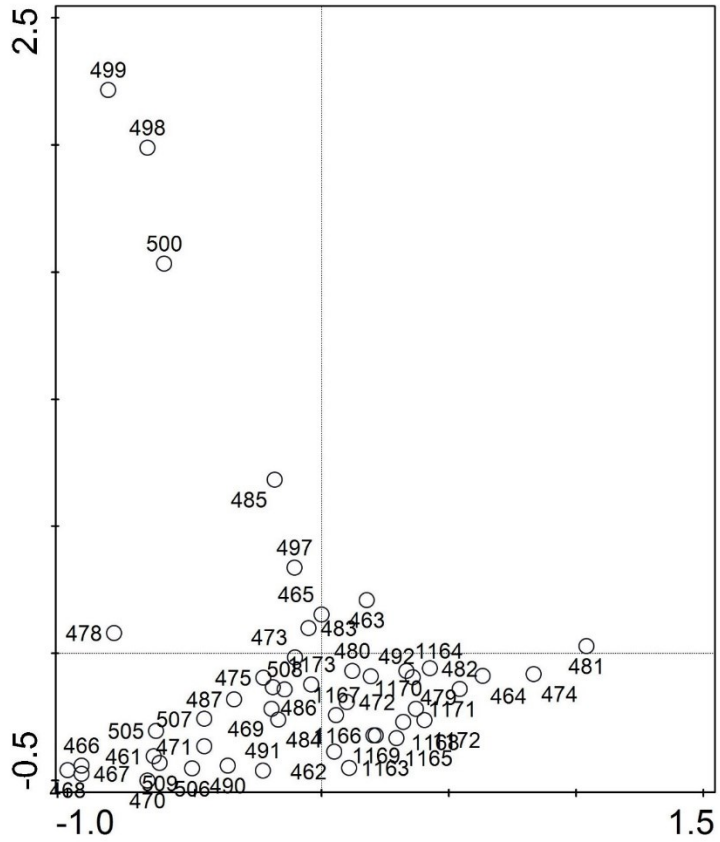
31. Stafford (Staffordshire)

Worksheet: **31_sta**

Note that this version differs from a correspondence analysis of the Stafford assemblage published previously (Hamerow *et al.*, 2020): while the present version includes only cereal *grain* records, for consistency with all other analyses presented here, the previously published analysis included both grain and rachis (chaff) records. In addition, as mentioned earlier in this report, perennial species are included among the autumn- and spring-associated weeds in the analyses presented here, whereas previous work (including that published in Hamerow *et al.* 2020) classified only annual species in this way. Nonetheless, it will be seen that both the earlier analysis and the present analysis reveal much the same patterns overall.

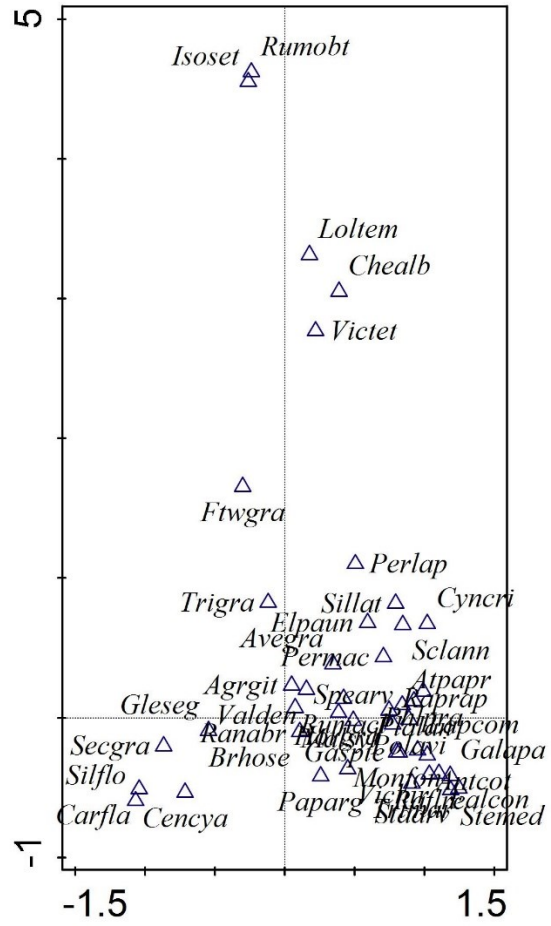
Begin with 44 species in 48 samples.

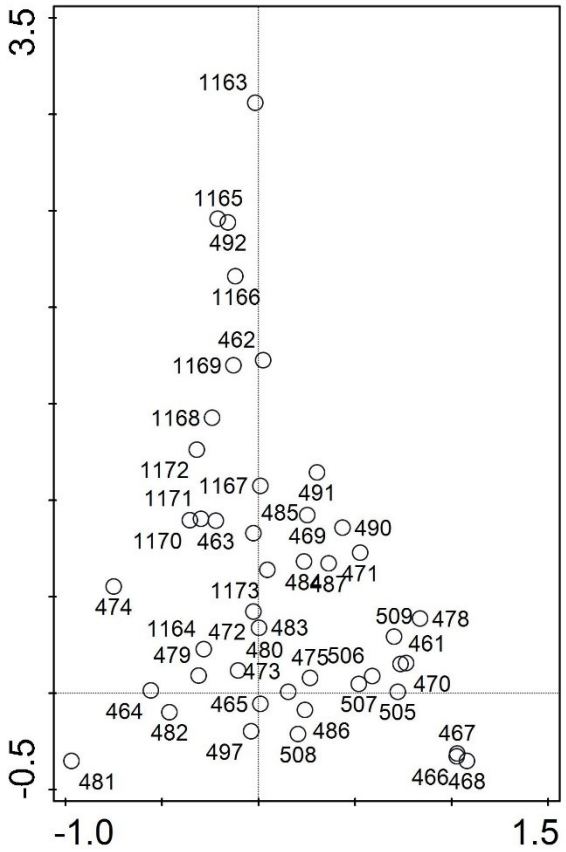


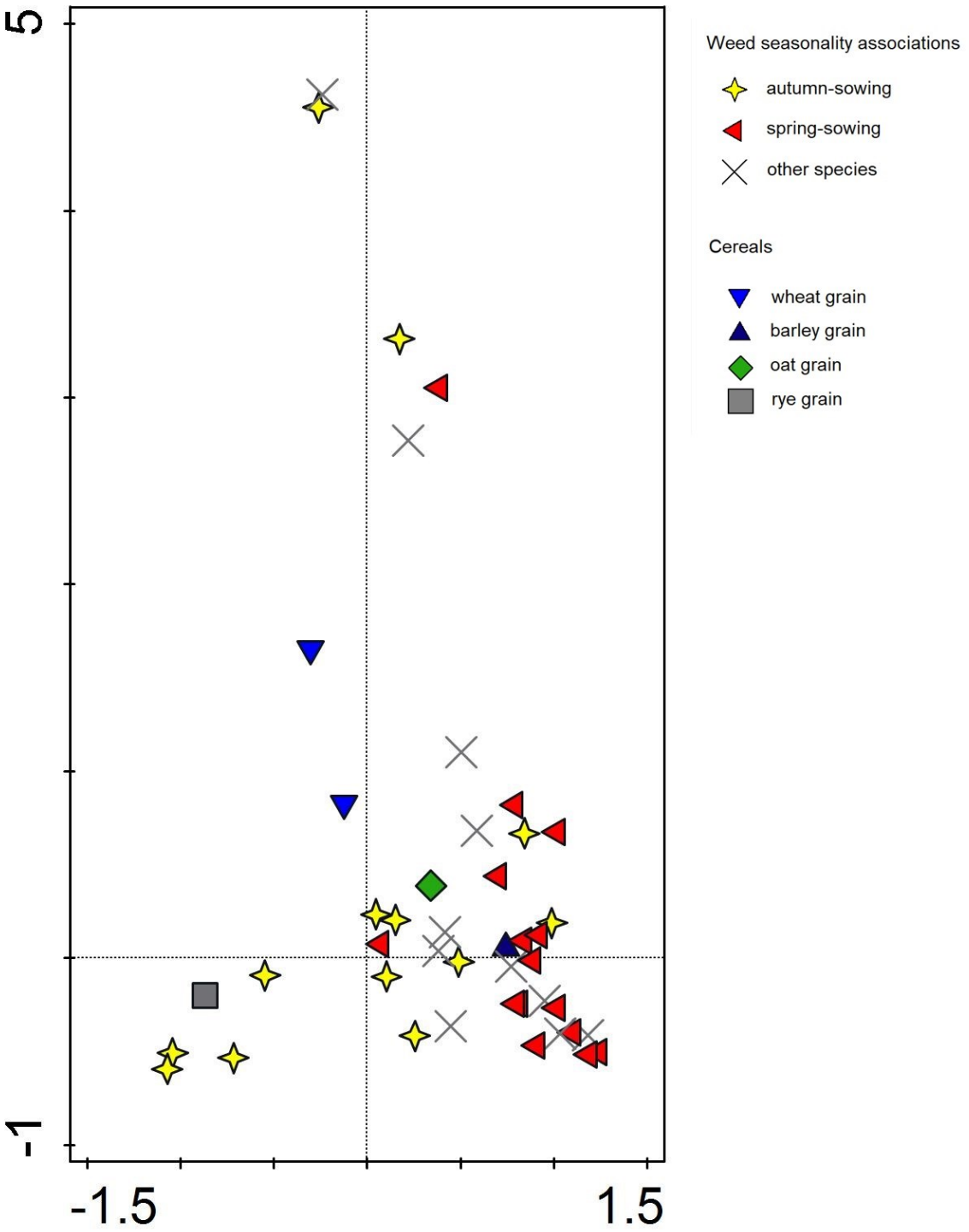


Delete outlier samples 498, 499 and 500, and re-run to produce a clearer distribution.

The results appear consistent with systematic seasonal sowing, with wheat, rye and autumn weeds tending towards the negative end of the x-axis, and barley and spring weeds (and less convincingly oats) towards the positive end.


5
-1
-1.5
1.5
Isoset
Rumobt
Loltem
Chealb
Victet
Ftwgra
Perlap
Trigra
Sillat
Cyncri
Elpaun
Avegra
Permac
Sclann
Agrgit
Atpapr
Gleseg
Secgra
Brhose
Galapa
Silflo
Carfla
Cencya
Paparg
Stemed

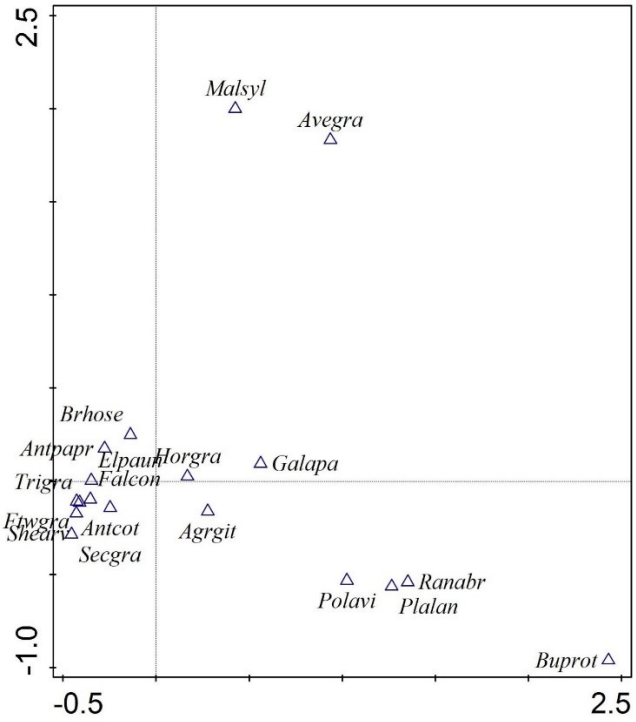

3.5
-0.5
-1.0
1.5
1163
1165
492
1166
462
1169
1168
1172
1171
1167
491
485
1170
463
469
490
471
484
487
474
1173
509
478
1164
472
483
461
479
480
475
506
473
470
464
465
507
505
482
486
467
497
508
481
466
468

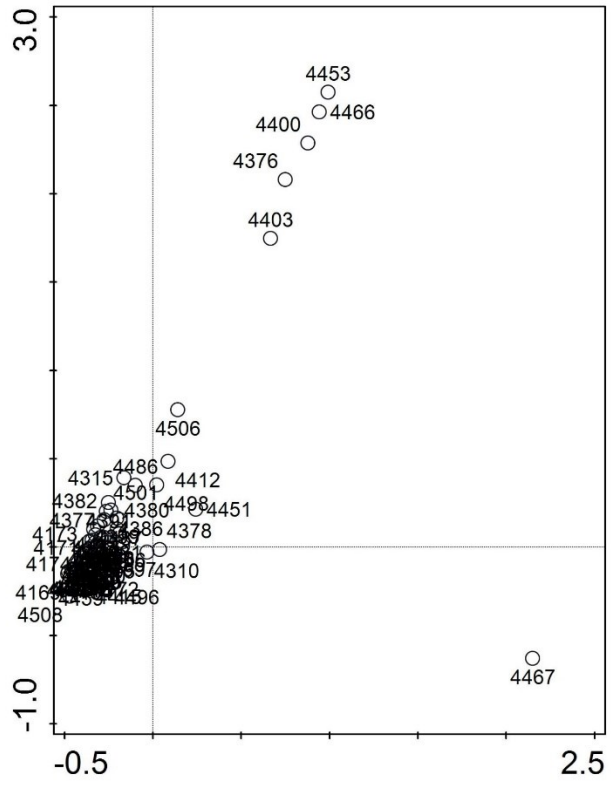

5
-1
-1.5
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

32. Stotfold (Bedfordshire)

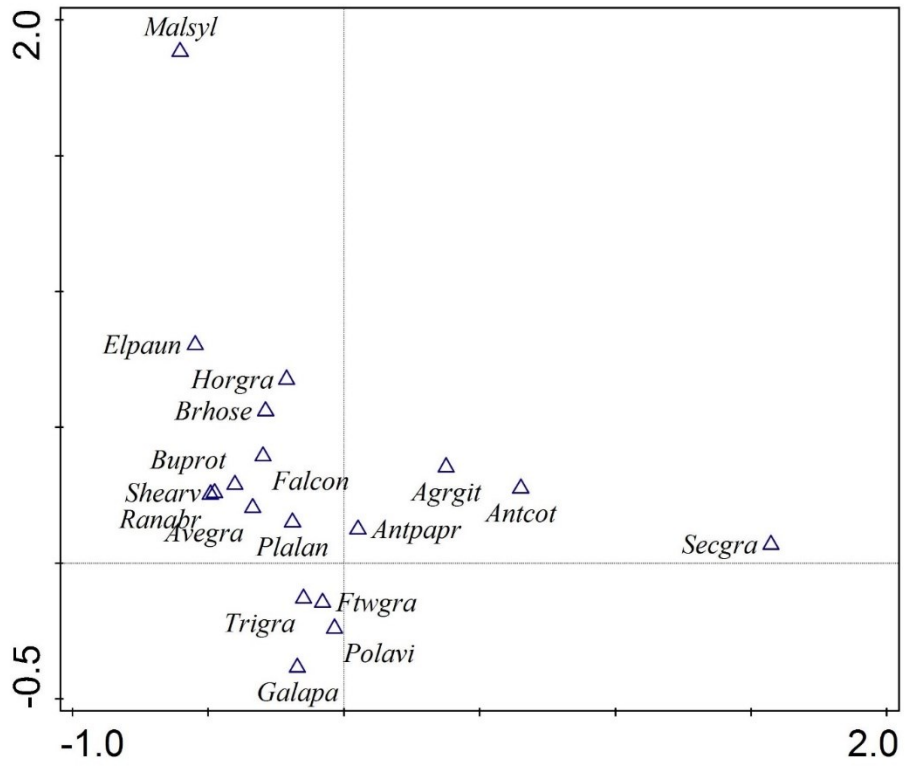
Worksheet: **32_sto**

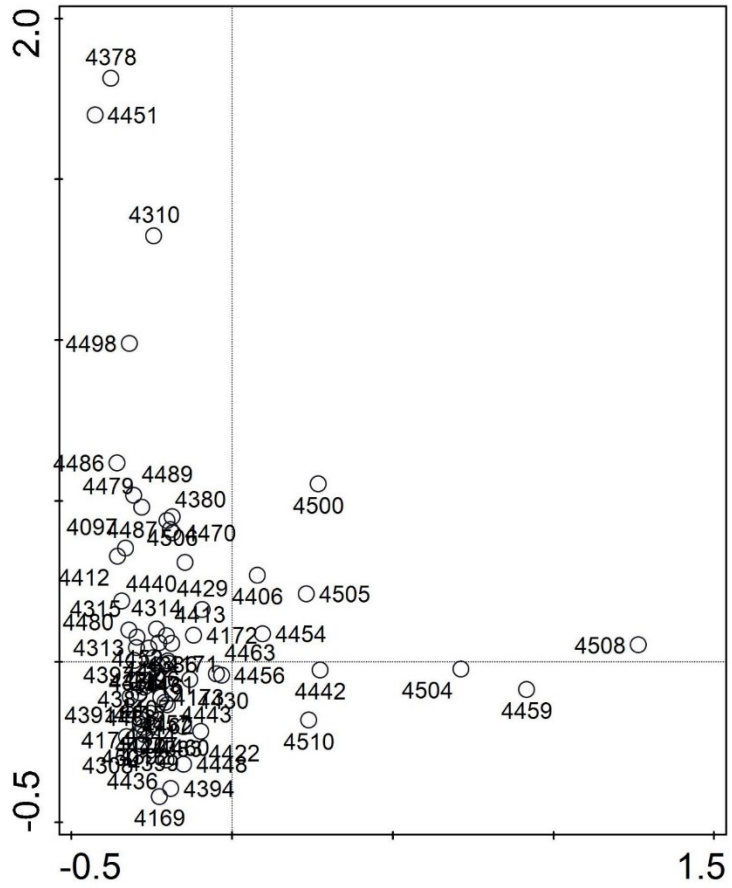
Begin with 18 species in 73 samples.





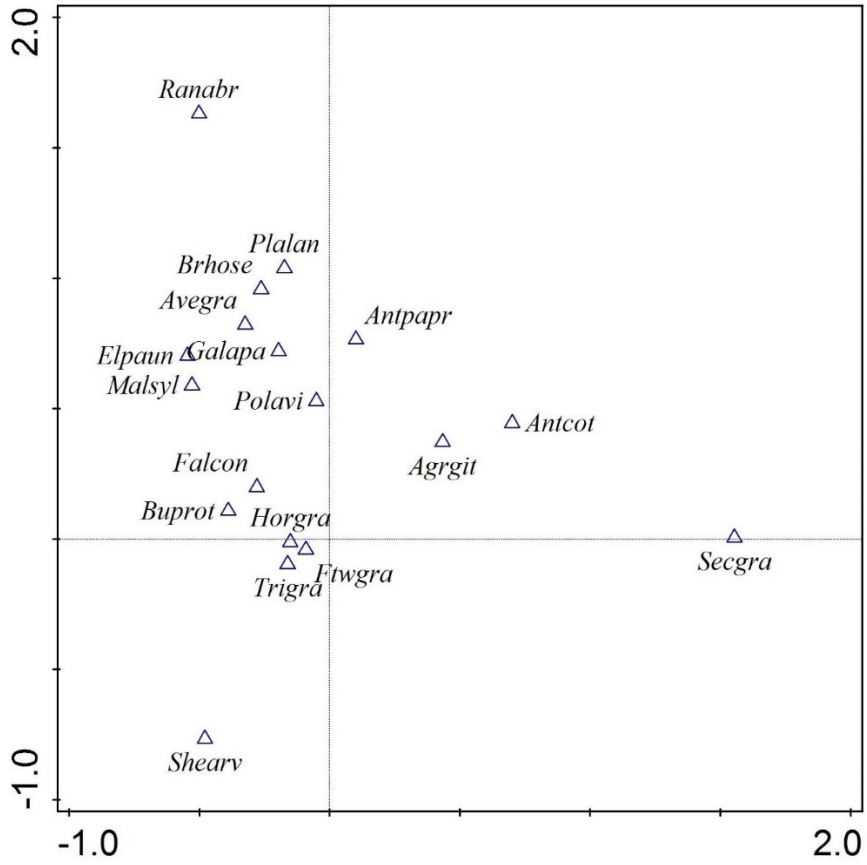
Delete outlier samples: 4376, 4400, 4403, 4453, 4466 and 4467, and re-run.

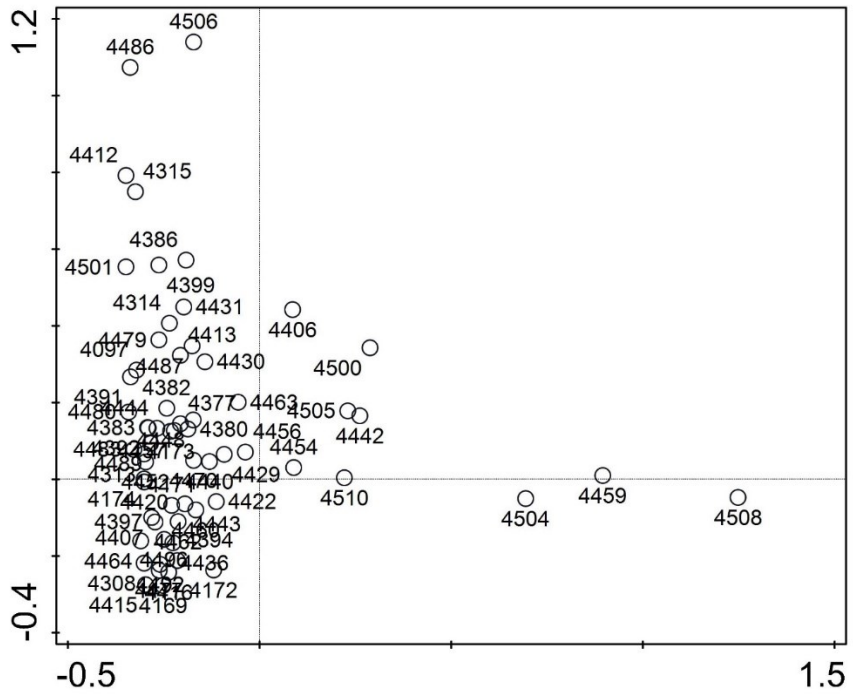


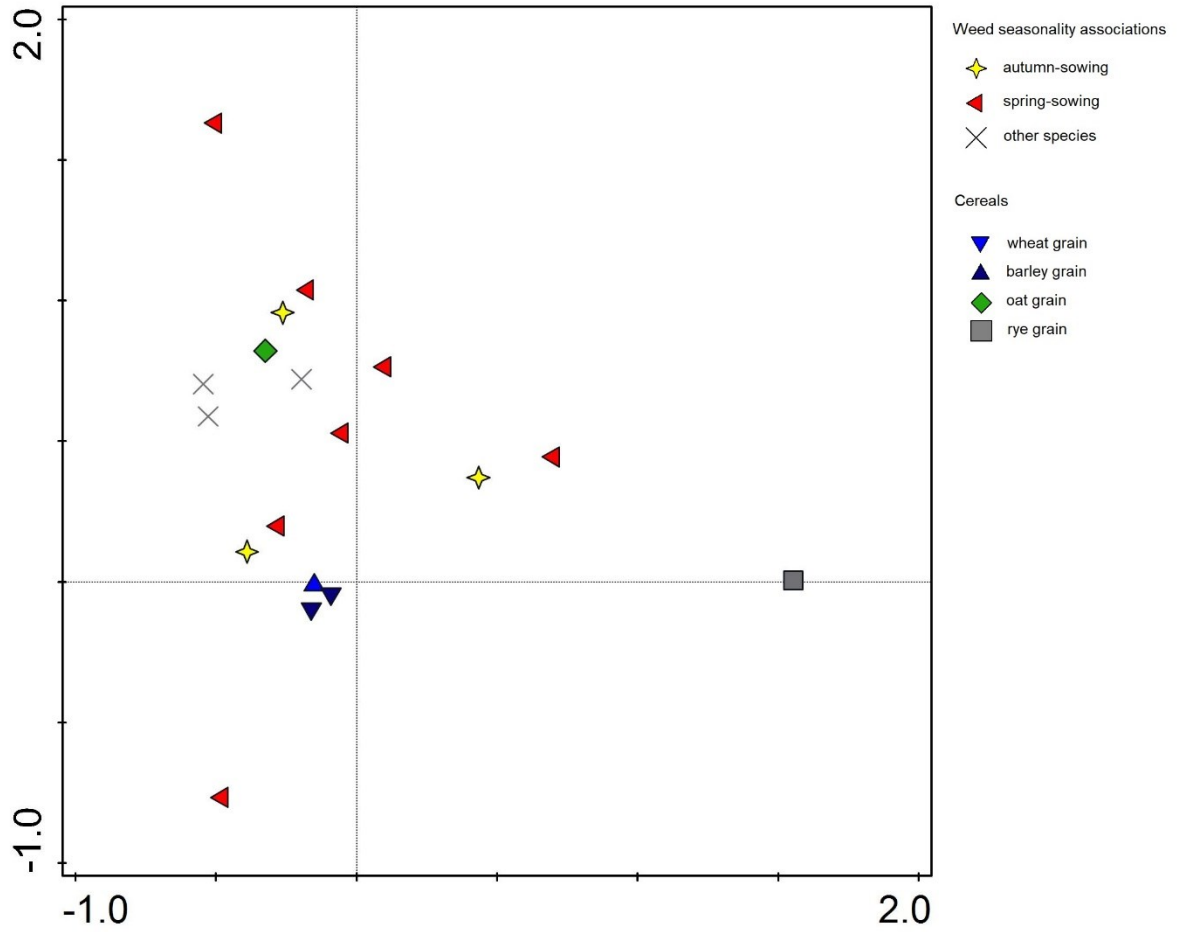


Delete outlier samples 4378, 4451, 4310 and 4498, and re-run to produce a clearer distribution.

There is no clear indication of systematic seasonal sowing for any of the cereals.



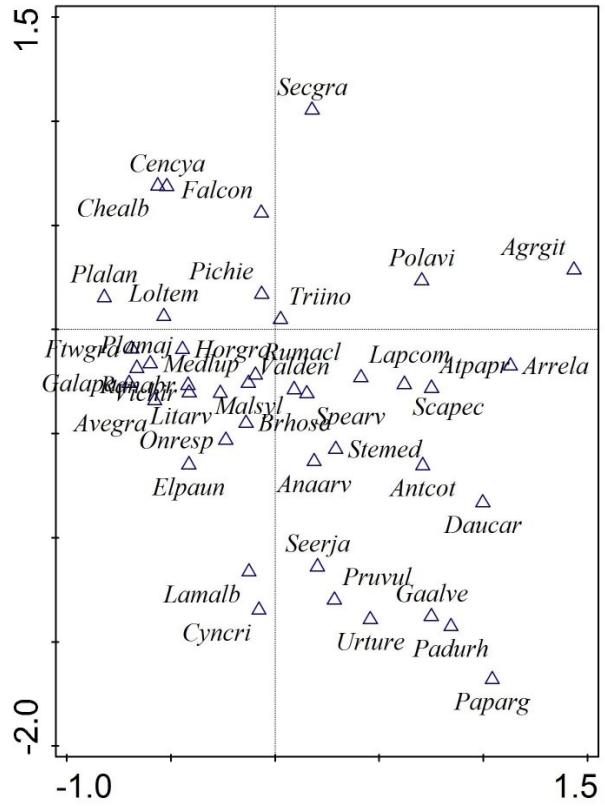


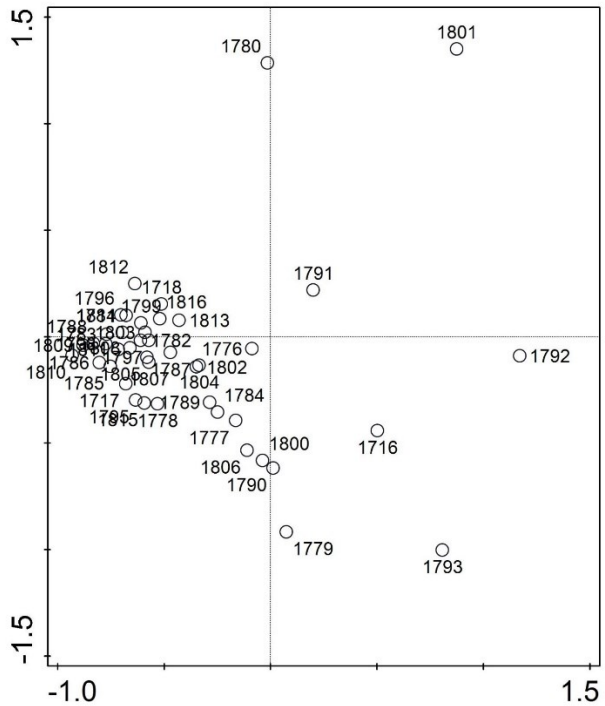

2.0
-1.0
-1.0
2.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

33. Stratton (Bedfordshire)

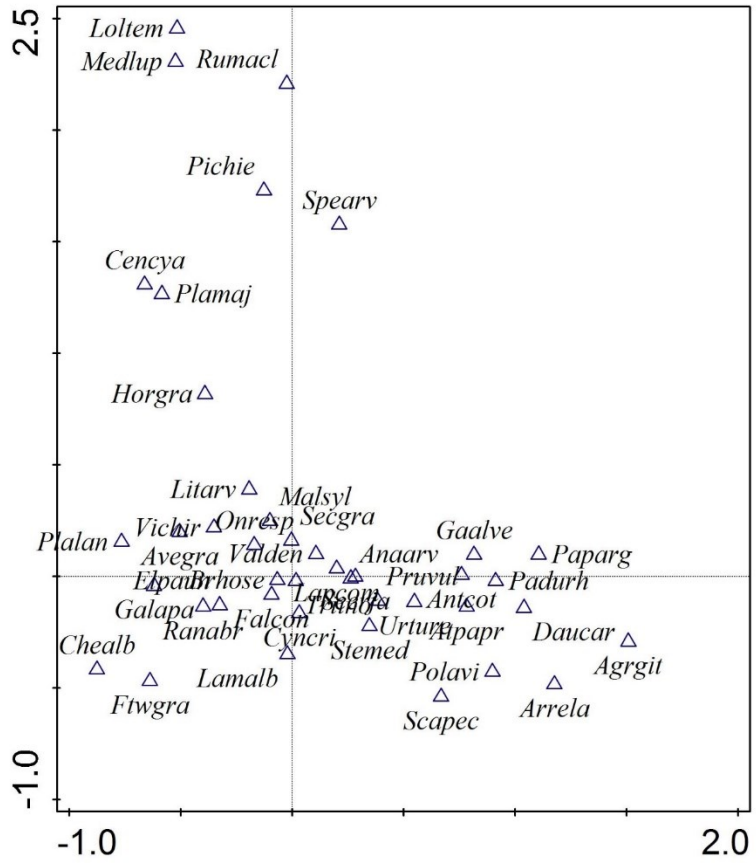
Worksheet: **33_str**

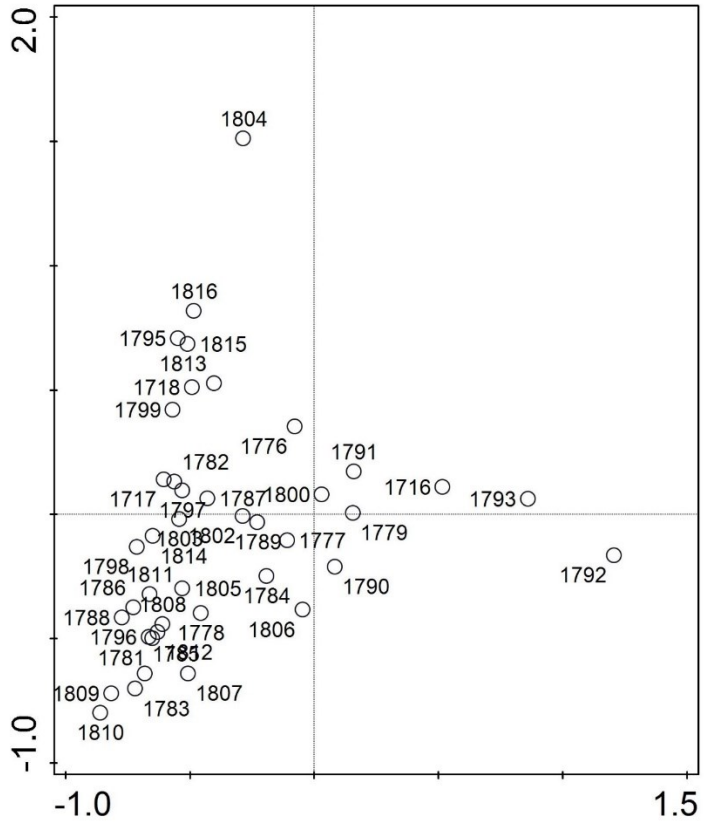
Begin with 46 species in 43 samples.



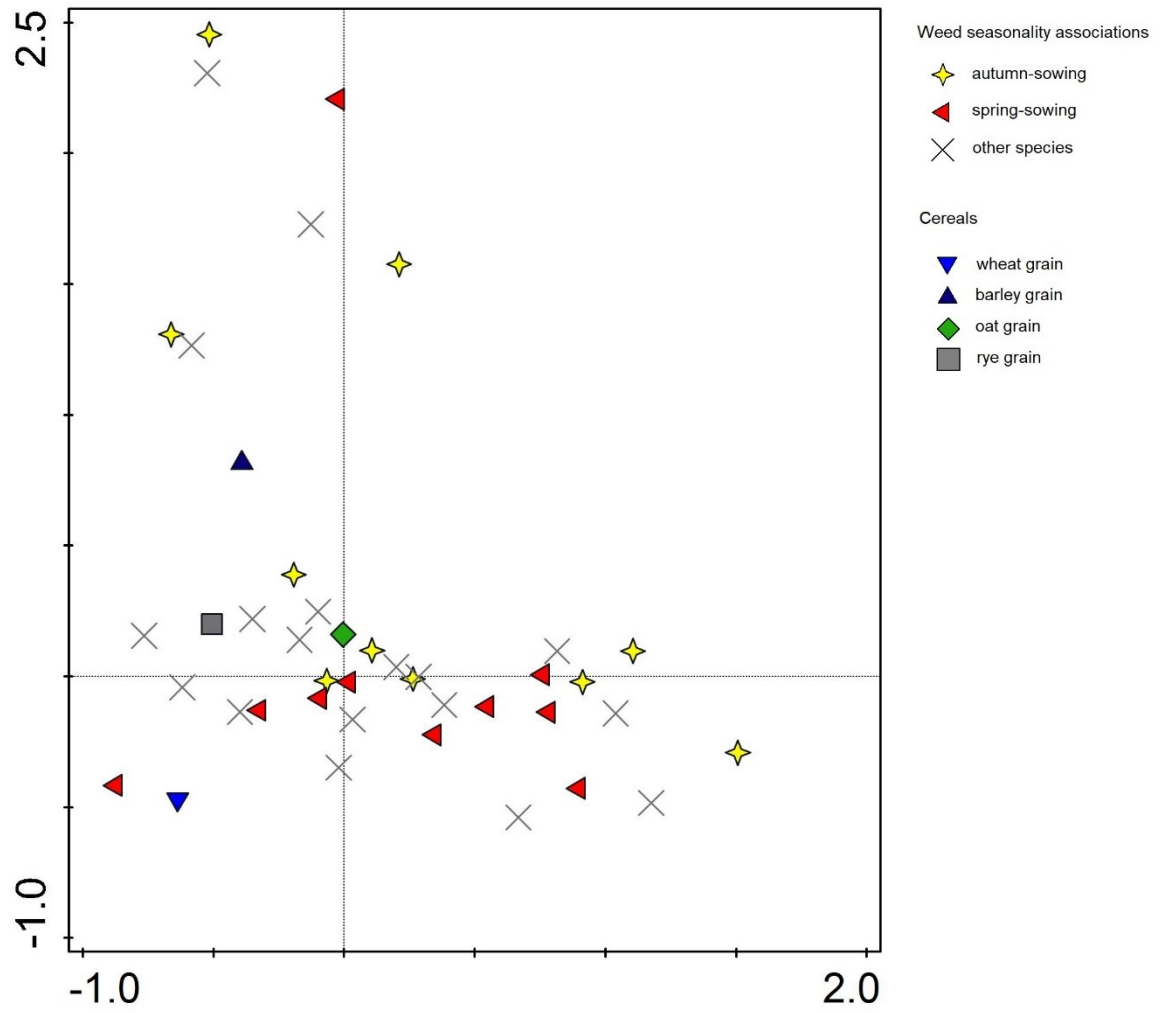


Delete outlier samples 1780 and 1801, and re-run to produce a clearer distribution.





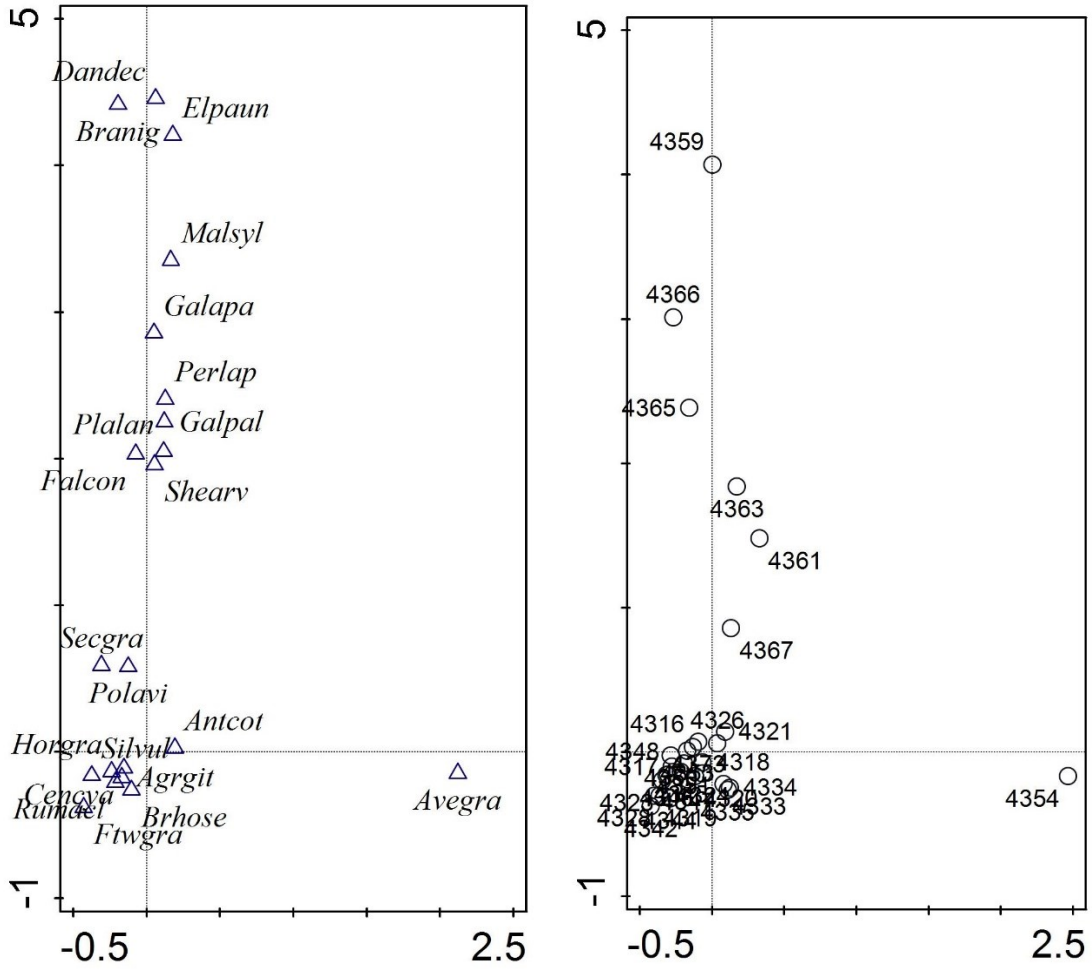
In terms of systematic seasonal sowing, the results are somewhat difficult to interpret. At first sight, there appears to be a weak separation between autumn weeds (towards the positive end of the y-axis, along with barley, rye and oats) and spring weeds (towards the negative end, along with wheat). But most of the weed species occupy a relatively narrow band around zero on the y-axis, suggesting that, on the whole, there are no major, systematic seasonal differences to be discerned.



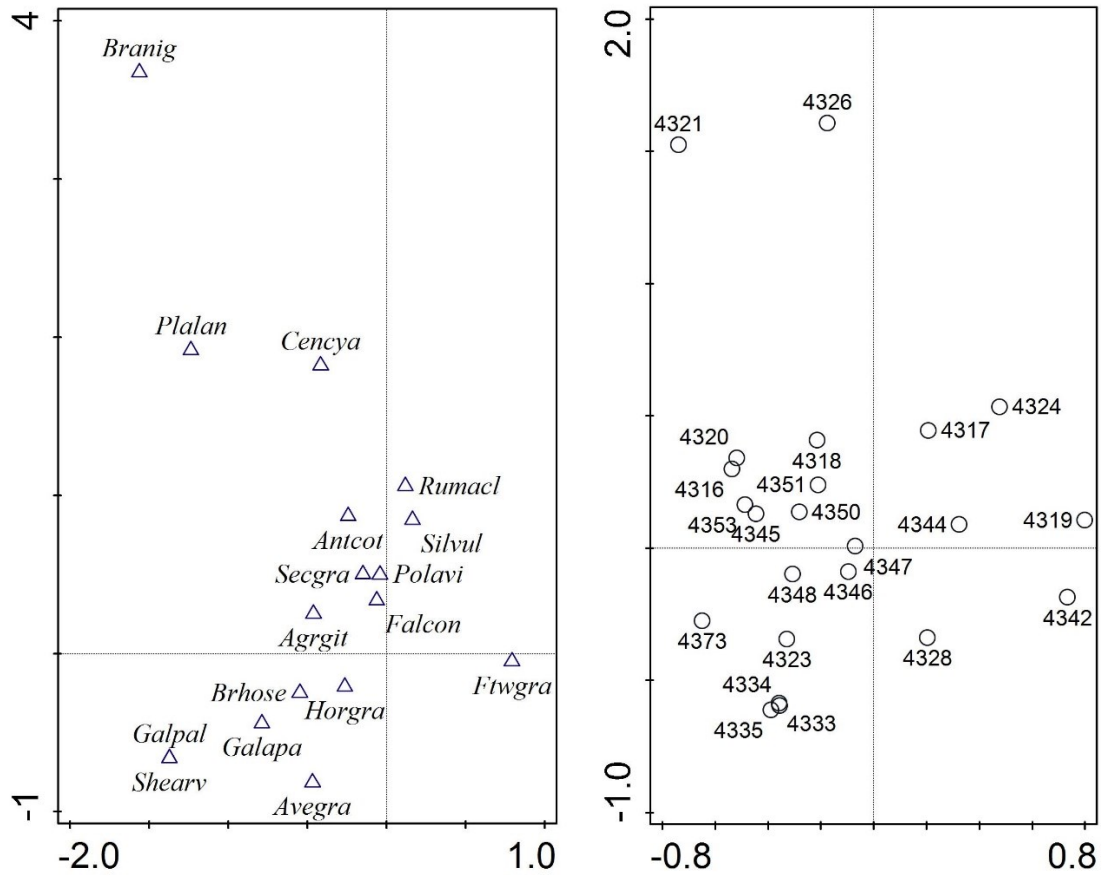
34. Thanet Earth (Kent)

Worksheet: **34_tha**

Begin with 21 species in 30 samples.

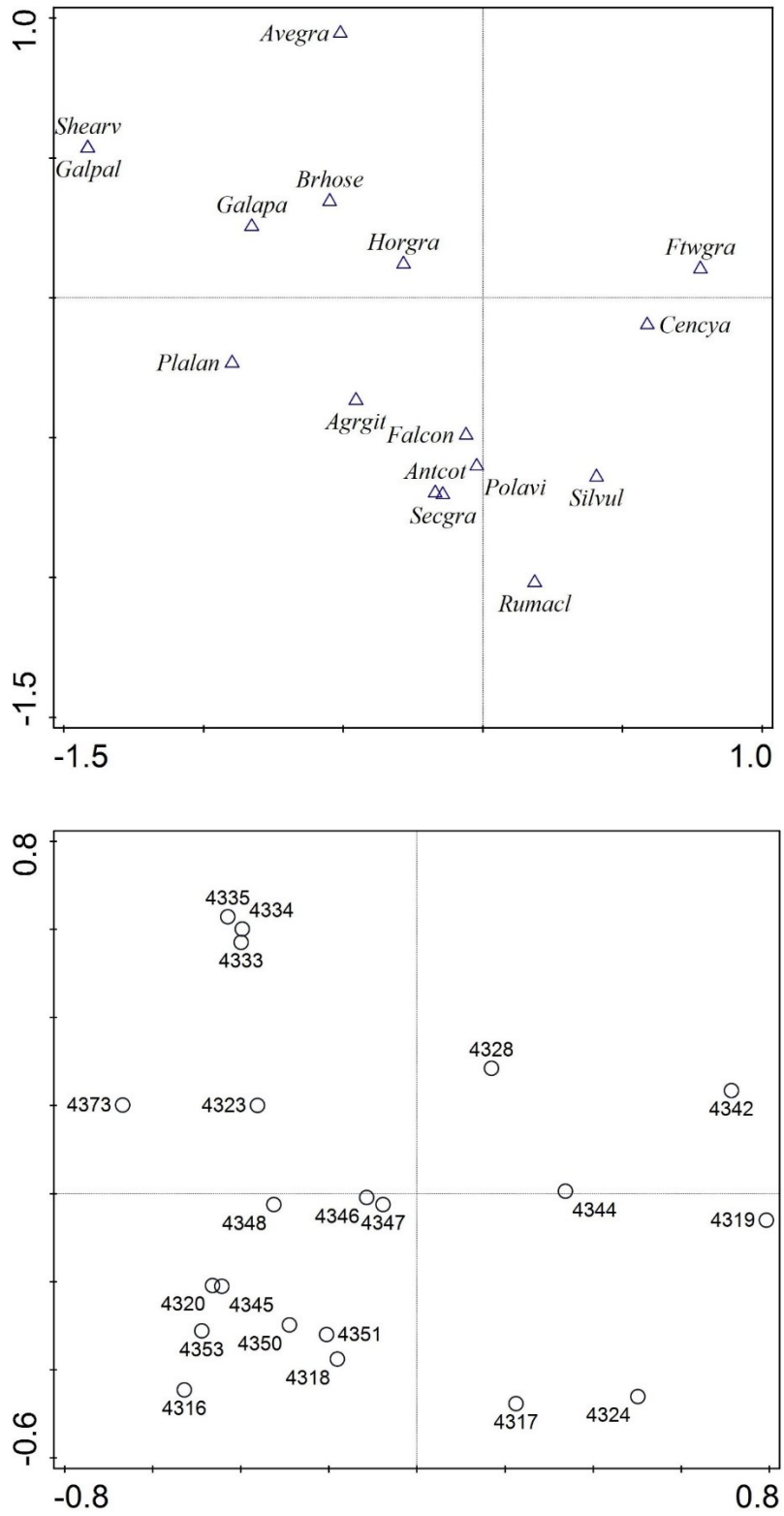


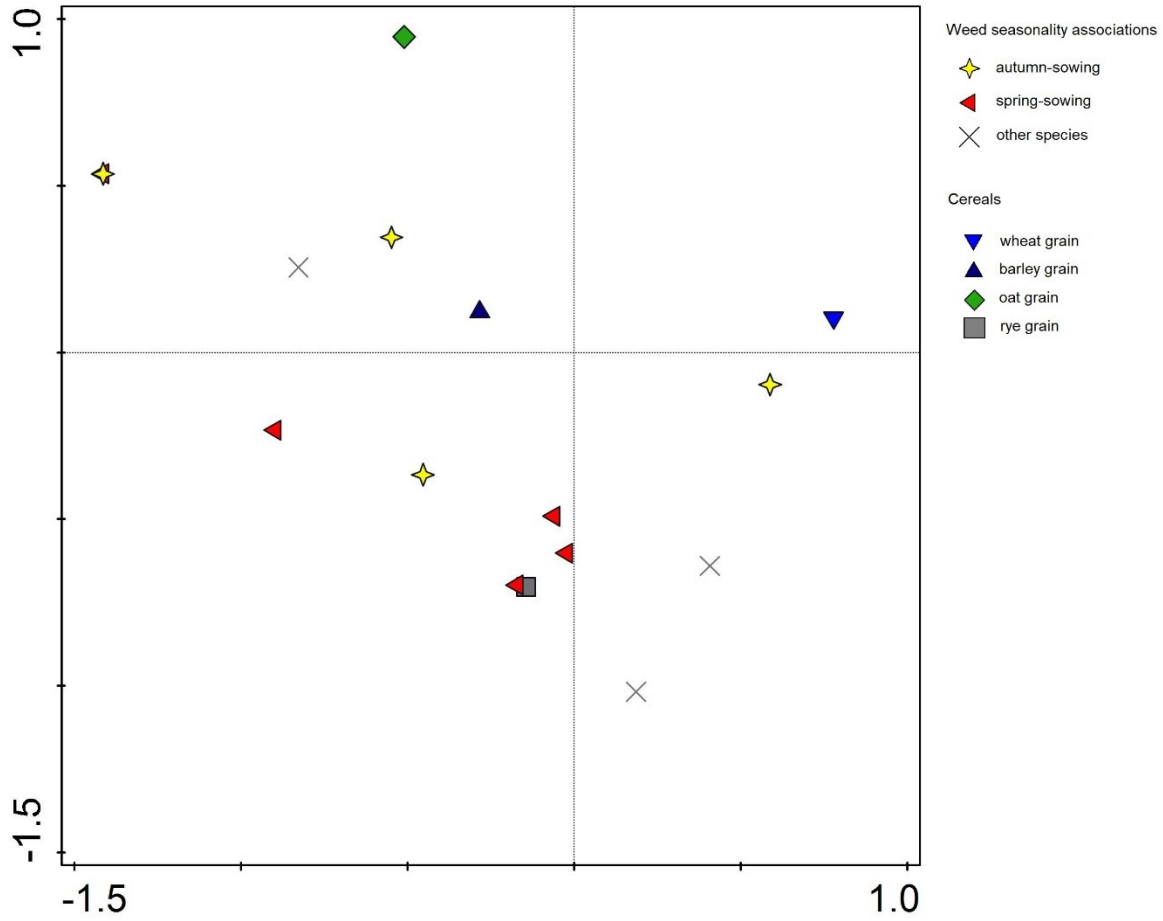
Delete outlier samples 4359, 4361, 4363, 4365, 4366, 4367 and 4354, and re-run analysis.



Delete outlier samples 4321 and 4326, and re-run to produce a clearer distribution.

Rye appears to be particularly associated with spring weeds, to the negative end of the y-axis, while wheat, barley and oats are more associated with the autumn weeds. By this point, all but one of the phase A samples have been removed as outliers, so this emergent pattern should be considered characteristic of the remaining samples' collective timespan, phases E1–G1 (*c.* AD 1030–1360).




1.0
-1.5
-1.5
1.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

35. Walpole St Andrew (Norfolk)

Worksheet: **15_ing**

See above, under (15) Ingleborough and Walpole St Andrew.

36. Wellington Quarry (Herefordshire)

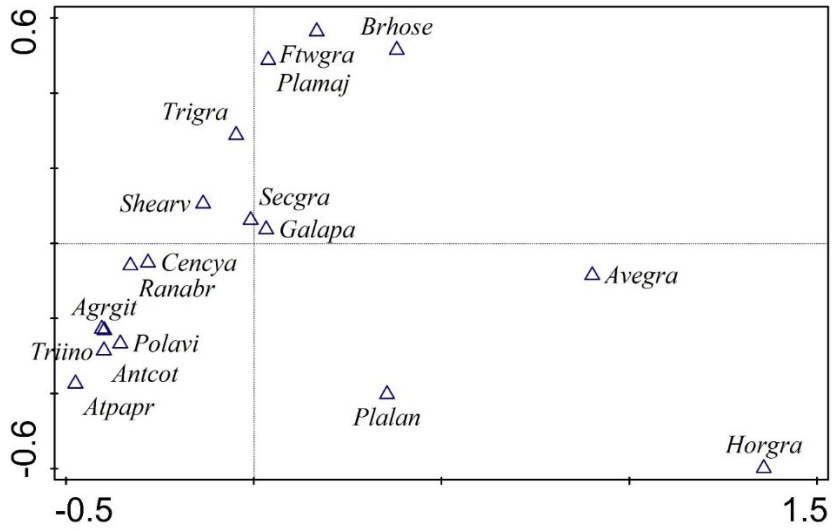
Worksheet: **13_hol**

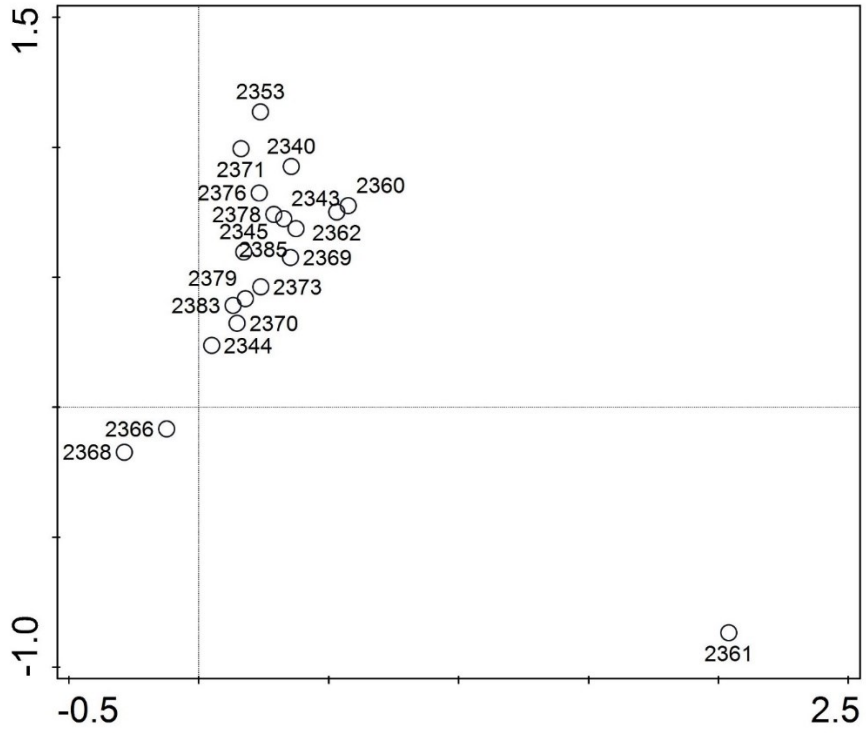
See above, under (13) Holmer and Wellington Quarry.

37. West of Kempston (Bedfordshire)

Worksheet: **37_wes**

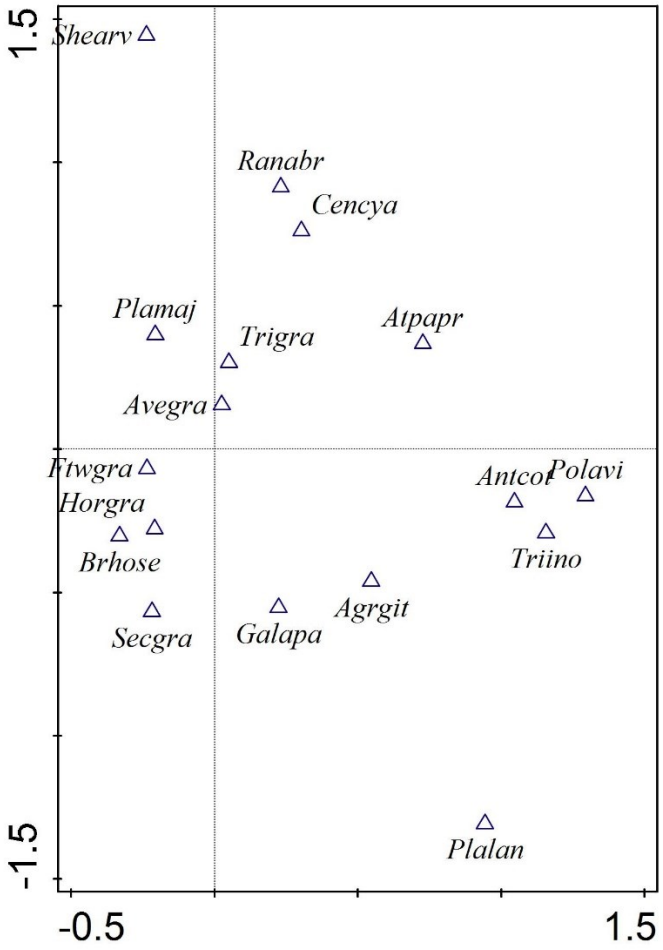
Begin with 17 species in 19 samples.

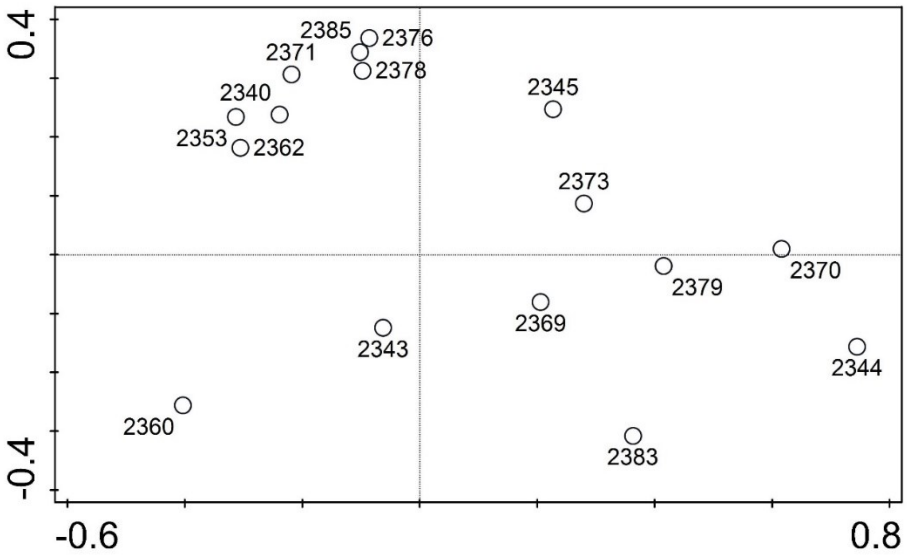


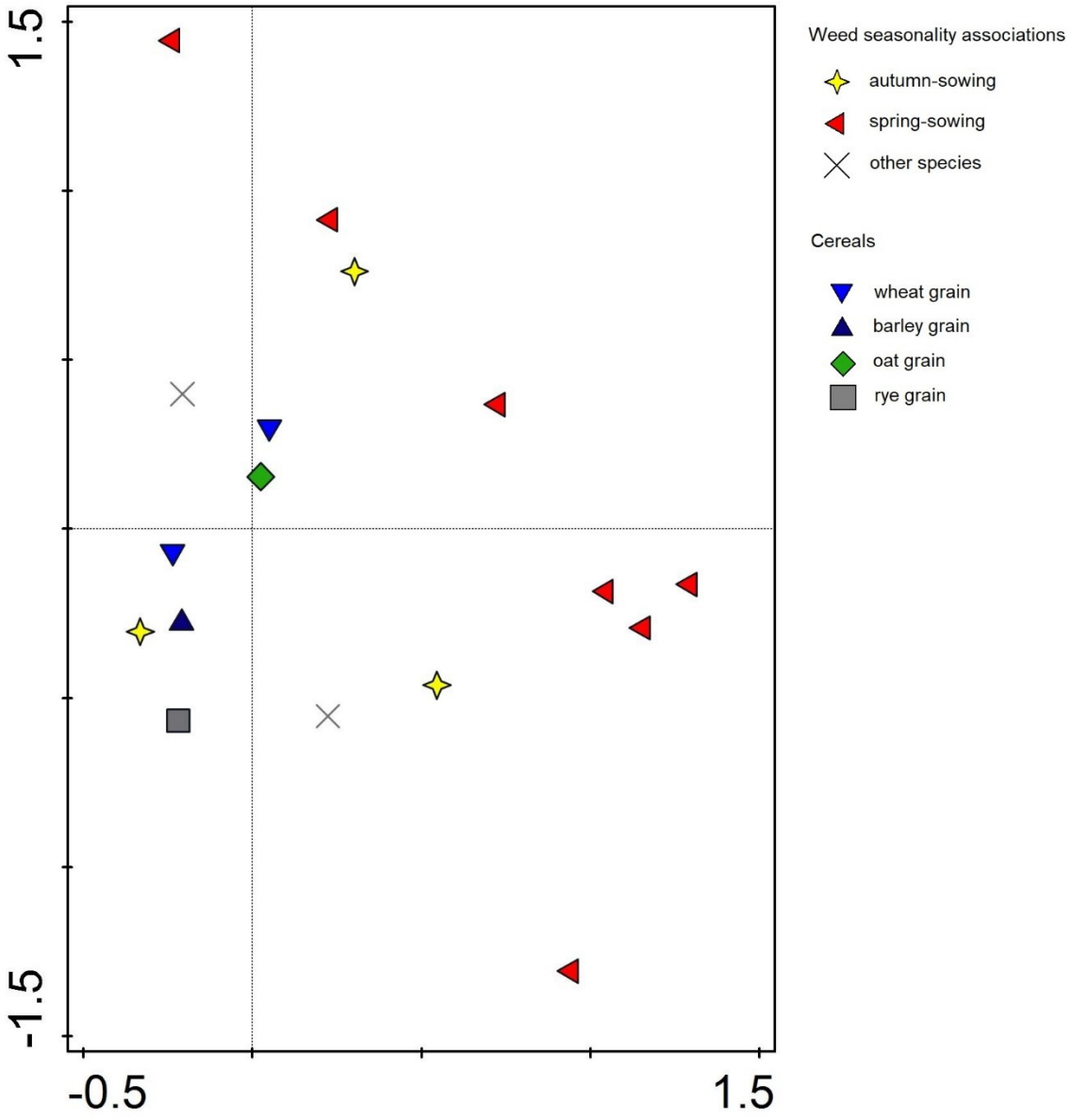


Delete outlier samples 2361, 2366 and 2368, and re-run produce a clearer distribution.

Both autumn- and spring-associated weed species are present, but there is no indication of systematic seasonal sowing of any of the cereals.






1.5
-1.5
-0.5
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

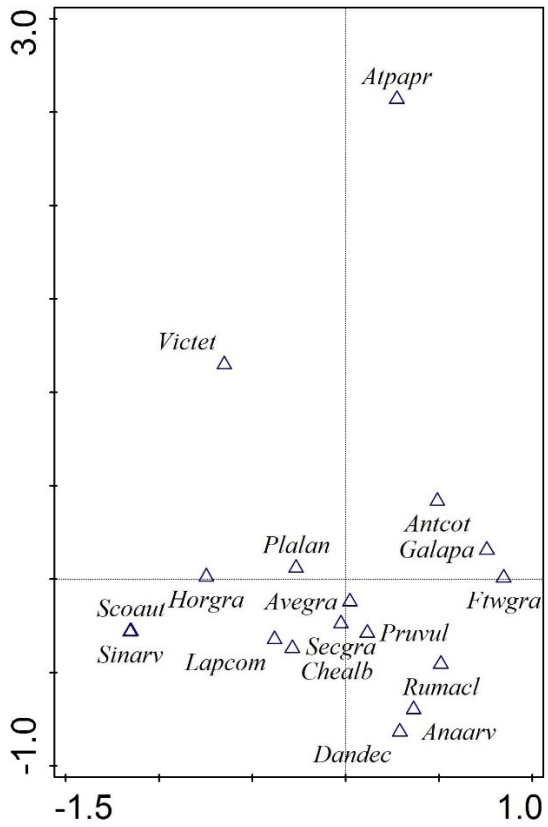
38. Wharram Percy (North Yorkshire)

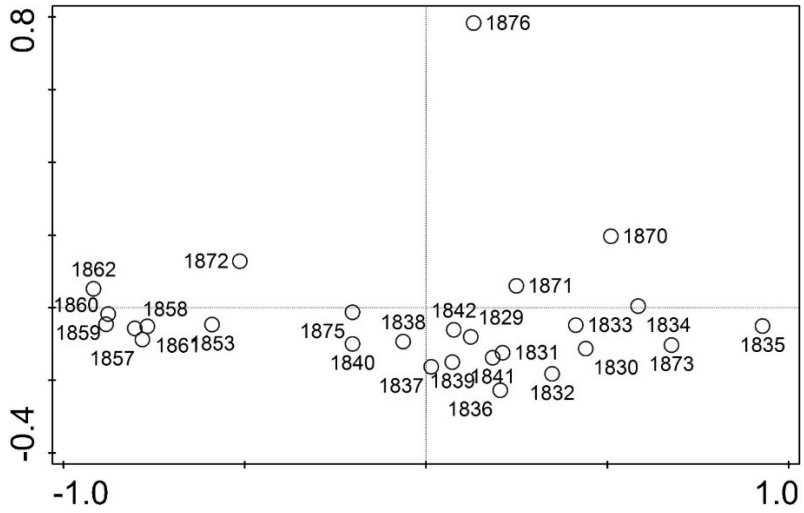
Worksheet: **38_wha**

Comprising the South Manor (93) and watermill sites (30 and 71).

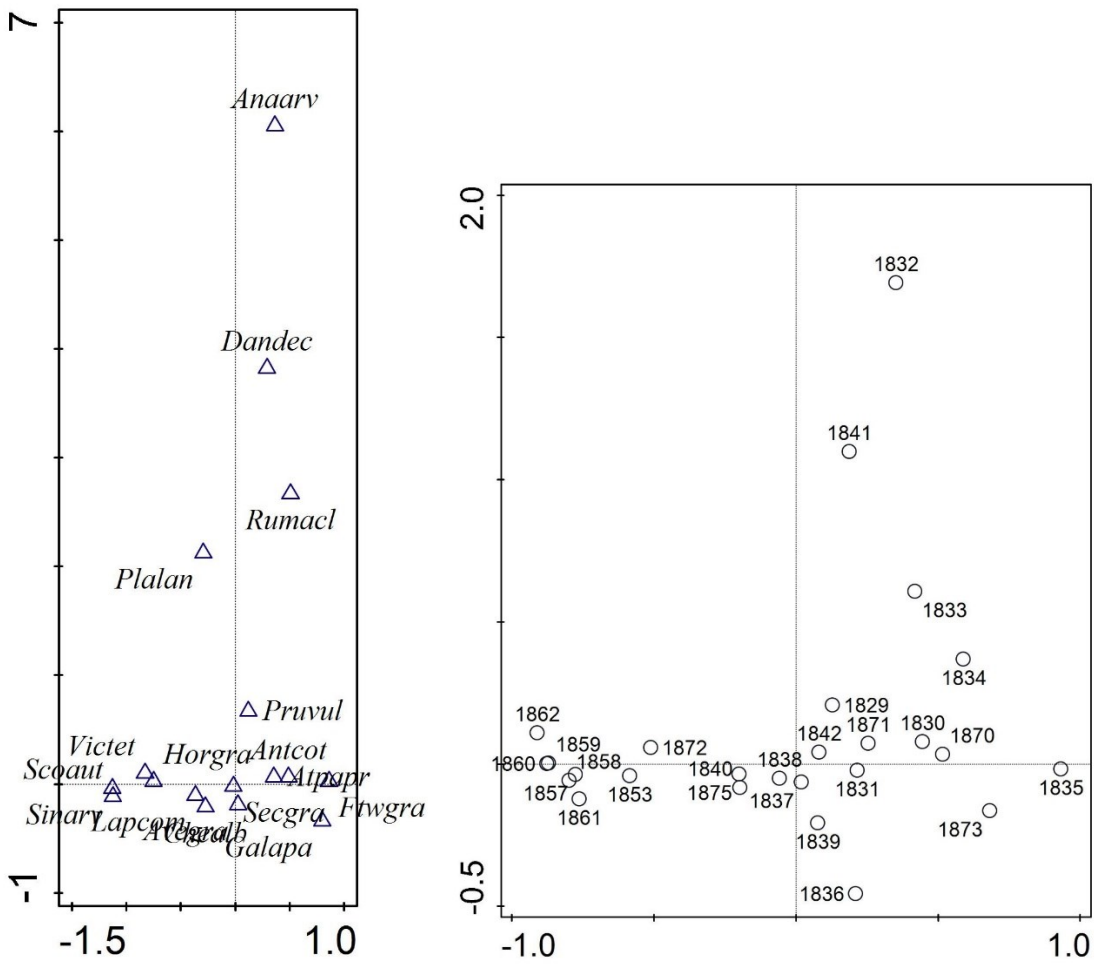
Both classes of wheat grain – *Trigra* and *Ftwgra* – have been combined as *Ftwgra* in this analysis, because differences between the two were found to be largely due to differences in identifiability/confidence between the Wharram sites.

Begin with 17 species in 27 samples.



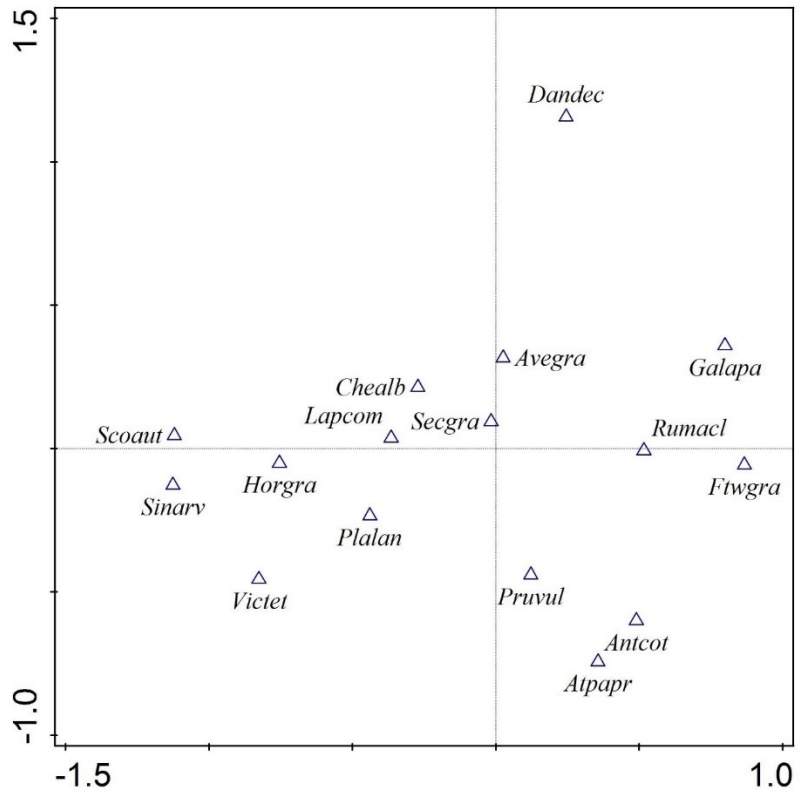


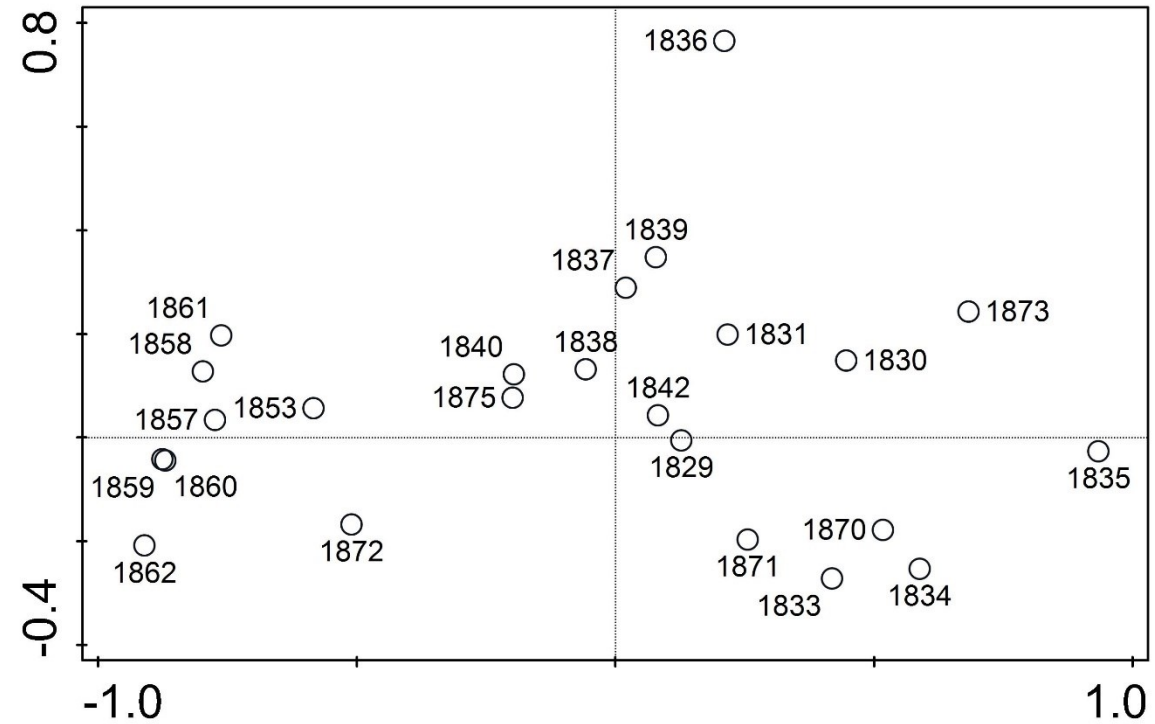
Delete outlier sample 1876 and re-run analysis,

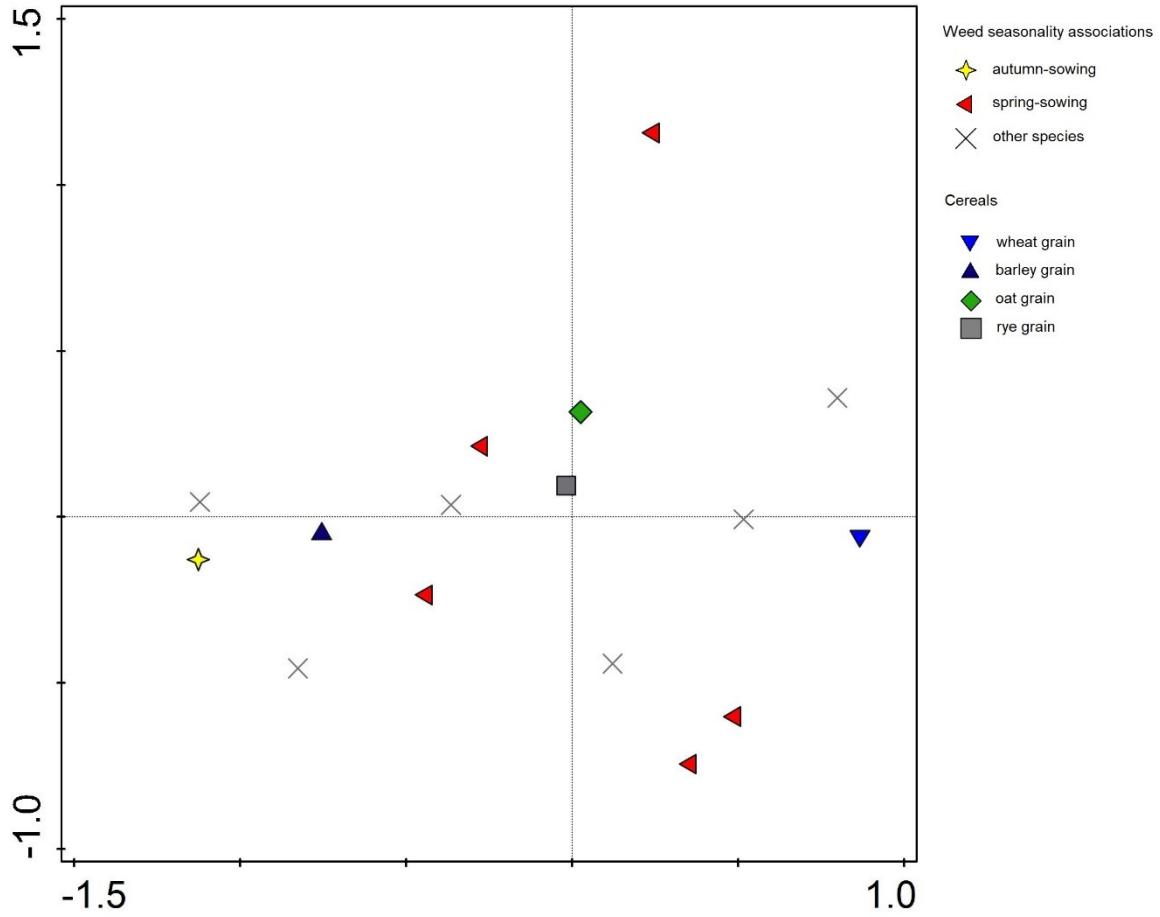


Delete outlier samples 1832 and 1841, and re-run analysis to produce a clearer distribution.

The deletion of the outliers, and consequent deletion of *Anaarv* as a species now present in fewer than three samples, has left only one autumn-associated weed, *Sinarv*. This species (i.e. charlock: *Sinapis arvensis* L.) occurs only in samples with a crop component dominated by barley (*Horgra*). Hence, the Wharram Percy assemblage is classified as 'spring-dominated' in the monograph, but with the observation that barley may conceivably have been preferentially autumn-sown, at least in phases C4–D3 (*c.* 820–980) to which those barley-rich samples largely belong.


1.5
-1.0
-1.5
1.0
Dandec
Avegra
Galapa
Chealb
Lapcom
Secgra
Scoaut
Rumacl
Horgra
Ftwgra
Sinarv
Plalan
Victet
Pruvul
Antcot
Atpapr

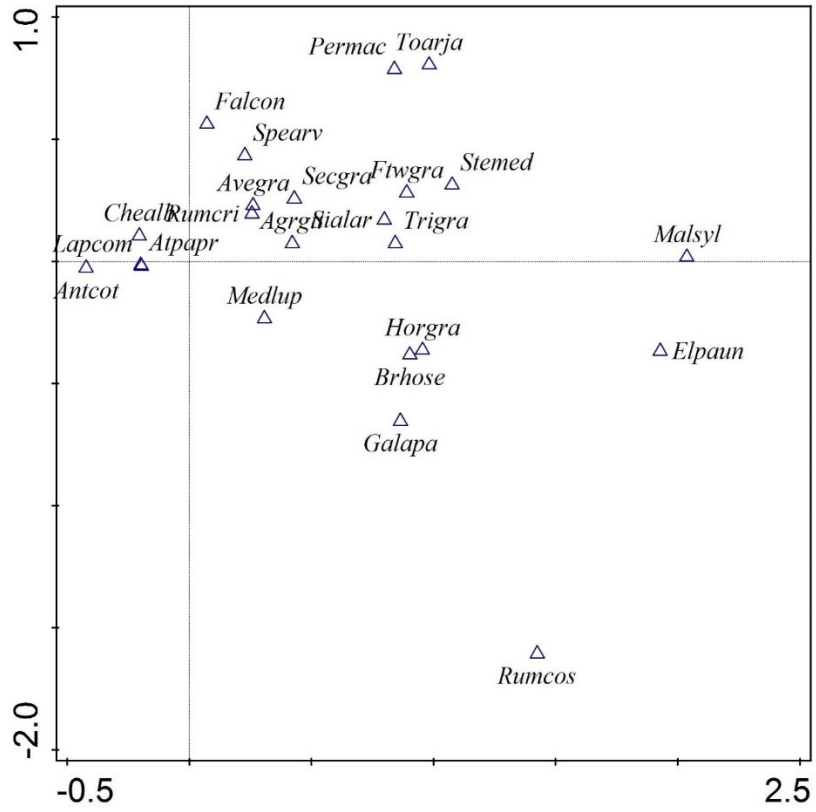

0.8
-0.4
-1.0
1.0
1836
1839
1837
1861
1858
1873
1831
1840
1838
1830
1875
1842
1857
1853
1829
1835
1859
1860
1870
1872
1871
1862
1834
1833

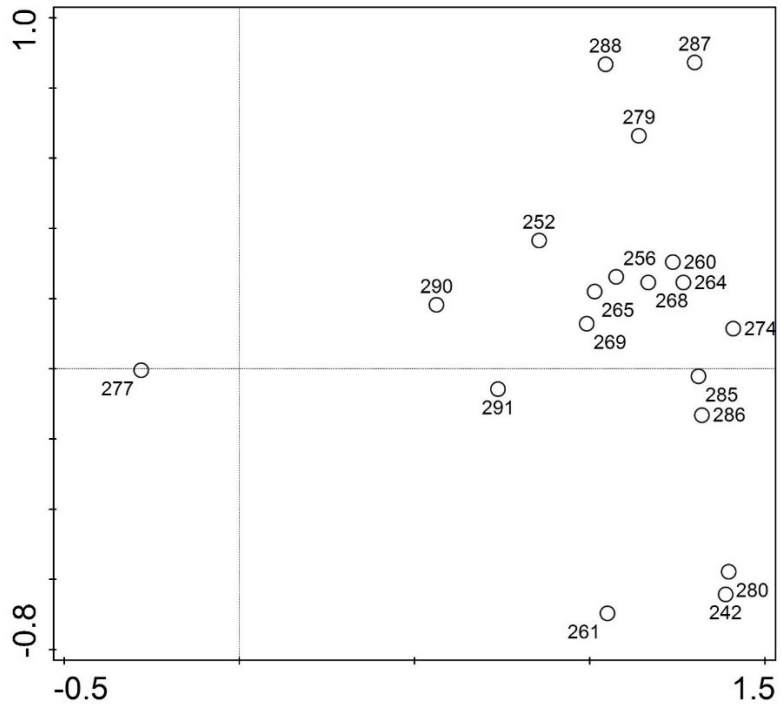

1.5
-1.0
-1.5
1.0
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

39. Yarnton (Oxfordshire)

Worksheet: **39_yar**

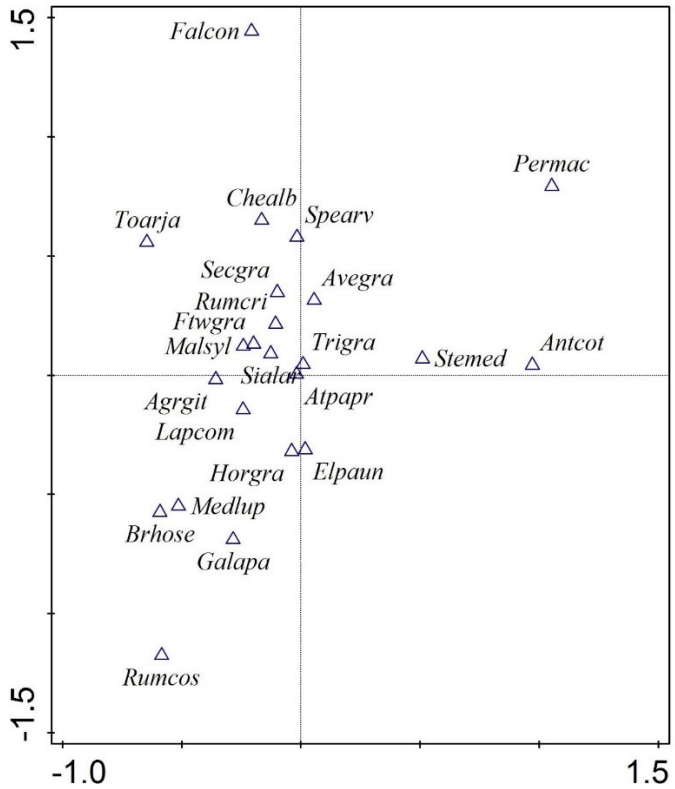
Begin with 23 species in 19 samples.

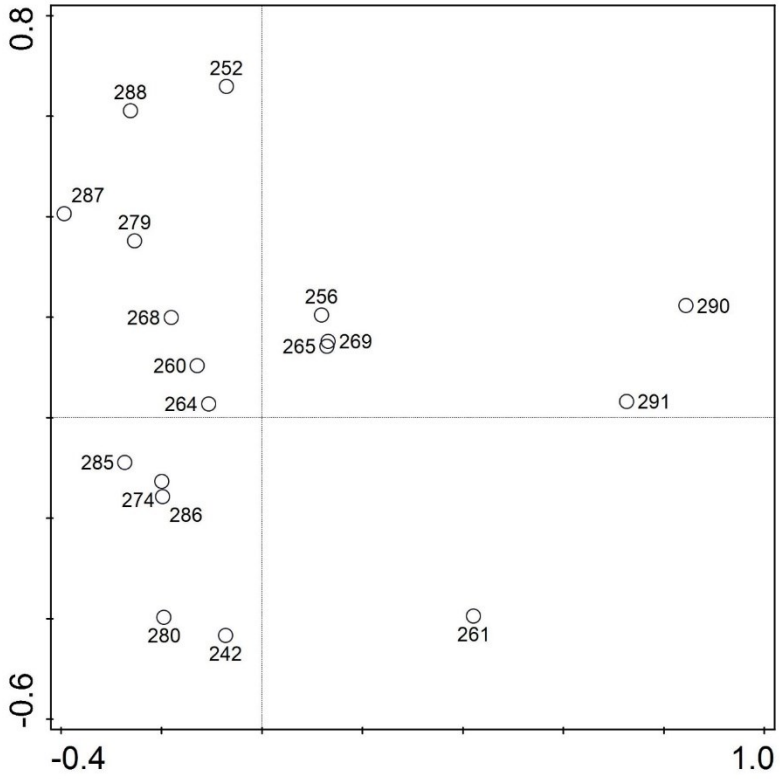


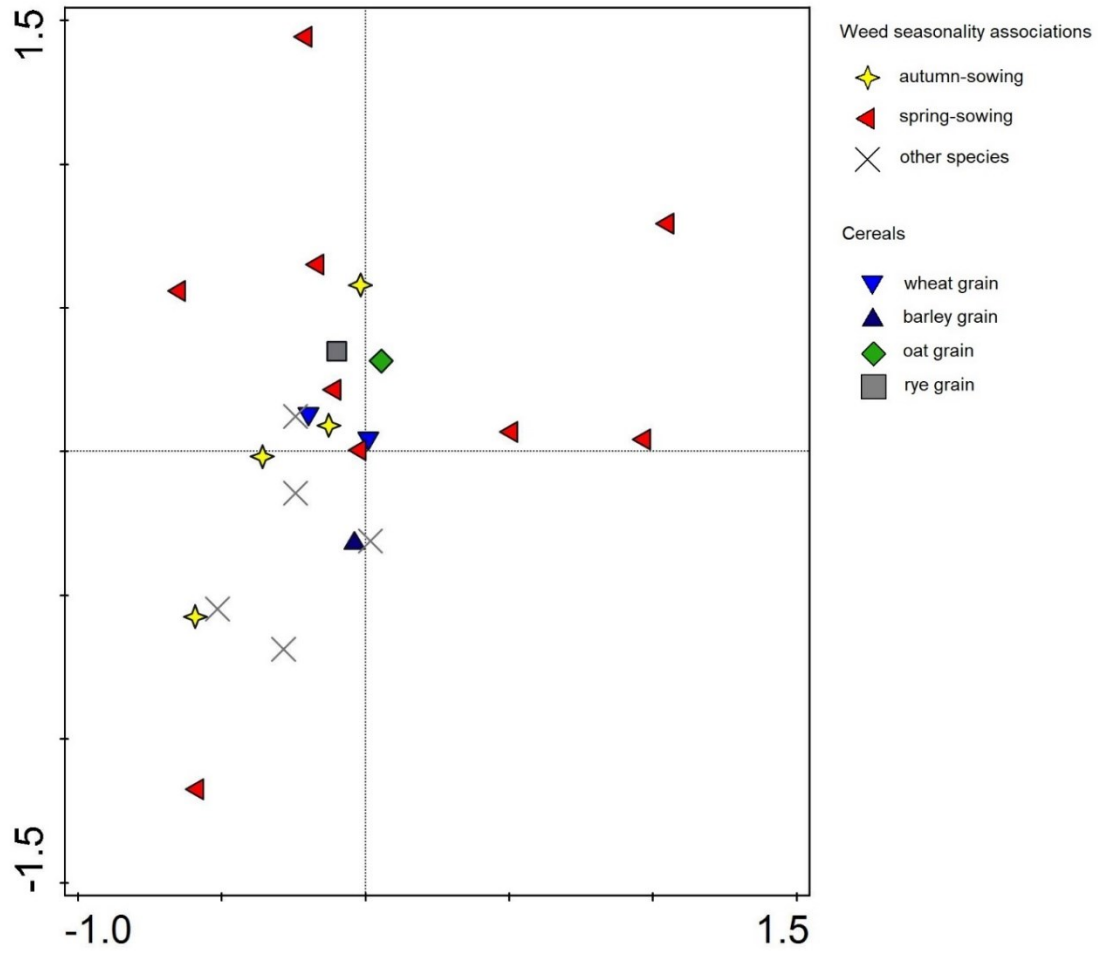


Delete outlier sample 277, and re-run analysis to produce a clearer distribution.

Both autumn- and spring-associated weed species are present, but there is no indication of systematic seasonal sowing for any of the cereals.






1.5
-1.5
-1.0
1.5
Weed seasonality associations
autumn-sowing
spring-sowing
other species
Cereals
wheat grain
barley grain
oat grain
rye grain

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