EFFECTS OF MANAGEMENT TREATMENTS ON CARABID COMMUNITIES OF CEREAL FIELD HEADLANDS

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ABSTRACT

The overall abundance and species composition of carabid beetles were compared in three different cereal field headland management regimes in the Breckland area of eastern England. Uncropped Wildlife Strips, which were cultivated but not sown, contained more species and a greater overall abundance of carabids than either sprayed headlands or 'Conservation Headlands', which were sown but which received reduced pesticide inputs. Both carabid abundance and species richness of the community were correlated with percentage cover of dicotyledonous plants and the abundance of other invertebrates. The species richness of the community was also strongly related to total vegetation cover and abundance of aphids and Collembola. Experimental reduction of vegetation in Uncropped Wildlife Strips lead to a decrease in abundance of most species of carabid except *Bembidion lampros*.

INTRODUCTION

Since the 1940's increased intensification of agricultural practices has lead to a general decline in the abundance of carabid beetles in arable farmland (Burn, 1988). However, during the last decade some reversal of this trend has occurred, with the increased interest in alternative farming practices. These include the use of Conservation Headlands, and Uncropped Wildlife Strips which have been included in the management prescriptions for the Breckland Environmentally Sensitive Area. Breckland is an arable area of land in eastern England which is historically associated with arable farming on a temporary basis. A unique community of flora and fauna has developed in association with areas of abandoned and extensive agriculture. The advent of modern agricultural techniques has led to the destruction and fragmentation of these habitats so that many species are now rare.

In this paper we examine the consequences of introducing Uncropped Wildlife Strips for the diversity and abundance of the carabid fauna in winter wheat fields and compare the carabid populations of an Uncropped Wildlife Strip with those of Conservation and fully sprayed headlands.

STUDY SITE

Two strips (120 m x 6 m each) of each of three headland treatments were arranged in a randomized block design along one side of a winter wheat field (18.6 ha). Sprayed headlands received pesticides and fertiliser applied at the same rates as the rest of the field. The Conservation Headland was treated as above but did not receive herbicides and insecticides, in accordance with specific guidelines for choice of compound and timing (Sotherton *et al*., 1989), thus allowing weeds and associated invertebrates to flourish. The Uncropped Wildlife Strip was rotovated annually in September and left unsown, without pesticides or lime.

METHODS

Sampling of carabid community

Beetles were sampled using covered pitfall traps consisting of 60 mm diameter plastic cups containing ethylene glycol and water with a drop of detergent. An area immediately around the trap was cleared of vegetation to standardise traps in the different habitats. Whilst species varied in their trapability and activity, these parameters did not differ significantly between treatments (Hawthorne, in press), thus allowing comparisons of catches from different headland treatments to be made. Traps were placed 20 m apart in the middle of the headland treatments, 3 m from, and parallel to, the field boundary. Three or five traps were used for each headland treatment. Opposite each of these traps a further trap was established in the crop at 8 m from the field boundary. Catches were emptied every two weeks in 1990 from April until July, weekly from April to August in 1991 and weekly from February until July in 1992.

Measurements of environmental variables

The following environmental variables were monitored during 1991 and correlated with both overall carabid abundance and species richness:

The percentage cover of all vegetation, and bare ground were estimated on four dates in five 0.25 m^2 quadrats for each headland treatment, 3m from the field boundary. Vegetation height diversity, (using Simpson's Index) were calculated from the percentage cover in each 10 cm height intervals between ground level and 60 cm for each quadrat. Data were pooled where species were recorded at heights greater than 61 cm. Relative humidity was monitored at the soil surface using cobalt thiocyanate paper Measurements were made at two-weekly intervals from May until July. Cereal aphids were counted on 30 tillers selected at random in each headland treatment on the days of the vegetation survey. Ground-active invertebrates, including Collembola were recorded from pitfall traps.

Experimental manipulation of environmental variables

The influence of vegetation cover on species composition and abundance was examined in twelve 4 m x 4 m plots on the most heavily vegetated treatment, the Uncropped Wildlife Strip, in 1992 in a randomised block design. Four plots were sprayed, with "Gramoxone" at field strength (0.5 g paraquat per litre) on 14 May to create bare, undisturbed ground. Any subsequent vegetation was removed by hand. Four other plots were hoed to remove vegetation and create bare, disturbed ground. The remaining plots were left undisturbed as fully vegetated plots. After two weeks 2 x 2m areas at the centre of each plot were enclosed. This was done using lengths of 4 mm plywood buried 0.1 m deep to leave 0.15 m above ground. Ground-active carabids were sampled from both control and bare ground plots using covered pitfall traps emptied weekly during June and July.

RESULTS

Community structure

Rank abundance, pooled for the three years, were broadly similar for each headland treatments (Table 1). The biggest difference was that the highest ranking species in the Uncropped Wildlife Strip accounted for 28 % of the individuals, compared with 16.2 % and 18.6 % in the Conservation and sprayed Headlands respectively. In all

TABLE 1.

Catch totals per species and proportions of the overall carabid total in Conservation Headlands (CH), Uncropped Wildlife Strips (UH) and sprayed headlands (SH) for the 10 most highly ranked species, using pooled data. *A.dors = Agonum dorsale, P.mel = Pterostichus melanarius, B.lamp = Bembidion lampros, B. tetra = B. tetracolum, D.atri = Demetrias atricapillus, T. quad = Trechus quadristriatus, H.ruf = Harpalus rufipes, H.aff = H.affinus, A.bif = Amara bifrons, A.aen = A.aenea, A.sim = A.similata, A.fam = A. familiaris*

Rank		CH %	Total		UH %	Total		SH %	Total
1	*A.dors*	16.15	238	*B.lamp*	28.03	697	*A.dors*	18.55	174
2	*P.mel*	14.18	209	*H.aff*	12.95	322	*B.lamp*	12.79	120
3	*A.bif*	13.77	203	A.bif	9.81	244	*H.ruf*	11.83	111
4	*T.quad*	8.68	128	*P.mel*	9.81	244	*P.mel*	10.34	97
5	*D.atri*	6.99	103	*H.ruf*	6.35	158	*D.atri*	9.28	87
6	*B.lamp*	6.38	94	*A.sim*	5.43	135	*T.quad*	7.57	71
7	*A.fam*	4.82	71	*A.den*	4.26	106	*H.aff*	3.20	30
8	*B.tetra*	4.75	70	*B.tetra*	3.70	92	*A.bif*	2.88	27
9	*H.ruf*	4.07	60	*T.quad*	3.38	84	*A.aen*	2.77	26
10	*A.sim*	2.85	42	*A.dors*	2.27	69	*A.sim*	1.92	18
	TOTAL		1474	TOTAL		2487	TOTAL		938

treatments six species contributed more than 5 % to the total catch, out of a total of 35 species for the normal sprayed Headland; 41 for the Conservation Headland and 43 species in the Uncropped Wildlife Strip (Table 1).

The most abundant species overall was *Bembidion lampros*, which was amongst the six most abundant species in each headland treatment. However it was more than twice as numerous in the Uncropped Wildlife Strip as any other species, and seven times more abundant there than in the sprayed headland. *Pterostichus melanarius* was the second most abundant species overall and amongst the top four species in all three treatments. *Agonum dorsale* was third most abundant overall but less common in the Uncropped Wildlife Strip than in the sprayed and Conservation Headlands, where it was the most abundant species.
Some the less common species were restricted to one treatment. Those restricted to Uncropped Wildlife Strips included *Bembidion femoratum*, *Amara tibialis*, *Acupalpus meridianus*, *Bradycellus harpalinus*, *Bradycellus distinctus* and *Harpalus rubripes*. Whilst *Amara nitida*, *Amara spreta* and *Pterostichus angustatus* were only found in Conservation Headlands. Only one species, *Calathus piceus*, was restricted solely to sprayed headlands.

<u>Relationships between environmental variables and community characterists.</u>

Analyses of the relationships between carabid community parameters and environmental variables are summarized in Table 2. Carabid abundance was strongly correlated with percentage cover of dicotyledonous plants and abundance of invertebrates. Species richness was most strongly correlated with total vegetation cover, % dicot cover and general invertebrate abundance, especially Collembola and aphids. Both carabid abundance and species richness were negatively correlated with relative humidity.

TABLE 2 Summary of significant correlations between carabid abundance and species richness with environmental measurements in 1991. Where ** = P < 0.01, *** = P < 0.001

	Carabid abundance	Species richness
No. dicot species	-	0.250**
% cover dicot species	0.302***	0.503***
No. monocot species	0.287***	0.253**
% cover bare ground	-0.272**	-0.386**
% cover all vegetation	0.247**	0.441***
Height diversity	-	0.254**
Collembola	0.282**	0.399***
Invertebrates	0.364***	0.458***
Aphids	0.226**	0.371***
Relative humidity	-0.399***	-0.420***

Experimental manipulation of environmental variables.

The overall number of carabids caught fell significantly when the vegetation cover was removed ($F_{(2,9)} = 16.55$; P <.0.001) (Table 3). One conspicuous exception to this trend was *B. lampros;* significantly fewer being caught in the fully vegetated plots than in the herbicide treated or hoed plots ($F_{(2,9)} = 79.71$, P < 0.001).

TABLE 3. Comparison of mean carabid density (m^{-2} ± one standard error) in fully vegetated, herbicide treated and hoed bare ground plots in 1992.

Species	Full vegetated control	Hoed bare ground	Herbicide treated bare ground
Harpalus affinis	18.31 ± 1.04	5.06 ± 0.60	4.38 ± 0.72
Amara similata	11.75 ± 3.56	0.75 ± 0.36	0.31 ± 0.21
Amara bifrons	9.19 ± 2.25	2.44 ± 0.53	0.88 ± 0.33
Amara aenea	6.44 ± 1.64	0.44 ± 0.26	0.88 ± 0.33
Harpalus rufipes	6.00 ± 1.91	1.94 ± 0.36	2.06 ± 0.56
Agonum dorsale	0.75 ± 0.29	0.31 ± 0.16	0.38 ± 0.19
Pterostichus melanrius	0.56 ± 0.42	0.13 ± 0.06	0
Bembidion lampros	7.56 ± 1.57	22.44 ± 1.61	37.06 ± 1.04
Bembidion tetracolum	0	0.19 ± 0.01	0.56 ± 0.29

DISCUSSION

Both the total carabid abundance and the number of species present were greatest in the Uncropped Wildlife Strips. This was probably because of their more complex structure and greater diversity of the vegetation which strongly influenced the abundance and species richness of carabid faunas (Speight & Lawton, 1976; Powell *et al.*, 1985). These parameters were strongly correlated with the percentage cover of all vegetation, but particularly with the cover by dicotyledonous species and with foliage height diversity. There are several probable reasons for this. Firstly plant tissues can be important directly as a source of food for carabids. Many *Amara* and *Harpalus* spp. are considered phytophagous (Hengeveld, 1980) while most species of carabids include some vegetation in their diet. A positive relationship exists between abundance and diversity for many insects and the species and height diversity of vegetation (Murdoch *et al.*, 1972). Thus the availability of potential invertebrate prey for carabids also increased with increasing complexity of the vegetation. The importance of this was confirmed by the strong positive correlations between carabid community characteristics and the density of Collembola and other invertebrates. High alternative prey densities could be important in encouraging polyphagous predators to persist in a field early in the season, when pest populations are low. A second indirect effect of increased vegetation complexity could be its influence in buffering fluctuations in microclimate (Speight & Lawton, 1976). This was considered to be critical in determining the distribution of species such as *P.melanarius* and *H.rufipes* (Skuhravy *et al.*, 1971) while a further benefit of structurally diverse vegetation was that it could provide shelter from predators and parasites (Lawton, 1978).

The experimental reduction of vegetation from the Uncropped Wildlife Strip provided confirmation that for most of the species the presence of complex vegetation was very important. However there were some species of carabid (*B. lampros*)which preferred and actively selected bare ground (Mitchel, 1963). The abundance of this species increased dramatically in the bare ground plots and it clearly preferred those with a smooth surface to the more disturbed hoed plots. This could account for why, early in the season, when numbers of this species normally peak, it was by far the commonest in the Uncropped Wildlife Strips, where little vegetation had developed.

Although one of the smallest carabid species caught in this survey, *B. lampros* is known to consume more aphids per unit of its body weight than any other species of carabids tested in the laboratory (Sopp & Wratten, 1988). Its very high abundance in the Uncropped Wildlife Strips could therefore be of considerable importance when evaluating their potential benefits in helping to control pest populations. The strong preference of *P. melanarius* for Uncropped Wildlife Strips later in the season may be of similar importance, because whilst less numerous than *B. lampros*, it is capable of consuming large numbers of aphids.

If these predators were to remain exclusively within the Uncropped Wildlife Strips they would be unlikely to have a very substantial influence on pests within the crop itself. This is not however the case as carabids sampled from 8 m out into the crop adjacent to the Uncropped Wildlife Strips, during 1992 were significantly ($F_{(2,180)}$ = 24.69, $P < 0.0001$) more abundant than they were adjacent to either of the other two headlands. Corresponding counts of aphids densities showed that there were significantly less ($F_{(2,348)} = 3.32$, $P = 0.037$) in crops adjacent to Uncropped Wildlife Strips than there were adjacent to the other two headlands.

Such evidence of carabids dispersing out from the favourable conditions of the Uncropped Wildlife Strip is of wider significance in relation to the broader status of these beetles within the modern agricultural environment. Cultivation of crops is known to deplete the populations of some species (Blumberg & Crossley, 1983). If favourable conditions for larval survival and/or increased adult reproductive rates are provided by the Uncropped Wildlife Strip then these increased populations could provide a reservoir from which depleted populations can be replenished through dispersal.

Populations can survive in an area only if they have sufficient powers of dispersal to 'refound' subpopulations that have become extinct, or find new suitable habitats. In the modern agricultural landscape, suitable habitats are becoming increasingly fragmented (Mader, 1988). If appropriately managed headlands provide suitable conditions, albeit temporary, for a species to survive and reproduce, before establishing in a more permanent habitat, they may provide an important link between fragments and so help to ensure the survival of local populations.

REFERENCES

Blumberg, A.Y.; Crossley, D.A. (1983) Comparison of soil surface arthropod populations in conventional tillage, no tillage and old field systems. Agro-ecosystems, **8**, 247-253.

Burn, A.J. (1988) Assessment of pesticides on the impact on invertebrate predation in cereal crops. Aspects of Applied Biology, **17**, 279-288

Hawthorne, A.J. (in press). Validation of the use of pitfall traps to study carabid populations in cereal field headlands. Acta Jutlandica, (in press)

Hengeveld, R. (1980) Qualitative and quantitative aspects of the food of ground beetles (Coleoptera, Carabidae): A review. Netherlands Journal of Zoology, **30**, 555-563.

Lawton, J.H. (1978) Host-plant influences on insect diversity: the effects of space and time. In: Diversity of insect faunas. L. A. Mound and N. Waloff (Eds), Symposia of the Royal Entomological Society No. 9. Oxford.Blackwell. pp 105-125.

Mader, H-J. (1988) Effects of increased spatial heterogeneity on the biocenosis in rural landscapes. Ecological Bulletins, **39**, 169-179.

Mitchel, B. (1963) Ecology of two carabid beetles *Bembidion lampros* (Herbst) and *Trechus quadristriatus* (Schrank). I. Lifecycles and feeding behaviour. Journal of Animal Ecology, **32**; 289-299.

Murdoch, W.M.; Evans, F.C.; Peterson, C.H. (1972) Diversity and pattern in plants and insects. Ecology, **53**, 819-828.

Powell, W.; Dean, G.J.; Dewar A. (1985) The influence of weeds on polyphagous arthropod predators in wheat. Crop Protection, **4**, 298-312.

Skuhravy, V.; Louda, J.; Sykora, J.(1971) Zur verteilung der Laufkaufer in Feldmonokulturen. Beitrage zur entomolgie, **21**, 539-546.

Sopp, P.I.; Wratten, S.D. (1986) Rates of consumption of cereal aphids by some polyphagous predators in the laboratory. Entomologia Experimentalis et Applicata, **41**, 69-73.

Sotherton, N.W.; Boatman, N.D.; Rands, M.R.W. (1989) The 'Conservation Headland' experiment in cereal ecosystems. The Entomologist, 108, 135-143.

Speight, M.R.; Lawton, J.H.(1976) The influence of weed cover on the mortality imposed on artificial prey by predatory ground beetles in cereal fields. Oecologia, **23**, 211-223.

HABITAT CREATION IN LARGE FIELDS FOR NATURAL PEST REGULATION

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ABSTRACT

Field experiments at Harnhill Manor Farm, Cirencester, were initiated in Spring 1993 by the Royal Agricultural College, in conjunction with AFRC IACR Long Ashton Research Station, with the aim of extending the earlier Less Intensive Farming and Environment (LIFE) project funded by the European Community, to a farm scale. The studies use field margins to encourage beneficial arthropods which may enhance natural regulatory mechanisms for pest control. In the first year numbers of predatory spiders were significantly higher in sown plant margins than in sterile margins. Staphylinidae were found to be significantly less abundant in the sterile and enhanced fallow margins than in the other treatments.

INTRODUCTION

Increasing concerns for production costs and environmental impact is stimulating recent research on integrated farming systems. Small plot research at the AFRC Institute of Arable Crops Research, Long Ashton, into less-intensive farming and the environment in the UK (LIFE project) (Jordan *et al*, 1990) is being furthered by the Royal Agricultural College, by extending this research into commercial practice where production costs and financial returns have priority.

One of the main objectives of the lower input system is to investigate the feasibility of enhancing biodiversity, by reducing the size of large fields and using smaller cropping areas in an integrated rotation. This approach lends itself ideally to the use of flower or grass margins for division of large fields into smaller cropping areas, and to enhance beneficial arthropods. The work therefore provides an opportunity to monitor arthropod communities in a practical integrated arable farming situation. These studies should indicate whether the use of integrated systems is likely to enable exploitation of field margins to enhance natural regulatory mechanisms for pest control in practice.

METHODS

Field experiments were initiated at the Royal Agricultural College's Harnhill Manor Farm, Cirencester, in April 1993 for an initial period of three years. The entire low-input site consists of a 30 ha field (Figure 1). Since reduced field size is fundamental to the LIFE approach, the field was divided into cropping areas of approximately 5 ha using raised margins. Raised margins were preferred to flat margins due to enhanced properties of drainage and habitat value. The raised margins (0.3 m high) were divided into 5 treatment plots (4 m x 50 m) of plant mixtures (Table 1) sown in randomised blocks (Figure 1). Randomised blocks were used to overcome biasing of results due to variations in the field (e.g. soil, drainage). The randomised block design and the shortest division between cropping areas dictated the length of the margins. The maximum possible length (50 m) was used to limit effects on results caused by invertebrate transfer between strips. A margin width of 4 m has enabled the margins to be managed in accordance with standard practices using farm machinery.

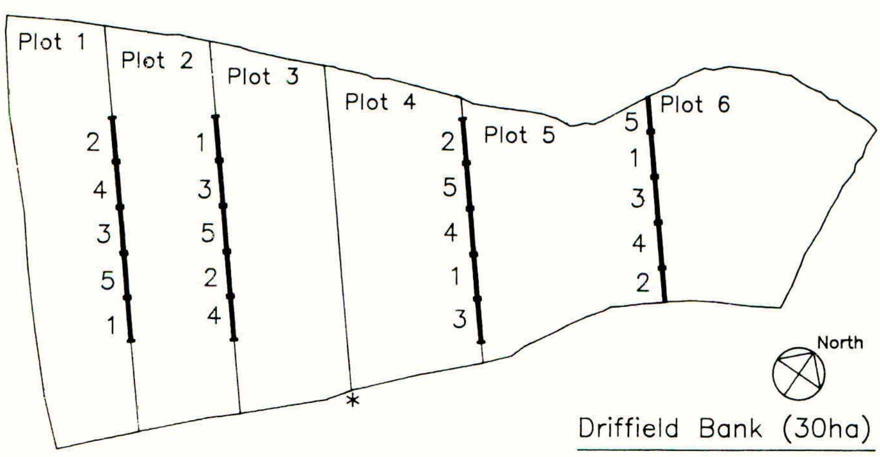
Plant mixtures (Table 1) were chosen for their suitability to the soil type of the site, potential arthropod habitat value (both winter and summer habitats), ease of management, cost and low invasive nature. Treatment 1 is the standard grass mix recommended by the Game Conservancy Trust for beetle banks. Treatment 2, a wild flower and grass mix suitable to the soil type, was chosen for its low cost, ease of establishment and seed availability. Treatment 3, represents an "enhanced fallow" to investigate the qualities of a low density wild flower mixture, allowing for natural regeneration. The headland mix used in Treatment 4 compared standard farm practice routinely used on Harnhill Manor farm. Finally, the sterile margin (Treatment 5) was kept free of plant cover using herbicide (glyphosate), representing standard farm practice for field margins in other farming systems. The sterile and headland margins in effect provide control conditions.

Standard ecological methods (pitfall traps, soil samples, D-vac, mark and recapture) are being used to determine arthropod colonisation and holding capacity of each treatment throughout seasons. Arthropod dispersal into crops in the spring will be measured by sampling at regular distances into the cropping areas. Insect pests will also be monitored at regular distances into the crops. Pest numbers will be correlated with predator numbers and related to adjacent margin treatments.

A comprehensive soil and weed map is being made of the site. Details of agronomy, yield (using a global positioning crop yield monitoring system in addition to standard sampling techniques) and costs are being recorded. This information will be used when more detailed data on beneficial arthropod populations are available, to analyse the potential for natural pest regulation and the influence of this and other environmental factors on yield, as well as the costs involved.

Reported here are preliminary results from the first winter on the site. In October 1993, 3 x 0.04 m^2 soil samples were taken from each treatment plot. Arthropods were extracted from the samples using a modified version of the flotation technique of Sotherton (1984), identified and quantified. Results were subjected to analysis of variance after square root transformation (sqrt) to correct for non-normality in the data distribution.

Figure 1. Plan of integrated cropping system project area and wild plant margins at Harnhill Manor Farm.



* = Tree strip to be planted. For details of treatments 1-5, see Table 1.

Table 1. Wild plant mixes and planting densities used in the integrated cropping systems study at Harnhill Manor Farm.

Treatment number	Planting Density (g/m^2)	Plant Species	% Total wt
1 (Grass)	4	*Dactylis glomerata*	50
		Holcus lanatus	50
2 (Wild flower)	4	*Plantago lanceolata*	5
		Galium verum	5
		Leucanthemum vulgare	5
		Daucus carota	5
		Festuca ovina	26.6
		Cynosorus crtistatus	26.6
		Agrostis castellana	26.6
3 (Enhanced fallow)	1.5	*Knautia arvensis*	20
		Centaurea nigra	20
		Geranium pratense	20
		Ranunculus acris	20
		Plantago lanceolata	20
4 (Clover headland)	4	*Lolium perenne*	91.5
		Trifolium repens	8.5
5 (Sterile)	-	No plants	-

RESULTS

Preliminary results on overwintering arthropods are shown in Table 2. Numbers of predatory spiders were significantly ($p = 0.02$) higher in sown plant margins than in sterile margins. Staphylinidae were found to be significantly ($p = 0.01$) less abundant in the sterile and enhanced fallow margins than in the grass and wild flower margins.

Table 2. Predatory beetles, spiders and mites found in soil samples analyses from field margin plots in October 1993.

Treatment	Carab. m^{-2}		Staph. m^{-2}		Spiders m^{-2}		Mites m^{-2}		Total m^{-2}	
	no.	sqrt	no.	sqrt	no.	sqrt	no.	sqrt	no.	sqrt
1	150	8.7	294	13.5	156	11.25	63	5.56	663	21.2
2	175	10.4	319	17.0	113	9.73	144	10.58	750	25.5
3	31	3.9	25	2.5	88	9.10	88	8.98	231	14.7
4	25	3.4	131	10.3	106	9.78	44	5.70	306	16.8
5	144	8.5	38	3.1	44	3.31	50	4.56	275	11.5
SED(12 df)		3.95		3.95*		2.10**		2.81		5.11

*, ** = significant at $p = 0.01$ and 0.02 respectively.

DISCUSSION

The numbers of predators found in this study are similar to those found by other workers in their first year (Wratten & Thomas, 1990).

Large variations in numbers were recorded for the same plant mix from different strips. This could perhaps be due to substantial differences in soils across the field (J. Conway, personal communication), or due to the early stages of arthropod colonisation of the strips. From previous studies it would appear that arthropod colonisation of newly sown wild plant strips takes up to 3 years (Thomas & Wratten, 1990).

The results suggest that the grass and wild flower margins may be more suitable for beneficial arthropods. These ongoing studies should clarify this, and establish the suitability of field margins for enhancing natural pest regulation in integrated cropping systems.

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REFERENCES

Jordan, V.W.L.; Hutcheon, J.A.; Perks, D.A. (1990) Approaches to the development of low input farming systems. In: *Organic and Low Input Agriculture*. R. Unwin (Ed.) *BCPC Monograph No.45*. Thornton Heath: BCPC Publications, pp. 9-18.

Sotherton, N.W. (1984) The distribution and abundance of predatory arthropods overwintering in farmland. *Annals of Applied Biology* **105**, 423-429.

Thomas, M.B.; Wratten, S.D. (1990) Ecosystem diversification to encourage natural enemies of cereal aphids. *Brighton Crop Protection Conference - Pests and Diseases 1990*, **2**, 691-696.

Wratten, S.D.; Thomas, M.B. (1990) Environmental manipulation for the encouragement of natural enemies of pests. In: *Organic and Low Input Agriculture*. R. Unwin (Ed.) *BCPC Monograph No.45*. Thornton Heath: BCPC Publications, pp. 87-92.

PLANT DISTRIBUTION ACROSS ARABLE FIELD ECOTONES IN THE NETHERLANDS

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ABSTRACT

Inventories made in crop edges and adjacent boundaries (no herbicide, no fertilizer; including fallow strips) on sandy soil in the eastern part of the Netherlands revealed the common plant species still occurring in today's field margins. The distribution of the species over crop edge and boundary is analysed and compared with historical data. Distribution classes and ecological status of the species are discussed, as well as the potential for restoration of species-richness in field margins.

INTRODUCTION

Current intensive farming practices in NW Europe are criticized for the widespread eutrophication and loss of biodiversity in the rural countryside Many species have disappeared, common species have become rare. In the Netherlands species such as *Cardamine pratensis, Papaver spp.* and *Centaurea cyanus*, very common until recently, are now considered valuable assets.

General concern has led to political consensus to implement measures that will restrict negative effects of agriculture and restore basic environmental qualities and nature conservation value (Joenje, 1991). In this context attention is increasingly focused on field margin management.

Why should we restore or maintain a certain level of diversity in the agricultural areas? Essentially three categories of arguments are being put forward: i) biodiversity for nature conservation purposes ii) diversity as indication of a safe environment related to human wellbeing, and iii) plant and animal species in communities along the crops *may* have beneficial effects as biocontrol agents (e.g. Welling, 1988) with economic significance in integrated pest management.

One means of restoring the diversity could be the establishment of enlarged field boundaries at the cost of arable surface (*viz.* Marshall *et al.* 1994). Such boundaries are expected to have a higher diversity potential which can be further increased by sensitive management. The actual diversity, however, is always the outcome of immigration and establishment. Species most probably stem from the local seedbank or from the direct vicinity of the (enlarged) field boundary. The potential diversity consists of all species available to colonise a particular spot. An impression of such a list can be obtained by making an inventory of species that grow in a larger area adjacent to the field boundary in roadsides, grasslands, hedgerows, etc.

In this paper we analyze species-lists of unsprayed and unfertilized margins, comparing the samples from both crop edge and boundary strip. The contemporary arable weed flora is compared with the flora of 1956 (Bannink *et al.*, 1974). Furthermore the short term, successional development on newly created boundary strips in the mid-east Netherlands is predicted on basis of presence, frequency and distribution of species in this inventory.

METHODS

Samples (with abundance classes 1-5, according to Tansley, 1935) were made in 19 arable field margins on sandy soils in the mid-east Netherlands, where a reasonable number of species is still present in a relatively small-scale landscape. As part of an experiment funded by the province of Gelderland, the crop edges did not receive artificial fertilizer or herbicides for the preceding one or two years. Weeds were controlled mechanically. Along a field margin two samples were made: one of the 3-4 m wide crop edge and one of the 3-5 m wide adjacent boundary. The arable fields, and thus the samples, were of different lengths depending on the size of the field. Four of these crop edges were kept fallow, the others were sown to various crops. The complete listing of the 38 samples is not presented here (copies from authors). References in the literature (Sissingh, 1950; Bannink *et al.*, 1974) with inventories of weed communities in the area were used for comparison. These data stem from arable fields in the same sandy region (plant cover and species-frequencies according to the Braun-Blanquet method); they give a relatively complete survey of the flora occurring in the 1956 crops.

RESULTS

A total of 221 species was recorded, comprising *ca*. 15 % of the Dutch flora, but belonging almost exclusively to the classes of 'common' and 'very common' species (Netherlands Central Bureau of Statistics, 1987). Twelve species were 'relatively common' and only three were 'less common', two of these being 'red list' species *(Stachys arvensis, Cuscuta europaea)* with limited and declining distribution. There were 28 species of trees and shrubs which are not considered further.

Arable weeds in 1956 and 1993

The species lists from the samples of 1993 and 1956 were compared. The most commonly found arable weed species are listed in Table 1. where the frequency ranking in the 1993-inventory is followed by the ranking in the 1956-inventory (Bannink *et al*. 1974). Taking the 10 most frequent species from the 1993-list, there are six species (+ in Table 1) in common with 1956 (*Chenopodium album, Bilderdykia convolvulus, Stellaria media, Viola arvensis, Galeopsis tetrahit, Elymus repens*). The remaining four most frequently occurring species of 1956 decreased strongly (- in Table 1). This resulted partly from specific control (*Apera spica-venti)*, but mostly from the known susceptability of 'old weeds' (*Anthoxanthum aristatum, Centaurea cyanus*) to intensified agricultural management.

The inventory of 1956 has another 27 species with low frequencies not found in the 1993 sample, among these are *Papaver rhoeas, Scleranthus annuus, Arenaria serpyllifolia* and *Veronica spp*. as well as *Avena fatua*. The total number of species found in crop edges in the 1993 inventory was as high as 174, apparently because the crop edges were included as opposed to the samples from the homogeneous crop in 1956. Furthermore the samples were larger (500 m^2 or more). The 1956 inventory was characterized by an even spread of species over the samples with frequencies well below 50%.

Species of crop edge and boundary

In the inventory of 1993, species were screened for their habitat preference. Ninety-eight species were found equally or more often in the

TABLE 1. Arable weed species in the 1993 inventory (no-input crop edges) in decreasing frequency of occurrence (A); ranking of species frequency in samples of 1956 (B), based on 119 plots of *ca*. 50 m^2, near Raalte.

	A	B	
Chenopodium album	1	10	+
Bilderdykia convolvulus	2	2	+
Stellaria media	3	4	+
Viola arvensis	4	1	+
Galeopsis tetrahit	5	9	+
Elymus repens	6	6	+
Polygonum hydropiper	7	12	
Spergula arvensis	8	18	
Myosotis arvensis	9	13	
Chamomilla recutita	10	14	
Vicia hirsuta	11	16	
Veronica arvensis	12	23	
Galium aparine	13	21	
Senecio vulgaris	14	15	
Apera spica-venti	15	5	-
Galinsoga parviflora	16	27	
Juncus bufonius	17	22	
Lamium purpureum	18	26	
Vicia sativa	19	8	-
Centaurea cyanus	20	3	-
Holcus mollis	21	24	
Polygonum lapathifolium	22	19	
Rumex acetosella	23	17	
Urtica urens	24	25	
Lamium amplexicaule	25	28	
Anthoxanthum aristatum	26	7	-
Agrostis stolonifera	27	11	
Aphanes microcarpa	28	20	

N.B.: The 1993 inventory also had eight frequent species (frequencies over 50%) which are not shown in the table, because they did not occur in the sample of 1956.

boundary than in the crop edge. This group of species, so-called boundary-species, is summarized in Table 2. It shows that 75% of the species was found in three or less boundaries; this of course is a common feature of many species distributions. About half of the species have a ruderal plant strategy (*sensu* Grime 1979; Grime *et al.* 1988) and are also characterized by high Nitrogen indicator-values (Anon. 1987).

The species of this inventory were then grouped in five classes according to their distribution over field boundary and crop edge:

1- Species limited to the boundary (13 spp.).
2- Species limited to the crop edge (20 arable weeds).
3- Species with the main distribution in the boundary, but also regularly found in the crop edge (22 spp.).
4- Species with the main distribution in the crop edge but also regularly found in the boundary (37 spp.).
5- Species equally occurring in the crop edge and the boundary (40 spp.). (another 66 species were found only once).

TABLE 2. Occurrence of the species with main distribution in the boundary in (n) of the 19 field margins and their plant strategies (according to Grime *et al.* 1988).

species	(n)	plant strategy
Urtica dioica	16	C
Holcus lanatus	13	C-S-R
Galeopsis tetrahit	12	R / C-R
& Holcus mollis		C
Agrostis capillaris	11	C-S-R
& Elymus repens		C / C-R
Galium aparine	10	C-R
& Dactylis glomerata		C / C-S-R
Arrhenatherum elatius	9	C / C-S-R
& Conyza canadensis		?
Ranunculus repens	8	C-R
& Lapsana communis		R / C-R
Festuca rubra	7	C-S-R
4 species	6	.
3 species	5	.
5 species	4	.
13 species	3	.
25 species	2	.
35 species	1	.

The five most frequent species of each distribution class are listed in Table 3. The first four distribution types are comparable with those described by Marshall (1985, 1989) analyzing normally cultivated crop edges. The fifth class, with species equally distributed over edge and boundary, may reflect the effect of unsprayed and unfertilized crop edge conditions. The high number of species in class 3 and 5 may indicate that a high proportion of boundary species has a ruderal plant strategy. Unfortunately there are no historical data of field boundary vegetation.

DISCUSSION

Since 1956 the arable weed flora of the sandy region studied has changed in a process of agricultural intensification and ruderalization whereby species associations from the syntaxonomical Class of the *Secalietea* shifted towards the *Chenopodietea*. This indicates nutrient enrichment of the field and the margin over the last four decades. The inventory of boundary communities is more dependent on differing local ecological conditions and cannot easily be compared with general data of an old species-inventory. It is expected, however, that boundary nutrient levels have also increased. This, in combination with disturbance from herbicide use, may well have led to communities dominated by a few species of grasses and herbs with characteristic ruderal/competitive strategy. This trend is by no means unique to the Netherlands. In an inventory of meadow boundaries in Wales (GB) on clay soils, six out of the 15 most frequent species were also found in the Netherlands, with the highest ranking *Urtica dioica* and *Holcus lanatus* in common (Marshall, E.J.P., pers. comm.).

We conclude that the present-day field-margin is characterized by (i) *Chenopodietea* species in the crop edge, (ii) a boundary with dominance of a small number of very common species with a high proportion of ruderals.

TABLE 3. The five most frequent species for each distribution class, with nB and nC: the number of Boundaries or Crop edges (in a total of 19 field margins) where a species was present; A: abundance (average of Tansley values 1-5).

species	nB	A	nC	A
class 1 (13 spp.)				
Arrhenatherum elatius	9	(3.0)	0	
Agrostis canina	3	(4.3)	0	
Deschampsia flexuosa	3	(2.7)	0	
Hieracium spec.	3	(2.7)	0	
Chamaemelum angustifolium	3	(1.7)	0	
class 2 (20 spp.)				
Echinochloa crus-galli	0		9	(2.2)
Galinsoga parviflora	0		6	(3.2)
Sonchus arvensis	0		5	(1.8)
Symphytum officinale	0		4	(2.0)
Polygonum lapathifolium	0		3	(2.7)
class 3 (22 spp.)				
Urtica dioica	16	(2.8)	8	(1.8)
Holcus lanatus	13	(2.8)	6	(1.7)
Holcus mollis	12	(3.4)	3	(1.7)
Agrostis capillaris	11	(3.5)	5	(1.4)
Galium aparine	10	(2.2)	6	(1.7)
class 4 (37 spp.)				
Chenopodium album	4	(3.0)	19	(2.7)
Polygonum persicaria	2	(1.5)	19	(3.0)
Polygonum convolvulus	5	(1.8)	18	(2.6)
Stellaria media	10	(2.5)	17	(2.9)
Viola arvensis	6	(2.2)	16	(2.5)
class 5 (40 spp.)				
Galeopsis tetrahit	12	(2.3)	13	(2.3)
Elymus repens	11	(2.9)	12	(2.7)
Ranunculus repens	8	(2.8)	7	(1.6)
Lapsana communis	8	(2.1)	6	(2.2)
Plantago major	4	(2.3)	6	(1.5)

What does this mean for the species diversity to be expected in a newly created strip / enlarged field boundary? Here a so-called old field succession is likely to take place, starting with a rapid colonization and dominance of arable weeds, including perennials. In subsequent years the vegetation will probably be increasingly dominated by perennial ruderal species, notably grasses, especially from distribution-classes 3 and 5. Their dominance is likely to reduce establishment of other species from the seedbank, or from nearby or more distant provenances. Thus, the diversity to be expected on a new boundary strip will generally be moderate. However, in a few decades the increase in species diversity could be substantial, depending on the presence of seed sources in a larger area (Schmidt, 1993). However, Borstel (1974) reported decreasing diversity.

If current input levels of agrochemicals and management practices were reduced, dispersal barriers could be bypassed by the introduction of desired species in the **first** year of the succession. This would greatly enhance the establishment of these species (even when sown with grasses). Such improved boundary communities could then resume their importance as indicators of a safe environment for sustainable agricultural production.

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REFERENCES

Anon. (1987) *Botanical database*. Voorburg: Centraal Bureau voor de Statistiek, 121 pp.
Bannink, J.F.; Leys, H.N.; Zonneveld, I.S. (1974) *Akkeronkruidvegetatie als indicator van het milieu, in het bijzonder de bodemgesteldheid*. Bodemkundige studies 11. Mededelingen Stiboka, Wageningen, 88 pp.
Borstel, U. (1974) Untersuchungen zur Vegetationsentwicklung auf ökologisch verschiedenen Grünland- und Ackerbrachen hessischer Mittelgebirge (Westerwald, Rhön, Vogelsberg). *Dissertation Universität Giessen*.
Grime, J.P. (1979) *Plant strategies and vegetation processes*. Chichester: John Wiley & Sons, 222 pp.
Grime, J.P.; Hodgson, J.G.; Hunt, R. (1988) *Comparative plant ecology*. London: Unwin Hyman Ltd.
Joenje, W. (1991) Perspectives for nature in dutch agricultural landscapes. *Proceedings British Crop Protection Conference Weeds - 1991*, 365-376.
Marshall, E.J.P. (1985) Weed distributions associated with cereal field edges - some preliminary observations. *Aspects of Applied Biology*, **9**, 49-58.
Marshall, E.J.P. (1989) Distribution patterns of plants associated with arable field edges. *Journal of Applied Ecology*, **26**, 247-257.
Marshall, E.J.P.; Thomas, C.F.G.; Joenje, W.; Kleijn, D; Burel,F.; Le Coeur, D. (1994) Establishing vegetation strips in contrasted European farm situations. *Field Margins - Integrating Agriculture and Conservation*, N. D. Boatman (Ed.), B.C.P.C. Monograph *No. 58*, Farnham: BCPC Publications.
Schmidt, W. (1993) Sukzession und Sukzessionslenkung auf Bracheäckern - Neue Ergebnisse aus einem Dauerflachenversuch. *Scripta Geobotanica*, **20**, 65-104.
Sissingh, G. (1950) Onkruidassociaties in Nederland. *Verslagen Landbouwkundig Onderzoek*, Wageningen, 56.15.
Tansley, A.G. (1935) The use and abuse of vegetational concepts and terms. *Ecology*, **16**, 284-307.
Welling, M. (1988) Auswirkungen von Ackerschonstreifen. *Mitteilungen der Biologische Bundesanstalt für Land- und Forstwirtschaft*, Berlin-Dahlem, Heft 247.