BOUNDARY STRIPS IN CEREAL FIELDS: DYNAMICS OF FLORA, WEED INGRESS AND IMPLICATIONS FOR CROP YIELD UNDER DIFFERENT STRIP MANAGEMENT REGIMES

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ABSTRACT

An experiment was carried out to evaluate the effects, over five years, of three types of uncropped boundary strip on weed ingress and cereal yield. The treatments (sown perennial ryegrass sward, rotovated strip and sterile strip receiving regular herbicide treatments) and a control (winter wheat) were arranged along the margin of a cereal field using a randomised block design with four replicates.

Four weed species, characteristic of field margins (*Galium aparine*, *Bromus terilis*, *Elymus repens* & *Poa trivialis*), were used as indicators of weed ingress. All were scarce initially, but became more abundant as the experiment progressed. The boundary strips influenced the rate of weed spread but did not halt it. Yields of winter wheat in the crop margin decreased considerably as weed populations increased. The association between yield loss and weed ingress is discussed.

INTRODUCTION

Field margins are important refuges or corridors for wildlife on intensively managed arable farms but are often perceived by farmers as reservoirs of pernicious weeds and are sprayed accordingly with broad-spectrum herbicides. However, repeated applications of non-selective herbicides, combined with misplaced fertiliser applications, may exacerbate the weed problem over the long-term by favouring competitive annuals, such as *Galium aparine* (Cleavers) and *Bromus sterilis* (Barren Brome), over less invasive perennials (Boatman 1992). Uncropped boundary strips, which receive no fertilisers and have modified herbicide programmes, show promise as weed barriers (Lainsbury *et al* 1992, Rew *et al* 1992) and may have additional environmental benefits by encouraging perennial herbaceous species which comprise suitable habitat for valuable insects and gamebirds (Boatman 1992). However, the efficacy of this alternative strategy for weed management has yet to be demonstrated fully (Marshall 1988).

This paper describes the effects, over the medium-term, of boundary strip management on the dynamics of four weed species: *Galium aparine*, *Bromus sterilis*, *Poa trivialis* (Rough Meadow-grass) and *Elymus repens* (Couch-grass). All show distribution patterns which imply that they originate from field margins (Marshall 1989). They are, therefore, good indicators for evaluating the effectiveness of boundary strips as weed barriers.

METHODS

A boundary strip, two metres wide, was maintained over five growing seasons (1988-1992) along the margin of a cereal field at ADAS High Mowthorpe. Three treatments plus a control were applied to 20 metre sections of the strip in a randomised block design with four replicates. The treatments were as follows: (i) a *Lolium perenne* (Perennial Rye-grass) sward, sown in 1988 and mown twice a year to prevent seeding, (ii) a bare strip rotavated twice a year, (iii) a sterile strip maintained by annual applications of a residual herbicide (propyzamide) in winter and a foliar systemic herbicide (glyphosate) during summer. The control plots contained winter wheat which received the same pesticide and fertiliser treatments as the main cropped area, where winter wheat was grown throughout.

Yield assessments were made annually within the crop margin and were matched to the plots in the boundary strip. From 1990, a 6m band of the crop margin adjacent to the boundary strip was not sprayed with herbicides to allow weed ingress into the crop.

Weed assessments were made annually in July from fixed transects, three per plot. Each transect line lay at 90 degrees to the field boundary and comprised 50 contiguous 10*10cm quadrats, numbered sequentially from 1 at the mid-line of the boundary to 50 in the crop margin. The presence or absence of each weed species was noted in each quadrat.

Weed ingress was assessed by comparing the distribution and abundance of each species between years. The farthest occupied quadrat from the mid-line of the hedge was defined as the weed front. Its position in each plot was taken as the median from the three transect lines. The number of occupied quadrats from the three transects, expressed as a proportion of the total number available, was used as an index of relative abundance in the strip and crop margins of each plot. Proportions were used because the number of quadrats in the strip and crop margin varied slightly between years due to shifts in the plough line that separated the two zones.

The analyses focussed upon trends in the position of the weed front and relative abundance, and whether they differed between treatments. Trends were quantified by subtracting values for a given year of the experiment from those for 1988. These differences were used as dependent variables when assessing treatment effects by analysis of variance.

RESULTS

The weed fronts of all four species moved out from the boundary during the course of the experiment but at different rates (Fig. 1). *Galium*, *Bromus*, and *Elymus* were restricted to the boundary in 1988. *Galium* had reached the crop margin by 1990, whereas the other two did not do so until 1991. In contrast, the weed front of *Poa* lay near the outer margin of the boundary strip in 1988 and had moved well beyond it by 1989.

The rate of movement of the weed fronts of *Bromus* and *Elymus*, differed between treatments in 1990 (ANOVA, $F_{3,12}$=5.84; P=0.011) and 1992 (ANOVA, $F_{3,12}$=6.65; P=0.007) respectively but not in other years (Fig. 1). There were no significant differences between treatments in the rate of spread of either *Galium* or *Poa*.

The relative abundance of each species in the boundary strip increased between 1988 and 1991, as their weed fronts advanced, but declined between 1991 and 1992 (Fig. 2). There were few significant treatment effects on trends in weed abundance in the boundary strips and effects were not consistent between species. In the case of *Galium*, the rate of increase in abundance between 1988 and 1990 differed between treatments (ANOVA, $F_{3,12}$=7.53; P=0.004) but peak abundance and the rate of decrease did not (Fig. 3). In contrast, *Poa* abundance differed between treatments in 1991, the peak year (ANOVA, $F_{3,12}$=5.45; P=0.014), but not when the species was increasing or decreasing. The rate of increase of *Elymus* between 1988 and 1992 differed between treatments (ANOVA, $F_{3,12}$=8.507; P=0.003) but no treatment effects were detected in other years. Trends in *Bromus* abundance were not related to boundary strip treatments in any year.

All species became more abundant in the crop margin, in step with the increases in the boundary strip (Fig. 2). In general, however, the abundance of each species in the boundary strip plots did not correspond with that in adjacent sections of the crop margin. The exception was *Elymus*, in 1992, when the proportion of occupied quadrats in strip and crop respectively were positively correlated (r = +0.686, $F_{1,14}$=12.413, P=0.003).

The mean annual wheat yield decreased markedly as the combined abundance of the four weed species in the crop margin increased but it recovered slightly in the last year of the experiment when weed abundance declined (Fig. 4). This inverse relationship was explored further by using multiple regression analysis to fit a linear model of weed abundance to the yield data from all crop margin sections in all years. The proportion of quadrats in each crop margin section occupied by the four weed species accounted for about 55% of the variance in yield. When year factors were entered as dummy variables, the percentage of variance in yield explained by the model increased to just over 75% (R^2=0.753, $F_{4,71}$=58.30, P<0.001).

The relationship between yield depression from 1988 levels and increase in weed abundance was of particular interest but the two variables were not correlated in either 1990, 1991 or 1992. However, in 1991, yield depression did differ between sections of the crop margin according to the treatments applied to adjacent plots in the boundary strip (ANOVA $F_{3,8}$=6.003, P=0.019; Table 1).

TABLE 1: Depression in winter wheat yield (t/ha) in crop margin between year shown and the 1988 reference levels, in relation to boundary strip treatment.

	Adjacent treatments							
Year	Mown strip		Rotivated strip		Sterile Strip		Control	
	mean SE 1	n	mean SE	n	mean SE	n	mean SE	n
	Reference yields							
1988	7.02±0.39	4	7.19±0.31	4	6.69±0.23	4	6.82±0.31	4
	Yield depression							
1990	3.97±0.46	4	4.59±0.22	4	2.95±0.39	4	2.98±0.89	4
1991[2]	3.98±0.43	3	4.87±0.39	3	3.40±0.38	3	2.45±0.46	3
1992	2.92±0.86	4	2.46±0.82	4	2.09±0.78	4	2.42±0.91	4

Notes: 1. SE = standard error of the mean. 2. One block of replicates was deleted from analysis because of extensive damage due to wheel rutting.

DISCUSSION

In all cases, where trends in weed abundance differed between treatments, *a posteriori*, comparisons of the treatment means suggested that increases or peaks in abundance were greater in the winter wheat control plots than in the boundary strips. Analagous comparisons of the weed front data showed that the rate of spread was faster in the cereal control plots than in the strip treatments. These findings imply that the boundary strips partially regulated the spread of the four weed species though they were not able to halt it. There was no evidence that a particular treatment performed better than the others.

The lack of correspondence between the weed distributions in the boundary strip and crop margin respectively suggests that the species did not simply advance across the strip and into the crop margin. Indeed, there was some evidence to suggest that, in some plots in the boundary strip, the weeds had reached the crop margin at an early stage of the experiment and then spread laterally along the crop margin which had not been sprayed with herbicides. This lateral spread may well have been facilitated by cultivation, particularly in the case of *Elymus repens*.

The depression of wheat yield in the middle years of the experiment was considerable and coincided with the removal of herbicide treatments on the crop margin and the build up of weed populations from the hedge and boundary strip. As the depression of yield ran counter to trends elsewhere on the Research Centre, it seems likely that it was due to conditions specific to the experimental site. Though the weed species considered in this paper may have been partially responsible, the poor fit of the regression model and the lack of a correlation between yield depression and weed abundance suggest that other factors, perhaps other weed species, played a significant role. The association between yield depression in 1991 and the boundary strip treatments is puzzling, particularly as the yield depression was smallest adjacent to the winter wheat control plots which were least effective as weed barriers.

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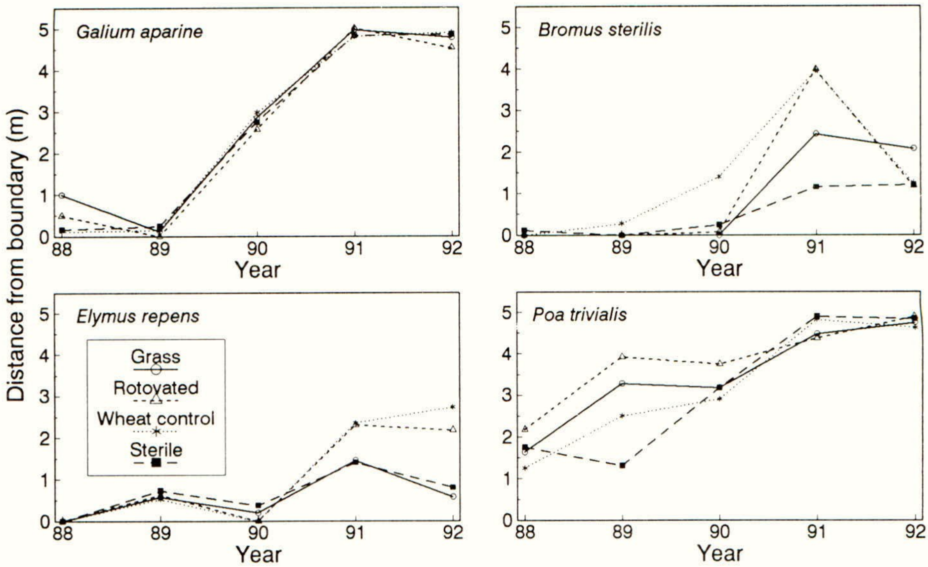

Fig. 1. Trends in the distance of the weed front from the mid-line of the hedge in relation to boundary strip treatment.

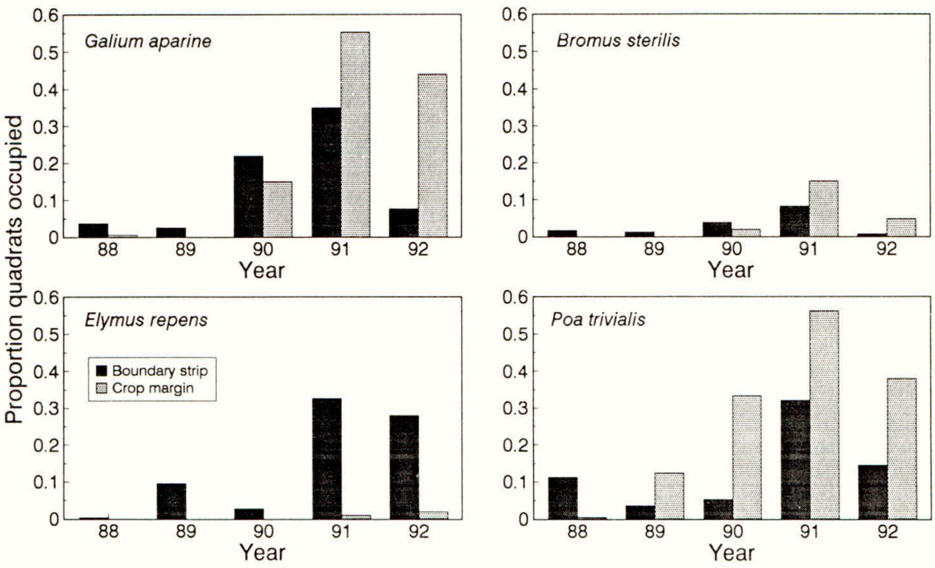

Fig. 2. Trends in overall weed abundance in boundary strip and crop margin.

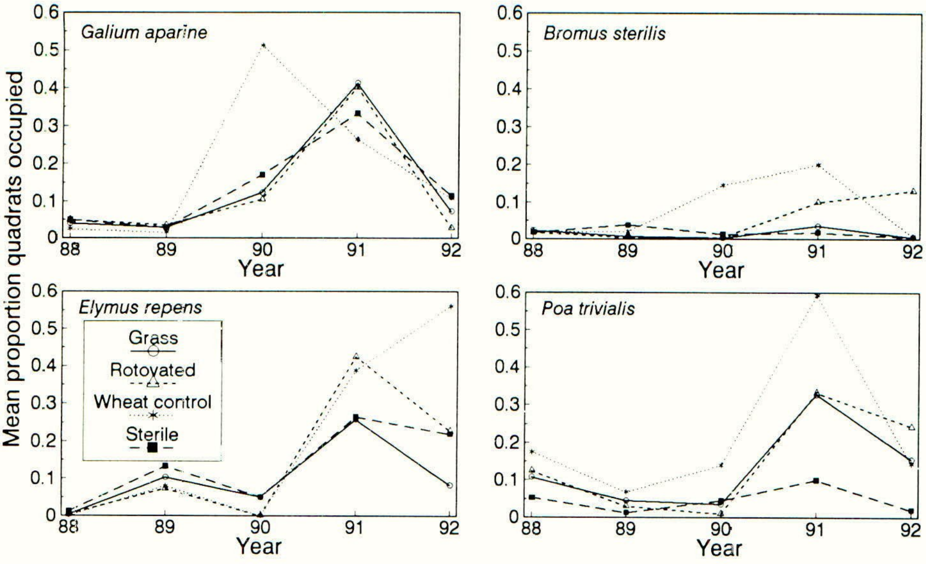

Fig. 3. Trends in abundance of weeds in boundary strip in relation to treatment.

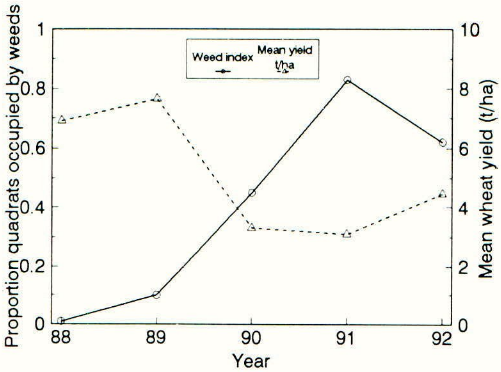

Fig. 4. Trends in combined abundance of four weed species in crop margin and winter wheat yields.

LARGE-SCALE FIELD TRIALS WITH CONSERVATION HEADLANDS IN SWEDEN

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ABSTRACT

The Conservation Headland technique, pioneered by The Game Conservancy U.K., has been tested in Sweden in large-scale field trials during 1991 - 1993. Ten pairs of farms in central and southern Sweden were chosen. One farm in each pair was sprayed normally, whilst on the other farm cereal field headlands received no pesticides. Unsprayed headlands had significantly more weed species, higher weed densities and a higher percentage weed cover. Unsprayed headlands supported higher densities of non-target arthropods, particularly the non-pest species which are important in the diet of insect-eating game-bird chicks. Mean brood sizes and chick survival rates of both partridges and pheasants were higher on farms with unsprayed headlands. The benefits of unsprayed headlands to the fauna associated with arable land are discussed.

INTRODUCTION

In 1986, the Swedish government launched a plan of action aimed at reducing the amounts of pesticides used in agriculture by 50% over a period of five years from 1986 - 1991 (Bernson, 1988). Following this a new target was set to reduce the 1991 level by a further 50% during the period 1991 - 1995 (Bernson & Ekström, 1991). As part of this latest programme, the Ministry of Agriculture commissioned research aimed at protecting the flora and fauna in agricultural land, including margins between cultivated and uncultivated areas (Jonsson, 1991).

Work was already in progress at our department testing the technique known as Conservation Headlands pioneered by The Game Conservancy in the U.K. (Chiverton, 1991). This involves the modification of pesticide use on cereal crop margins to encourage the growth of certain broadleaved weeds and their associated insect faunas (Sotherton et al., 1985).

The method was originally designed to improve survival of game-bird chicks, particularly those of the Grey Partridge (*Perdix perdix*). This species is associated with arable field margins and has declined dramatically since the 1950's both in England (Potts, 1986) and Sweden (Dahlgren, 1987). Partridge chicks are dependent for food on insects, many of which live on arable weeds (Potts, 1986). The use of broad-spectrum herbicides can indirectly reduce food-item insects by removing the host plants on which they depend. Large-scale field trials were started in 1991 to examine the benefits of Conservation Headlands to the flora and fauna in areas under intensive agriculture in central and southern Sweden. This paper describes these trials and presents some of the results obtained to date. The benefits of this method to other wildlife are discussed.

METHODS AND MATERIALS

Study sites.

In 1991, ten pairs of farms in central and southern Sweden were chosen for their similarity in size (mean = 107.1 ha, S.E. 8.38), cropping and agricultural practice. Paired farms were a minimum of 5 km apart and all had previously reported resident populations of partridges. All cereal fields on one farm in each pair ("control" farms) were sprayed normally (i.e. c. 100% of fields treated with herbicides; insecticides and fungicides usually after threshold levels are exceeded), whilst on the other farm ("experimental" farms) Conservation Headlands were employed. In contrast to the Game Conservancy's guide-lines for Conservation Headlands which allow the use of certain preparations at certain times, no pesticides are used at any time in our Conservation (unsprayed) Headlands. During routine applications of herbicides and other pesticides in cereal fields, spray nozzles on the outer boom of tractor mounted sprayers on the experimental farms were turned off so that the outer 6 m of crop on one half of the headlands in each field received no pesticides. In 1992, where crop rotation allowed, the headlands in the opposite half received no pesticide. In other cases, headlands on adjacent fields with cereals were used. In 1993 a similar 'rotation' occurred. This within-field, between-year rotation allowed farmers on experimental farms to treat the excess of weeds in the year following an unsprayed headland.

On individual experimental farms the actual positioning of the unsprayed headlands was determined by the location of pairs of partridges found during the spring survey (see below).

Partridge surveys.

In spring and after harvest each year, partridge counts were done using highly trained gundogs to flush the birds. The spring count established the number of pairs per farm and their locations and, in the case of the experimental farms, where to position the unsprayed headlands. On each farm, the number of cock and hen pheasants flushed in spring, and the size of pheasant broods flushed in autumn was also recorded. Autumn brood counts were conducted to estimate the productivity of game-birds on both experimental and control farms.

Weed assessments.

Weeds were assessed in the sprayed and unsprayed headlands on experimental farms and on sprayed headlands in corresponding cereal crops on control farms. Within each headland plot assessments of weed density, number of species and weed cover (on the Domin scale) were made in ten x 0.25 m^2 quadrats during the first weeks of July each year. Analysis of weed cover was conducted on an arcsine transformation of the percentage cover corresponding to the Domin measurements (Currall, 1987). Only data concerning weed cover will be presented here.

Arthropod assessments.

Vacuum-suction (D-vac) samples were taken from all headland plots at the same time as the weed assessments. In each plot ten samples of 0.5 m^2 were taken to extract the small, diurnal epigeal fauna and the crop/weed fauna. Some of the group or guilds of arthropods selected for analysis include a) Polyphagous predators e.g. Carabidae, Staphylinidae and Lycosid and Liniphiid spiders. b) Aphid specific predators e.g. adults and larvae of Coccinellidae, and the larvae of Neuroptera and Syrphidae. c) Chick food insects: Heteroptera and Homoptera (except Aphididae), Curculionidae, Chrysomelidae, and larvae of both Lepidoptera and Tenthredinidae. Only the results concerning group c) for 1991 - 1993 will be presented here.

RESULTS

Weed assessments.

Percentage weed cover was significantly greater on unsprayed headland plots in each cereal crop (winter- or spring-sown) and in each year (Fig. 1). For data regarding weed densities, and number of weed species see Chiverton (1993).

Arthropod assessments.

Two to four-fold increases in mean densities of chick food insect groups were observed in unsprayed headlands of winter and spring sown cereals on experimental farms compared to densities on sprayed headlands on experimental and control farms in each year (Fig. 2). The majority of these differences were statistically significant.

Partridge surveys.

A total of 21 pairs of partridges were found on experimental farms, and 15 pairs on control farms in 1991. Mean brood size on experimental farms in autumn in 1991 was found to be twice as large as the mean brood size on the control farms (Table 1). This difference was however not statistically significant (t_{12} = 1.17, n.s.). Chick survival rates (CSR = 3.665 x $^{1.293}$, where x is the geometric mean brood size (Potts, 1986)) were doubled where chicks had access to unsprayed headlands (Table 1). During the spring survey in 1992 a total of 20 pairs were found on the experimental farms and 19 pairs on the control farms respectively. Mean brood sizes were again found to be larger on experimental farms (Table 1) although these differences were not statistically significant (t_{19} = 1.33, n.s.). Chick survival rates, generally higher than the previous year, were larger on the experimental farms (Table 1). A total of 30 pairs were found on experimental farms and 23.5 pairs on control farms during the spring surveys in 1993. Autumn brood sizes were again larger on experimental farms but these differences were not statistically significant (t_{33} = 0.65, n.s.). Chick survival rates were high generally, but highest on experimental farms.

Pheasant brood sizes on experimental farms were almost double those on control farms in 1991, but these differences were not significant (t_{11} = 1.23, n.s.). Pheasant chick survival rates (CSR = 3.665 $(1.5x)^{1.293}$, (Sotherton, pers. comm.)) were correspondingly higher (Table 2). In 1992, there was little difference in pheasant brood size (t_{14} = 0.03, n.s.) and corresponding survival rates (Table 2). Differences in brood size and chick survival in 1993 were similar to those in 1991, though not significant (t_{22} = 0.76, n.s.) (Table 2).

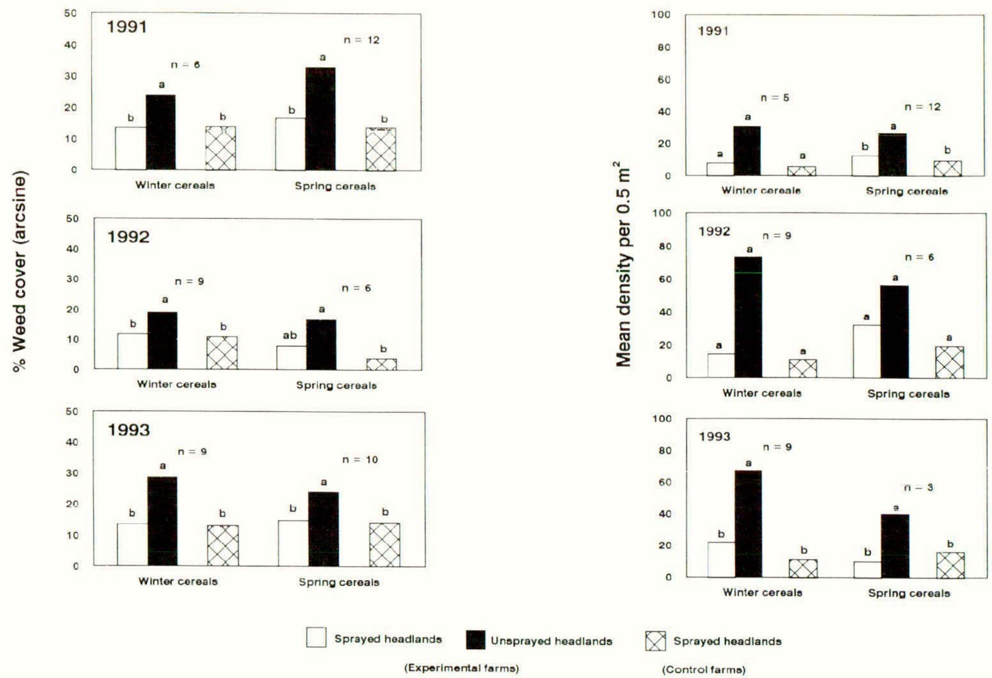

Fig. 1. Estimate of weed cover per 0.25 m^2 in headland plots of winter- and spring-sown cereals either treated with herbicide or remaining untreated, 1991 - 1993.

Fig. 2. Mean densities of insects which are important chickfood items in headland plots of winter- and spring-sown cereals either treated with herbicide or remaining untreated, 1991 - 1993.

(Different letters = $p < 0.05$, SNK; n = no. of farm pairs)

TABLE 1. Mean grey partridge brood sizes and chick survival rates on Swedish farms with unsprayed cereal field headlands and on farms where headlands were fully sprayed, August 1991, 1992 and 1993.

	Unsprayed headlands			Fully sprayed headlands		
	1991	1992	1993	1991	1992	1993
Mean brood size	6.6	8.4	8.9	3.3	6.0	8.0
(S.E.)	(1.5)	(1.1)	(1.1)	(1.4)	(0.9)	(0.8)
Number of broods	10	15	19	4	6	16
% chick survival rate	26.3	47.8	53.6	10.8	34.6	46.7

TABLE 2. Mean pheasant brood sizes and chick survival rates on Swedish farms with unsprayed cereal field headlands and on farms where headlands were fully sprayed, August 1991, 1992 and 1993.

	Unsprayed headlands			Fully sprayed headlands		
	1991	1992	1993	1991	1992	1993
Mean brood size	5.3	4.1	5.0	2.8	4.1	4.1
(S.E.)	(1.2)	(0.6)	(0.9)	(0.6)	(0.9)	(0.8)
Number of broods	7	9	11	6	7	13
% chick survival rate	38.7	34.4	37.1	20.2	31.4	25.7

DISCUSSION

In 1991 the weather during the peak hatch of partridges (last week in June) was very poor with more than double the rainfall, and much lower temperatures compared to 30-year averages (1961 - 1990). Despite this, unsprayed headlands supported significantly greater densities of weeds and, consequently, greater densities of the groups of insects that are vital for game-bird chick survival (Green, 1984). As a result Partridge and Pheasant chick survival rates were higher on experimental farms employing unsprayed headlands.

By contrast, in 1992 many areas in southern Sweden received little or no rainfall throughout the summer months of May, June and the first weeks of July, and temperatures during this period were well above the 30-year average. Several unsprayed headlands in spring sown cereal crops in southern and south eastern Sweden were destroyed by the drought. This probably explains the lack of significant effects of the herbicide treatments (see Chiverton, 1993).

Nevertheless, the trends were similar to those in 1991 with greater densities of both weeds and insects in the unsprayed headlands. Partridge chick survival rates were correspondingly higher on experimental farms employing unsprayed headlands. Chick survival rates for pheasants were however similar on both experimental and control farms. In 1993 favourable weather during, and immediately after, the main period of chick hatch resulted in comparatively high chick survival rates - particularly on the Baltic islands of Gotland and Öland. As in the two previous years however survival rates and brood sizes were higher on farms with unsprayed headlands.

The above results confirm earlier investigations demonstrating the value of unsprayed cereal field headlands for the survival of partridges (see e.g. Rands, 1985; Rands & Sotherton, 1987).

Current work in Sweden is aimed at establishing the agronomic consequences of omitting pesticide treatments on cereal headlands. Preliminary results from 1991 regarding grain yield and quality have shown no significant differences in spring sown cereals, but significant yield reductions in unsprayed headlands of winter wheat. It is anticipated however that Swedish farmers will find that unsprayed headlands offer a practical, realistic and effective method of protecting their game and benefiting other wildlife, at a cost which they find acceptable.

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ADOPTION OF CONSERVATION HEADLANDS TO FINNISH FARMING

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ABSTRACT

Changes in Finnish agricultural practices, including the reduction in pasture area and increase in autumn ploughing, shift to subsurface drainage from open field ditches, and introduction of pesticides have in recent decades altered agricultural biotopes of naturally occuring plants and animals. As a consequence, 25 animal and 14 plant species are listed as endangered. Weed densities decreased by 70% in less than 25 years. Conservation Headlands, i.e. selectively sprayed crop margins, have been studied since 1992 and increased weed and insect densities are reported already.

INTRODUCTION

Finnish agricultural landscapes have undergone similar changes during past decades as other agricultural areas under modern mechanized production. Consequences to wildlife are not well known and management recommendations to farmers for protection of biotopes of naturally occurring plants and animals are either too general or lacking. Conservation Headlands have been shown to offer resources and create habitats for a wider diversity of species than cereal farming would otherwise support (Sotherton, 1991). The aim of the Finnish Conservation Headland study is to assess the suitability of the technique to Finnish spring cereals, and to arable crop production in general.

AGRICULTURAL LAND USE AND FIELD MARGINS

One of the most important changes in Finnish agriculture was the introduction of pesticides some forty years ago. In 1953, agriculture used 235 t AI of pesticides, out of which 72% was herbicides and 16% insecticides (Markkula *et al.*, 1990). In spite of the increase in efficiency, the 1429 t AI sold in 1992 (65% herbicides and 6% insecticides) was six times more than forty years earlier (Hynninen & Blomqvist, 1993). The peak use was 2331 t AI in 1980 (Markkula *et al.*, 1990). The UK use in 1992 was 23,800 t AI.

In 1992 herbicides were used on 0.63 million ha which corresponds to 69% of the area under cereals. During the last thirty years most of the volume (58.5% in 1992) has been phenoxy acids. Insecticides were applied to 0.28 million ha corresponding to 11% of arable land; 48% of the volume was dimethoate. An obvious explanation for the decline in abundance of arable weeds in Finnish cereals is the regular use of herbicides. Total weed density decreased by 70% in less than 25 years, and as an example, the average decline in species that provide prreferred seed food of grey partridge was 29% in terms of frequency and 64% in terms of density (Table 1).

In parallel to introduction of pesticides, two other major forces have reshaped the

TABLE 1. Decline in frequency (% of fields in the survey from which the species was found in the sample) of some common weed species, and decline in density of these and of all species combined in Finnish spring cereal fields in two decades.

Taxon	Frequency %		Density, nos. m^{-2}	
	1962-1964*	1982-1986**	1962-1964	1982-1986
All species	.	.	550	164
Chenopodium album	92	55	60	12
Fallopia convolvulus	59	42	3	2
Galeopsis sp.	94	72	67	11
Polygonum aviculare	42	33	3	1
P. lapathifolium	73	27	16	3
Stellaria media	85	72	83	16

*Mukula *et al.* (1969) (N = 2548 fields)
**Erviö & Salonen (1987) (N = 267 fields) and Mela (1988) (N = 166 fields) combined.

TABLE 2. 'Species of primarily agricultural habitats' listed in the RED BOOK (Rassi *et al.*, 1991) as extinct or endangered, 'primarily because of' changes in agricultural habitats.

BIRDS:	VASCULAR PLANTS:
Crex crex, endangered	*Agrostemma githago*, disappeared
Perdix perdix, declined	*Camelina alyssum*, disappeared
	Cuscuta epilinum, disappeared
LEPIDOPTERA:	*Lolium remotum*, disappeared
Ochsenheimeria taurella, disappeared	*Papaver dubium*, disappeared
Agonopterix laterella, endangered	*Spergula arvensis maxima*, disappeared
	Bromus secalinus, endangered
COLEOPTERA:	*Consolida regalis regalis*, endangered
Aclypea undata, declined	*Fumaria vaillantii*, endangered
Ceutorhynchus pallidactylus, declined	*Odontites verna*, endangered
Longitarsus parvulus, declined	*Vicia villosa*, endangered
Aphthona euphorbiae, poorly known	*Lithospermum arvense*, declined

agricultural landscape. Traditional drainage system is a dense network of open field ditches, which has to a large extent been replaced by subsurface drainage. In the main argricultural area, the proportion of fields that had ditches removed increased from 15.3% in 1960 to 62.2% in 1990 (Anon., 1963, 1991). In thirty years, subsurface drainage resulted in loss of ca. 0.5 million km of field boundary habitat. During the same period, the proportion of arable land that is ploughed in autumn increased from ca. 60% to 80% (Anon., 1963, 1991). This is a consequence of increase in annual crops, especially spring cereals, at the expense of pasture leys. In ploughed fields, boundary habitats with permanent vegetation stand out in sharp ecological contrast to the arable land.

The RED BOOK (Rassi *et al.*, 1991) does not directly attribute any plant or animal species being endangered because of the above mentioned changes. However, out of the four bird, 21 insect and 14 vascular plant species that are included because of 'changes in agricultural habitats' (Table 2), grey partridge (*Perdix perdix*) (see Potts, 1986), possibly corncrake (*Crex crex*), kestrel (*Falco tinnunculus*) and even the now extinct quail (*Coturnix coturnix*) have suffered from indirect effects of herbicides, from disappearance of boundary habitats and from autumn ploughing. Some declines have obvious reasons: e.g. many dung beetles are endangered because cow droppings are no longer available in certain types of meadow pastures (many more endangered or extinct species are associated to disappearance of traditional forest meadows in absence of grazing), and *Cuscuta epilinum* disappeared along with growing of flax.

Decreasing trends in plant and arthropod diversity in arable ecosystems are reported, and among other measures, Conservation Headland techniques to prevent further loss are being developed, elsewhere (e.g. in England: Potts & Vickerman, 1974; Potts, 1986; Rands & Sotherton, 1986; Boatman, 1987; Wilson *et al.*, 1990; in Germany: Schumacher, 1980, 1987; in Sweden: P.A. Chiverton, unpublished). The available data suggest declining trends in diversity in Finland as well.

THE CONSERVATION HEADLAND STUDY

Materials and methods

Altogether 12 experimental Conservation Headlands and control headlands were established for 1992-1994 in four farms in Central and Southern Finland. Pesticides were excluded: not even selective sprayings are allowed in the experimental headlands. The crops are spring cereals barley, oats and wheat. Each year, decision on the crop species and all other management except crop protection is left to the farmer. The control headlands and the main crop always received one spraying of phenoxy acid herbicides, and of these, three received one spraying of dimethoate insecticide in both years and an additional two received one spraying of pyrethroid insecticide in 1992 against bird cherry-oat aphid (*Rhopalosiphum padi*). The pesticides were applied at GS 1 to GS 2. Nine of the headlands are 6m wide and three (in one of the farms) are 4m wide. The length of a Conservation Headland varies from 100m to 200m, the adjacent control headland always being of same length as the experimental headland.

In late July, six 0.25 m^2 quadrats per headland are sampled for above ground phytomass of the crop plant, for AGP of weeds, and for species abundance. The scheme is systematic: the quadrats are evenly spaced into three 'sampling stations' within a crop margin. At each station, two parallel quadrats are sampled, 1.5 m and 3.0 m from the

TABLE 3. Number of weed species or genera (total from all the sites), and mean density and phytomass of weeds in experimental unsprayed Conservation Headlands (CH) and control headlands. (SE in parentheses)

Year	Treatment	Species number	Density nos. m^{-2}	Phytomass g d.m. m^{-2}
1992	CH	31	274.7 (36.7)	13.7 (1.8)
	Control	31	160.0 (20.9)	7.4 (1.5)
1993	CH	38	419.9 (44.6)	36.9 (4.8)
	Control	36	370.7 (63.1)	20.8 (4.3)

crop edge. The stations are the same each year, in order to minimize spatial variation.

In the first year, cereal grain yields were estimated by combining two samples of 4.0 row metres (rows are sown 12.5 cm apart) at each station, for three samples equalling 1.0 m^2 each. Three additional samples were taken within the main crop, 20 m from the crop edge. In order to improve accuracy, in 1993 grain yields were harvested by a plot combine. Three samples representing 10 m^2 to 20 m^2 (varied with the make and model of the harvester) were sampled from each crop margin and from the main crop. The procedure will be repeated in 1994.

In early July, arthropods are sampled by D-Vac® (five x 10 s per sample) around each of the vegetation quadrats described above. A sample consists of five 10s suctions parallel to the crop edge. In addition, a sweep net sample of two x 15 sweeps (method: Heikinheimo & Raatikainen, 1962) is taken from each headland.

First years' results and discussion

Weed densities and phytomass of weeds were significantly higher in the Conservation Headlands than in control headlands (Table 3). Altogether 47 weed species or genera has been identified so far. No difference in total number of species was detectable (Table 3). Twenty species were common to both treatments in both years. Conservation headlands shared 80% of the species with conventional headlands. Further analysis of species composition is required for detecting possible effects on diversity. Comparisons to earlier data (Table 1) suggest greater weed abundance in crop margins than in the main crop.

In most cases, weeds remained as an undergrowth and did not hamper combine harvesting. At one site, an infestation of *Cirsium arvense* and *Sonchus arvensis* was spreading from the Conservation Headland into the main crop. Development of selective spraying schemes (see Sotherton, 1991) will be necessary. Because of weed competition, cereal yields in Conservation Headlands were significantly ($p<0.05$, LSD=0.59t) reduced by 15% from 3.9t ha^{-1} (SE 0.4) to 3.3t ha^{-1} (SE 0.3); in comparison to the main crop's 4.2t ha^{-1} (SE 0.3), conventional headlands produced 7% and Conservation Headlands 21% less (1992 data only). Drought stress during the season may have aggravated the weed problem.

TABLE 4. Mean sweep net catch (nos. per 30 sweeps) of the six most abundant insect orders from experimental unsprayed Conservation Headlands (CH) and control headlands. (SE in parentheses)

Order	1992				1993			
	CH		Control		CH		Control	
Thysanoptera	959.6	(669.8)	1846.0	(1670.4)	590.5	(166.1)	745.9	(290.8)
Homoptera	1401.2	(457.5)	706.4	(384.5)	112.4	(30.3)	85.2	(16.8)
Diptera	76.9	(24.9)	69.4	(23.2)	79.8	(16.7)	74.2	(11.8)
Hymenoptera	58.0	(15.1)	46.2	(18.9)	34.3	(9.6)	29.4	(7.6)
Heteroptera	108.5	(91.7)	43.0	(34.0)	8.5	(2.9)	7.3	(3.4)
Coleoptera	13.5	(5.3)	6.5	(2.6)	7.0	(2.6)	5.2	(1.5)

Variation in insect diversity between Conservation Headlands and control headlands was much smaller than between-site variation (sweep net data at Order-level). Overall, thrips (Thysanoptera) were more abundant in conventionally sprayed headlands in both years, whereas other main groups were more abundant in the Conservation Headlands (Table 4). In order to reveal patterns, a closer analysis at lower taxonomic level (preferably at species level) and site by site is needed. Survey data from thirty years ago is available for, e.g. leafhopper (Raatikainen & Vasarainen, 1971) and spider faunas (Raatikainen & Huhta, 1968) in cereals. These can be used for detecting long term changes in abundance and diversity.

CONCLUSIONS

Conservation Headlands are designed to conserve biodiversity in cereal ecosystems. In this respect, the need and importance of Conservation Headlands depend on intensity of management. Earlier survey data and information on endangered species indicate that in Finland, changes in agricultural practices have resulted in loss of diversity. Conservation Headlands would be most appropriate to specialized cereal farms in South and South-West Finland. The results from the ongoing study suggest that the benefits to wildlife from creating Conservation Headlands in Finland would be similar to those obtained in other countries. It is obvious that the effect on biodiversity in not immediate; rather, environmental benefits would accumulate over years. Conservation Headlands should be included as one option of a set of management practices designed to conserve wildlife in arable ecosystems.

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