Effectiveness of new agri-environment schemes in conserving arable plants in intensively farmed landscapes

Defra Cereal Field Margin Evaluation. Phase 3.
Evaluation of Agri-environment Cultivated Options in England

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K.J. Walker[a], C.N.R. Critchley[b], A.J. Sherwood[c], R. Large[a],
P. Nuttall[a], S. Hulmes[a], R. Rose[d], I. Moy[d], J. Towers[e], R. Hadden[e],
J. Larbalestier[e], A. Smith[e], J.O. Mountford[a], J.A. Fowbert[b]

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[a]*NERC Centre for Ecology and Hydrology Monks Wood, Abbots Ripton, Huntingdon, Cambridgeshire PE28 2LS*
[b]*ADAS UK Ltd., ADAS Redesdale, Rochester, Otterburn, Northumberland NE19 1SB*
[c]*ADAS UK Ltd., Boxworth, Cambridge CB3 8NN*
[d]*NERC Centre for Ecology and Hydrology Dorset, Winfrith Technology Centre, Dorchester, Dorset DT2 8ZD*
[e]*ADAS UK Ltd, 15 Eastway Business Village, Olivers Place, Fulwood, Preston PR2 4WT*

ADAS

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Summary

1. The abundance and diversity of annual, arable plants declined substantially in the UK and Western Europe during the second half of the twentieth century due to changes in agricultural practices. Plants of arable habitats declined more than any other group in the UK and many species are now rare nationally. To help reverse these declines a range of options for field margin management have been introduced in agri-environment (AE) schemes in England, with large areas of arable land now within targeted options (i.e. cultivated uncropped margins, conservation headlands). Cereal field margins have also been allocated Priority Habitat status under the UK Biodiversity Action Plan (UKBAP) and Species Action Plans produced for several rare arable species.
2. The aims of this study were to (1) determine the effectiveness of a range of AE scheme cereal field margin options in conserving arable plant diversity and populations of rare and declining arable plants, (2) verify options are being targeted effectively to areas of known arable weed diversity, (3) provide an estimate of the 'stock' of species in cereal field margins within scheme options intended to conserve arable plants and (4) assess the relative importance of option management prescribed under the schemes compared to other environmental factors in accounting for variation in species composition.
3. Five types of field margin were surveyed in 2005, being uncropped, cultivated field margins ('RAWMs'), conservation headlands ('CH1'), no-fertiliser conservation headlands ('CH2'), spring fallow ('OS3') and conventionally managed cereal crops as controls. These were selected at random from the pooled Countryside Stewardship (CS) and Environmentally Sensitive Area (ESA) scheme agreements and stratified within eight Defra administrative regions. In total, 195 sites (CS = 193; ESA = 2) were surveyed with the number sampled within each region proportional to uptake of targeted AE options (i.e. excluding OS3). Each sample site was a randomly located 100 m long by 6 m wide 'sample zone' located at least 10 m from field corners and directly adjacent to a cereal field boundary. Within this zone botanical data were collected from 30 randomly located quadrats on transects at 1, 3 and 5 m from the boundary. In addition, all species present within a 1 × 100 m boundary plot were recorded to compare with the results of Countryside Survey 2000. The entire field margin was also searched for a set of 41 'core' rare species (UKBAP Priority and Species of Conservation Concern, IUCN critically rare) and an 'additional' 45 local or declining arable species. Data on management practices, soil properties, climate and the surrounding cropping and landscape structure were collected from a combination of field data and existing environmental datasets. Data were

analysed using Analysis of Variance, ordination, and variation partitioning via Partial Redundancy Analysis.

4. In total of 225 dicotyledons and 39 monocotyledons were recorded including four UKBAP Priority Species (*Centaurea cyanus*, *Fumaria purpurea*, *Scandix pecten-veneris* and *Silene gallica*) and a further 30 rare arable species which are known to have declined in recent decades.
5. RAWM sites were by far the most diverse option in terms of the numbers of annuals, perennials, grasses, forbs and spring and autumn germinating species. CH2 and OS3 sites were next most diverse (with few differences in species numbers between them). CH1 and controls were least diverse, also with few differences between them. Controls had the highest proportion of annuals and RAWM sites the lowest. The proportions of forbs and spring-germinating species were highest in CH2 sites and lowest in controls. Cover of non-crop species was highest at RAWM sites and lowest in controls. Bare ground and litter cover were highest in OS3 sites. Ellenberg N (fertility) scores were greatest in controls and CH1 sites. Soil extractable P was lowest in CH2 and highest in control and CH1 sites. Soil pH and extractable K and Mg did not vary among margin types.
6. Overall, species richness declined from 1 m to 5 m from the field boundary, with the exception of RAWM sites.
7. There were clear differences in plant diversity between regions, being highest in the South East and South West, followed by East, and lowest in the North East. Ellenberg N values were lowest in the South East and North West. Soil pH was lowest in northern and western regions and highest in the south and east. Soil extractable P was lowest in the North East. Soil extractable K showed a similar, but less marked pattern, and extractable Mg the reverse.
8. There were 145 records of 34 rare species including 11 core and 23 additional species. A much greater proportion (39%) of AE scheme margins had rare species than control sites (15%). RAWM sites accounted for 45% of all records, followed by CH2 (23%), OS3 (19%), CH1 (9%) and controls (4%). The distribution of rare species was highly biased to the East, South East and South West, together accounting for 87% of records. North East, North West, West Midlands and Yorkshire/Humberside were by far the poorest. The 11 core species were mainly confined to base-rich (pH > 8) soils.
9. Overall species composition varied between margin types, with the exception of CH1 and control sites. It also varied regionally, except that East Midlands, West Midlands and Yorkshire/Humberside were not differentiated from one another. January and July

temperature and rainfall, the intensity of arable cropping (denoted by proportion of spring barley) and soil pH also accounted for some variation in species composition.

10. Species composition was related to the potential rare species-pool in the surrounding landscape and soil extractable P and K in uncropped (RAWM, OS3) but not cropped (CH1, CH2, control) sites. Cultivation regime and age of site was also significant at uncropped sites. Season of sowing, crop species and fertiliser application was related to species composition at cropped sites.
11. Margin type accounted for more variation in species composition than habitat context, physical/climatic variables, soil properties or region. At cropped sites, there was some overlap between margin type and habitat context, and physical/climate and region but soil properties acted independently of other variable sets and explained less variation. At uncropped sites, management and physical/climate explained most variation but soil properties were more important than at cropped sites.
12. These findings suggest that there are around 2500 populations (6% core species) of rare species on AE options in the UK although this is likely to be an overestimate due to the biasing of OS3 options to richer areas (i.e. around RAWMs) in this sample. Correlations between the distributions of rare species and AE agreements showed that RAWMs tend to be located in the richest 10-km grid squares whereas more precise targeting will be required to improve the overall effectiveness of both conservation headland and OS3 options.
13. Although the ability of European AE schemes to benefit farmland biodiversity has recently been questioned (Kleijn et al., 2006) this study provides the first unequivocal evidence that geographically targeted options, specifically designed to benefit arable plants, are effective in sustaining high levels of arable plant diversity, including rare species, within intensively managed landscapes in the UK. RAWMs were the most effective option followed by CH2 and OS3 options although more precise geographical targeting is required to improve the effectiveness of these two options at the regional scale. In contrast, CH1 was the least effective option although given the abundance of very common species (e.g. *Poa annua*) these margins continue to provide wider benefits for farmland biodiversity more generally (e.g. gamebirds, invertebrates).

1. Introduction

Changes in agricultural practices in the second half of the twentieth century have caused dramatic changes in the flora of arable farmland throughout Western Europe. Improved seed cleaning and crop management techniques, including increased fertiliser inputs, new crop varieties and the introduction of herbicides, have resulted in more efficient control of weeds, changing cropping patterns (including a shift from spring to autumn cultivation) and steadily increasing crop yields (Marshall et al., 2003). Not surprisingly there have been concomitant declines in the abundance of arable weeds, not least cornfield annuals, such as *Centaurea cyanus*, *Ranunculus arvensis* and *Scandix pecten-veneris*, which were formerly pernicious weeds in arable areas of lowland England (Salisbury, 1961). The results of recent surveillance of the UK flora showed that, as a group, plants of arable habitats suffered the greatest relative declines of any habitat during the second half of the twentieth century (Preston et al., 2002) with at least five species now thought to be extinct in the wild (e.g. *Bromus interruptus*) (Rich and Lockton, 2002) and many more now confined to just a handful of sites in the UK (Wilson and King, 2003). In addition, agricultural changes have reduced overall weed abundance and diversity on field margins (Andreasen et al., 1996; Chancellor and Froud-Williams, 1984; Ewald and Aebischer, 1999) as well as in the seed bank (Jensen and Kjellsson, 1992; Robinson and Sutherland, 2002). The shift from spring to winter-sown cropping has also favoured autumn germinating species, such as *Anisantha sterilis* and *Galium aparine* (Chancellor, 1985; Hald, 1999), whereas changes in herbicide usage have increased the number of broad-leaved weeds that are being controlled, particularly *Veronica* spp., *Lamium* spp. and Polygonaceae (Ewald and Aebischer, 2000; Marshall et al., 2003). As a result, the flora of cereal fields is now typically dominated by a small number of ubiquitous, often nitrophilous weeds and few rare species (e.g. Whitehead and Wright, 1989).

Within most crops the majority of weeds, including rare species, are confined to the extreme edge of the field where competition from the crop is less intense due to soil compaction, poor seed-bed preparation and the less efficient application of fertilisers and herbicides (Marshall, 1989; Wilson and Aebischer, 1995; Kleijn and van der Voort, 1997; Critchley and Fowbert, 2000). As a consequence, a range of management options have been introduced within UK agri-environment (AE) schemes to maximise the botanical diversity of field margins and conserve rare species included in the Cereal Field Margin Habitat Action Plan (HMSO, 1995; Smallshire et al., 2000). A number of options within the Countryside Stewardship (CS) and Environmentally Sensitive Area (ESA) schemes are potentially beneficial to arable plants. The removal of field margins from intensive agriculture followed by annual cultivation (uncropped wildlife strips) has been shown to promote the abundance and diversity of annual arable weeds in two experimental pilot areas for arable options in southern England (Critchley et al., 2004a), although perennials tended to increase after the first year (Critchley et al., 2004b). Similarly, restricted pesticide and herbicide use in cereal headlands (conservation headlands) has been shown to increase the diversity of dicotyledons, with proven benefits to invertebrates and gamebirds (Sotherton, 1991), although in English pilot areas the numbers and cover of annual arable species was lower than on uncropped wildlife strips due to the presence and competitive effect of the crop and limited herbicide use (Critchley et al., 2004a). British and Dutch studies have also shown that the diversity of weeds on conservation headlands is higher if no fertilisers are applied to headlands due to the more open crop-canopy (and hence greater light penetration) at the no-fertiliser option sites (Kleijn and van der Voort, 1997; Critchley et al., 2004a). The retention of overwinter stubble under set-aside provides foraging habitat for some farmland birds although plant species diversity is usually low (Firbank et al., 2003). However, if spring cultivation is carried out, there is potential for spring-germinating annuals to establish (Critchley et al., 2004a), although in the absence of further cultivation (i.e. in set-aside) these will be replaced by perennials and grass-dominated communities (Kleijn et al., 1998; Critchley and Fowbert, 2000).

As well as the management regime, environmental factors account for considerable variation in the arable flora. Climatic and physical factors, landscape complexity, soil properties and the crop can affect arable plant species diversity and composition (Lososová et al., 2004; Pyšek et al., 2005; Roschewitz et al., 2005). For successful targeting of AE schemes it will therefore be important to know the relative importance of these environmental factors in influencing the composition of arable plant communities, compared to the management imposed by the schemes.

Since the introduction of arable options large areas of agricultural land have been entered into AE scheme arable options which offer benefits to arable plants through reduced fertiliser and herbicide use and regular cultivations (e.g. uncropped wildlife strips, conservation headlands). This study was carried out as part of a wider assessment of the contribution of these schemes towards enhancing the biodiversity of farmland in the UK. The overall aim was to determine (1) the effectiveness of AE schemes in conserving arable plant diversity and, in particular, populations of rare and declining arable plants, (2) to verify options are being targeted effectively to areas of known arable plant diversity and (3) provide an estimate of the ‘stock’ of species (i.e. the number present) in cereal field margins options intended to conserve arable plants. The study was carried out on a large random sample of agreements situated in contrasting soil types, regions and landscape contexts in order to (4) assess the relative importance of option management prescribed under the schemes compared to other environmental factors accounting for variation in cereal field margin vegetation.

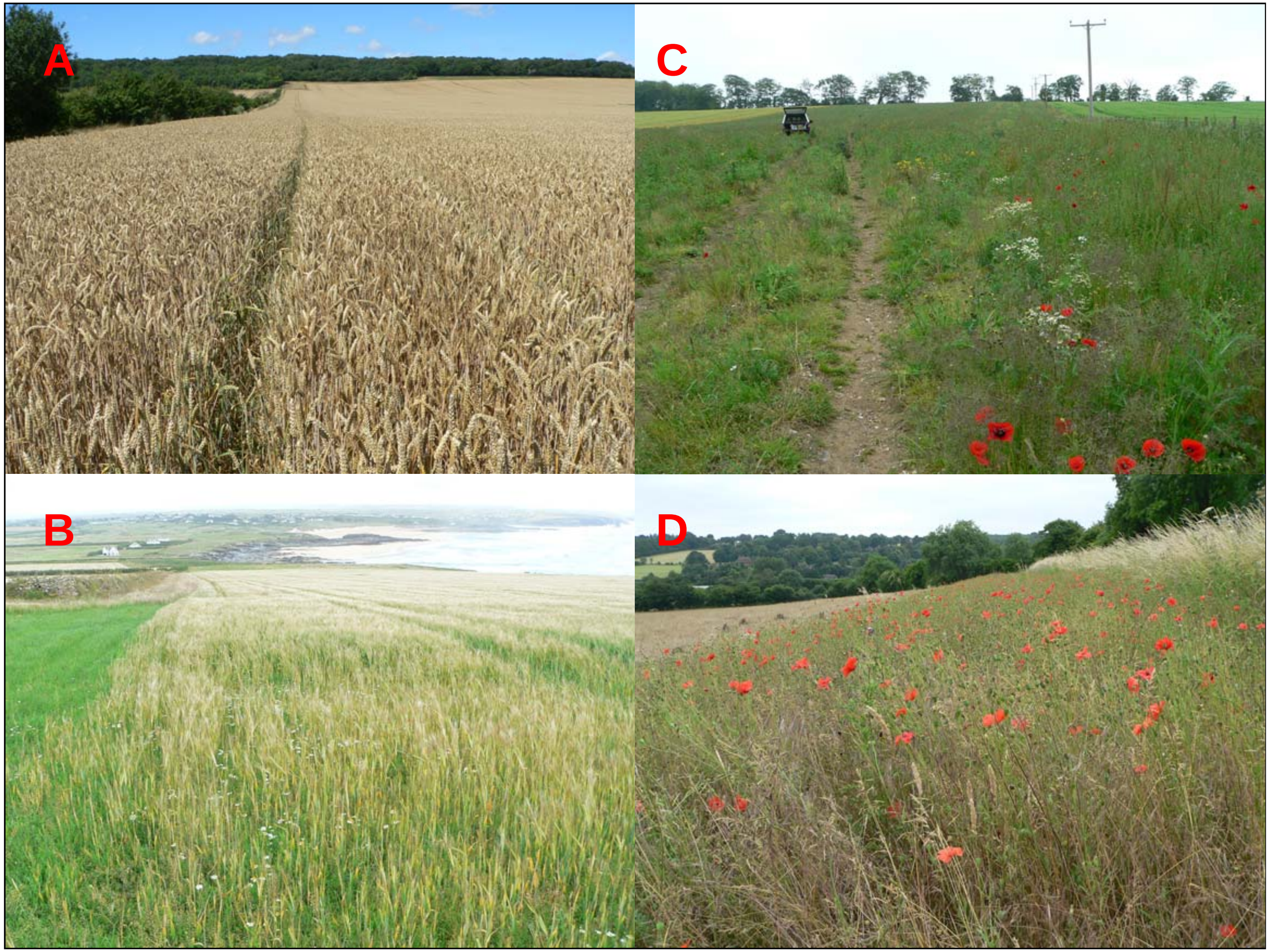

Plate 1. Examples of the agri-environment scheme arable options included in this study: a) conservation headland (CH1); b) no-fertiliser conservation headland (CH2); c) overwintered stubble followed by a spring/summer fallow (OS3); d) uncropped 'rare arable weed margin' (RAWM).

2. Methods

2.1 Sampling design

The richness and abundance of all higher vascular plant species, including rare species, were compared on the following field margin management treatments available under Defra Countryside Stewardship (CS) and Environmentally Sensitive Area (ESA) schemes in England (Plate 1; Table 1):

1. Conservation headland (CH1) and CH in South Downs ESA and South Wessex Downs ESA;
2. No-fertiliser conservation headland (CH2);
3. Over-wintered stubble followed by a spring/summer fallow (OS3);
4. Uncropped, cultivated margins (Rare Arable Weed Margin; RAWM) and Uncropped Wildlife Strips in the East Anglian Breckland ESA;
5. Conventionally managed cereal crop (control).

RAWMs are 6 m wide cereal field margins, which are cultivated regularly (usually annually) in the absence of a crop or other sown species, and without herbicide or fertiliser inputs in order to encourage the natural regeneration of annual arable plant communities including rare species. CH1 and CH2 are 6 - 24 m wide ‘headlands’ along the edge of cereal crops where the use of insecticides and herbicides are restricted to provide foraging habitat for threatened farmland birds. CH2 are unfertilised and therefore provide a more open-structured crop margin with greater benefits for arable plants. OS3 is a whole or part field option following a cereal crop and is primarily aimed at providing foraging-habitat for birds and mammals but may also provide conditions for spring-germinating arable plants during the fallow phase. The stubble is kept until March following harvest and then a fallow produced by shallow cultivation and maintained over the summer months (till at least the 31 July). With the exception of RAWMs all options are rotational and are therefore moved between fields to fit in with the crop rotation and to help reduce the build-up of pests and diseases. In addition, selected herbicides and insecticides can be applied within specific time periods in order to control serious infestations of annual grasses and other injurious weeds (e.g. *Alopecurus myosuroides*, *Cirsium arvense*). With the exception of OS3 all options are ‘targeted’ to field margins, farm holdings or regional ‘hot-spots’ known to support populations of rare arable species (M. Stevenson, pers comm., 2005).

Sampling was carried out in 39 20 × 20 km squares in the eight administrative regions of England (excluding Greater London), with the number in each region proportional to the area of geographically targeted options (East, South East, South West = 7; North East = 6; East Midlands, West Midlands, Yorkshire & Humberside, North West = 3) (Figure 1). Each square contained a conventional cereal crop control and a sample agreement of all four management options with a few exceptions where options were absent, landowners could not be contacted or had left the scheme, or where sites were rejected due to inappropriate management. Cereal crop controls were recorded on one of the agreement farms visited to record AE options. RAWM was the least frequent option and was absent from ten squares (3 in the North West, 4 in North East, and 1 each in the South East, South West and West Midlands) whereas CH1 was absent from one square (West Midlands) and OS3 from two squares (East and East Midlands). Replacements for each agreement were recorded in the nearest adjacent cluster with the exception of RAWMs in the North West which were sampled outside sample squares due to the scarcity of option agreements. This gave a total sample of 195 field margin agreements. All regions were visited simultaneously by several survey teams during the summer of 2005 with 97% of agreements surveyed in June and July.

2.2 Vegetation recording

On each field margin a 100 m long by 6 m wide 'sample zone' was randomly located at least 10 m from field corners and directly adjacent to the field boundary (e.g. hedge, track, etc.) although on 89 agreements this was a sown (R3) grass margin (Defra, 2002). The vegetation composition of each sample zone was recorded from thirty 0.5 × 0.5 m quadrats randomly positioned along three transects at 1 m, 3 m and 5 m from the outer edge of the margin. All vascular plants rooted in the quadrat (including crop species) were recorded. To obtain top-cover estimates, a single pin-hit was recorded, by lowering a pin in the corner of the quadrat and noting the first hit of plant species, bare ground, bryophytes, litter or seedlings. In addition, all species present within the outer 100 × 1 m of the margin nearest to the field boundary were recorded in order to allow comparison with Countryside Survey field margin plots (Firbank et al., 2002). Nomenclature for vascular plants follows Stace (1997) for higher plants.

2.3 Soil analysis

Soil samples were collected to a depth of 15cm from each quadrat location using a 2.5 cm hand-held augur and bulked to provide one sample per agreement. Soil samples were analysed for pH, extractable phosphorus (P), potassium (K) and magnesium (Mg) and soil texture using standard laboratory techniques (MAFF, 1986). A hand texture assessment was also carried out and texture classes converted to estimate available water content (AWC) for data analysis (MAFF, 1988). Samples were stored at 4ºC for up to three months prior to analysis.

2.4 Rare species

The entire field margin was systematically searched for the presence of 86 rare or declining arable plants comprising 12 UKBAP Priority Species included in the Cereal Field Margin Action Plan (HMSO, 1995), and a further 30 species known to be threatened, endangered or extinct in the UK. These were termed the 'core species'. In addition, we included a further 44 'additional' species of lower conservation concern which have localised distributions or have declined markedly in recent decades (Byfield and Wilson, 2005; Cheffings and Farrell, 2005). The full list of core and additional species is given in Appendix 1 with information on their conservation (threat) status and recent trends. In selecting species we included archaeophytes, and some neophytes if they are known to have declined (Preston et al., 2004), but excluded rare species which only occasionally occur on arable land (Hill et al., 2004).

Field margins were searched by walking at a slow to moderate pace in a zig-zag pattern over the entire width of RAWM, CH1 and CH2 margins and the outer 6 m of OS3 plots and conventional cereal crop controls. Centroids for the locations of rare species were recorded using a hand-held GPS and the population size estimated on a logarithmic scale (i.e. 1-10, 11-100, 101-1000, >1000). Vegetation communities including 'core' species were sampled in five representative 2 × 2 m quadrats and assigned to National Vegetation Classification (NVC) communities using Tablefit (Hill, 1996).

2.5 Option management and site details

Management details for each margin were compiled from agreement schedules (supplied by Defra) and discussions with farmers during site visits. This included the current crop (species and season of sowing) for conservation headlands and controls and the previous crop for OS3. Because RAWMs are non-rotational options we also recorded the age of the margin and cultivation frequency (annual or less), as well as the timing, method (e.g. disc, tine, plough) and depth of the most recent cultivation and whether margins were cut and the cuttings removed. The use of herbicides to control invasive weeds (e.g. spot treatment) was recorded for all options except controls (where it was assumed that a full weed control programme was practised) as well as the method and target species. For each margin we also recorded the location (using a hand-held GPS), altitude, aspect (converted to absolute degrees from due south), slope, presence and type of boundary and adjacent land use.

2.6 Landscape context and environmental variables

For the 5 × 5 km grid square surrounding each site, the percentage of arable and horticultural land and Simpson's diversity index (Magurran, 1988) of land cover classes were calculated from the UK Land Cover Map 2000 (LCM2000) (Fuller et al., 2002). The total area of arable cropping, the proportion of cereals that was spring barley (indicating less intensive cereal cropping) and Simpson's diversity index of crop types were calculated from the Agricultural Census of England data for 2000 (Edina Agcensus, 2006). The average monthly rainfall (mm) and temperatures for January and July (1971-2000) were also obtained (UKCIP, 2005). The potential pool of 86 rare arable species (Appendix 1) was calculated for each surrounding 10 × 10 km square using post-1987 records.

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2.7 Quality assurance

Field surveys were carried out following a formally documented, project-specific protocol. Field surveyors received training at the beginning of the survey and field forms were checked weekly by two nominated botanical field managers (KJW & AJS). For rare species, the Botanical Society of the British Isles Code of Conduct was followed and records for UKBAP species were validated by a second recorder (either by photograph or where appropriate, by retaining a voucher specimen). Data were input from field forms to Microsoft Excel® software and imported to Microsoft Access®. All data were validated by comparing hardcopy outputs with the original field forms.

2.8 Statistical analyses

2.8.1 Species richness, cover and indicator values

Overall species richness was expressed as the mean number of non-crop species (but including crop volunteers), annuals, perennials, grasses, forbs, spring/summer germinating and autumn/winter germinating species per 0.5 × 0.5 m quadrat and 100 × 6 m sample zone. The proportion of pinhits (30 per sample zone) across the sample zone was used as the measure of cover of each plant species, bare ground, bryophytes, litter and seedlings. Presence/absence data were used to calculate the mean British Ellenberg fertility (N) and reaction (R) indicator values for each sample zone. Perennation and Ellenberg indicator values were taken from Hill et al. (2004) and germination time from Fitter and Peat (1994) with additions from Wilson and King (2003). For the germination time data were missing for 41 species (15%).

The richness of rare species was expressed as the mean number per 0.5 × 0.5 m quadrat, 100 × 6 m sample zone and field margin. Although the area of field margin options was variable (mean = 3079 ± 291 m^2) there was no was no relationship between the area searched and the number found (number of rare species = 2.068 + 0.000036*area searched (m^2); $F_{1,65}$ = 0.14; p = 0.713) and consequently 'area searched' was not included in subsequent analyses.

Differences in species richness, cover, indicator values, rare species and soil variables between field margin treatments and regions were examined using analysis of variance (ANOVA) with treatment and region as factors using Genstat® 7.0 for Windows (Payne et al., 2002). The Student-Neuman-Keuls post-hoc test was used to make pairwise comparisons of the 5 field margin treatments and 8 regions. Differences in overall and rare species richness per 0.5 × 0.5 m quadrat was also examined in relation to distance from the edge of the margin using analysis of variance (ANOVA) with treatment and region as factors with distance nested within treatment and individually within treatments.

2.8.2 Species-environment relationships

A Principle Components Analysis (PCA) was used to determine the overall variation in the non-crop plant species composition. A preliminary Detrended Correspondence Analysis showed a linear response of species along the first axis, confirming that PCA was the appropriate method to use (ter Braak and Šmilauer, 1998). This and subsequent multivariate analyses were carried out on log-transformed species frequencies (excluding unidentified seedlings and bryophytes) for each site, using Canoco V.4.02 software (ter Braak and Šmilauer, 1998).

A variation partitioning procedure (Økland and Eilertsen, 1994; Økland, 2003) was used to determine the relative importance of different subsets of environmental variables in explaining variation in species composition of the cultivated margins. Variation partitioning was performed using Redundancy Analysis (RDA) and Partial Redundancy Analysis (PRDA). Environmental variables were grouped into subsets (option, region, physical/climatic, habitat context, soil properties). For each subset in turn, an RDA was carried out to select those variables that contributed significantly to the model (at $p < 0.05$). Each variable was tested in turn using forward selection and Monte Carlo tests with 999 permutations. The significance of the first axis and the overall RDA were also tested using 999 Monte Carlo permutations.

For each reduced environmental variable subset (i.e. including only the significant variables), the variation explained only by the subset was calculated from a PRDA in which the subset of interest was specified as environmental variables, and the remaining subsets as covariables. Variation shared by the subset with other variables is the variation explained by the subset of interest minus the variation explained only by the subset. This shared variation was further subdivided into all possible combinations of two or more variable subsets by carrying out a series of PRDAs in which the combined subsets of interest were environmental variables and the remainder were covariables. Variation components attributable uniquely to combinations of subsets were calculated as the variation explained by the union of the subsets of interest minus the sum of that explained by all other unique components making up the union.

Variation partitioning produces a large number of variation components ($2n - 1$ where n is the number of variable subsets; potentially 31 in this case) and so to simplify the final results it is desirable to exclude those explaining negligible amounts of variation. A threshold for retention of these components was calculated as AVE = TVE/($2^n - 1$) where AVE is the average variation explained (Økland, 2003). Variation components that were less than AVE were rejected and the variation associated with them was redistributed equally among the components of order $n - 1$. For example, if the variation shared by option, region and physical/climatic variables was lower than the threshold value, the combination of option + region + physical/climatic variables was rejected and the associated shared variation was redistributed amongst option + region, option + physical/climatic variables, region + physical/climatic variables.

The same variation partitioning procedure was then carried out separately on sub-samples comprising cropped margins only (CH1, CH2, controls) and uncropped margins only (OS3, RAWM). More detailed management information was included in these analyses. For cropped margins, pesticide input (conventional or reduced), fertiliser application (present or absent), crop species and season of sowing were specified. For uncropped margins, data on cultivation, cutting, weed control and site age were used. An RDA was carried out for cropped and uncropped options respectively, including the significant variables only, to interpret the relationships between species and environmental variables.

2.9 ‘Stock’ of species and effectiveness of targeting

The overall ‘stock’ of species, including rare species, was calculated for the five field margin options, eight regions and three soil pH classes as a surrogate for soil type (acid, pH 5.7-6.9; circumneutral, pH 7-7.9; basic, pH 8-8.5). We also calculated the likely total resource of rare and declining species present on AE margins by multiplying the mean number of rare species found on field margins by the uptake of individual options (number of agreements) within regions. These extrapolations are likely to provide robust, albeit crude, estimates of the numbers of populations of rare species on targeted options (CHs, RAWMs). However, this analysis is likely to overestimate the numbers present on OS3s as the sample was biased towards the richest areas (i.e. RAWMs).

To test the effectiveness of targeting we calculated the coincidence between the area of targeted options and the number of rare arable weeds recorded since 1987 in 10 × 10 km squares containing agreements in England. Correlations were calculated for each of the 5 field margin options within and across all regions. Area figures were taken from the Agri-Environmental Schemes Information System (AESIS) database and 10 × 10 km data on rare species distributions from the National Vascular Plants Database held at the Centre for Ecology and Hydrology, Monks Wood.

3. Results

In total 225 dicotyledons and 39 monocotyledons were recorded including four UKBAP (core) species (*Centaurea cyanus*, *Fumaria purpurea*, *Scandix pecten-veneris*, *Silene gallica*) and a further 30 additional rare species with localised distributions in the UK (Table 3). Overall the most widespread and abundant species was the annual grass *Poa annua* recorded in 71% of sites and 37% of quadrats (Table 2; Appendix 2). *Poa trivialis*, *Anisantha sterilis*, *Alopecurus myosuroides* and *Lolium perenne* were also very frequent and abundant across all options whereas the perennials *Agrostis stolonifera*, *Arrhenatherum elatius* and *Elytrigia repens* were more frequent and abundant on RAWM margins and the annual *Bromus hordeaceus* on OS3 agreements. The most frequently recorded dicotyledons were *Galium aparine* (control and CH1), *Polygonum aviculare* (CH2), *Senecio vulgaris* (OS3) and *Cirsium arvense* (RAWM) whereas *Veronica persica* was recorded in 72% of RAWM sites and *Sonchus asper* in 69% and 72% of OS3 and RAWM margins respectively. In contrast, *Viola arvensis* was the most abundant dicotyledon, occurring in 15% of quadrats and 16% of CH1 agreements whereas *Polygonum aviculare*, *Veronica persica* and *Senecio vulgaris* were the most abundant dicotyledons on RAWM, CH2 and OS3 margins respectively. However, the majority of species were recorded on very few sites. Indeed, 187 dicotyledons and 25 monocotyledons were recorded from fewer than 10% of sites.

3.1 Treatment effects on species richness, cover and indicator values

Univariate ANOVA based on species richness confirmed large differences between field margin treatments (Table 4). At the quadrat scale RAWM margins were the most diverse in terms of the numbers of annuals, perennials, grasses, forbs and spring and autumn germinating species, although the number of perennials and grasses were not significantly greater than on OS3 margins. CH2 and OS3 were the next most diverse options and with the exception of grasses there were no significant differences between the two options. CH1 and cereal crop controls were the least diverse options and similarly, with a few exceptions (perennials and spring germinating species) there were no significant differences between the two treatments. In contrast, the proportions (%) of annuals, forbs and spring germinating species were more variable between options. Cereal controls had the highest proportion of annual species followed by CH1, CH2 and OS3 margins and lowest in the RAWM margins. In comparison, the proportions of forbs and spring-germinating species were highest on CH2 and RAWM margins and lowest on cereal crop controls although the proportions of spring germinating species on agri-environment options were not significantly different from one another. With a few exceptions differences in the diversity of sample zones were almost identical with RAWM margins having significantly greater numbers of annuals, perennials, forbs, grasses and spring and autumn germinating species than all other options and cereal crop controls followed by OS3 and CH2 options. CH1 and crop controls had the lowest diversity of all the treatments and again there were few significant differences between CH1 and cereal crop controls. The proportion of annuals was greatest on crop controls and lowest on RAWMs whereas the opposite was true for forbs. The proportion of spring germinating species was significantly lower within crops than on AE scheme margins although there were no significant differences between individual options.

Not surprisingly the cover of non-crop species was greatest on fallow RAWM (79%) and OS3 (49%) margins followed by conservation headlands and lowest on cereal crop controls whereas the cover of crop and volunteers was exactly the reverse (Table 4). For both crop and non-crop cover there were no significant differences between CH1 and cereal crop controls and for cover of crops and volunteers on RAWM and OS3 sites. Bare ground and litter was significantly higher on OS3 than all other options whereas there were no significant differences in the cover of bryophytes and seedlings which were very low on all options.

Ellenberg indicator scores for fertility (N) were significantly higher on cereal crop controls and CH1 whereas reaction (R) values were significantly higher on cereal crop controls than on other field margin types.

There were highly significant differences in species richness at 1 m, 3 m and 5 m from the edge of the margin and, with the exception of RAWMs, richness declined progressively with increasing distance from the field margin (Table 5). However, at the level of individual options these declines were only significant for CH1 sites, although *F*-values were high for cereal crop controls and other rotational options (CH2, OS3). In contrast, there were virtually no differences in richness between the three distances on RAWMs. Similarly, there were no consistent declines in the numbers of rare species on RAWMs, OS3 and CH2 options, whereas there were small, but progressive declines on more intensively managed cereal crops and CH1 options.

3.2 Regional effects on species richness, cover and indicator values

With a few exceptions the univariate ANOVA of the effects of region showed clear cut regional differences in the diversity of field margins both within quadrats and sample zones (Table 6). Sites in the South East and South West were the most diverse, followed by those in the East (sample zone) whereas those in the North East were the most species-poor. There were no significant differences in the diversity of margins between other regions. The regional differences in the numbers of annuals, forbs and spring and autumn germinating species (sample zone only) were very similar to overall richness whereas there were no significant regional differences in the numbers of perennials, grasses (marginally significant) and the proportions of annuals and spring germinating species.

With the exception of the cover of bryophytes, which was significantly greater in sites in the North West, there were no significant regional differences in cover values (crops, non-crop species, bare ground, litter and seedlings) although crop cover was lowest in the predominantly mixed farming regions of the North West, South West and North East (Table 6). Indicator values for N were significantly lower in the South East and North West than all other regions, presumably because the majority of sites in these regions are on very infertile, either acidic or basic soils. This was reflected in the lowest (6.1) and highest (6.7) reaction (R) values recorded for both regions respectively.

3.3 Comparison with Countryside Survey 2000 arable boundary plots

The differences in diversity of the CS boundary plots in relation to both treatment and region were very similar to those for the sample zone with RAWMs being the most diverse option, with significantly more species than all other options (Table 7). OS3 and CH2 were the next most diverse options, whereas CH1 and controls were the least diverse and were not significantly different from on another. Overall boundary plots in the East, South East and South West regions were significantly more diverse than all other regions and plots in the North East were the least diverse. In CS2000 252 boundary plots were recorded on the edge of cereal fields mainly in the lowlands of eastern England (Zone 1) (Firbank et al. 2002). The overall mean number of taxa recorded on these plots was 13.3 which is similar to the figures reported here for controls in the East (13.6 ± 3.2) and the South East (11.9 ± 2.5) regions. Similarly, the greater richness of plots in the lowland west (Zone 2 = 15.5 taxa/plot) is similar to the results of this survey for controls in the South West (17.1 ± 1.4), although the slightly lower value recorded in CS is possibly due to the inclusion of less diverse Welsh sites (Firbank et al., 2002).

With the exception of CH1 more rare arable plants were found on AE options than in CS2000 boundary plots even though the sample size for CS was 13 times greater (Table 8). In total 26 rare species were recorded on the 156 AE margins in comparison to 11 on the 507 CS2000 sample plots. Overall *Euphorbia exigua* and *Kickxia spuria* were the most frequently recorded species in both surveys whereas *Legousia hybrida* and *Spergula arvensis* were widespread on AE margins but absent from the wider CS sample. Only two species (*Hyoscyamus niger, Viola tricolor*) were not recorded in the AE boundary plots although they were recorded elsewhere on some agreements. Two UKBAP species were recorded on AE sample (*Scandix pecten-veneris, Silene gallica*) whereas none were recorded on the CS boundary plots.

3.4 Treatment and regional differences in soil pH and nutrients

With the exception of extractable P there were no significant differences in soil pH and nutrient levels between the four options and cereal crop controls (Table 9). P levels were lowest on no-fertiliser conservation headlands, followed by OS3 and RAWM options which had been unfertilised for at least 12 months and highest on fertilised CH1 and cereal crop controls. In contrast, there were highly significant differences between regions. Soil pH was lowest in the north and west and highest the south and east whereas P was lowest in the North East region, followed by the North West and Yorkshire and Humberside, with only slight differences between southern and midland regions. Soil K followed a similar but less marked pattern whereas the reverse was true for Mg with southern and eastern regions having the lowest values (< 80 mg l^{-1}) and northern regions (including West Midlands) the highest (< 120 mg l^{-1}).

3.5 Treatment and regional differences in the numbers of rare species

In total 145 records of 34 rare (core and additional species), including four UKBAP species (*Centaurea cyanus*, *Fumaria purpurea*, *Scandix pecten-veneris*, *Silene gallica*) and a further seven core species, were recorded during this survey (Tables 3 and 10; Appendix 3). The most widespread species were *Euphorbia exigua* (19 sites), *Legousia hybrida* (16 sites), *Kickxia spuria* (13 sites), *Spergula arvensis* (10 sites), *Fumaria densiflora* (9 sites), *Papaver argemone* (7 sites), *Filago vulgaris* and *Stachys arvensis* (both 6 sites) whereas *Apera spica-venti*, *Chrysanthemum segetum*, *Descurainia sophia* and *Silene noctiflora* were all recorded from 5 sites. In comparison, the most frequently recorded core and UKBAP species were *Valerianella dentata* (4 sites) and *Scandix pecten-veneris* (3 sites) respectively. Of the remaining 20 rare species only *Anthemis cotula*, *Misopates orontium* and *Papaver hybridum* were recorded from more than two sites.

Overall 39% of the AE field margins (n = 61) held populations of rare species in comparison to 15% of cereal crop controls (Table 10). RAWMs were by far the most diverse option with 26 species accounting for 45% of all records, followed by CH2 (18 species; 23% of records) and OS3 (16 species; 19% of records). Few rare species were recorded on CH1 (10 species; 9% of records) or conventional crop controls (3 species; 4% of records). In addition, there were highly significant regional differences in the numbers of rare species with 87% of records confined to agreements in the East, South East and South West (Table 10). Only *Ranunculus parviflorus* (West Midlands) and the UKBAP species *Fumaria purpurea* (North West), which has a predominantly northern and western distribution in the UK (Preston et al., 2002), were not recorded in these regions. Overall the East was the richest region, with the greatest number of rare species (21) and records (30%) whereas the South West had the greatest proportion of sites with rare species (49%). In contrast the North East, North West, West Midlands and Yorkshire and Humberside were by far the poorest regions with only 3 records in each region.

The differences between option types were also reflected in the numbers of rare species recorded at the quadrat, sample zone and field margin scale with RAWMs having significantly greater numbers than all other options at all scales (Table 10; Figure 2). In contrast there were few significant differences between other options although both cereal controls and CH1 margins had much lower numbers than CH2 and OS3. In addition, there were clear regional differences with the East, South East and South West, followed by the East Midlands, having the greatest number and the North East the lowest numbers of rare species.

Populations of core species were mainly confined to base-rich (pH > 8) silty loams with low fertility (Table 11). Exceptions included *Silene gallica* and *Fumaria purpurea* which were both confined to single sites on more acid soils. The NVC community containing the greatest number of core species was the *Papaver rhoeas-Viola arvensis* community (NVC OV3) which is the typical annual weed assemblage of cereal field margins on light soils which are not too calcareous and have escaped herbicide treatment (Rodwell, 2000). *Hypochaeris glabra* and *Anthemis arvensis* were both confined to two sandy OS3 sites in East Anglia assigned to the ruderal *Poa annua-Senecio vulgaris* (OV10) open vegetation community type, and *Euphorbia platyphyllos* and *Scandix pecten-veneris* to the *Veronica persica-Alopecurus myosuroides* community (OV8) which is a more characteristic assemblage of winter-sown cereal fields on loamy or clay soils (Rodwell, 2000).

3.6 Species-environment relationships

The majority of sites had a grass/tall herb verge forming part of the permanent field boundary, a hedge was present in more than half and broadleaved trees in just under 20% (Table 12). Other field boundary types were present at low frequency. Arable land was the most common adjacent land cover type (62%), followed by metalled surface/urban (usually metalled roads), grassland and woodland. The majority of margins were lowland (mean altitude = 67 m; range 2 – 217 m).

The proportions of control, CH1 and OS3 sites associated with wheat and autumn sown crops were very similar (identical in the latter) (Table 13). There were slightly more CH2 sites located in barley or other cereals and in spring sown crops. RAWM sites were aged up to 11 years but with mean elapsed time since last cultivation of less than a year. One site had not been cultivated for over three years. The majority were last cultivated in spring but less than one quarter were cultivated annually. Approximately half of the sites were cut but few always had the cuttings removed.

Plots from the PCA illustrate how species composition varied between sites with those with similar species tending to occupy the same space in the plots. Control sites were separated from RAWM sites along axis 1 of the PCA, although there was some overlap between the two options (Figure 3a). Most CH1 sites occupied the same ordination space as the controls. Few species (and none with fit 6 or more) were strongly associated with controls; the strongest association of most species was with RAWM sites (Figure 3b). Axis 2 was a gradient separating perennials from annuals. Perennials were mainly associated with RAWM and OS3 sites. In contrast, most CH2 sites were associated with annuals.

Species composition was related to RAWM, OS3 and CH2 options but controls and CH1 sites did not add significantly to the RDA model (Table 14). Five of the eight regions were also significant but not Yorkshire and Humberside, East Midlands or West Midlands. January and July temperature and rainfall were all significant, as were altitude and aspect. Tall herb/grass verge and grassland were the only adjacent field boundary or land cover types respectively that were related to species composition. In the surrounding landscape, area of arable cropping and spring barley as the proportion of cereals and the potential rare species-pool were significant. Neither of the statistics from the land-cover map were significant, nor was the overall diversity of cropping. Two soil variables (pH, Mg) were also significant.

The threshold of retention from the variation partitioning procedure was 0.77%. Only two second order intersections and none of the higher order intersections were retained in the model after the redistribution procedure. The hypothesised relationship between environmental variables and species composition is shown on the path model diagram (Figure 4a). A small amount of variation was shared between region and physical/climatic variables and between option and habitat context. Individually, these groups also accounted for notable amounts of the TVE. Option explained a greater percentage of the TVE compared to the other groups. The relationship of soil with species composition was independent of other variable groups and explained a lower percentage of TVE.

In the sub-sample of cropped margins (control, CH1, CH2), spring crops, fertiliser application (i.e. the distinction between CH2 sites and cereal control plus CH1 sites) and wheat crop were related to species (Table 15). Reduced pesticides (i.e. the distinction between controls and CH1 plus CH2 sites) and barley crop were just outside the limits of statistical significance (both $p = 0.06$). The same regions were significant as in the whole sample. Fewer variables from the other groups were significant compared to the whole sample but no new significant variables emerged.

The threshold of retention from the variation partitioning procedure was 0.80%. After redistribution of variation, the overall model was similar to that for the whole sample (Figure 4b). However, relatively more variation was now explained by region alone and this was now similar to both management and physical/climatic variables alone.

In the RDA of all significant variables, one end of axis 1 represented less intensively managed, mixed landscapes (high proportion of spring barley, adjacent grassland, spring crops), which also coincided with the South West region, higher January rainfall and CH2 sites (as signified by nil fertiliser input) (Figure 5a). Most species were associated with this end of the main environmental gradient (as shown by their positions in the plot in relation to the plot environmental variables). The other end of this gradient was typified by wheat crops and fertiliser inputs (i.e. CH1 and control sites). Only *Anisantha sterilis* and *Alopecurus myosuroides* had a strong association here. Along the second axis, high soil pH coincided with higher July temperatures and the South East and Eastern regions. Conversely, low soil pH coincided with the North West and North East regions. Examples of species associated with high pH were *Fumaria officinalis*, *Aethusa cynapium* and *Papaver rhoeas* and with low pH, *Poa annua*, *Papaver dubium* and *Silene gallica*. The latter species were also associated with high January temperature and July precipitation.

Species composition of uncropped sites was related to the method, timing and depth of cultivation and to the age of the site (Table 16). The elapsed time since the most recent cultivation was just outside the limits of statistical significance (p = 0.06). The same regions were significant as in the whole sample and cropped options sub-sample, with the exception of North West. Physical/climatic variables included in the model were also similar to the whole sample; only aspect was not retained. Potential rare species-pool and proportion of cereal cropping that was spring barley were the only significant habitat context variables. In contrast to the whole sample, soil extractable P and K were related to species composition, as well as pH.

The threshold of retention for uncropped sites was 1.05%. Only one second order intersection was retained in the model, *viz* the intersection of physical/climatic variables and region (Figure 4c). Therefore, variation explained by management, habitat context and soil properties were largely independent of other variable groups. Management and physical/climatic variables explained the greatest percentage of TVE. Compared to the whole sample and to cropped options, soil properties explained a greater percentage of TVE.

The RDA of all significant variables showed several environmental gradients (Figure 6). Soil pH, species-pool, altitude, cultivation method (i.e. cultivation severity) and autumn cultivation coincided to form a strong gradient. Examples of species associated with high values were the annual dicotyledons *Anagallis arvensis*, *Kickxia elatine*, *Legousia hybrida* and *Veronica persica*. In contrast, perennials and grasses tended to occur at the opposite end of this gradient, for example *Holcus lanatus*, *Lolium perenne*, *Bromus hordeaceus* and

Epilobium ciliatum. Axis 2 was principally a gradient from high soil extractable K to high P. High summer rainfall coincided with high extractable soil P. *Artemisia vulgaris*, *Agrostis stolonifera* and *Lamium hybridum* were associated with the latter and also with older sites. Volunteers of *Triticum aestivum* were associated with younger sites (OS3 and young RAWM sites). *Sinapis arvensis*, *Senecio vulgaris* and *Petroselinum crispum* were associated with high extractable soil K (although the latter being a single record only).

3.7 Overall stock of species and effectiveness of targeting

264 species including 34 rare species were recorded during this survey. RAWMs were the richest option with 211 species with over twice the numbers found on CH1 (103) and cereal crop controls (90) (Table 17). The richest sites were RAWMs in the East, South East and South West (>100 species) and the least rich sites were cereal crop controls in the north and west (< 25 species). However, cereal crop controls in the richest regions held as many species as AE scheme options in other regions. Overall OS3 were marginally richer than CH2, although the opposite was true in some regions (e.g. South West, West Midlands, North West), whereas the diversity of CH1 was much lower in all regions but, with the exception of the East, was slightly higher than cereal crop controls. There was also a marked effect of soil pH with species diversity on all options positively correlated to higher values (pH 8-8.5) despite the fact that these included the smallest proportion of sites (Table 17). The distribution of rare species by option and region followed a very similar pattern with the greatest diversity of species being recorded on RAWMs in the East, South East and South West and lowest on cereal crop controls and CH1 margins in the north, west and midlands. In addition, the majority of rare species were recorded on sites with pH > 8.

Based on the numbers of species found in this study and overall uptake we predict that there are around 2500 populations of rare species on AE margin options in the UK with core species (i.e. UKBAP Priority Species) accounting for around 6% of these populations (Table 18). The majority of populations are likely to be found on OS3 and RAWM agreements in the South East, South West and East and CH2 margins in the East. However, this prediction is likely to be an overestimate due to the biasing of OS3 options to richer areas (i.e. around RAWMs) in this sample. Therefore the overall resource is more likely to be in the range 1500-2000 populations.

There were no significant correlations between the uptake of both conservation headland options and the numbers of rare species in 10 × 10 km grid squares in England (Table 19). In contrast, the uptake of RAWMs was greatest in 10 × 10 km grid squares with high numbers of rare species, particularly in the East and South West regions, whereas the national uptake of OS3 was negatively correlated with rare species diversity. However, the area of OS3 was positively correlated with the number of rare species in the East.

4. Discussion

4.1 Effectiveness of arable options in conserving arable plant diversity

The observed effects of field margin management options on species diversity and rare species was largely explained by scheme prescriptions (e.g. reductions in herbicide and fertilisers, spring cultivation, reduced competition from crop) with strong regional effects due to large variations in arable weed species-pools, soils and climate. Although these results for species richness were as predicted from previous studies they provide the first unequivocal evidence that AE scheme options are effective in conserving arable plant diversity, including a range of UK rare and threatened species, across a variety of intensively managed landscapes.

Recent surveys have shown that arable weed communities in cereal fields are dominated by a small number of ubiquitous weeds (e.g. *Anisantha sterilis*, *Elytrigia repens*, *Galium aparine*, *Poa annua*, *Polygonum aviculare*, *Stellaria media*, *Veronica persica*) with very few rare species (e.g. Whitehead and Wright, 1989; Firbank et al., 2002; Heard et al., 2003). Perhaps unsurprisingly, the results of this survey were very similar with cereal crop controls (mainly winter-wheat) having fewer species than all AE scheme options, although numbers were not significantly lower than CH1 margins. Overall the greater incidence of annual grasses and autumn germinating species (and lower numbers of dicotyledons and rare species) and higher fertility indicator scores on controls reflects the greater broad-leaved weed control, dominance of winter-cropping and the greater inputs of mineral nutrients on cereal fields than AE scheme options within intensively managed landscapes (Chancellor, 1985; Hald, 1999).

Conservation headlands are intended to support a range of dicotyledonous species that are important food resources for a range of gamebirds and invertebrates (Sotherton, 1991). To achieve this, broad-leaved herbicide applications are prohibited, apart from selective treatments to control serious weeds. However, despite these restrictions there were few significant differences between weed diversity in CH1 margins and conventional cereal crop controls although CH1 sites did have greater numbers of perennials, forbs and spring-germinating species as well as a limited number of rare species, such as *Kickxia spuria* and

Fumaria densiflora, which are still locally abundant in some regions (e.g. East, South East). In addition, common annual plants such as *Poa annua*, *P. trivialis*, *Stellaria media*, *Veronica persica* and *Viola arvensis*, which can be important food resources for gamebirds and invertebrates, occurred at greater frequency and abundance than on cereal crop controls. Overall, therefore, conservation headlands offer few benefits for rare or declining arable plants but continue to provide important food resources for threatened gamebirds and invertebrates.

No-fertiliser conservation headlands are intended to provide additional benefits for arable plants, including rare species, because of reduced competition from the standing crop. Experiments in winter rye crops in the Netherlands showed that, in the absence of herbicide applications, the incidence of weeds was greater if no fertiliser was applied due to greater light penetration through the crop (Kleijn and van der Voort, 1997). In addition, the biomass of five rare species, four of which were recorded on CH2 margins in this study (*Centaurea cyanus, Chrysanthemum segetum, Misopates orontium, Papaver argemone*), was positively related to light levels and therefore greatest in unfertilised headlands. Similar results were found in two pilot areas for arable options in England where more annuals, perennials and dicotyledons were found in no-fertiliser conservation headlands than other conservation headlands (Critchley et al. 2004a). In addition, crop cover was lower and bare ground cover higher on sites receiving no fertiliser inputs. In this survey differences between CH1 and CH2 options were very similar, with higher species richness (annuals, perennials, dicotyledons) and a more open crop canopy at the no-fertiliser option sites. Notably almost double the numbers of dicotyledons were recorded on CH2 than CH1 sites with annual herbs such as *Anagallis arvensis, Fallopia convolvulus*, *Papaver rhoeas* and *Polygonum aviculare* being particularly abundant on the no-fertiliser sites. In addition, 18 rare species were recorded on no-fertiliser option sites including the UKBAP species *Centaurea cyanus*. This study therefore, has shown that the cessation of fertiliser inputs has important benefits for arable plants, including a number of rare species which are known to decline under increasing fertiliser applications (Wilson, 1990; Kleijn and van der Voort, 1997). However, overall diversity and cover was lower than in uncropped options (OS3 and RAWMs) due to the presence and competitive effect of the crop, and limited weed control permitted.

The retention of over-wintered stubble under set-aside provides foraging habitat for bird species although plant species diversity is usually low with few rare species and a rapid decline in the cover of annual arable weeds after the first year (Critchley and Fowbert, 2000; Firbank et al., 2003). Consequently, annual cultivation of fallow land in the spring (OS3) was introduced as an option within the Countryside Stewardship Scheme in order to encourage the establishment of spring-germinating annual plants that are important in the diet of seed-eating birds (Marshall et al., 2003) as well as providing bare-ground for some ground nesting birds. A comparison of over-wintered stubbles and spring fallow in the Arable Stewardship Pilot Areas showed that overwinter stubble was similar to that created under the set-aside scheme, with a small number of common, annual arable species becoming dominant by mid-summer whereas spring fallows had a greater cover of bare ground, annuals and spring-germinating species (Critchley et al., 2004a). Our results were very similar with OS3 margins (equivalent to spring fallow) having the greatest cover of bare ground and litter and substantial cover of non-crop species (second only to RAWMs) whereas diversity was lower than on uncropped, cultivated margins (RAWMs) but not significantly different from no-fertiliser conservation headlands. However, the incidence of rare species was much higher than found in previous surveys of fallow land (e.g. Critchley and Fowbert, 2000; Firbank et al., 2003; Critchley et al., 2004a) and presumably reflects the clustering of OS3 options around more geographically targeted RAWMs in this survey.

RAWMs had by far the highest richness of all options sampled, both in overall richness and numbers of rare species. Typically uncropped margins had very high cover of non-crop species dominated by annual dicotyledons and spring germinating species. These results were consistent with predictions from previous research (Table 1) which have shown that uncropped, cultivated strips have greater benefits for annual arable plants than either spring/summer fallows or conservation headlands. In non-rotational sites that are cultivated annually this type of species-rich vegetation, and populations of rare species with long-lived seedbanks, can be expected to persist although experimental studies have shown that there is likely to be an increase in the numbers of grasses and perennials such as *Cirsium arvense* which may need to be controlled in the longer term (Critchley et al., 2006). In contrast, less frequent cultivation quickly results in the dominance by perennial grasses (Kleijn et al., 1998; Critchley et al., 2004a) especially in mixed farming regions where species of more permanent grassland communities are more abundant (Critchley and Fowbert, 2000).

Within sites, botanical diversity was higher at the field boundary, reflecting normal patterns within crops (e.g. Marshall, 1989; Wilson and Aebischer, 1995) although these differences were greatest on controls and CH1 margins, presumably due to more effective weed control within intensively managed crops. As in previous studies (e.g. Kleijn and van der Voort, 1997) differences were less marked in the absence of fertilisers on CH2 margins and similarly on OS3 sites. In contrast, there were no differences on RAWMs presumably because significant replenishment of seed banks had already taken place on non-rotational margins in the absence of fertilisers and herbicides.

The correlations between the distributions of rare species and AE agreements confirmed that geographical targeting has been effective for RAWMs, particularly in the richest regions, whereas more precise targeting will be required improve the effectiveness of CH2 and OS3 options in the future.

4.2 Environmental influences on arable plant species composition and diversity

Many significant relationships were detected between non-crop species composition and environmental variables but despite this, a large amount of variation in species composition remained unexplained. This was partly an artefact of the multivariate analysis method, which tends to underestimate the proportion of explained variation (Økland, 1999). There might also be important environmental factors influencing species composition that were not measured, for example soil available nitrogen and recent weather conditions. In addition, the established vegetation of arable plant communities at a given time is only a fraction of the potential species-pool in the soil seedbank and can vary markedly within relatively short periods of time. However, the analyses did highlight the relative importance of different sets of environmental variables. All environmental variable groups explained some variation in the species composition and the relationships between the groups were similar in cropped and uncropped sites and the whole sample. The exception was that in uncropped sites, the intersection between management and habitat context was negligible. The relationships between the environmental variable groups were relatively simple, as indicated in the path model diagrams. It is important to note that the links with species composition are only correlative, although some could signify causal relationships.

Field margin management, including the scheme options and specific management practices, accounted for a relatively high proportion of the total explained variation. This indicates that management imposed by AE schemes influences the composition of the non-crop plant community in addition to the obvious, major differences in the overall vegetation structure of cropped and uncropped sites. The sequence OS3 < RAWM < CH2 < CH1 < control represents an increasing gradient of disturbance, in terms of cultivations, fertiliser and pesticide inputs. Species diversity tends to mirror this sequence, as it declines with increasing disturbance across these options. The exception is OS3, which is only subjected to shallow cultivation in spring. This suggests that, for arable plant communities there is an optimum level of disturbance that, in this sample, is most closely represented by RAWMs.

In cropped sites, the relation of vegetation with crop species, fertiliser application and time of sowing might be explained by variation in competition intensity. In the absence of fertiliser (as in CH2 sites), there was less crop cover, which allows more non-crop vegetation to develop through reduced competition for light (Kleijn and Van der Voort, 1997). The time of cultivation also has a strong effect on species composition, by selecting for species whose germination periodicity coincides with the season of cultivation (Chancellor, 1985; Crawley, 2004; Critchley et al., 2006). Many more CH2 sites than controls were spring sown crops, which would explain the greater proportion of spring germinators there. The number of spring-sown CH1 sites was similar to controls, yet the proportion of spring germinators was higher in CH1 sites. That might have been attributable to the permitted herbicide applications in CH1 sites, which are targeted at autumn-germinating species such as *Galium aparine*.

The cultivation regime (timing, depth and method) and age of site was related to species composition in OS3 and RAWM sites. This concurs with a plot-scale experiment, where cultivation timing and depth, plus age of site all had strong effects on species composition (Critchley et al., 2006). Species with long- or short-lived seedbanks were favoured, respectively, by deep or shallow cultivation, and perennials and grasses tended to increase over time. In this study, grasses and perennials tended to be associated more with the less severe cultivation methods (tine/disc/harrow). Perennial grasses such as *Elytrigia repens* survive moderate levels of disturbance by regenerating from vegetative fragments (Marshall, 1990). OS3 sites were all less than one year old and were characterised by relatively high cover of litter and bare ground, and also had more volunteer wheat compared to RAWM sites.

Inter-regional differences in species diversity, composition and the incidence of rare species were striking, with the south, midlands and north forming the main distinctions. Regional differences in arable plant species composition have been noted previously, with more species characteristic of grassland tending to occur in mixed farming landscapes and more annual, early successional species in intensive arable landscapes (Critchley and Fowbert, 2000; Critchley et al., 2004a). Similar patterns were evident in this study, grass species numbers being lowest in the predominantly arable East region and highest in the North West, and there was evidence that species composition was related to land use (as denoted by adjacent grassland). Climatic variation accounted for some of these regional differences. Influences of climate appeared to act at the general, regional level (as denoted by temperature and rainfall) and at a more local level (as indicated by altitude and aspect). The lowest mean altitude was in the North West and Yorkshire/Humberside regions, and highest in West Midlands. Therefore, higher altitude did not necessarily correspond with wetter, cooler regions (and vice versa) but was subject to more local variation. This contrasts with the situation in Central Europe where weed communities of colder, wetter conditions occur at higher altitudes and those of warmer, drier conditions at low altitudes (Lososová et al., 2004). However, in this study the prevalence of bryophytes in the North West region probably did reflect the cooler, wetter climate.

Species composition was related to the intensity of arable cropping and the potential species-pool in the surrounding landscape but not to the overall habitat diversity. Semi-natural habitats composed of perennial species are unlikely to act as a colonisation source for arable species. This suggests that less intensively managed arable land (as indicated here by a higher proportion of spring barley cropping) could be important for maintaining metapopulations of particular arable species. Landscape diversity affects organic farming less than conventional farming (Roschewitz et al., 2005) and therefore could also be relatively unimportant for the AE scheme field margin options, which are more diverse and less intensively managed than conventionally managed crops.

It was surprising that the variation explained by regions was relatively independent of soil properties and habitat context, particularly since soil properties differed significantly between regions. Soil properties are highly variable at small spatial scales and probably have a much more localised effect on species composition than regional variation or habitat context. The incidence of rare species was strongly associated with higher soil pH values and overall species composition was also clearly related to soil pH in both cropped and uncropped sites. Soil properties had more effect on species composition at uncropped sites. In the presence of a crop, the influence of soil properties might be overridden by increased competition and agrochemical inputs associated with the crop. A possible explanation for the lack of shared variation between regions and habitat context might also be differences in spatial scale, particularly since habitat context included local variables (e.g. adjacent grassland) as well as landscape-scale variables (e.g. proportion of spring barley cropping).

The shared variation between habitat context and option, or management in the case of cropped sites, appeared to be linked to differences between CH1 and CH2 sites. The latter were more often located in spring crops, where the species complement was more similar to that from extensively managed landscapes. There was, however, no indication of any bias in the location of CH1 and CH2 sites with respect to the surrounding landscape. This suggests that the shared variation was more attributable to the type of crop in which CH2 sites were located, than their being targeted in particular landscapes.

4.3 Implications for arable plant conservation

Although the ability of European agri-environment schemes to benefit farmland biodiversity has recently been questioned (Kleijn et al., 2006; but see Potts et al., 2006) this study provides the first unequivocal evidence that, in the UK at least, specifically designed and geographically targeted options are effective in sustaining high levels of arable plant diversity within intensively managed landscapes. Despite the relatively small sample size of this survey (5% of English AE scheme agreements) 40% of the UK's rare and declining arable flora were found on AE scheme margins and, with the exception of CH1, all were significantly more diverse than conventional cereal crop controls. Extrapolation of these figures to the national scale suggests that AE options may hold up to 2500 populations of rare and declining species of which around 6% are likely to UKBAP Priority Species. Similarly, AE margins appear to 'capture' a relatively high proportion of the rare species-pool present in the surrounding landscape (10-km squares), especially RAWM margins which on average supported 13% of the surrounding rare species-pool (21% and 24% in the SE and SW respectively). Countryside Survey boundary plots (100 × 1 m) on CH2, OS3 and RAWM options were also up to three times more diverse and had greater numbers of UK rare species than the random, and much larger sample of cereal fields surveyed as part of Countryside Survey 2000 (Firbank et al., 2002).

Uncropped, cultivated margins (RAWM), currently the least widespread AE option, offer the greatest benefits for arable plants because it is both geographically targeted and designed specifically for the conservation of arable species. Typically RAWM margins support a diverse, annual-dominated assemblage, usually containing rare species, although as on other non-rotational options in England there may be a slow but gradual build-up of perennial species which could pose agronomic problems in the longer term (Firbank et al., 2003). Although spring/summer fallow following stubble (OS3) is not geographically targeted option overall diversity, including occurrence of rare species, was surprisingly high and equivalent to no-fertiliser conservation headlands (CH2). Previous studies have shown that that this option supports very high plant diversity due to reduced competition from the crop and similarly, in this study, CH2 was the most effective of the cropped AE scheme options with both high diversity and numbers of rare species. In contrast, CH1 provided few benefits for rare arable plants, although the abundance of very common species, such as *Poa annua*, confirmed the importance of this option in providing food resources for gamebirds and invertebrates (Marshall et al., 2003).

Six of the rare arable species included in this survey are UKBAP Priority Species for which there are a number of national targets for the maintenance and expansion of populations (e.g. *Centaurea cyanus*, *Galeopsis angustifolia*, *Scandix pecten-veneris*, *Silene gallica*, *Torilis arvensis*, *Valerianella rimosa*). Recently revised targets include the maintenance of viable populations at long-established sites (e.g. *Centurea cyanus*) or within 10-km squares known to support populations (e.g. *Scandix pecten-veneris*) as well as doubling the area of suitable habitat through AE scheme arable options by 2010 in Joint Character Areas deemed to be important for individual species. Given the rarity of all these species the discovery of three species (*Centaurea cyanus, Silene gallica*, *Scandix pecten-veneris*) at a small number of sites in this survey suggests that AE options are already making a significant contribution to these targets. Therefore more precise targeting of AE options to sites of know or likely importance for rare species in the future is likely to provide the most effective, and possibly the only, delivery-mechanism for achieving these targets in the future.

There is now a growing body of evidence to suggest that despite declining abundance many rare arable weeds still persist on historic sites within known 'hot-spots' on light, sandy or calcareous soils (e.g. Albrecht and Matheis, 1998; Kay et al., 2000; Sutcliffe and Kay, 2000). Therefore, more precise geographical targeting of agreements within such areas is likely to provide significant benefits to rarer species, in particular UKBAP Priority Species which were not found, or recorded at very low frequencies, during the current survey (see below). A targeted approach is currently being piloted in the UK (Important Arable Plant Areas) with the aim of identifying sites of European, national and regional importance for arable plants using an objective methodology (Byfield and Wilson, 2005). The IAPA assessment aims to identify important sites based on the presence of threatened (i.e. Red List) and/or exceptional assemblages of arable species. This approach is based on a scoring system which tallies weighted individual scores (1-9) of each the arable species present according to their rarity and decline across Britain. The level of importance is then assessed against a series of thresholds set for different soil types. It is likely that AE schemes will make a significant contribution to the IAPA. Indeed five of the agreements included in this study exceeded the threshold for county importance (3 RAWMS, 1 OS3, 1 CH2) and in two cases agreements were of national importance (1 RAWM, 1 OS3). Such evidence-based approaches, which have been extremely effective in the conservation of a number of threatened farmland birds (Smallshire et al., 2004), could be used to select agreements for entry into the new Environmental Stewardship Scheme in England as well as providing a standardised, objective means of measuring the condition of individual agreements and effectiveness of management in the future.

Arable bryophytes have received scant attention from bryologists and conservationists and as a consequence their distribution and ecology is poorly understood (Porley, 2000). However, a recent stratified random sample of 812 arable fields throughout the UK (Survey of Bryophytes of Arable Land) has shown that arable land is an important habitat for many species, including rare species (SBAL, 2005). In addition, patterns of diversity were shown to be unrelated to those for higher plants, with the richest assemblages (and most rare species) present in the more oceanic and extensively farmed regions of the north and west. In contrast, fields in the drier south and east of England tended to be less diverse and dominated by generalists (often reproducing vegetatively) which occur throughout the UK. Analysis of the diaspore banks of the sites included in this study has confirmed these findings with sites in the west supporting a much more diverse community including most notably the rare arable hornwort *Anthoceros agrestis* and uncommon liverworts such as *Riccia glauca* and *R. sorocarpa* (K.J. Walker, unpublished data). Over-wintered stubbles provide ideal conditions for these species because most species are able to complete their lifecycles in fallow periods between cultivations. Therefore uncultivated AE options, particularly OS3 and RAWMs in northern and western regions, are likely to support diverse assemblages of regional or national importance on sites which are of little interest for their higher vascular plant flora.

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Table 1
Agri-environment scheme arable options sampled and predicted vegetation characteristics

AE option	Management	Rotational	Targets	Vegetation characteristics
Conservation headland (CH1)	• On a 6-24 m wide cereal headland, no control of broad-leaved weeds except using amidosulfuron before 31 March and selective herbicides thereafter • Grass weeds controlled using specified graminicides only • No insecticides applied between 15 March and harvest	Yes	Gamebirds, invertebrates	High incidence of dicotyledon annual arable plants (Sotherton, 1991; Critchley et al., 2004a)
No-fertiliser conservation headland (CH2)	• Conservation headland managed as above • No organic or inorganic fertilisers applied after harvest of previous crop	Yes	As above, arable plants	Similar to CH but with greater abundance of dicotyledons (Critchley et al., 2004a; Kleijn and van der Voort, 1997)
Over-wintered stubble followed by a spring/summer fallow (OS3)	• Cereal or linseed stubble retained after harvest until 1 March • Cultivated once during 1-20 March to 75-100 mm deep using tine or disc • Fallow maintained with no other inputs except selective control of serious weeds until 31 July • Whole/part fields or plots within fields	Yes	Farmland birds, spring-germinating arable plants	Dominated by a few widespread, annual arable weeds (Critchley and Fowbert, 2000) and high cover of bare ground (Derksen et al., 1994)
Rare arable weed margin (RAWM)	• Uncropped 6-12 m wide boundary strip managed for 5 years • Cultivated once a year or every other year in spring • No other inputs except selective control of serious weeds • Vegetation cut in the autumn	No	Annual arable plants	Dominated by annual arable plants in first year (Critchley et al., 2004a) but increasingly by monocots and perennials if uncultivated (Critchley and Fowbert, 2000)

CH1 includes Conservation Headlands in South Downs ESA (Tier 4C) and South Wessex Downs ESA (Tier 2, part 3).
OS3 options were sampled during the fallow phase which runs from 20 March to at least 31 July.
RAWM includes Uncropped Wildlife Strips in Breckland ESA (Tier 4A).

Table 2
The most widespread and frequent species recorded across all AE options. Species present in more than 40% of sites (>15, *n* = 39) and 10% of quadrats (>117, *n* = 1170) are highlighted in bold. Figures for all species are given in Appendix 2.

Species	Sites (%) Control	CH1	CH2	OS3	RAWM	Total	Species	Within-site frequency (%) Control	CH1	CH2	OS3	RAWM	Total
Monocotyledons							Monocotyledons						
Poa annua	**56.4**	**69.2**	**76.9**	**82.1**	**71.8**	71.3	*Poa annua*	**25.6**	**38.0**	**34.8**	**51.3**	**33.4**	36.6
Poa trivialis	25.6	**48.7**	**43.6**	**53.8**	**71.8**	48.7	*Poa trivialis*	4.6	**16.2**	**10.6**	**17.0**	**28.7**	15.4
Anisantha sterilis	**43.6**	25.6	33.3	**53.8**	**48.7**	41.0	*Anisantha sterilis*	5.9	5.7	5.4	**27.7**	**25.1**	14.0
Agrostis stolonifera	20.5	20.5	25.6	35.9	**66.7**	33.8	*Alopecurus myosuroides*	**10.6**	**10.9**	**11.4**	**12.5**	**11.5**	11.4
Alopecurus myosuroides	30.8	30.8	28.2	33.3	30.8	30.8	*Agrostis stolonifera*	3.3	2.9	8.6	**10.4**	**19.8**	9.0
Elytrigia repens	17.9	15.4	30.8	35.9	**51.3**	30.3	*Elytrigia repens*	2.2	1.1	5.6	4.7	**16.9**	6.1
Lolium perenne	12.8	30.8	23.1	35.9	38.5	28.2	*Lolium perenne*	0.9	6.9	6.6	8.7	5.6	5.7
Bromus hordeaceus	5.1	10.3	10.3	**43.6**	**41.0**	22.1	*Bromus hordeaceus*	0.3	0.9	1.5	**14.2**	**11.5**	5.7
Arrhenatherum elatius	5.1	5.1	7.7	20.5	**64.1**	20.5	*Holcus lanatus*	0.1	0.4	1.8	0.7	**13.2**	3.2
Dicotyledons							Dicotyledons						
Galium aparine	**46.2**	**51.3**	38.5	**46.2**	**61.5**	48.7	*Viola arvensis*	6.8	**16.2**	**20.6**	9.1	**24.6**	15.5
Polygonum aviculare	35.9	38.5	**59.0**	**43.6**	**64.1**	48.2	*Polygonum aviculare*	8.4	9.0	**22.1**	5.0	**26.8**	14.2
Cirsium arvense	23.1	33.3	**43.6**	**41.0**	**74.4**	43.1	*Veronica persica*	2.9	**12.0**	**23.8**	6.9	**25.0**	14.1
Veronica persica	20.5	33.3	**51.3**	35.9	**71.8**	42.6	*Tripleurospermum inodorum*	3.8	9.1	9.5	**13.6**	**17.0**	10.6
Sonchus asper	15.4	12.8	30.8	**69.2**	**71.8**	40.0	*Stellaria media*	2.3	**13.3**	**11.8**	3.8	**20.3**	10.3
Senecio vulgaris	23.1	23.1	25.6	**71.8**	**56.4**	40.0	*Sonchus asper*	3.3	1.5	6.1	**19.9**	**20.5**	10.3
Viola arvensis	25.6	33.3	**43.6**	30.8	**56.4**	37.9	*Senecio vulgaris*	4.1	1.5	4.9	**26.1**	**14.1**	10.1
Stellaria media	15.4	**41.0**	33.3	23.1	**66.7**	35.9	*Papaver rhoeas*	1.0	7.8	**15.2**	6.8	**19.0**	10.0
Tripleurospermum inodorum	7.7	25.6	33.3	**46.2**	**51.3**	32.8	*Galium aparine*	7.7	7.9	6.3	9.3	**17.3**	9.7
Chenopodium album	15.4	20.5	35.9	38.5	**48.7**	31.8	*Cirsium arvense*	1.4	3.3	6.8	8.4	**23.5**	8.7
Anagallis arvensis	12.8	20.5	33.3	38.5	**43.6**	29.7	*Anagallis arvensis*	0.7	1.5	**14.3**	7.9	**18.7**	8.6
Veronica arvensis	7.7	30.8	28.2	33.3	**43.6**	28.7	*Chenopodium album*	2.6	1.0	8.0	**12.8**	**13.2**	7.5
Myosotis arvensis	7.7	15.4	23.1	30.8	**53.8**	26.2	*Veronica arvensis*	0.7	7.3	7.8	6.0	**10.9**	6.5
Plantago major	2.6	12.8	25.6	28.2	**51.3**	24.1	*Fallopia convolvulus*	1.7	0.6	**10.5**	0.9	**13.0**	5.4
Capsella bursa-pastoris	2.6	7.7	30.8	28.2	**46.2**	23.1	*Myosotis arvensis*	0.3	1.0	4.8	5.0	**10.7**	4.3
Papaver rhoeas	5.1	20.5	33.3	23.1	33.3	23.1	*Geranium dissectum*	1.3	5.4	1.6	3.0	**10.0**	4.3
Geranium dissectum	15.4	20.5	15.4	20.5	35.9	21.5	*Capsella bursa-pastoris*	0.1	2.1	5.0	4.4	9.7	4.3
Fallopia convolvulus	10.3	5.1	**41.0**	15.4	35.9	21.5	*Sinapis arvensis*	0.5	0.2	5.7	2.5	**10.0**	3.8
Cirsium vulgare	7.7	17.9	7.7	25.6	**43.6**	20.5	*Matricaria discoidea*	1.8	1.8	2.8	2.9	9.5	3.8
Trifolium repens	5.1	15.4	20.5	15.4	**41.0**	19.5	*Plantago major*	2.4	0.9	3.8	3.5	7.9	3.7

Table 3
The frequency (% sites, *n* = 39) of rare arable plants in AE field margin options (*n* = 156) and cereal crop controls (*n* = 39). Core species are highlighted in bold. Species recorded in a single option are listed below.

Species	Control	CH1	CH2	OS3	RAWM	Total AE	Total
Euphorbia exigua	10.3		10.3	12.8	15.4	9.6	9.7
Legousia hybrida		2.6	10.3	7.7	20.5	10.3	8.2
Kickxia spuria		7.7	5.1	5.1	15.4	8.3	6.7
Spergula arvensis			7.7	2.6	15.4	6.4	5.1
Fumaria densiflora		5.1	7.7		10.3	5.8	4.6
Papaver argemone	2.6	2.6	2.6		10.3	3.8	3.6
Filago vulgaris				5.1	10.3	3.8	3.1
Stachys arvensis		2.6	7.7	2.6	2.6	3.8	3.1
Apera spica-venti			5.1	2.6	5.1	3.2	2.6
Chrysanthemum segetum		2.6	2.6		7.7	3.2	2.6
Descurainia sophia			2.6	5.1	5.1	3.2	2.6
Silene noctiflora		2.6	2.6	5.1	2.6	3.2	2.6
Anthemis cotula			2.6	2.6	5.1	2.6	2.1
Valerianella dentata[SCC]			**2.6**		**7.7**	**2.6**	**2.1**
Misopates orontium			5.1		2.6	1.9	1.5
Papaver hybridum			2.6		5.1	1.9	1.5
Scandix pecten-veneris[BAP]		**2.6**			**5.1**	**1.9**	**1.5**
Anthriscus caucalis				2.6	2.6	1.3	1.0
Bromus secalinus				5.1		1.3	1.0
Centaurea cyanus[BAP]			**2.6**		**2.6**	**1.3**	**1.0**
Euphorbia platyphyllos[SCC]		**2.6**			**2.6**	**1.3**	**1.0**
Hypochaeris glabra[SCC]				**5.1**		**1.3**	**1.0**
Total	3	10	18	16	25	34	34

Rare species recorded from a single option:
Control – *Viola tricolor*;
CH1 – ***Petroselinum segetum***[SCC];
CH2 – *Ranunculus parviflorus*, ***Silene gallica***[BAP];
OS3 – ***Anthemis arvensis***, *Apera interrupta*, ***Lithospermum arvense***[SCC];
RAWM – *Fumaria parviflora*, ***F. purpurea***[BAP], *F. vaillantii*, *Hyoscyamus niger*, ***Legousia speculum-veneris***.
BAP = UK Biodiversity Action Plan species.
SCC = UK Species of Conservation Concern.

Table 4
Treatment effects on mean (± SE) species richness, cover and indicator values per 6 × 100 m sample zone

	Margin type										Treatment
	Control		CH1		CH2		OS3		RAWM		Anova $F_{4,190}$
(a) Quadrat											
Annuals	1.1a	±0.2	1.8a	±0.2	3.1b	±0.4	3.0b	±0.3	4.9c	±0.5	17.77***
Perennials	0.3a	±0.1	0.6b	±0.1	1.0bc	±0.1	1.4cd	±0.2	2.6d	±0.2	28.55***
Forbs	0.8a	±0.2	1.4a	±0.2	3.1b	±0.5	2.6b	±0.3	5.4c	±0.5	24.35***
Grasses	0.7a	±0.1	1.0a	±0.1	1.0a	±0.1	1.8b	±0.2	2.2b	±0.2	20.93***
Autumn germination	0.7a	±0.1	0.9a	±0.1	1.5b	±0.2	1.8b	±0.2	2.9c	±0.2	35.53***
Spring germination	0.6a	±0.2	1.4b	±0.2	2.4c	±0.3	2.2c	±0.2	4.3d	±0.3	28.77***
Total	1.4a	±0.3	2.4a	±0.3	4.1b	±0.5	4.3b	±0.4	7.5c	±0.4	36.76***
% annual	79.3b	±3.0	73.0ab	±4.1	74.8ab	±3.8	68.4ab	±3.6	61.7a	±4.3	3.20*
% forb	42.8a	±5.1	50.5ab	±4.5	67.4c	±4.6	57.6bc	±3.6	67.2c	±3.6	6.46***
% spring germination	40.2a	±5.0	56.1b	±3.5	58.7b	±3.9	55.1b	±2.2	58.5b	±1.4	5.15***
(b) Sample zone											
Annuals	5.5a	±0.6	7.4a	±0.8	11.5b	±1.1	11.4b	±1.0	17.3c	±1.3	23.38***
Perennials	2.3a	±0.4	3.6ab	±0.4	5.4b	±0.7	8.5c	±0.9	13.4d	±0.9	37.22***
Forbs	5.0a	±0.7	7.6a	±1.0	13.1b	±1.5	14.4b	±1.4	23.3c	±1.5	34.77***
Grasses	2.8a	±0.3	3.4a	±0.3	3.9a	±0.4	5.5b	±0.4	7.4c	±0.5	22.26***
Autumn germination	3.3a	±0.3	3.6a	±0.4	6.6b	±0.6	7.2b	±0.6	11.6c	±0.6	42.27***
Spring germination	4.0a	±0.5	6.9b	±0.8	9.8c	±1.1	11.2c	±0.9	17.2d	±1.0	33.91***
Total	7.8a	±0.8	11.0a	±1.1	16.9b	±1.7	19.9b	±1.6	30.7c	±1.6	43.65***
% annual	71.7c	±3.3	65.8abc	±3.9	67.3bc	±3.5	57.7ab	±2.8	55.0a	±2.9	4.61***
% forb	55.5a	±4.3	60.6a	±3.6	70.3b	±4.1	70.2b	±2.6	74.1b	±2.4	5.27***
% spring germination	48.0a	±4.1	62.9b	±2.4	58.3b	±3.0	60.2b	±1.9	59.5b	±0.9	4.61***
(c) % cover											
Non-crop	8.3a	±1.9	14.5a	±2.6	28.0b	±4.5	48.6c	±4.4	79.0d	±3.8	62.96***
Crop & volunteers	73.3c	±3.8	67.4c	±3.3	47.7b	±4.7	3.2a	±1.2	0.2a	±0.1	125.15***
Bare ground	17.4a	±2.6	17.1a	±3.2	24.0a	±3.1	37.4b	±4.7	18.4a	±3.8	5.53***
Bryophytes	0.3	±0.2	0.3	±0.2	0.2	±0.1	0.2	±0.1	0.0	±0.0	0.87ns
Litter	0.3a	±0.2	0.4a	±0.4	0.4a	±0.2	9.8b	±2.6	2.0a	±0.8	10.54***
Seedlings	0.0	±0.0	0.1	±0.1	0.1	±0.1	0.1	±0.1	0.0	±0.0	0.50ns
(d) Indicator values											
N	6.58b	±0.06	6.39b	±0.05	6.18a	±0.08	6.22a	±0.05	6.20a	±0.04	10.71***
R	6.79b	±0.10	6.54a	±0.03	6.58a	±0.03	6.61a	±0.03	6.58a	±0.03	5.89***

Means with the same letter are not significantly different. ns = no significant difference. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Table 5
Species richness (mean ± SE) in relation to distance from edge of margin

	Distance from edge			Distance
	1 m	3 m	5 m	Anova $F_{2,35}$
(a) Species richness				
Control	5.3a ±0.9	4.5a ±0.6	3.9a ±0.5	1.58ns
CH1	8.5b ±1.3	5.9a ±0.7	5.9a ±0.7	3.62*
CH2	12.3c ±0.6	10.3b ±1.2	10.1b ±1.2	0.94ns
OS3	13.9c ±1.1	12.1b ±1.1	12.1b ±1.1	0.89ns
RAWM	20.5d ±1.2	20.4c ±1.1	20.3c ±1.0	0.01ns
Treatment $F_{4,190}$	32.67 ***	42.87 ***	48.69 ***	
Region $F_{7,187}$	3.40 **	2.06 ns	2.66 *	
Treatment × region $F_{28,155}$	0.94 ns	1.02 ns	0.94 ns	
(b) Rare species				
Control	0.03a ±0.03	0.00a ±0.00	0.00a ±0.00	1.00ns
CH1	0.08a ±0.06	0.05a ±0.03	0.03a ±0.03	0.38ns
CH2	0.46a ±0.15	0.41a ±0.15	0.46b ±0.14	0.04ns
OS3	0.26ab ±0.14	0.26a ±0.13	0.23ab ±0.12	0.01ns
RAWM	0.69b ±0.19	0.85b ±0.17	0.69c ±0.16	0.26ns
Treatment $F_{4,190}$	4.85 ***	8.68 ***	7.26 ***	
Region $F_{7,187}$	1.95 ns	2.05 ns	1.70 ns	
Treatment × region $F_{28,155}$	0.88 ns	0.94 ns	0.90 ns	

Mean numbers of species in 10 × 0.25 m^2 quadrats within each distance class per sample zone. Means with the same letter are not significantly different. ns = no significant difference. * $p < 0 .05$. ** $p < 0 .01$. *** $p < 0 .001$. The effect of distance from margin (nested within option) and interactions on species richness and rare species was also calculated: species richness - distance (option), $F_{2,570} = 4.20$, $p < 0.05$*; Distance (option) × option, $F_{12,570} = 38.59$, $p < 0.001$***; rare species - distance (option), $F_{2,570} = 0.09$ns, $p > 0.05$; Distance (option) × option, $F_{12,570} = 6.67$, $p < 0.001$***.

Table 6
Regional differences in mean (± SE) species richness, cover and indicator values per 6 × 100 m sample zone

	E	SE	SW	EM	WM	YH	NW	NE	Region $F_{7,187}$	Region × Treatment $F_{28,155}$
(a) Quadrat										
Annuals	2.7ab ±0.5	3.6b ±0.6	3.5b ±0.5	2.4ab ±0.4	2.1ab ±0.6	2.5ab ±0.5	2.7ab ±0.6	1.8a ±0.2	2.59*	1.18ns
Perennials	1.0 ±0.2	1.1 ±0.3	1.0 ±0.2	1.4 ±0.4	1.5 ±0.4	1.5 ±0.3	1.7 ±0.4	0.8 ±0.2	1.91ns	1.14ns
Forbs	2.6ab ±0.5	3.6b ±0.6	3.3b ±0.5	2.5ab ±0.5	2.4ab ±0.6	2.6ab ±0.6	2.4ab ±0.7	1.2a ±0.2	3.07**	1.01ns
Grasses	1.1a ±0.2	1.2ab ±0.3	1.3ab ±0.1	1.3ab ±0.2	1.1ab ±0.2	1.4ab ±0.3	2.1b ±0.2	1.4ab ±0.2	2.31*	0.79ns
Autumn germ.	1.4ab ±0.2	1.8b ±0.3	1.7b ±0.3	1.7ab ±0.3	1.3ab ±0.3	1.7ab ±0.3	2.0b ±0.2	1.0a ±0.1	2.84**	0.94ns
Spring germ.	2.1 ±0.4	2.7 ±0.4	2.5 ±0.3	1.9 ±0.4	2.1 ±0.4	2.2 ±0.4	2.2 ±0.6	1.4 ±0.2	1.75ns	1.07ns
Total	3.7ab ±0.6	4.7b ±0.7	4.5b ±0.6	3.8ab ±0.7	3.6ab ±0.7	4.0ab ±0.7	4.4ab ±0.8	2.6a ±0.3	2.29*	1.04ns
% annual	70.9 ±4.5	75.8 ±3.8	78.4 ±3.8	68.5 ±5.9	64.0 ±7.4	62.1 ±5.9	64.5 ±6.2	72.3 ±4.8	1.41ns	1.10ns
% forb	63.9 ±4.4	59.9 ±5.0	64.8 ±3.6	56.4 ±7.0	59.0 ±6.9	61.3 ±7.1	40.8 ±7.3	42.5 ±6.1	3.03**	0.87ns
% spring germ.	59.2 ±3.3	53.0 ±4.0	54.9 ±3.2	47.3 ±5.4	58.3 ±6.8	53.2 ±5.7	42.2 ±6.4	53.6 ±4.4	1.28ns	1.07ns
(b) Sample zone										
Annuals	11.4bc ±1.5	12.3bc ±1.5	14.3c ±1.2	9.6abc ±1.8	8.9ab ±1.5	9.4abc ±1.4	8.5ab ±1.5	6.5a ±0.7	5.17***	0.99ns
Perennials	6.7 ±0.9	7.4 ±1.3	6.4 ±0.9	7.3 ±1.5	7.9 ±1.9	6.9 ±1.7	7.3 ±1.3	4.7 ±0.8	1.20ns	0.90ns
Forbs	13.9c ±1.9	15.1c ±2.2	16.2c ±1.5	11.9ab ±2.4	12.7ab ±2.2	11.5ab ±2.0	10.4bc ±2.1	6.6a ±1.0	4.92***	0.89ns
Grasses	4.1 ±0.5	4.6 ±0.4	4.5 ±0.4	4.9 ±0.8	4.0 ±0.7	4.8 ±0.9	5.9 ±0.8	4.7 ±0.6	0.95ns	0.78ns
Autumn germ.	6.8b ±0.8	7.5b ±0.9	7.2b ±0.7	6.9ab ±1.1	5.5ab ±0.9	6.7ab ±1.1	6.3ab ±0.8	4.1a ±0.6	3.33**	0.80ns
Spring germ.	9.5ab ±1.2	11.3b ±1.5	12.1b ±1.0	9.5ab ±1.9	10.6ab ±1.8	9.2ab ±1.7	8.6ab ±1.4	6.4a ±0.8	3.27**	0.84ns
Total	18.1b ±2.1	19.7b ±2.6	20.7b ±1.8	16.9ab ±3.1	16.7ab ±2.5	16.3ab ±2.8	15.9ab ±2.3	11.2a ±1.3	3.61***	0.83ns
% annual	61.9 ±4.1	67.5 ±3.3	70.8 ±3.0	58.3 ±4.1	57.7 ±6.4	58.9 ±5.7	56.0 ±5.2	63.9 ±4.2	1.62ns	1.24ns
% forb	72.5b ±3.2	65.6a ±4.5	74.4b ±2.9	64.3ab ±5.9	70.1ab ±5.1	64.2ab ±5.6	55.1ab ±6.3	54.8a ±4.3	3.14**	0.95ns
% spring germ.	59.8 ±2.6	54.9 ±3.4	60.8 ±2.4	53.8 ±3.9	61.0 ±5.8	51.7 ±5.2	54.6 ±3.1	60.4 ±3.3	1.06ns	1.07ns
(c) % cover										
Non-crop	30.0 ±6.0	33.2 ±5.7	35.0 ±4.8	37.8 ±8.9	40.9 ±10.9	40.0 ±9.6	49.6 ±9.3	33.2 ±6.1	1.45ns	0.82ns
Crop	44.4 ±6.6	38.8 ±6.6	33.1 ±5.9	40.9 ±10.1	41.8 ±10.3	45.1 ±10.2	27.8 ±7.2	35.8 ±6.2	1.92ns	0.75ns
Bare ground	22.2 ±3.9	26.3 ±4.3	28.6 ±3.6	14.9 ±4.8	16.5 ±6.8	12.9 ±3.6	20.0 ±6.2	26.6 ±4.8	1.41ns	0.51ns
Bryophytes	0.0a ±0.0	0.0a ±0.0	0.5a ±0.2	0.0a ±0.0	0.0a ±0.0	0.0a ±0.0	1.3b ±0.5	0.0a ±0.0	5.52***	0.92ns
Litter	3.1 ±2.4	1.8 ±0.8	3.4 ±1.3	5.8 ±2.9	1.3 ±1.1	0.2 ±0.2	2.7 ±0.9	3.7 ±1.7	0.77ns	0.87ns
Seedlings	3.1 ±2.4	1.7 ±0.8	2.9 ±1.2	5.5 ±2.7	1.3 ±1.1	0.2 ±0.2	1.3 ±0.6	3.7 ±1.7	0.72ns	1.08ns
(d) Indicator values										
N	6.3ab ±0.1	6.1a ±0.1	6.3ab ±0.0	6.3abc ±0.1	6.5c ±0.1	6.5bc ±0.1	6.1a ±0.1	6.5bc ±0.1	6.12***	1.61*
R	6.6b ±0.0	6.7b ±0.0	6.6b ±0.0	6.7b ±0.0	6.6b ±0.0	6.7b ±0.1	6.4a ±0.0	6.6c ±0.1	2.42*	0.83ns

Means with the same letter are not significantly different. ns = no significant difference. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Table 7
Treatment and regional effects on mean (± SE) species richness of Countryside Survey 100 × 1 m boundary plots recorded adjacent to all sample zones in this survey.

	n	Control		CH1		CH2		OS3		RAWM		Total		Anova $F_{7,187}$ Region
E	7	13.6	±3.2	13.3	±2.5	22.7	±4.4	31.1	±3.9	36.4	±1.1	23.4b	±2.1	12.76***
SE	7	11.9	±2.5	16.7	±4.6	28.7	±4.8	28.4	±4.8	42.1	±3.9	25.6b	±2.5	
SW	7	17.1	±1.4	21.9	±3.0	26.9	±5.4	30.0	±3.3	33.6	±3.1	25.9b	±1.8	
EM	3	8.3	±2.7	11.7	±3.3	12.3	±0.3	18.3	±4.1	32.3	±11.8	16.6a	±3.2	
WM	3	9.7	±3.7	14.3	±7.1	15.0	±5.9	14.3	±2.9	18.0	±0.6	14.3a	±1.9	
YH	3	11.0	±3.1	13.7	±2.6	14.0	±5.1	14.0	±1.0	33.0	±3.5	17.1a	±2.5	
NW	3	7.3	±0.7	13.7	±3.0	16.7	±2.9	19.3	±4.3	19.0	±1.0	15.2a	±1.6	
NE	6	6.0	±1.9	8.2	±1.3	9.3	±1.2	14.8	±1.6	15.2	±2.2	10.7a	±1.0	
Total		11.4a	±1.1	14.7a	±1.4	20.0b	±1.9	23.4b	±1.7	30.3c	±2.0			
Anova $F_{4,190}$ Treatment		29.99	***											

Table 8
The number of agreements on which rare arable plants (core and additional species) were recorded on 100 × 1 m boundary plots in this survey compared to Countryside Survey 2000 plots (Firbank et al., 2002).

	Control	CH1	CH2	OS3	RAWM	AE (n = 156)	CS2000 (n = 507)
Anthemis cotula			1	1	1	3	2
Anthriscus caucalis				1	2	3	1
Apera interrupta				1		1	
Apera spica-venti			2		2	4	
Chrysanthemum segetum			1		3	4	1
Descurainia sophia				1	1	2	1
Euphorbia exigua	2		4	3	5	14	7
Euphorbia platyphyllos					1	1	
Filago vulgaris				2	2	4	6
Fumaria densiflora			2		1	3	
Fumaria vaillantii					1	1	
Hyoscyamus niger							1
Hypochaeris glabra				2		2	
Kickxia spuria		3	2	2	4	13	6
Legousia hybrida		1	4	3	5	13	
Legousia speculum-veneris					1	1	
Lithospermum arvense				1		1	
Misopates orontium			1			1	
Papaver argemone			1		1	2	
Papaver hybridum			1		1	2	
Petroselinum segetum		1				1	
Scandix pecten-veneris					2	2	
Silene gallica			1			1	
Silene noctiflora		1	1	1	1	4	1
Spergula arvensis			3	1	5	9	
Stachys arvensis	1		2	1	1	5	6
Valerianella dentata			1		1	2	
Viola tricolor							4
Number of species	2	4	15	13	20	26	11
Number or records	3	6	27	20	41	99	36

Table 9
Treatment and regional differences (mean ± SE) in soil pH and mineral nutrients (mg l^{-1}).

	pH	P	K	Mg
(a) Option				
Control	7.3 ±0.1	33.1ab ±2.7	192.1 ±24.0	118.4 ±25.0
CH1	7.4 ±0.1	36.6b ±3.2	201.2 ±20.7	107.4 ±13.7
CH2	7.4 ±0.1	25.1a ±2.2	168.3 ±13.8	116.2 ±17.0
OS3	7.1 ±0.1	28.9ab ±2.0	200.8 ±16.9	115.8 ±17.1
RAWM	7.3 ±0.1	29.9ab ±2.5	170.8 ±12.9	81.3 ±8.9
(b) Region				
E	7.9f ±0.1	32.1b ±2.3	181.3ab ±14.0	45.5a ±3.3
SE	7.7cef ±0.1	34.2b ±3.4	232.1b ±28.5	60.0a ±6.8
SW	7.3bcd ±0.2	32.6b ±2.8	233.8b ±20.3	75.9ab ±7.8
EM	7.3bc ±0.2	39.2b ±4.8	197.5ab ±22.8	70.6ab ±9.2
WM	7.0b ±0.1	34.8b ±4.1	167.9ab ±7.8	223.8c ±52.2
YH	7.3bcde ±0.2	29.1ab ±4.6	130.5a ±16.2	138.9b ±31.8
NW	6.4a ±0.1	26.3ab ±2.2	101.1a ±10.5	127.3b ±17.2
NE	6.9b ±0.1	19.6a ±1.8	159.6ab ±17.0	208.8c ±21.7
Treatment $F_{4,190}$	1.10 ns	3.40 *	0.84 ns	1.35 ns
Region $F_{7,187}$	11.69 ***	3.95 **	4.02 **	16.63 ***
Treatment × region $F_{28,155}$	0.91 ns	1.51 ns	0.72 ns	1.61 *

Means with the same letter are not significantly different. ns = no significant difference. * $p < 0 .05$. ** $p < 0 .01$. *** $p < 0.001$.

Table 10
Treatment and regional effects on the number of rare arable species. Percentages are given in parentheses and means ± 1SE.

	No. of rare species	Records of rare species	Sites with rare species	Mean per quadrat	Mean per sample zone	Mean per field margin
(a) Option						
Control	3 (3)	6 (4)	6 (15)	0.00a ±0.00	0.13a ±0.05	0.15a ±0.06
CH1	10 (12)	13 (9)	8 (20)	0.02a ±0.02	0.15a ±0.08	0.33a ±0.11
CH2	18 (21)	33 (23)	15 (38)	0.15a ±0.06	0.77a ±0.22	0.85a ±0.23
OS3	16 (19)	28 (19)	12 (31)	0.07a ±0.05	0.64a ±0.21	0.72a ±0.26
RAWM	25 (29)	65 (45)	26 (67)	0.31b ±0.10	1.41b ±0.29	1.67b ±0.32
(b) Region						
E	21 (24)	44 (30)	17 (49)	0.14 ±0.06	0.97a ±0.26	1.26a ±0.32
SE	16 (19)	43 (30)	15 (43)	0.21 ±0.09	1.09a ±0.32	1.23a ±0.36
SW	15 (17)	39 (27)	20 (57)	0.15 ±0.07	0.91ab ±0.21	1.11a ±0.22
EM	5 (6)	7 (5)	4 (27)	0.15 ±0.11	0.40ab ±0.24	0.47ab ±0.24
WM	3 (3)	3 (2)	2 (13)	0.01 ±0.01	0.13ab ±0.09	0.20ab ±0.15
YH	1 (1)	3 (2)	3 (20)	0.05 ±0.04	0.20ab ±0.11	0.20ab ±0.11
NW	3 (3)	3 (2)	3 (20)	0.05 ±0.05	0.20ab ±0.11	0.20ab ±0.11
NE	3 (3)	3 (2)	3 (10)	0.01 ±0.01	0.10b ±0.06	0.10b ±0.06
Anova						
Treatment $F_{4,190}$	- -	- -	- -	5.33 ***	8.32 ***	8.06 ***
Region $F_{7,187}$	- -	- -	- -	1.32 ns	3.59 ***	4.21 ***
Treatment × region $F_{28,155}$	- -	- -	- -	0.96 ns	1.08 ns	0.94 ns

The area of margin varied between sites but there was no correlation between the area surveyed and the number of rare species recorded for all options.
Means with the same letter are not significantly different. ns = no significant difference. *** $p < 0.001$.

Table11
National Vegetation Classification (NVC) communities and soil characteristics of agreements with core species. UKBAP species are highlighted in bold.

	Sites	NVC communities (% fit)	Soil characteristics				
			Texture	pH	P	K	Mg
Anthemis arvensis	1	OV10 (21)	LS	8.3	34	95	23
Centaurea cyanus	**2**	**OV3 (20); OV7 (74)**	**ZCL/LS**	**7.4**	**27**	**152**	**82**
Euphorbia platyphyllos	2	OV8 (15, 25)	ZL/ZCL	8.2	19	185	63
Fumaria purpurea	**1**	**OV7 (65)**	**OSL**	**7.2**	**31**	**73**	**263**
Hypochaeris glabra	2	OV10 (47, 21)	LS	8.3	37	111	28
Legousia speculum-veneris	1	OV3 (36)	ZL	8.1	15	144	31
Lithospermum arvense	1	OV3 (47)	ZL	8.2	37	579	81
Petroselinum segetum	1	OV3 (37)	ZL	8.0	23	145	71
Scandix pecten-veneris	**3**	**OV8 (15, 25); MC11a (36)**	**ZL/ZCL**	**8.0**	**25**	**191**	**59**
Silene gallica	**1**	**OV19 (33)**	**ZL**	**6.4**	**16**	**269**	**242**
Valerianella dentata	4	OV3 (21, 36); OV15b (50); MG1 (37)	ZL/ZCL	8.1	26	197	51

Communities were classified to NVC-types using Tablefit (Hill,1996) based on frequency and maximum abundance within five quadrats per rare species loci.
NVC communities are as follows (after Rodwell, 1992, 2000):
OV3 - *Papaver rhoeas-Viola arvensis* community
OV7 - *Veronica persica-Veronica polita* community
OV8 - *Veronica persica-Alopecurus myosuroides* community
OV10 - *Poa annua-Senecio vulgaris* community
OV15b - *Anagallis arvensis-Veronica persica* community; *Legousia hybrida-Cheanorhinum minus* sub-community
OV19 - *Poa annua-Matricaria perforata* community
MC11a - *Festuca rubra-Daucus carota* ssp. *gummifer* maritime grassland; *Bromus hordeaceus* ssp. *ferronii* sub-community
MG1 - *Arrhenatherum elatius* grassland
C = clay, L = loam, O = organic, S = sand, Z = silt.

Table 12
Incidence of land cover and field boundary categories adjacent to arable weed options (n = 195). Sites can have more than one category present.

Field boundary	% of sites	Adjacent land cover	% of sites
Grass/tall herb verge	70.8	Arable	62.1
Hedge	57.4	Metalled surface/urban	19.5
Broadleaved trees	19.5	Grassland	16.9
Metalled surface	8.2	Woodland	13.3
Cultivated	7.7	Scrub	2.1
Ditch	5.1	Disturbed ground	4.1
Coniferous trees	3.1	Open water	1.0
Unmetalled surface	2.6		
Overhanging trees	2.1		

Table 13
Summary of management practices (% of sites, n = 39). Cropping for OS3 sites refers to that immediately preceding the stubble phase. Cultivation data refer to the most recent cultivation in RAWM sites. Data were incomplete for a small number of sites.

	Option			
	Control	CH1	CH2	OS3
(a) Cropped CH1, CH2 and OS3 sites				
Wheat	76.9	74.4	59.0	74.4
Barley	17.9	25.6	30.8	23.1
Other cereal	6.7	0.0	10.3	2.6
Autumn sown	84.6	84.6	64.1	84.6
Spring sown	12.8	15.4	35.9	15.4

(b) RAWM sites		
Age (years)		3.0 (1-11)
Time since cultivated (months)		8.4 (3-38)
Cultivation depth (cm)		11.8 (5-22)
Cultivation time	Autumn	20.5
	Spring	71.8
Cultivation method	Disc/tine/harrow	53.8
	Plough/power harrow	33.3
Cultivation frequency	Annual	23.1
	Less often	71.8
Cutting	Never cut	51.3
	Cuttings not always removed	41.0
	Cuttings always removed	7.7

Table 14
Variation explained by each environmental variable subset from RDAs of all margins. TVE = total variation explained by all significant variables. ** $p < 0.01$.

Subset	Significant variables	Variation explained (%)	% of TVE	Axis 1 (*F*)	Overall (*F*)
Option	RAWM OS3 CH2	8.0	33.6	12.07**	5.47**
Region	North East North West South West South East East	6.2	26.1	4.14**	2.47**
Physical/climatic	January precipitation Altitude July temperature January temperature July precipitation Aspect	7.1	29.8	4.49**	2.37**
Habitat context	Spring barley Rare species-pool Field boundary verge Arable cropping Adjacent grassland	6.3	26.5	6.46**	2.55**
Soil properties	pH Mg	3.0	12.6	4.51**	2.93**
All sig. variables (TVE)		23.8		14.72**	2.56**

Table 15
Variation explained by each environmental variable subset from RDAs of cropped margins only. TVE = total variation explained by all significant variables. * $p < 0.05$, ** $p < 0.01$.

Subset	Significant variables	Variation explained (%)	% of TVE	Axis 1 (*F*)	Overall (*F*)
Management	Spring crop Fertiliser Wheat crop	7.3	29.6	6.26**	2.95**
Region	South West North West North East South East East	8.3	33.6	2.67*	1.99**
Physical/climatic	January precipitation January temperature July temperature July precipitation	7.5	30.4	3.11**	2.26**
Habitat context	Spring barley Adjacent grassland	4.8	19.4	3.91**	2.82**
Soil properties	pH	2.1	8.5		2.42**
All sig. variables (TVE)		24.7		8.35**	2.19**

Table 16
Variation explained by each environmental variable subset from RDAs of uncropped margins only. TVE = total variation explained by all significant variables. ** $p < 0.01$.

Subset	Significant variables	Variation explained (%)	% of TVE	Axis 1 (*F*)	Overall (*F*)
Management	Cultivation method Age Cultivation autumn Cultivation depth	10.3	31.8	3.54**	2.09**
Region	South East South West East North East	8.7	26.9	2.73**	1.74**
Physical/climatic	January precipitation Altitude July precipitation July temperature January temperature	10.2	31.5	2.31**	1.64**
Habitat context	Rare species pool Spring barley	5.3	16.4	2.89**	2.09**
Soil properties	pH P K	7.6	23.5	3.21**	2.03**
All sig. variables (TVE)		32.4		4.56**	1.57**

Table 17
The overall 'stock' of arable plants on different options in relation to region and soil pH. The numbers of core species are given in parentheses.

	Sites	Control		CH1		CH2		OS3		RAWM		Total	
		Spp.	Rare	Spp.	Rare	Spp.	Rare	Spp.	Rare	Spp.	Rare	Spp.	Rare
(a) Region													
E	35	44	2	31	1	68	10 (1)	80	10 (2)	118	13 (1)	157	21 (4)
SE	35	28	1	49	4 (1)	72	6 (1)	87	3 (1)	109	13 (2)	159	16 (5)
SW	35	44	2	54	5 (2)	84	7 (1)	75	5	106	12 (3)	148	15 (4)
EM	15	14	0	24	2	31	0	35	1	68	3	91	5
WM	15	27	0	34	0	49	1	38	0	51	2 (1)	99	3 (1)
YH	15	20	0	28	0	30	1	33	1	64	1	79	1
NW	15	10	0	26	0	39	1	33	0	55	2 (1)	80	3 (1)
NE	30	24	0	29	0	33	0	47	1	55	1	75	3
(b) Soil pH													
5.7-6.9	70	67	1	57	0	87	5 (1)	98	5	116	5 (1)	172	12 (2)
7-7.9	66	46	1	72	3	83	3	79	2	138	12 (3)	172	15 (3)
8-8.5	59	42	1	63	8 (3)	101	12 (2)	113	12 (3)	137	17 (4)	189	27 (9)
Total	195	90	3	103	10 (3)	149	18 (3)	164	16 (3)	211	25 (6)	264	34 (11)

Table 18
The predicted number of populations of rare arable plants on AE options based on the numbers recorded in this survey and overall uptake of individual options by region

	Rare species (including core)				Core species only			
	CH1	CH2	OS3	RAWM	CH1	CH2	OS3	RAWM
E	6	175	532	221	0	0	76	0
EM	20	0	98	9	0	0	0	0
NE	0	0	58	1	0	0	0	0
NW	0	14	0	2	0	0	0	1
SE	48	55	140	257	10	0	35	0
SW	51	89	243	309	0	9	0	21
WM	0	32	0	24	0	0	0	0
YH	0	19	105	11	0	0	0	0
Total	125	383	1175	833	10	9	111	22

Table 19
Correlations between the number of rare arable weeds and the area of agri-environment scheme arable options within 10 × 10 km grid squares in England

Option	E	SE	SW	EM	WM	YH	NW	NE	All
CH1	0.12ns	0.005ns	0.06ns	-0.11ns	-0.18ns	0.16ns	0.33ns	0.16ns	0.02ns
CH2	-0.13ns	0.05ns	0.07ns	-0.08ns	-1.23ns	0.19ns	-0.13ns	0.23ns	-0.10ns
OS3	**0.25****	-0.02ns	-0.08ns	-0.02ns	-0.15ns	0.16ns	0.14ns	-0.01ns	**-0.13*****
RAWM	**0.18****	0.13ns	**0.32****	-0.14ns	-0.13ns	0.29ns	-	-	**0.14***
Targeted options	0.05ns	0.07ns	0.10ns	-0.11ns	**-0.24***	0.15ns	0.29ns	0.16ns	-0.03ns

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$; ns = no significant differences. Targetted options = CH1, CH2, RAWM.

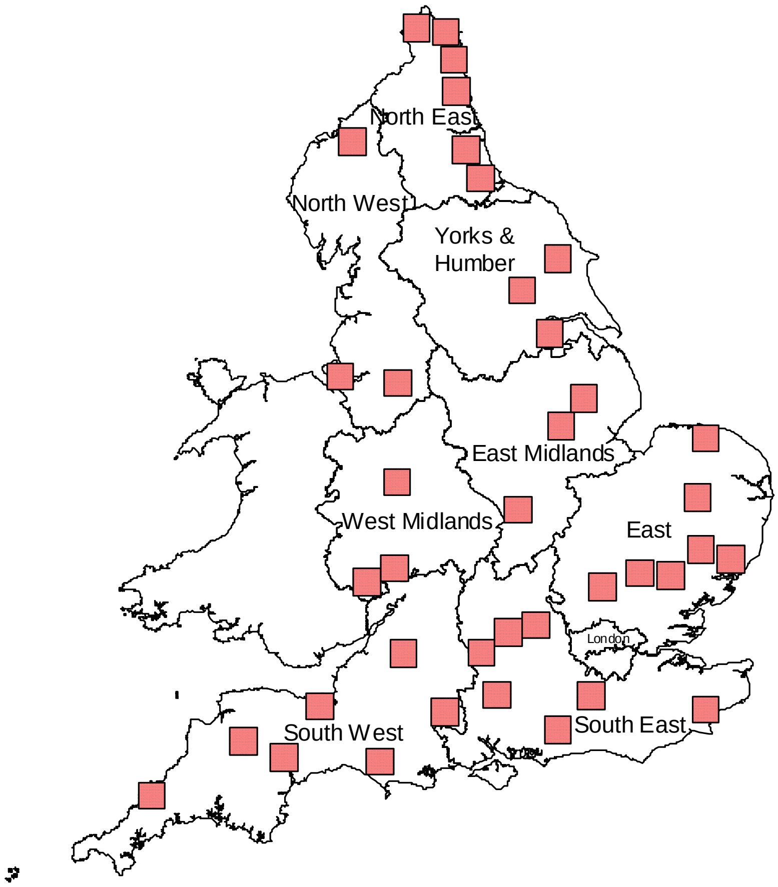


Figure 1 – Location of the 39 20 × 20 km sample squares

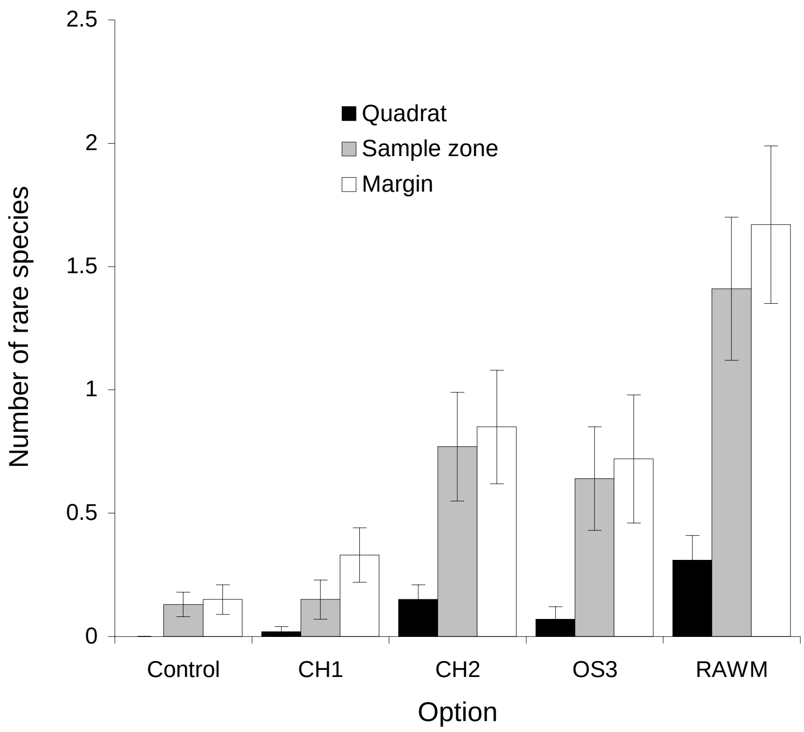


Figure 2 - The mean (± SE) number of rare arable species recorded per 0.5 × 0.5 m quadrat, 100 × 6 m sample zone and field margin within the field margin options.

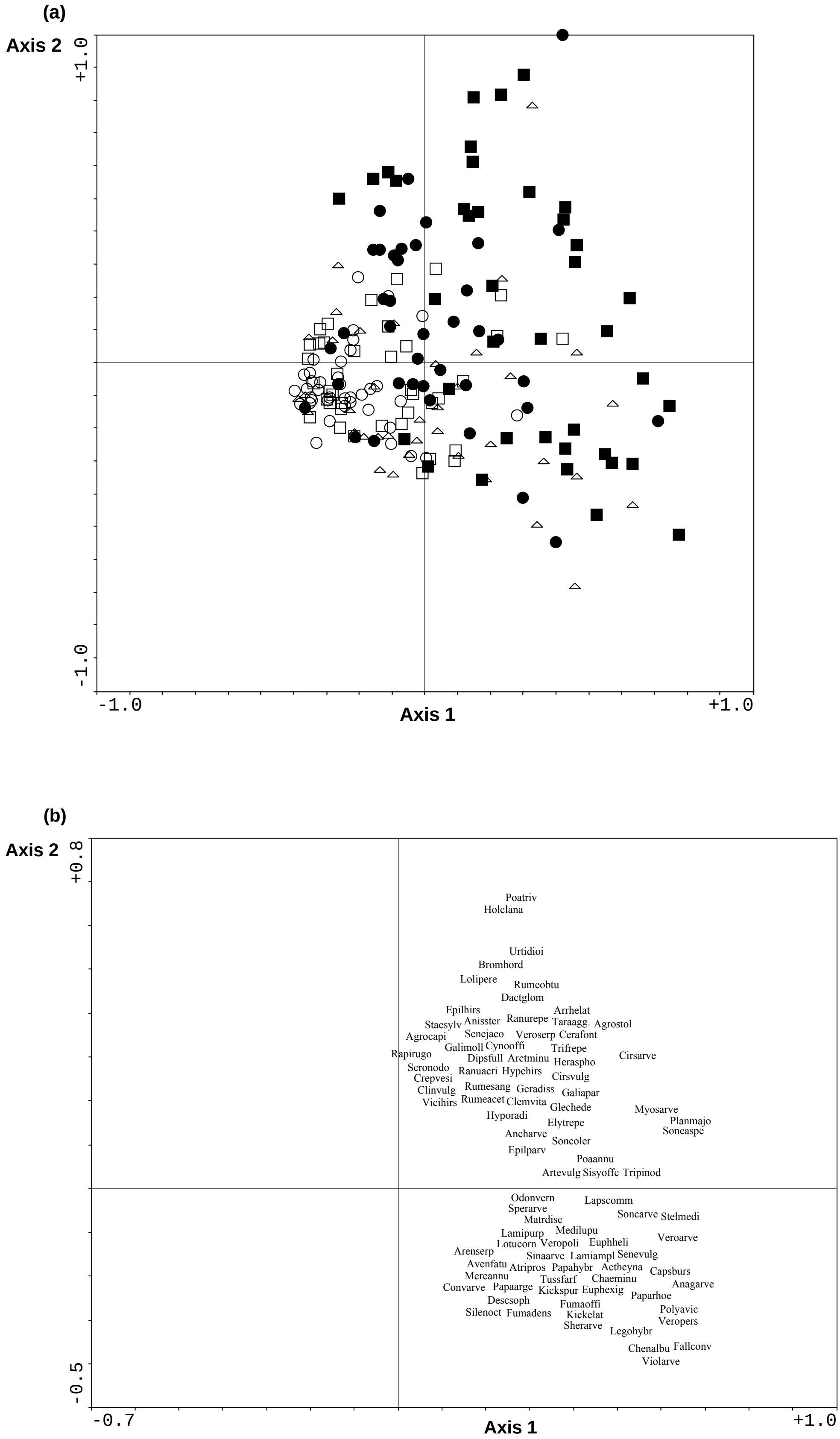
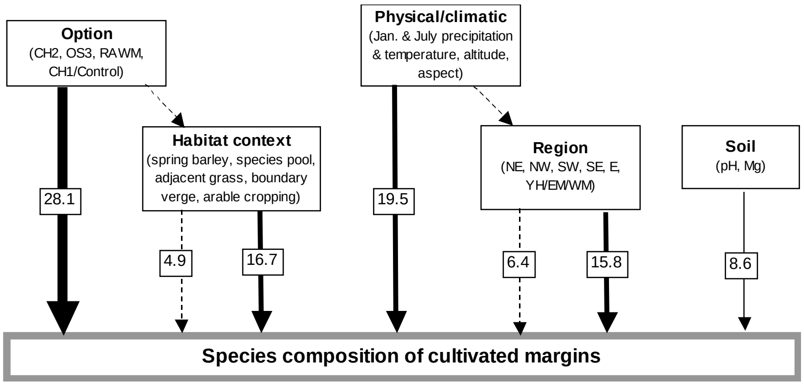
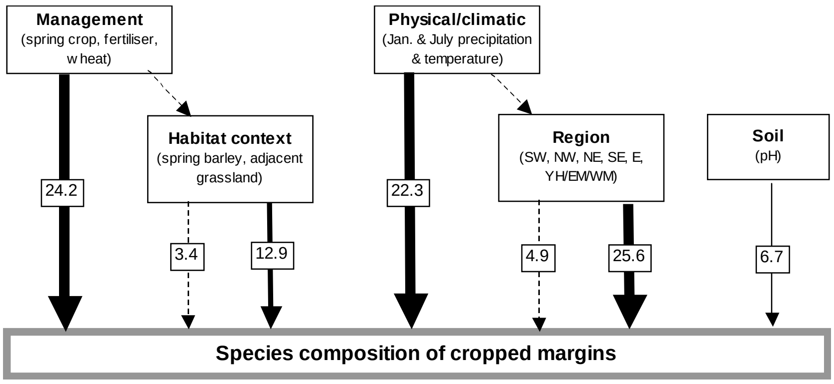


Figure 3 - Scatter plots of axes 1 and 2 from PCA ordination of all options. (a) sites: controls (empty circles), CH1 (open squares), CH2 (open triangles), OS3 (filled circles), RAWM (filled squares). (b) species: for clarity only those with fit ≥6 shown and arrows representing species' axes omitted; for species codes see Appendix 4.

(a)



(b)



(c)

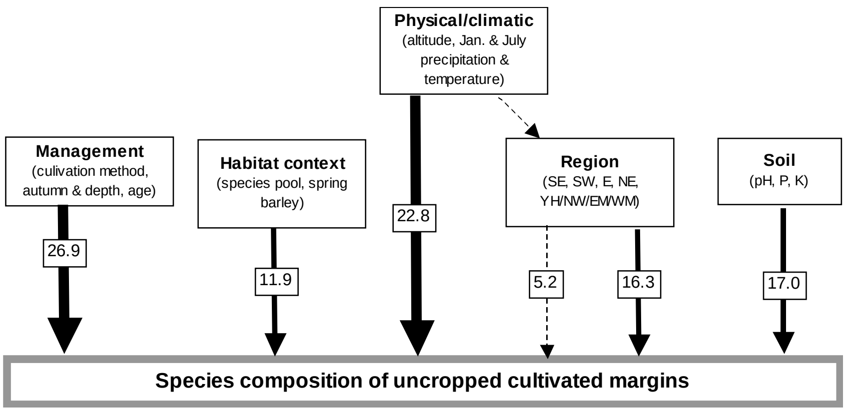


Figure 4 - Path model diagrams showing relative amounts of variation explained (% of TVE, arrow thickness corresponds approximately) by environmental variable groups and their intersections (dotted arrows). Option and region are all nominal variables and therefore shown. (a) all options (n = 195), (b) cropped options only (n = 117), (c) uncropped options only (n = 78).

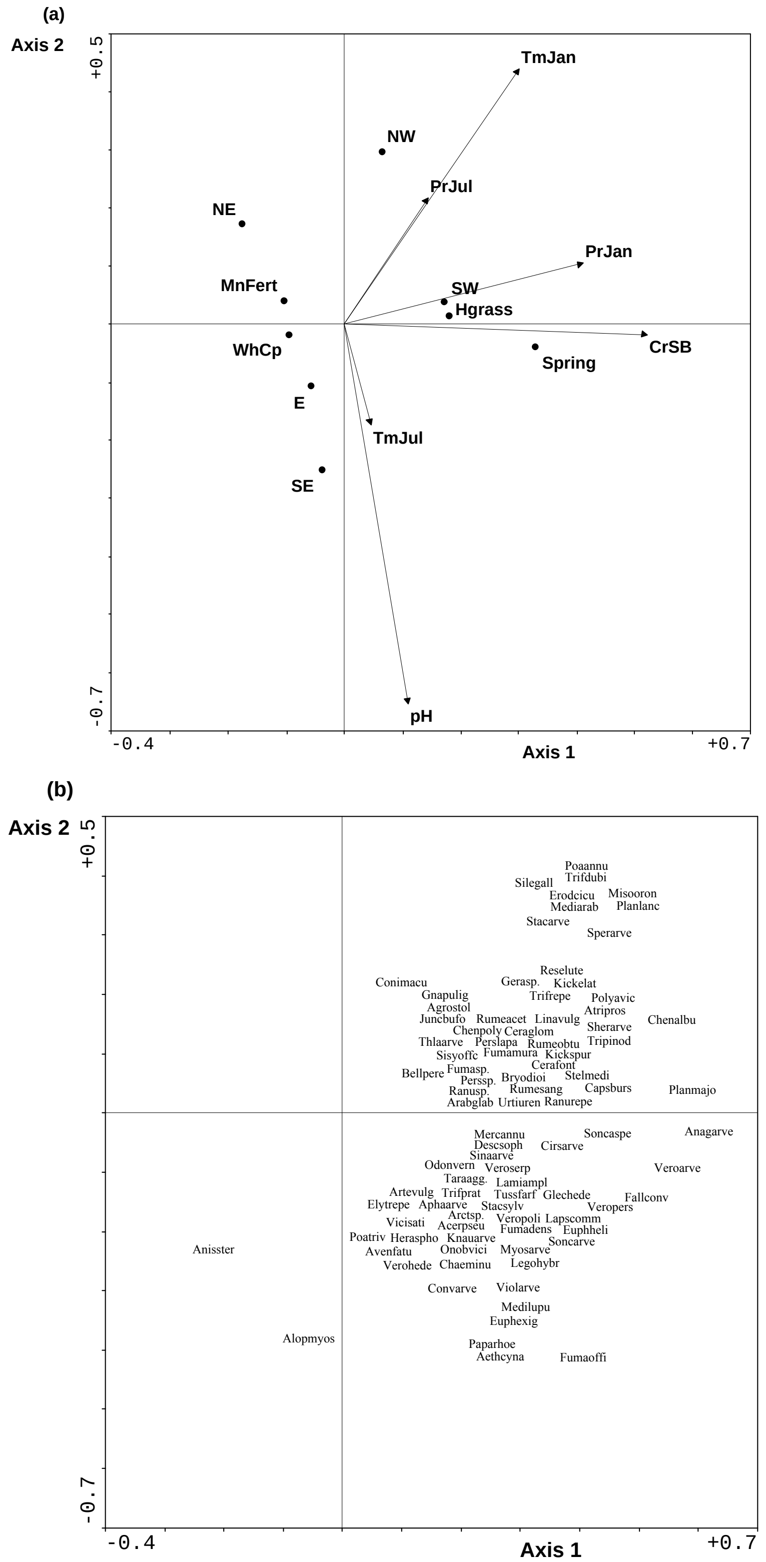


Figure 5 - Scatter plots of axes 1 and 2 from RDA of cropped margins. (a) environmental variables. Management – Mnfert = fertiliser, Spring = spring crop, WhCp = wheat crop; Regions - E = Eastern, NE = North Eastern, SE = South Eastern, SW = South Western; Physical/climatic – PrJan, PrJul = January, July precipitation; TmJan, TmJun = January, July precipitation; Habitat context – Hgrass = adjacent grassland, CrSB = spring barley cropping. (b) species: for clarity only those with fit ≥4 shown and arrows representing species' axes omitted; for species codes see Appendix 4.

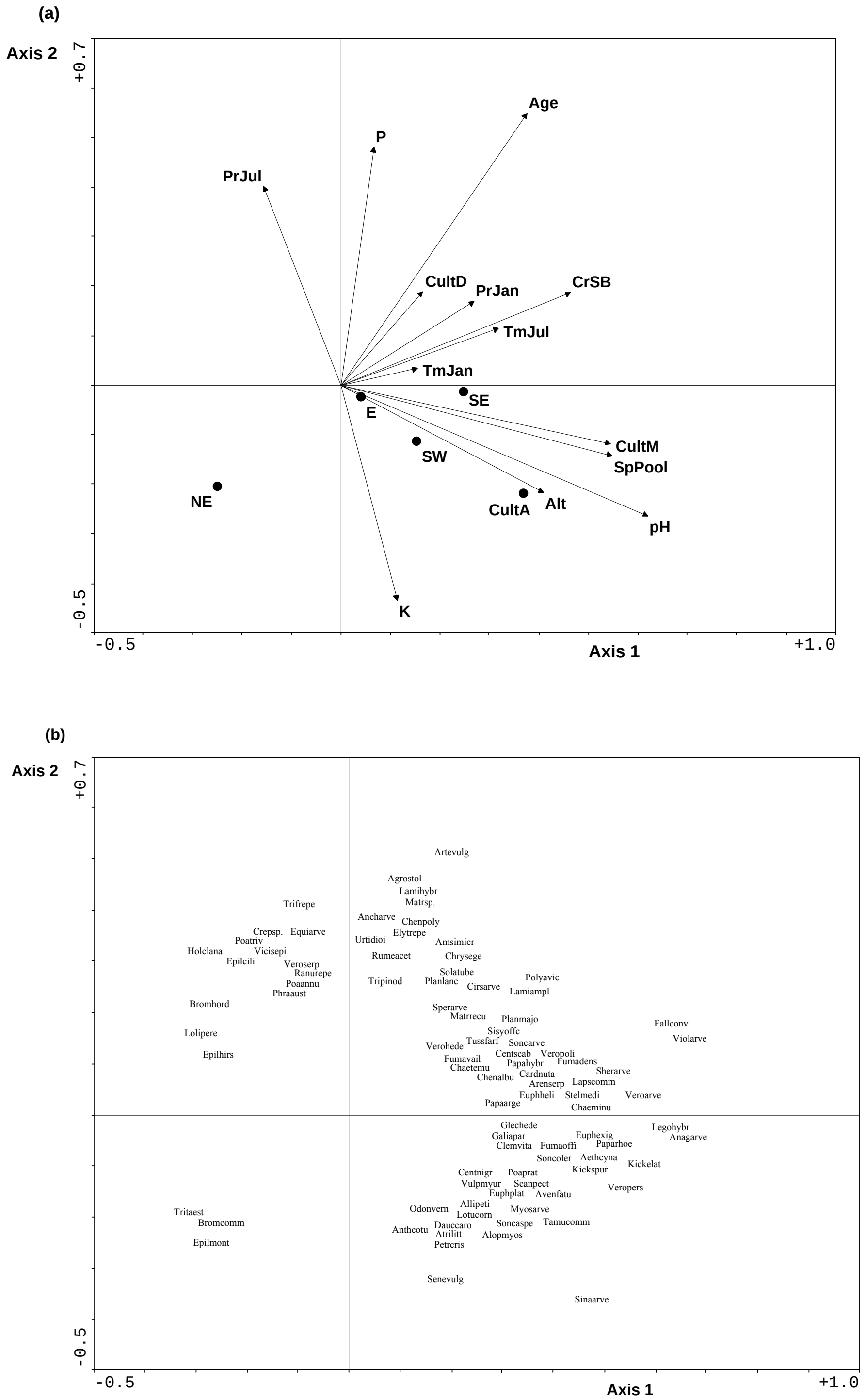


Figure 6 - Scatter plots of axes 1 and 2 from RDA of uncropped margins. (a) environmental variables. Codes as in Figure 5 plus: Management – CultA, CultD, CultM = cultivation autumn, depth, method; Physical/climatic – alt = altitude; Habitat context – SpPool = species pool. (b) species: for clarity only those with fit ≥6 shown and arrows representing species' axes omitted; for species codes see Appendix 4.

Appendix 1. Core and additional rare UK arable plants included in this study (n = 86). Species were classified as core or additional species based on one or more of the following criteria: core = UKBAP, SCC, IAPA score >8, England Change Index > -1.5, Old IUCN = CR; additional – IAPA score >3, English range size <1000 10-km grid squares post-1987. The old and new IUCN categories for all species are shown for comparison (Cheffings and Farrell, 2005).

	Native status	UKBAP	IAPA scores	Change Index	10-km 1987+	Old IUCN	New IUCN
CORE SPECIES (n = 41)							
Adonis annua	AR	SCC	8	-1.9	29	VU	EN
Agrostemma githago	AR		7	-0.6	227	EW	WL
Althaea hirsuta	AN		8			EN	
Ajuga chamaepitys	NA	SCC	8	-0.5	17	VU	EN
Alyssum alyssoides	AR	SCC	8	-0.9	9		
Anthemis arvensis	AR		8	-1.5	191		EN
Anthoxanthum aristatum	AN		9	-2.9	3		
Arnoseris minima	AR		9	-4.3	1	EX	EX
Bupleurum rotundifolium	AR		9	-3.8	13	EW	CR
Centaurea cyanus	AR	BAP	8	-0.3	329	EN	LC
Chenopodium urbicum	AR		9	-3.6	10		CR
Echium plantagineum	AR		8	0.4	28	EN	PL
Euphorbia platyphyllos	AR	SCC	3	-0.2	117		LC
Filago gallica	AR		9	0.3	5	CR	EW
Filago lutescens	NA	BAP	8	-0.2	22	VU	EN
Filago pyramidata	AR	BAP	8	-1.1	17	EN	EN
Fumaria occidentalis	NE	BAP	5	0.3	26		LC
Fumaria purpurea	N	BAP	4	-0.5	29		LC
Fumaria reuteri	AN	SCC	8	-0.7	4	EN	WL
Galeopsis angustifolia	AR	BAP	9	-2.8	89		CR
Galeopsis segetum	AR		9			EX	EX
Galium tricornutum	AR	BAP	9	-3.8	12	CR	CR
Gnaphalium luteoalbum	NA			0.7	10	CR	PL
Hypochaeris glabra	N	SCC	7	-0.9	102		VU
*Legousia speculum-veneris**	AN						
Lithospermum arvense	AR	SCC	8	-1.5	214		EN
Lolium temulentum	AR		9	-3.4	12		CR
Lythrum hyssopifolium	AR	SCC	8	-0.7	17	VU	EN
Melampyrum arvense	AN	SCC		-0.2	9		WL
Petroselinum segetum	N	SCC	3	0.0	292		LC
Ranunculus arvensis	AR	SCC	9	-3.1	163		CR
Scandix pecten-veneris	AR	BAP	9	-3.0	162		CR
Silene gallica	AR	BAP	8	-2.4	61		EN
Teucrium botrys	AN		7	-0.2	7	VU	PL
Thlaspi perfoliatum	N	BAP	7	-1.0	9	VU	VU
Torilis arvensis	AR	BAP	8	-2.1	78		EN
Valerianella dentata	AR	SCC	8	-1.5	160		EN
Valerianella rimosa	AR	BAP	8	-2.1	20	CR	EN
Veronica praecox	AN		8				
Veronica triphyllos	AR	SCC	8	-1.1	3	EN	EN
Veronica verna	N		8			VU	EN

Appendix 1. Continued.

	Native status	UKBAP	Old IUCN	New IUCN	IAPA scores	10-km 1987+	Change Index
ADDITIONAL SPECIES (*n* = 45)							
Anthemis cotula	AR			VU	7	519	-1.5
Anthriscus caucalis	N			LC	3	353	-0.2
Apera interrupta	AN				4	62	1.0
Apera spica-venti	AR			NT	6	141	-0.1
Avena strigosa	AN				5		
Briza minor	AR			LC	5	45	0.3
Bromus arvensis	AN				6		
Bromus secalinus	AR			VU	7	91	-0.8
Bunium bulbocastanum	N			NT	6	12	0.3
Chenopodium murale	AR			VU	7	109	-1.3
Chrysanthemum segetum	AR			VU	7	591	-0.8
Descurainia sophia	AR			LC	3	250	-0.3
Euphorbia exigua	AR			NT	6	585	-1.2
Filago vulgaris	N			NT	6		
Fumaria densiflora	AR			LC	3	115	-0.5
Fumaria parviflora	AR			VU	7	47	-0.5
Fumaria vaillantii	AR			VU	7	49	-0.5
Galeopsis speciosa	AR			VU	7	194	-1.3
Galium spurium	AN				6	3	-2.0
Gastridium ventricosum	NA			LC	5	30	-0.4
Hyoscyamus niger	AR			VU	7	246	-1.2
Iberis amara	N			VU	7		
Kickxia spuria	AR			LC	3	436	-0.2
Lamium confertum	AR			LC	3	10	0.0
Lathyrus aphaca	NA			VU	7	92	-1.1
Lavatera cretica	AN		VU	WL	7	11	0.8
Legousia hybrida	AR			LC	3	295	-0.6
Lepidium campestre	AR			LC	3	405	-0.7
Misopates orontium	AR			VU	7	195	-0.8
Myosurus minimus	NA			VU	7	117	-0.5
Nepeta cataria	AR			VU	7		
Papaver argemone	AR			VU	7	315	-1.5
Papaver hybridum	AR			LC	3	156	-0.3
Polycarpon tetraphyllum	NA			LC	5	16	0.4
Polygonum boreale	N			LC	4		
Polygonum rurivagum	AR			LC	3		
Ranunculus muricatus	AN				6		
Ranunculus parviflorus	N			LC	3		
Scleranthus annuus	N			EN	8	216	-2.3
Silene noctiflora	AR			VU	7	236	-1.7
Spergula arvensis	N			VU	7	955	-2.0
Stachys arvensis	AR			NT	6	575	-1.0
Torilis nodosa	N			LC	3		
Vicia parviflora	N			VU	7	54	-0.8
Viola tricolor	N			NT	6	584	-1.1

*Currently known from only one site in Hampshire (Wilson and King 2003) and therefore included as a core species. Codes are as follows. Native status follows Preston et al. (2002): AR = archaeophyte; AN = neophyte; NA = native or alien; N = native; NE = native endemic. SCC = Species of Conservation Concern; BAP = UKBAP priority species. IAPA scores follow Byfield and Wilson (2005) and range from 3-9 with higher scores indicating greater conservation priority. 10-km 1987+ are the number of 10-km squares in which the species has been recorded in England since 1987 regardless of status. Change Index (CI) is the regional CI for England. Old IUCN: EX = extinct; EW = extinct in the wild; CR = critically endangered; EN = endangered; VU = vulnerable. Additional codes for New IUCN: NT = near threatened; LC = least concern; PL = parking list; WL = waiting list.

Appendix 2. The proportion of sites and quadrats species were recorded in during this survey. Species present in more than 40% of sites (>15, n = 39) and 10% of quadrats (>117, n = 1170) are highlighted in bold.

	Sites (%)						Within-site frequency (%)					
	C	CH1	CH2	OS3	RAWM	Total	C	CH1	CH2	OS3	RAWM	Total
Acer pseudoplatanus			0.4			0.1			10.3			2.1
Achillea millefolium	0.1		0.3	0.3	0.6	0.2	2.6		2.6	2.6	7.7	3.1
Aegopodium podagraria		0.1				0.0		2.6				0.5
Aethusa cynapium	0.9	1.2	5.6	0.9	3.4	2.4	5.1	5.1	23.1	5.1	12.8	10.3
Agrostis capillaris					0.9	0.2					7.7	1.5
Agrostis gigantea		0.3		0.3		0.1		2.6		7.7		2.1
Agrostis stolonifera	3.3	2.9	8.6	**10.4**	**19.8**	9.0	20.5	20.5	25.6	35.9	**66.7**	33.8
Alliaria petiolata					0.3	0.1					5.1	1.0
Alopecurus geniculatus		0.5	0.3	1.6	0.2	0.5		2.6	2.6	7.7	5.1	3.6
Alopecurus myosuroides	**10.6**	**10.9**	**11.4**	**12.5**	**11.5**	**11.4**	30.8	30.8	28.2	33.3	30.8	30.8
Amsinckia micrantha				0.8	1.0	0.4				2.6	2.6	1.0
Anagallis arvensis	0.7	1.5	**14.3**	7.9	**18.7**	8.6	12.8	20.5	33.3	38.5	**43.6**	29.7
Anchusa arvensis				0.8	2.0	0.5				5.1	15.4	4.1
Angelica sylvestris				0.1		0.0				2.6		0.5
Anisantha diandra	2.8		0.2		0.3	0.6	5.1		5.1		2.6	2.6
Anisantha sterilis	5.9	5.7	5.4	**27.7**	**25.1**	**14.0**	**43.6**	25.6	33.3	**53.8**	**48.7**	**41.0**
Anthemis cotula			1.3		0.2	0.3			2.6		2.6	1.0
Anthriscus caucalis				0.1	0.3	0.1				2.6	2.6	1.0
Anthriscus sylvestris	0.8	0.1	0.3	0.5	0.7	0.5	5.1	2.6	2.6	5.1	10.3	5.1
Apera spica-venti			0.3		1.5	0.4			2.6		2.6	1.0
Aphanes arvensis	0.1	3.3	4.5	0.5	3.3	2.4	2.6	12.8	23.1	7.7	20.5	13.3
Arabidopsis thaliana					0.5	0.1					5.1	1.0
Arabis glabra			0.1			0.0			2.6			0.5
Arctium lappa					0.9	0.2					2.6	0.5
Arctium minus	0.1	0.3	0.2	0.4	0.9	0.4	2.6	5.1	5.1	7.7	12.8	6.7
Arenaria serpyllifolia	0.1	0.5	0.3	0.7	1.0	0.5	2.6	2.6	2.6	5.1	5.1	3.6
Arrhenatherum elatius	0.2	0.4	0.5	4.0	**10.5**	3.1	5.1	5.1	7.7	20.5	**64.1**	20.5
Artemisia vulgaris		1.3	3.2	2.0	9.9	3.3		2.6	7.7	7.7	23.1	8.2
Atriplex littoralis					0.2	0.0					2.6	0.5
Atriplex patula	0.2	0.7	0.7	0.1	0.2	0.4	5.1	5.1	7.7	2.6	5.1	5.1
Atriplex prostrata	0.1	0.4	3.1	0.7	3.0	1.5	2.6	2.6	10.3	2.6	5.1	4.6
Avena fatua	0.6	2.1	1.5	1.7	4.8	2.1	7.7	20.5	12.8	15.4	23.1	15.9
Avena sativa	0.3		0.2	0.1	0.7	0.2	2.6		2.6	2.6	7.7	3.1
Barbarea vulgaris					0.6	0.1					2.6	0.5
Bellis perennis			0.3			0.1			2.6			0.5
Beta vulgaris		0.2			0.2	0.1		2.6			2.6	1.0
Brassica napus	0.2			0.5	1.5	0.4	2.6			2.6	5.1	2.1
Brassica nigra					0.1	0.0					2.6	0.5
Brassica oleracea					0.2	0.0					2.6	0.5
Bromus commutatus	0.2			6.2		1.3	2.6			10.3		2.6
Bromus hordeaceus	0.3	0.9	1.5	**14.2**	**11.5**	5.7	5.1	10.3	10.3	**43.6**	**41.0**	22.1
Bromus racemosus				0.8		0.2				2.6		0.5
Bromus secalinus				0.7		0.1				2.6		0.5
Bryonia dioica			0.1			0.0			2.6			0.5
Calystegia sepium			0.3	2.0	0.7	0.6			2.6	2.6	2.6	1.5
Capsella bursa-pastoris	0.1	2.1	5.0	4.4	9.7	4.3	2.6	7.7	30.8	28.2	**46.2**	23.1
Cardamine flexuosa				0.2		0.0				2.6		0.5
Cardamine hirsuta					0.1	0.0					2.6	0.5
Carduus crispus				0.3	0.4	0.1				5.1	5.1	2.1
Carduus nutans				0.1	0.6	0.1				2.6	5.1	1.5

Appendix 2. Continued

	Sites (%)						Within-site frequency (%)					
	C	CH1	CH2	OS3	RAWM	Total	C	CH1	CH2	OS3	RAWM	Total
Centaurea nigra			0.2		0.1	0.1			5.1		2.6	1.5
Centaurea scabiosa					0.2	0.0					2.6	0.5
Cerastium fontanum	0.1	0.3	1.7	0.7	3.3	1.2	2.6	5.1	12.8	10.3	23.1	10.8
Cerastium glomeratum		2.0	0.2	0.1	0.2	0.5		7.7	2.6	2.6	5.1	3.6
Cerastium semidecandrum				0.6		0.1				5.1		1.0
Chaenorhinum minus			1.0		4.7	1.1			5.1		10.3	3.1
Chaerophyllum temulum				0.3	0.6	0.2				5.1	5.1	2.1
Chamerion angustifolium				0.3	0.6	0.2				7.7	2.6	2.1
Chenopodium album	2.6	1.0	8.0	**12.8**	**13.2**	7.5	15.4	20.5	35.9	38.5	**48.7**	31.8
Chenopodium ficifolium	0.3		0.6		0.3	0.2	2.6		7.7		5.1	3.1
Chenopodium polyspermum		0.3			2.0	0.5		2.6			5.1	1.5
Chenopodium rubrum	0.9		0.1		0.2	0.2	2.6		2.6		2.6	1.5
Chrysanthemum segetum			0.1		6.1	1.2			2.6		7.7	2.1
Cirsium arvense	1.4	3.3	6.8	8.4	**23.5**	8.7	23.1	33.3	**43.6**	**41.0**	**74.4**	**43.1**
Cirsium vulgare	0.3	1.5	0.7	4.3	3.3	2.0	7.7	17.9	7.7	25.6	**43.6**	20.5
Clematis vitalba				0.6	0.6	0.2				5.1	5.1	2.1
Clinopodium vulgare				0.1		0.0				2.6		0.5
Conium maculatum	0.6			0.3	1.4	0.5	5.1			2.6	7.7	3.1
Convolvulus arvensis	1.1	0.9	6.9	2.4	3.7	3.0	15.4	5.1	25.6	10.3	28.2	16.9
Coronopus squamatus	0.3		0.1	0.4	0.4	0.3	5.1		2.6	2.6	2.6	2.6
Crataegus monogyna		0.1		0.2	0.5	0.2		2.6		5.1	5.1	2.6
Crepis biennis				0.1		0.0				2.6		0.5
Crepis capillaris				0.3	1.2	0.3				5.1	5.1	2.1
Crepis vesicaria				1.5	0.3	0.3				5.1	2.6	1.5
Cruciata laevipes					0.1	0.0					2.6	0.5
Cynoglossum officinale				0.2		0.0				2.6		0.5
Cynosurus cristatus			0.3	0.2	2.5	0.6			5.1	5.1	7.7	3.6
Dactylis glomerata	0.5	0.9	0.2	5.2	7.5	2.9	7.7	10.3	5.1	30.8	30.8	16.9
Daucus carota	0.2	1.3	1.5		0.2	0.6	2.6	5.1	10.3		2.6	4.1
Descurainia sophia			0.1	2.0	0.1	0.4			2.6	2.6	2.6	1.5
Digitalis purpurea					0.1	0.0					2.6	0.5
Diplotaxis muralis				0.1		0.0				2.6		0.5
Dipsacus fullonum				0.6		0.1				2.6		0.5
Elytrigia repens	2.2	1.1	5.6	4.7	**16.9**	6.1	17.9	15.4	30.8	35.9	51.3	30.3
Epilobium ciliatum			0.9	4.0	1.1	1.2			2.6	20.5	7.7	6.2
Epilobium hirsutum	0.5	0.1	0.2	1.5	3.2	1.1	2.6	2.6	5.1	25.6	20.5	11.3
Epilobium lanceolatum				0.1	0.2	0.1				2.6	2.6	1.0
Epilobium montanum		0.3	0.2	3.6	0.6	0.9		2.6	5.1	17.9	7.7	6.7
Epilobium parviflorum		0.2	2.5	4.7	1.3	1.7		5.1	10.3	23.1	7.7	9.2
Epilobium tetragonum	0.2		0.4	3.2	2.8	1.3	2.6		2.6	15.4	10.3	6.2
Equisetum arvense	0.7	0.9	0.7	1.0	2.1	1.1	7.7	5.1	5.1	5.1	17.9	8.2
Equisetum sylvaticum					0.3	0.1					2.6	0.5
Erodium cicutarium			0.1		0.1	0.0			2.6		2.6	1.0
Erophila verna					0.1	0.0					2.6	0.5
Euphorbia exigua	0.1		3.5	0.2	5.7	1.9	2.6		10.3	5.1	12.8	6.2
Euphorbia helioscopia		0.2	1.2		0.9	0.4		2.6	12.8		12.8	5.6
Euphorbia platyphyllos					2.0	0.4					2.6	0.5
Fagopyrum esculentum					0.6	0.1					2.6	0.5
Fallopia convolvulus	1.7	0.6	**10.5**	0.9	**13.0**	5.4	10.3	5.1	**41.0**	15.4	35.9	21.5
Festuca arundinacea				0.1	0.1	0.0				2.6	2.6	1.0
Festuca pratensis					0.9	0.2					5.1	1.0

Appendix 2. Continued

	Sites (%)						Within-site frequency (%)					
	C	CH1	CH2	OS3	RAWM	Total	C	CH1	CH2	OS3	RAWM	Total
Festuca rubra		0.3	0.7	1.0	4.4	1.3		2.6	15.4	7.7	25.6	10.3
Filago vulgaris				1.9	0.9	0.6				5.1	5.1	2.1
Fraxinus excelsior	0.2	2.0	0.2	5.0	0.7	1.6	5.1	7.7	5.1	25.6	12.8	11.3
Fumaria densiflora			0.3		0.2	0.1			7.7		2.6	2.1
Fumaria muralis			3.7	0.9	0.2	0.9			5.2	7.7	5.2	3.6
Fumaria officinalis	0.1	0.3	6.0	0.3	1.8	1.7	2.6	7.7	17.9	2.6	17.9	9.7
Fumaria purpurea					0.1	0.0					2.6	0.5
Fumaria vaillantii					0.2	0.0					2.6	0.5
Galeopsis tetrahit		0.3	0.1	0.2	0.1	0.1		2.6	2.6	2.6	2.6	2.1
Galium aparine	7.7	7.9	6.3	9.3	**17.3**	9.7	**46.2**	**51.3**	38.5	**46.2**	**61.5**	**48.7**
Galium mollugo				0.3		0.1				5.1		1.0
Geranium dissectum	1.3	5.4	1.6	3.0	**10.0**	4.3	15.4	20.5	15.4	20.5	35.9	21.5
Geranium molle	0.3		0.5		1.0	0.4	2.6		10.3		10.3	4.6
Geranium pusillum	0.2			0.3	0.3	0.1	2.6			2.6	5.1	2.1
Geranium robertianum				0.1	0.9	0.2				2.6	5.1	1.5
Geum urbanum				0.4		0.1				2.6		0.5
Glechoma hederacea			0.3		0.5	0.2			5.1		7.7	2.6
Glyceria fluitans			0.1			0.0			2.6			0.5
Gnaphalium uliginosum	0.1	0.3	0.1		0.1	0.1	2.6	5.1	2.6		2.6	2.6
Hedera helix				0.6	0.1	0.1				5.1	2.6	1.5
Heracleum sphondylium	0.7	0.1	0.7	1.4	2.3	1.0	12.8	2.6	12.8	15.4	33.3	15.4
Holcus lanatus	0.1	0.4	1.8	0.7	**13.2**	3.2	2.6	5.1	10.3	15.4	38.5	14.4
Holcus mollis		2.4	0.3	0.4	2.2	1.1		2.6	2.6	2.6	10.3	3.6
Hordeum vulgare	3.0	0.9	1.2		1.5	1.3	7.7	7.7	7.7		7.7	6.2
Hypericum hirsutum				0.1		0.0				2.6		0.5
Hypericum humifusum			0.1	0.1		0.0			2.6	2.6		1.0
Hypericum perforatum					0.1	0.0					2.6	0.5
Hypochaeris glabra				0.3		0.1				5.1		1.0
Hypochaeris radicata					0.3	0.1					7.7	1.5
Juncus bufonius	0.2	0.2	0.6	2.0	0.1	0.6	2.6	5.1	7.7	5.1	2.6	4.6
Kickxia elatine	0.3	0.1	2.1	0.3	3.1	1.2	2.6	2.6	7.7	5.1	17.9	7.2
Kickxia spuria		0.2	0.6	0.3	3.0	0.8		2.6	5.1	2.6	12.8	4.6
Knautia arvensis			0.1			0.0			2.6			0.5
Lactuca serriola				0.2	0.9	0.2				5.1	5.1	2.1
Lactuca virosa				0.1		0.0				2.6		0.5
Lamium album					1.0	0.2					7.7	1.5
Lamium amplexicaule			0.5	0.1	2.1	0.5			5.1	2.6	10.3	3.6
Lamium hybridum					0.3	0.1					5.1	1.0
Lamium purpureum	0.3	1.3	0.7	0.2	1.3	0.7	5.1	5.1	10.3	2.6	12.8	7.2
Lapsana communis	0.3	0.3	1.4	1.1	5.6	1.7	2.6	5.1	12.8	15.4	35.9	14.4
Legousia hybrida		0.1	1.4	1.5	4.8	1.5		2.6	7.7	5.1	15.4	6.2
Linaria vulgaris			0.3			0.1			5.1			1.0
Linum perenne			1.0			0.2			2.6			0.5
Linum usitatissimum			0.3	0.1		0.1			2.6	2.6		1.0
Lithospermum arvense				0.2		0.0				2.6		0.5
Lolium multiflorum	0.5	1.2	0.5	2.0	3.9	1.6	5.1	10.3	5.1	7.7	12.8	8.2
Lolium perenne	0.9	6.9	6.6	8.7	5.6	5.7	12.8	30.8	23.1	35.9	38.5	28.2
Lotus corniculatus				0.3	0.1	0.1				2.6	2.6	1.0
Malva sylvestris				0.1	0.2	0.1				2.6	2.6	1.0
Matricaria discoidea	1.8	1.8	2.8	2.9	9.5	3.8	10.3	7.7	20.5	25.6	25.6	17.9
Matricaria recutita	0.1	0.9	1.5	0.2	5.1	1.6	2.6	7.7	12.8	2.6	10.3	7.2

Appendix 2. Continued

	Sites (%)						Within-site frequency (%)					
	C	CH1	CH2	OS3	RAWM	Total	C	CH1	CH2	OS3	RAWM	Total
Medicago arabica			0.1			0.0			2.6			0.5
Medicago lupulina			1.0	0.6	0.1	0.3			7.7	7.7	2.6	3.6
Mercurialis annua			0.1		0.2	0.1			2.6		2.6	1.0
Misopates orontium			0.2			0.0			2.6			0.5
Myosotis arvensis	0.3	1.0	4.8	5.0	**10.7**	4.3	7.7	15.4	23.1	30.8	**53.8**	26.2
Odontites vernus			0.3	0.3	0.4	0.2			7.7	5.1	2.6	3.1
Oenanthe crocata					0.1	0.0					2.6	0.5
Onobrychis vicilifolia			2.6			0.5			2.6			0.5
Papaver argemone			0.9		0.3	0.2			2.6		5.1	1.5
Papaver dubium				0.3	1.7	0.4				5.1	2.6	1.5
Papaver dubium ssp. *lecoqii*				0.1		0.0				2.6		0.5
Papaver hybridum			0.1		0.2	0.1			2.6		2.6	1.0
Papaver rhoeas	1.0	7.8	**15.2**	6.8	**19.0**	**10.0**	5.1	20.5	33.3	23.1	33.3	23.1
Pastinaca sativa					0.9	0.2					2.6	0.5
Persicaria hydropiper				0.1	0.1	0.0				2.6	2.6	1.0
Persicaria lapathifolia	2.0	0.4	1.3	2.2		1.2	2.6	5.1	2.6	7.7		3.6
Persicaria maculosa	0.9	0.1	3.2	1.5	1.7	1.5	5.1	2.6	15.4	20.5	17.9	12.3
Petroselinum crispum					0.2	0.0					2.6	0.5
Petroselinum segetum		0.1				0.0		2.6				0.5
Phleum bertolonii					0.2	0.0					5.1	1.0
Phleum pratense		2.6	0.3	4.5	2.6	2.0		7.7	5.1	20.5	10.3	8.7
Phragmites australis					0.3	0.1					2.6	0.5
Picris echioides		0.1			0.3	0.1		2.6			5.1	1.5
Plantago lanceolata			0.2	0.2	0.4	0.2			2.6	5.1	10.3	3.6
Plantago major	2.4	0.9	3.8	3.5	7.9	3.7	2.6	12.8	25.6	28.2	**51.3**	24.1
Poa annua	**25.6**	**38.0**	**34.8**	**51.3**	**33.4**	**36.6**	**56.4**	**69.2**	**76.9**	**82.1**	**71.8**	**71.3**
Poa pratensis	1.3	3.1	1.3		2.7	1.7	2.6	7.7	2.6		10.3	4.6
Poa trivialis	4.6	**16.2**	**10.6**	**17.0**	**28.7**	**15.4**	25.6	**48.7**	**43.6**	**53.8**	**71.8**	**48.7**
Polygonum aviculare	8.4	9.0	**22.1**	5.0	**26.8**	**14.2**	35.9	38.5	**59.0**	**43.6**	**64.1**	**48.2**
Potentilla reptans					0.3	0.1					2.6	0.5
Prunella vulgaris					0.3	0.1					2.6	0.5
Prunus spinosa					0.4	0.1					5.1	1.0
Pteridium aquilinum					0.6	0.1					2.6	0.5
Quercus robur			0.2	0.1		0.1			2.6	2.6		1.0
Ranunculus acris	0.1		0.3	0.1	0.2	0.1	2.6		2.6	2.6	5.1	2.6
Ranunculus ficaria					0.1	0.0					2.6	0.5
Ranunculus repens	0.1	0.4	1.6	2.4	5.1	1.9	2.6	10.3	17.9	10.3	28.2	13.8
Ranunculus sardous		0.1				0.0		2.6				0.5
Raphanus raphanistrum	0.5		4.3	1.9	2.8	1.9	5.1		5.1	5.1	7.7	4.6
Raphanus sativus					0.3	0.1					2.6	0.5
Rapistrum rugosum				0.1		0.0				2.6		0.5
Reseda lutea			0.1		1.3	0.3			2.6		2.6	1.0
Reseda luteola			0.4	0.2	0.1	0.1			2.6	2.6	2.6	1.5
Rosa arvensis	0.1				0.1	0.0	2.6				2.6	1.0
Rubus fruticosus	0.2	0.1		0.2	1.1	0.3	2.6	2.6		5.1	10.3	4.1
Rumex acetosa				0.1	0.2	0.1				2.6	2.6	1.0
Rumex acetosella		0.1			0.3	0.1		2.6			2.6	1.0
Rumex conglomeratus				0.2		0.0				2.6		0.5
Rumex crispus	0.3			0.2	1.7	0.4	5.1			2.6	20.5	5.6
Rumex obtusifolius	1.5	1.2	1.9	2.4	6.4	2.7	5.1	10.3	10.3	20.5	25.6	14.4
Rumex sanguineus			0.1	0.2	0.9	0.2			2.6	2.6	5.1	2.1

Appendix 2. Continued

	Sites (%)						Within-site frequency (%)					
	C	CH1	CH2	OS3	RAWM	Total	C	CH1	CH2	OS3	RAWM	Total
Sagina procumbens				0.6		0.1				7.7		1.5
Scandix pecten-veneris					2.4	0.5					2.6	0.5
Scrophularia nodosa					0.3	0.1					5.1	1.0
Senecio erucifolius				0.3		0.1				5.1		1.0
Senecio jacobaea			0.1	2.1	0.7	0.6			2.6	10.3	12.8	5.1
Senecio vulgaris	4.1	1.5	4.9	**26.1**	**14.1**	**10.1**	23.1	23.1	25.6	**71.8**	**56.4**	**40.0**
Sherardia arvensis	0.4	1.1	4.1	0.1	3.5	1.8	2.6	7.7	7.7	2.6	15.4	7.2
Silene dioica		0.4				0.1		2.6				0.5
Silene gallica			2.4			0.5			2.6			0.5
Silene latifolia				0.7	1.0	0.3				5.1	10.3	3.1
Silene noctiflora		2.0	0.5	0.4	0.3	0.6		2.6	2.6	2.6	2.6	2.1
Silene vulgaris			1.6			0.3			2.6			0.5
Silene × hampeana					0.1	0.0					2.6	0.5
Sinapis alba		0.1	0.1		0.3	0.1		2.6	2.6		2.6	1.5
Sinapis arvensis	0.5	0.2	5.7	2.5	**10.0**	3.8	5.1	2.6	17.9	12.8	33.3	14.4
Sison amomum	0.1					0.0	2.6					0.5
Sisymbrium officinale	1.0	2.3	1.1	1.3	6.4	2.4	2.6	17.9	10.3	10.3	28.2	13.8
Solanum nigrum			0.2	0.1		0.1			2.6	2.6		1.0
Solanum tuberosum	0.3	0.2		0.1	0.3	0.2	2.6	2.6		2.6	5.1	2.6
Solidago canadensis				2.9		0.6				5.1		1.0
Sonchus arvensis	0.3	0.1	2.6	1.1	6.1	2.0	2.6	2.6	12.8	7.7	25.6	10.3
Sonchus asper	3.3	1.5	6.1	**19.9**	**20.5**	**10.3**	15.4	12.8	30.8	**69.2**	**71.8**	**40.0**
Sonchus oleraceus	2.2	0.4	2.0	1.2	4.7	2.1	2.6	5.1	5.1	12.8	30.8	11.3
Spergula arvensis			4.0		3.0	1.4			7.7		15.4	4.6
Stachys arvensis			0.3	0.1	0.2	0.1			5.1	2.6	2.6	2.1
Stachys palustris					0.1	0.0					2.6	0.5
Stachys sylvatica			0.1	0.1	1.1	0.3			2.6	2.6	12.8	3.6
Stellaria graminea					0.1	0.0					2.6	0.5
Stellaria media	2.3	**13.3**	**11.8**	3.8	**20.3**	**10.3**	15.4	**41.0**	33.3	23.1	**66.7**	35.9
Tamus communis					0.3	0.1					5.1	1.0
Taraxacum officinale agg.	0.3	0.6	1.3	2.6	7.2	2.4	5.1	5.1	15.4	23.1	30.8	15.9
Thlaspi arvense		0.1		0.5	0.3	0.2		2.6		5.1	2.6	2.1
Torilis japonica	0.4	0.1				0.1	2.6	2.6				1.0
Trifolium campestre					0.3	0.1					2.6	0.5
Trifolium dubium		0.1	0.3		0.6	0.2		2.6	5.1		5.1	2.6
Trifolium pratense			1.4	0.1		0.3			7.7	2.6		2.1
Trifolium repens	1.2	0.7	4.4	1.6	6.7	2.9	5.1	15.4	20.5	15.4	**41.0**	19.5
Tripleurospermum inodorum	3.8	9.1	9.5	**13.6**	**17.0**	**10.6**	7.7	25.6	33.3	**46.2**	**51.3**	32.8
Trisetum flavescens					0.1	0.0					2.6	0.5
Triticum aestivum	2.5		2.6	0.2	2.7	1.6	12.8		5.1	2.6	30.8	10.3
Tussilago farfara			0.3		1.4	0.3			5.1		7.7	2.6
Urtica dioica		0.5	0.9	2.8	5.4	1.9		15.4	5.1	25.6	**41.0**	17.4
Urtica urens		1.1	0.5	1.3	0.7	0.7		2.6	2.6	5.1	5.1	3.1
Valerianella dentata			0.1			0.0			2.6			0.5
Veronica agrestis		0.3	1.2	2.1	3.8	1.5		2.6	5.1	7.7	10.3	5.1
Veronica arvensis	0.7	7.3	7.8	6.0	**10.9**	6.5	7.7	30.8	28.2	33.3	**43.6**	28.7
Veronica chamaedrys		0.3		0.1	0.8	0.2		2.6		2.6	7.7	2.6
Veronica hederifolia		0.4	1.4		0.4	0.4		2.6	5.1		7.7	3.1
Veronica persica	2.9	**12.1**	**23.8**	6.9	**25.0**	**14.2**	20.5	33.3	**51.3**	35.9	**71.8**	**42.6**
Veronica polita		1.5	2.6	0.1	1.3	1.1		2.6	5.1	2.6	5.1	3.1

Appendix 2. Continued

	Sites (%)						Within-site frequency (%)					
	C	CH1	CH2	OS3	RAWM	Total	C	CH1	CH2	OS3	RAWM	Total
Veronica serpyllifolia		0.1	0.5	1.5	2.8	1.0		2.6	5.1	10.3	10.3	5.6
Vicia cracca					0.4	0.1					5.1	1.0
Vicia hirsuta					0.2	0.0					5.1	1.0
Vicia sativa			0.3			0.1			5.1			1.0
Vicia sepium					0.6	0.1					5.1	1.0
Vicia tetrasperma					0.2	0.0					2.6	0.5
Viola arvensis	6.8	**16.2**	**20.6**	9.1	**24.6**	**15.5**	25.6	33.3	**43.6**	30.8	**56.4**	37.9
Vulpia bromoides				0.2		0.0				5.1		1.0
Vulpia myuros					0.3	0.1					2.6	0.5
× *Triticosecale*	0.6					0.1	2.6					0.5

Appendix 3. Records of rare arable weeds recorded in this survey by agreement option and region. Core species are highlighted in bold.

Species	No. sites	Agreement option					Region							
		Control	CH1	CH2	OS3	RAWM	E	SE	SW	EM	WM	YH	NW	NE
Anthemis arvensis	**1**				**1**		**1**							
Anthemis cotula	4			1	1	2		2	2					
Anthriscus caucalis	2				1	1	2							
Apera interrupta	1				1		1							
Apera spica-venti	5			2	1	2	2					3		
Bromus secalinus	2				2		1							1
Centaurea cyanus[BAP]	**2**			**1**		**1**		**1**			**1**			
Chrysanthemum segetum	5		1	1		3	3	1		1				
Descurainia sophia	5			1	2	2	5							
Euphorbia exigua	19	4		4	5	6	2	9	7					1
Euphorbia platyphyllos[SCC]	**2**		**1**			**1**			**2**					
Filago vulgaris	6				2	4	3			2			1	
Fumaria densiflora	9		2	3		4	3	3	3					
Fumaria parviflora	1					1	1							
Fumaria purpurea[BAP]	**1**					**1**							**1**	
Fumaria vaillantii	1					1		1						
Hyoscyamus niger	1					1		1						
Hypochaeris glabra[SCC]	**2**				**2**		**2**							
Kickxia spuria	13		3	2	2	6	2	7	4					
Legousia hybrida	16		1	4	3	8	5	6	4	1				
Legousia speculum-veneris	**1**					**1**		**1**						
Lithospermum arvense[SCC]	**1**				**1**			**1**						
Misopates orontium	3			2		1			3					
Papaver argemone	7	1	1	1		4	2	4	1					
Papaver hybridum	3			1		2	1	1	1					
Petroselinum segetum[SCC]	**1**		**1**					**1**						
Ranunculus parviflorus	1			1							1			
Scandix pecten-veneris[BAP]	**3**		**1**			**2**	**1**		**2**					
Silene gallica[BAP]	**1**			**1**					**1**					
Silene noctiflora	5		1	1	2	1	4			1				
Spergula arvensis	10			3	1	6	1	2	2	2	1		1	1
Stachys arvensis	6		1	3	1	1	1		5					
Valerianella dentata[SCC]	**4**			**1**		**3**	**1**	**2**	**1**					
Viola tricolor	1	1							1					

Appendix 4. Abbreviated species names used in ordination plots

Abbreviation	Latin Name	Abbreviation	Latin Name	Abbreviation	Latin Name	Abbreviation	Latin Name
Acerpseu	*Acer pseudoplatanus*	Clinvulg	*Clinopodium vulgare*	Knauarve	*Knautia arvensis*	Rumesang	*Rumex sanguineus*
Aethcyna	*Aethusa cynapium*	Conimacu	*Conium maculatum*	Lamiampl	*Lamium amplexicaule*	Scanpect	*Scandix pecten-veneris*
Agrocapi	*Agrostis capillaris*	Convarve	*Convolvulus arvensis*	Lamihybr	*Lamium hybridum*	Scronodo	*Scrophularia nodosa*
Agrostol	*Agrostis stolonifera*	Crepsp.	*Crepis* sp.	Lamipurp	*Lamium purpureum*	Senejaco	*Senecio jacobaea*
Allipeti	*Alliaria petiolata*	Crepvesi	*Crepis vesicaria*	Lapscomm	*Lapsana communis*	Senevulg	*Senecio vulgaris*
Alopmyos	*Alopecurus myosuroides*	Cynooffi	*Cynoglossum officinale*	Legohybr	*Legousia hybrida*	Sherarve	*Sherardia arvensis*
Amsimicr	*Amsinckia micrantha*	Dactglom	*Dactylis glomerata*	Linavulg	*Linaria vulgaris*	Silegall	*Silene gallica*
Anagarve	*Anagallis arvensis*	Dauccaro	*Daucus carota*	Lolipere	*Lolium perenne*	Silenoct	*Silene noctiflora*
Ancharve	*Anchusa arvensis*	Descsoph	*Descurainia sophia*	Lotucorn	*Lotus corniculatus*	Sinaarve	*Sinapis arvensis*
Anisster	*Anisantha sterilis*	Dipsfull	*Dipsacus fullonum*	Matrdisc	*Matricaria discoidea*	Sisyoffc	*Sisymbrium officinale*
Anthcotu	*Anthemis cotula*	Elytrepe	*Elytrigia repens*	Matrrecu	*Matricaria recutita*	Solatube	*Solanum tuberosum*
Aphaarve	*Aphanes arvensis*	Epilcili	*Epilobium ciliatum*	Matrsp.	*Matricaria* sp.	Soncarve	*Sonchus arvensis*
Arabglab	*Arabis glabra*	Epilhirs	*Epilobium hirsutum*	Mediarab	*Medicago arabica*	Soncaspe	*Sonchus asper*
Arctminu	*Arctium minus*	Epilmont	*Epilobium montanum*	Medilupu	*Medicago lupulina*	Soncoler	*Sonchus oleraceus*
Arctsp.	*Arctium* sp.	Epilparv	*Epilobium parviflorum*	Mercannu	*Mercurialis annua*	Sperarve	*Spergula arvensis*
Arenserp	*Arenaria serpyllifolia*	Equiarve	*Equisetum arvense*	Misooron	*Misopates orontium*	Stacarve	*Stachys arvensis*
Arrhelat	*Arrhenatherum elatius*	Erodcicu	*Erodium cicutarium*	Myosarve	*Myosotis arvensis*	Stacsylv	*Stachys sylvatica*
Artevulg	*Artemisia vulgaris*	Euphexig	*Euphorbia exigua*	Odonvern	*Odontites vernus*	Stelmedi	*Stellaria media*
Atrilitt	*Atriplex littoralis*	Euphheli	*Euphorbia helioscopia*	Onobvici	*Onobrychis viciifolia*	Tamucomm	*Tamus communis*
Atripros	*Atriplex prostrata*	Euphplat	*Euphorbia platyphyllos*	Papaarge	*Papaver argemone*	Taraagg.	*Taraxacum* agg.
Avenfatu	*Avena fatua*	Fallconv	*Fallopia convolvulus*	Papahybr	*Papaver hybridum*	Thlaarve	*Thlaspi arvense*
Bellpere	*Bellis perennis*	Fumadens	*Fumaria densiflora*	Paparhoe	*Papaver rhoeas*	Trifdubi	*Trifolium dubium*
Bromcomm	*Bromus commutatus*	Fumamura	*Fumaria muralis*	Perslapa	*Persicaria lapathifolia*	Trifprat	*Trifolium pratense*
Bromhord	*Bromus hordeaceus*	Fumaoffi	*Fumaria officinalis*	Perssp.	*Persicaria* sp.	Trifrepe	*Trifolium repens*
Bryodioi	*Bryonia dioica*	Fumasp.	*Fumaria* sp.	Petrcris	*Petroselinum crispum*	Tripinod	*Tripleurospermum inodorum*
Capsburs	*Capsella bursa-pastoris*	Fumavail	*Fumaria vaillantii*	Phraaust	*Phragmites australis*	Tritaest	*Triticum aestivum*
Cardnuta	*Carduus nutans*	Galiapar	*Galium aparine*	Planlanc	*Plantago lanceolata*	Tussfarf	*Tussilago farfara*
Centnigr	*Centaurea nigra*	Galimoll	*Galium mollugo*	Planmajo	*Plantago major*	Urtidioi	*Urtica dioica*
Centscab	*Centaurea scabiosa*	Geradiss	*Geranium dissectum*	Poaannu	*Poa annua*	Urtiuren	*Urtica urens*
Cerafont	*Cerastium fontanum*	Gerasp.	*Geranium* sp.	Poaprat	*Poa pratensis*	Veroarve	*Veronica arvensis*
Ceraglom	*Cerastium glomeratum*	Glechede	*Glechoma hederacea*	Poatriv	*Poa trivialis*	Verohede	*Veronica hederifolia*
Chaeminu	*Chaenorhinum minus*	Gnapulig	*Gnaphalium uliginosum*	Polyavic	*Polygonum aviculare*	Veropers	*Veronica persica*
Chaetemu	*Chaerophyllum temulum*	Heraspho	*Heracleum sphondylium*	Ranuacri	*Ranunculus acris*	Veropoli	*Veronica polita*
Chenalbu	*Chenopodium album*	Holclana	*Holcus lanatus*	Ranurepe	*Ranunculus repens*	Veroserp	*Veronica serpyllifolia*
Chenpoly	*Chenopodium polyspermum*	Hypehirs	*Hypericum hirsutum*	Ranusp.	*Ranunculus* sp.	Vicihirs	*Vicia hirsuta*
Chrysege	*Chrysanthemum segetum*	Hyporadi	*Hypochaeris radicata*	Rapirugo	*Rapistrum rugosum*	Vicisati	*Vicia sativa*
Cirsarve	*Cirsium arvense*	Juncbufo	*Juncus bufonius*	Reselute	*Reseda luteola*	Vicisepi	*Vicia sepium*
Cirsvulg	*Cirsium vulgare*	Kickelat	*Kickxia elatine*	Rumeacet	*Rumex acetosella*	Violarve	*Viola arvensis*
Clemvita	*Clematis vitalba*	Kickspur	*Kickxia spuria*	Rumeobtu	*Rumex obtusifolius*	Vulpmyur	*Vulpia myuros*