MANAGING FIELD MARGINS FOR THE CONSERVATION OF THE ARABLE FLORA.

Philip Wilson.

**Farmland Ecology Unit, The Game Conservancy Trust,
Fordingbridge, Hampshire, SP6 1EF.**

ABSTRACT

The margins of arable fields are of great value for the conservation of endangered plants. Changes in farming practices during recent years have resulted in the severe decline of many species including some which were once very common, and some have even become extinct. There is therefore an urgent need for guidelines for the conservation management of these species and their communities. "The Wildflower Project" carried out between 1987 and 1990 showed that herbicide and nitrogen use were very important factors that could be easily manipulated within modern farming practice. The second phase of this project is designed to test these factors in practice and to provide some indication of the costs of management for the conservation of endangered arable plants.

INTRODUCTION

Since the revolution in arable farming since 1945, many species of arable weed such as *Scandix pecten-veneris* and *Ranunculus arvensis* which were once common, have become very rare. Others such as *Arnoseris minima* and *Caucalis platycarpos* have become extinct. In addition to the progressive restriction of many species to sites with conditions that are favorable to annual plants of mediterranean origin near the edge of their climatic range in Britain, most species are also becoming restricted to the extreme edges of arable fields where agricultural inputs are less efficient and crop yields are reduced (Wilson, in press).

Britain's arable field margins still contain populations of a number of threatened plant species. These include 25 that are classified as "Nationally Scarce" (recorded from fewer than 100 10km squares), and 24 "Red Data Book" species recorded from 15 or fewer 10km squares (Perring & Farrell, 1983). At least five further species are now of "Red Data Book" status. Of these "Red Data Book" species seven are now extinct, and ten others no longer occur in strictly arable habitats. Nine now receive full legal protection, although only two of these still occur at all in arable habitats (Wilson, 1994).

There is an urgent need for the conservation of these endangered species and the communities within which they occur, however until recently, little information has been available on which management can be based. It has also been difficult to persuade many conservationists that the arable habitat is of any importance.

THE WILDFLOWER PROJECT - PHASE 1.

A three-year research project was started in 1987 with the aim of investigating factors in the biology and ecology of a range of uncommon arable weeds which may be manipulated within the context of modern farming. Some of the findings are summarised below.

Germination periodicity and performance in relation to crop sowing time.

As a result of the germination periodicity of individual weed species, crops sown on different dates can support very different communities, even when the seed-bank is similar. Differences are greatest between autumn- and spring-sown crops, but can also be large between early and late autumn sowings and early and late spring sowings (Table 1). Changes in crop rotations and sowing times may have affected species with narrow germination periods.

TABLE 1. Mean numbers of plants in $4m^2$ plots of cereal sown on seven dates. Significance levels: *** $P<0.001$, ** $P<0.01$, * $P<0.05$.

Crop	Winter barley			Winter wheat			Spring barley			
Date	29:9	13:10	2:11	13:10	2:11	19:11	16:2	9:3	28:3	P
Agrostemma githago	20.2	6.1	0	7.3	0	0	0	0	0	***
Petroselinum segetum	4.3	8.0	5.0	6.1	3.0	0	0	0	0	***
Torilis arvensis	8.1	12.4	14.4	8.0	12.2	8.0	0	0	0	***
Scandix pecten-veneris	1.4	5.4	5.2	5.6	5.0	4.2	0.4	0.1	0	***
Ranunculus arvensis	2.5	10.3	13.0	12.4	16.5	5.4	0	0.1	0	***
Buglossoides arvensis	3.7	14.6	16.6	17.4	17.3	9.6	2.2	9.5	8.7	***
Adonis annua	0.1	1.7	3.7	3.3	5.7	7.1	0.2	0.9	0	***
Papaver argemone	0.1	0.6	2.8	0.2	4.9	5.9	0.7	2.0	1.3	**
Valerianella rimosa	2.6	5.2	9.5	0.9	6.0	12.7	4.4	7.4	5.1	*
Papaver hybridum	0	0	2.4	0	2.7	13.5	2.1	4.8	3.5	***
Chrysanthemum segetum	3.4	0	0.2	1.0	0	0.4	5.7	9.7	8.9	***
Silene noctiflora	0	0	0	0	0	3.6	6.6	7.1	15.5	***
Misopates orontium	0	0	0	0	0	0	0	0.3	4.8	*

Effects of crop type.

It was also possible to compare fruit production in winter wheat and winter barley in the experiment described above. *Agrostemma githago, Buglossoides arvensis, Papaver hybridum, Ranunculus arvensis* and *Scandix pecten-veneris* all produced significantly more fruit per plot in winter wheat, while only *Valerianella rimosa* produced more fruit in winter barley.

Herbicides.

Many uncommon species are susceptible to a wide range of herbicides (Wilson, 1990), and it is likely that the introduction of modern herbicides from 1945 onwards has been a very important factor in the decline of many species. Species are however differentially susceptible to different herbicides, and even some uncommon species are non-susceptible to commonly used compounds (Table 2).

TABLE 2. The susceptibilities in relation to unsprayed control plants of seven uncommon annual plant species to four commonly used herbicides as determined in an experiment using pot-grown plants. Significance levels: *** P<0.001, ** P<0.01, * P<0.05.

	Chlor-toluron	Mecoprop	MCPA	Ioxynil/ Bromoxynil
Buglossoides arvensis	*	*	ns	**
Chrysanthemum segetum	*	ns	ns	*
Misopates orontium	-	***	*	*
Papaver hybridum	**	***	*	*
Ranunculus arvensis	*	**	-	-
Silene noctiflora	*	*	-	***
Scandix pecten-veneris	**	***	**	*

TABLE 3. Number of plants per m^2 present at harvest time in plots of cereals to which nitrogen was applied at three levels. Significance levels: *** P<0.001, ** P<0.01, * P<0.05. - = not significant.

	Nitrogen Level (Kg/ha²) 0	75	150	
Misopates orontium	0.9	0.02	0	***
Myosurus minimus	0.3	0	0	**
Arnoseris minima	0.2	0	0	***
Papaver hybridum	1.2	0.6	0.06	***
Filago pyramidata	3.2	0.9	0.3	***
Valerianella rimosa	3.0	1.7	0.6	***
Papaver argemone	0.7	0.3	0.2	*
Scandix pecten-veneris	1.8	1.1	0.8	-
Chrysanthemum segetum	1.2	0.9	0.6	-
Silene noctiflora	2.3	2.0	1.2	-
Ranunculus arvensis	3.0	1.8	1.6	**
Buglossoides arvensis	2.0	1.3	2.2	-

Competitive ability in relation to crops at different levels of nitrogen application.

Mean levels of nitrogen applied to arable crops increased by over 600% between 1943 and 1988 (Chalmers et al, 1990), and the cereal cultivars that are now grown tend to be highly responsive to these high levels (Fischbeck, 1990). Most of the weeds which have decreased most rapidly are relatively slow-growing annuals which might be expected to compete poorly with a fully fertilised crop. In experiments, levels of nitrogen similar to those applied to modern cereal crops suppressed the growth of many weeds almost as effectively as herbicides (Table 3).

THE WILDFLOWER PROJECT - PHASE 2.

Phase 1 of the Wildflower Project identified several potential reasons for the decline of some arable weeds, but did not investigate the effects of manipulating any of these factors on existing populations, or the costs of conservation management to the farmer. The second phase which started in 1992 was designed to test options for the management of endangered arable weeds and their communities within the context of modern farming.

Ten experiments were set up in both winter and spring cereals in the south of England during 1992 and 1993. In these the effects of omitting herbicide and nitrogen on the numbers and seed production of a range of common and uncommon arable weeds were studied. Preliminary results suggest that omission of both nitrogen and broad-leaved herbicides result in the greatest floristic diversity and number of uncommon species (Table 4).

TABLE 4. Mean numbers of species of arable weed per $2.5m^2$ in plots of winter cereals grown under three regimes on three farms in Norfolk, Suffolk and Hampshire.

	Norfolk	Suffolk	Hampshire	Mean
Full nitrogen and herbicide	8.3	3.3	14.0	8.6
Full nitrogen, no herbicide	22.3	16.7	20.3	19.8
No nitrogen, no herbicide	24.3	19.0	25.7	23.0

A further series of experiments have been set up in 1993 and 1994. These have the aims of confirming the results of the previous year's investigations and also studying the effects of the use of selective graminicides on the growth and performance of uncommon broad-leaved species in fields where there are known to be large populations of highly competitive grass weeds including *Alopecurus myosuroides, Avena spp.* and *Lolium spp.*. It is possible that these grasses can have a detrimental competitive effect, especially where nitrogen applications are large. The effects of most of the modern selective graminicides on uncommon species are however not well known.

TOWARDS A MANAGEMENT STRATEGY FOR THREATENED ARABLE WEED COMMUNITIES.

Although the second phase of the "Wildflower Project" is at an early stage, it is possible to make some suggestions for the conservation management of endangered species and communities of arable land based on information gathered so far.

Conservation measures can, in most cases, be directed at the outermost four metres of fields, although there are exceptions where rare species grow outside this area. All broad-leaved herbicides must be omitted from conservation areas, although some selective graminicides may be permissible pending further work. Nitrogen should also be omitted as the competitive effect of a fertilised crop can suppress many uncompetitive species. It is important to drill crops at the correct time, although most species can withstand occasional years in crop rotations when conditions are not ideal. Practically this will mean either autumn or spring drilling, as the precise dates of farming operations are often determined by factors outside farmers' control. Winter wheat may allow better seed production than winter barley, and it is likely that modern crop varieties will be less competitive under low input conditions than older ones.

Some areas are already managed for their arable flora. Four sites have been scheduled as SSSIs by English Nature, although at only two of these are whole fields managed as part of a conventional arable farm. At one of these two sites, fertilisers and herbicides are applied as normal, while at the other no inputs are permitted. The headland only at the third site is managed. The fourth SSSI has recently been purchased by the Somerset Wildlife Trust, who intend to manage the three small fields as a working arable unit with minimal agrochemical inputs. The National Trust in Cornwall are currently managing some of their arable land for its arable flora, a particularly valuable initiative, as they are one of Britain's largest private landowners. Other sites are managed by informal agreement with landowners. One problem which has become apparant at some sites has been the build up of perennial weeds. Research into the selective control of these species will be essential future work.

In some fields where crops are not drilled up to the base of the field boundary, a zone of occasional cultivation exists between the crop and the perennial vegetation of the boundary. On nutrient-poor calcareous or sandy soils this zone can not only be of immense value for the least competitive arable annuals, but is also a habitat for annuals with atypical life-cycles and pauciennials, many of which, including *Ajuga chamaepitys* and *Teucrium botrys*, are now extremely rare. Research into the ecology of this habitat is also essential if the flora of the whole field margin is to be effectively conserved.

CONCLUSIONS.

It is already possible to propose provisional guidelines for the management of endangered arable plant communities and species, and on completion of the "Wildflower Project - Phase 2", detailed guidelines and costings of conservation management will be available. The implementation of such guidelines on a large scale is not impracticable. The experience of The Game Conservancy Trust with Conservation Headlands (Sotherton, 1990) has shown that given an incentive and soundly researched information, many farmers are happy to manipulate farming practices for environmental benefits (Thompson, 1993). Guidelines for the conservation of the arable flora can easily be incorporated into the management of Set-Aside land (Firbank & Wilson, in press) or the Countryside Commission's Stewardship scheme. Such programmes are already funded over large areas of Germany by local government (Schumacher, 1987), and with the political will, the future of some of our most endangered plants could become considerably brighter.

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COMPARISON OF FIVE DIFFERENT BOUNDARY STRIPS - INTERIM REPORT OF FIRST TWO YEARS' STUDY

M.J. MAY

Morley Research Centre, Morley, Wymondham, Norfolk, NR18 9DB,

CLARE EWIN

Wymondham College, Morley, Norfolk NR18 9SZ

J. MOTT

University of East Anglia, Norwich NR4 7TJ

R. PACK and CAROLINE RUSSELL

Anglia Polytechnic University, East Road, Cambridge CB1 1PT

ABSTRACT

An experiment was initiated in winter wheat during autumn 1991 to compare five different boundary strips. These were 2 m wide by 16.5 m long and comprised conventional cropping (up to the field boundary), a sterile strip (by rotary cultivation), sown grasses, a game conservancy style strip (conservation headlands with barrier + sterile boundary strips) and sown wild flowers. In the first two years of the experiment, changes in weed flora have been recorded. Some invasive weeds such as *Elymus repens*, *Cirsium arvense*, and *Urtica dioica* are starting to ingress from the field boundary into some boundary strips and, where competition is poor, *Galium aparine* and *Bromus sterilis* are also starting to invade the boundary strip. Large differences in the numbers and species of invertebrates were recorded in pitfall traps, but the reasons for the differences cannot currently be explained.

INTRODUCTION

There is an increasing demand from farmers for more information concerning the practical, biological and financial effects of various boundary strips on farming systems. There is some information regarding the effects of conservation headlands on crop yields (Boatman & Sotherton, 1988); in general there was no significant yield loss. However, there is little comparative information between various types of boundary strips, especially for arable situations as encountered in Eastern England. This paper is a preliminary report of the first two years of a long term experiment to compare different boundary strips and their effects on crop yield and insect and weed fauna.

METHOD

Five different boundary strips were established on the east side of a north south embankment adjacent to a public road. The experiment was on a sandy loam soil at Manor Farm, Morley, Norfolk and established on the 'non-turning headland' of the field. The bank itself was relatively uniform with only a few small (<2 m tall) trees. A winter wheat crop (cv Riband as a second wheat) was established on 24 October 1991 and the boundary strip treatments set up during the autumn and early spring. They comprised conventional cropping (up to the field boundary), a sterile strip (by rotary cultivation), sown grasses, a game conservancy style strip (a conservation headland with 1 m left next to the bank for the field boundary vegetation to expand and a 1 m sterile strip next to the crop) and sown wild flowers. These flowers were a modified Emorsgate EM1 mixture (Anon, 1992) sown on 11 November. The grass strips were sown on 2 April 1992 with an Emorsgate General Purpose Meadow mixture (Anon, 1992). The sterile strips were rotovated in autumn 1991 and again in May and September 1992 and 1993. The crop for the 1992 harvest year was winter beans (cv Punch) sown on 20 October. The plots were 2 m wide, 16 m long and replicated five times as a randomised block design. Only the cropped boundary strip received normal farm inputs, the rest received none, and the game conservancy style treatments did not receive herbicides or insecticides on the first 6 m of crop. The bean crop was not treated with herbicide.

Weeds were assessed by counts or scores. The numbers and frequency of weeds were assessed either by the use of five 0.1 m x 0.1 m quadrats in June and July 1993 or by ten 0.25 m x 0.25 quadrats/wildflower boundary and their presence recorded on a 1 m x 16 m transect along the plot. The wild flower boundary strip was assessed in detail in 1992, but other strips were assessed to record the major weed species present. Insects were monitored by pitfall (100 mm tall disposable plastic cups containing water and a few millilitres of washing up liquid) or specially constructed directional traps. Assessments on the game conservancy style boundary strips were meaned for the two separate sections unless otherwise stated. The crops were harvested using an adapted Claas Compact combine harvester; the wheat on 1 September 1992 and the beans on 1 September 1993. Yields from areas of the adjacent crop as assessed on seven 2 m wide strips each 14 m long. The yield of the conventional crop on the boundary strip was also recorded.

RESULTS

Plants

The two methods of assessment provided different results as to the number of species present. The transect system recorded fewer species than the two sets of five quadrats. The number of species and overall densities recorded in the quadrats is given in Table 1.

The most prolific vegetation along the bank was *Urtica dioica*, *Arrhenatherum elatius* and *Poa pratensis*. *Convolvulus arvensis*, *Dactylis glomerata*, *Rumex* spp, *Rubus fruticosus*, *Elymus repens*, *Cirsium arvense* and *Equisetum arvense* were also present, but to a much lesser degree. In 1992, *Bromus sterilis* and *Galium aparine* appeared to make use of the extra light available in the absence of crop or tall weeds and 'leant' over the boundary strip, where they could have shed seed.

In both years, each treatment gave different dominant vegetation in the boundary strip. The dominant vegetation in the cropped boundary strip was, of course, wheat in 1992 and beans in 1993. There were few weeds present in 1992, mainly *C. arvense* and a few *Achillea millefolium*, but in 1993 *A. elatius*, *Papaver rhoeas*, *Polygonum aviculare* and *Tripleurospermum inodorum* were recorded.

In 1992 there were few weeds in the sterile strips, mainly *Rumex obtusifolius* and *C. arvense* with a few annual weeds such as *Chenopodium album* and *Poa annua*. In 1993 *C. album* was the dominant weed, along with *A. elatius*, *Senecio vulgaris* and *Lamium purpureum*.

The grasses established reasonably well in 1992, but *P. aviculare*, *L. purpureum* and *Viola arvensis* were also present. In 1993, the sown-grass strips were dominated by *Cynosurus cristatus* (included in the sown mixture). The next most dominant were *Festuca rubra commutata, F. rubra purinosa* and *F. rubra rubra*) (collectively these made up 35% of the seedling mix). These were followed in cover by *Holcus mollis*, *D. glomerata*, *P. pratensis* and *A. elatius*. Invasive weeds included *C. arvense*, *E. repens* and *U. dioica*. *Leucanthemum vulgare*, *Achillea millefolium*, *Agrostemma githago*, *Plantago lanceolata* and *F. rubra*, each included in the wild flower mixture, were present on all wild flower plots.

Table 3 shows a comparison between 1992 and 1993 of the main species present on the wild flower boundary. In 1992 the most abundant species were *P. rhoeas*, *Agrostemma githago*, *C. cyanus* and *A. millefolium*. In 1993 the dominant species had changed to *L. vulgare*, *A. millefolium* and *P. lanceolata*. *P. rhoeas* was absent from all plots and density of *A. githago* was low. *L. vulgare* was very successful in 1993, but was apparently absent in 1992.

In 1992, the weed spectra were similar in the sterile area of the game conservancy style and sterile boundary strips. In 1993 the most dominant vegetation in the first metre transect (essentially an extension of the bank) was *Trisetum flavescens* and *P. pratensis*. The one metre sterile strip suffered an invasion of *C. album* which varied between a trace to over 75% cover. Other weeds included *P. rhoeas*, *Galium aparine*, *T. inodorum, Heracleum sphondylium* and *A. millefolium*.

There were very few weeds present in the crop in 1992 (including the 6 m untreated area adjacent to the game conservancy style boundary), those present were mainly *P. annua* with *P. aviculare* and *T. inodorum*. The weeds invading the field crop in 1993 differed slightly between treatment, but the most invasive and dominant species was *P. aviculare* followed by *C. album* and *T. inodorum*. There was a greater variety of weed species next to the game conservancy style strips, but these did not exceed those on the sprayed strips.

B. sterilis was the most abundant species on the game conservancy style grass strip whereas on the sown grass boundary it was *C. cristatus*, *C. album* on the sterile areas, *A. millefolium* on the wild flower boundary and *P. aviculare* on the cropped headland (Table 2).

TABLE 1. Number of species recorded and mean density/m² in each boundary strip in June and July 1993

	Crop	'Game' bank	'Game' sterile	Sterile	Grass	Wild flower	Total species
Number of species							
Perennial dicot.	10	15	10	10	19	14	25
Annual dicot.	18	12	15	11	11	7	25
Total grasses	7	12	8	6	12	11	17
Total species	35	39	33	27	42	32	67
Density/m²							
Perennial dicot.		92	94	64	44	40	112
Annual dicot.		126	20	172	188	12	28
Total grasses		64	152	28	40	220	120
Total		282	366	264	272	272	360

TABLE 2. Average percentage of the major species recorded on each boundary strip in June and July 1993

	Crop	'Game' bank	'Game' sterile	Sterile	Grass	Wild flower
Perennial dicotyledons						
Rumex obtusifolius	1.5	2.1	2.7	4.5	1.2	
Cirsium arvense	3.1	3.7	6.1	3.2	1.2	1.2
Equisetum arvense	2.3	5.8	3.3	0.6	0.2	0.9
Achillea millefolium	3.1	3.3	0.5	1.9	2.0	12.8
Annual and perennial grasses						
Poa annua	6.1	2.1	4.4	1.3	1.2	1.2
Bromus sterilis	4.6	16.5	0.5	2.6	7.7	3.1
Dactylis glomerata		4.1	1.1		4.2	3.4
Elymus repens	0.8	1.6	1.1	7.1		
Cynosurus cristatus					30.9	9.7
Arrhenatherum elatius	2.3	13.2	1.1	2.6	2.0	
Poa pratensis	0.8	12.3			12.3	4.4
Triticum aestivum	8.4	1.6	1.1	0.6	1.0	1.2
Annual dicotyledons						
Chenopodium album	3.8		46.7	56.5		
Galium aparine	8.4	2.9	2.2		0.5	0.9
Myosotis arvensis	0.8		0.5			
Viola arvensis	1.5	0.4			0.2	
Senecio vulgaris	1.5	0.4	4.4	5.2	0.5	
Sisymbrium officinale	1.5					
Polygonum aviculare	13.7	0.4	2.2	0.6		

TABLE 3. Changes in flora dynamics (plants/m^2) of wild flower boundary strip, 1992-93

	1992	1993
Achillea millefolium	22	95
Leucanthemum vulgare	0	58
Centaurea cyanus	26	1
Agrostemma githago	12	16
Plantago lanceolata	0	24
Tripleurospermum inodorum	18	12
Papaver rhoeas	32	0

Invertebrates

Table 4 contains data for the invertebrates found most frequently in pitfall traps in 1992 and 1993. Individual species were not identified, but the majority of beetles was *Amara aulica*. The figures for the 'Game' boundary are the mean of the two areas.

In July 1993 there was a trend for more invertebrates to be caught in directional traps set in the field boundary (21.8) and less in the field (15.5) but this was not statistically significant (p=0.05) for any individual or group of species (Table 5). The traps did not provide conclusive data as to whether the invertebrates were moving within or simply traversing the areas sampled.

TABLE 4. Invertebrates caught in pitfall traps 28 May and 7 July 1992 and 21 June 1993

	Wildflower	Grass	Sterile	Crop	'Game'	SED
28 May 1992						
'spiders'	20	19	10	17	14	6.7
'beetles'	23	38	52	11	33	5.9
'ladybird larvae'	15	8	3	2	6	1.4
'aphids'	0	0	0	0	0	
7 July 1992						
'spiders'	14	14	7	21	6	2.4
'beetles'	35	38	22	4	37	6.6
'ladybird larvae'	1	3	0	0	0	0.3
'aphids'	15	6	21	153	272	10.56
21 June 1993						
'spiders'	3	3	3	2	4	1.1
'beetles'	2	4	3	3	5	1.5
'ladybird larvae'	>1	0	0	0	>1	0.2
'aphids'	0	0	1	0	>1	0.5

TABLE 5. Invertebrates caught in directional traps in July 1993

	Wild flower	Grass	Sterile	Crop	Game	SED
Adalia bipunctata	0.37	0.06	0.75	0.00	0.31	0.278
Amara aulica	0.38	0.69	1.56	3.12	1.94	0.767
Anthocomus fasciatus	1.37	0.81	0.31	3.62	0.88	1.082
Spharite glabratus	0.37	1.62	0.12	2.37	0.25	0.857
'snails'	1.50	0.94	0.31	0.13	0.37	0.406

Crop yields

TABLE 6. Mean crop yields for all harvested strips (t/ha at 85% dm)

	Wild flower	Grass	Sterile	Crop	Game	SED
wheat 1992	8.2	8.3	7.9	8.6	8.2	0.64
beans 1993	3.6	3.8	3.5	4.4	3.4	0.42

Harvest was delayed in 1992 owing to wet weather and brackling increased from 17% (adjacent to the field boundary) to 78% (10 to 12 m into the crop), but there was no significant difference between treatments. Whilst there was a trend of slightly poorer wheat yields near the field boundary, there was no significant interaction between the boundary strip treatments and distance into the field. The lowest wheat yields occurred where the crop was grown with a sterile boundary and highest where wheat was grown on the boundary strip (Table 6). There was no significant difference between the other boundary treatments.

DISCUSSION

These data show the complexity of regrowth onto the headland strips. All the unsown species found can be expected to occur as opportunists in similar situations, and the generally low percentage incidence confirms the large number of species which will colonise in these circumstances. It is likely that this diverse flora is of considerable benefit. The experiment has been sown to winter wheat for 1994 and will be sugar beet in 1995.

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THE CASE FOR HEADLAND SET-ASIDE

D.L. SPARKES, R.K. SCOTT

Department of Agriculture and Horticulture, University of Nottingham, Sutton Bonington Campus, Loughborough, Leics LE12 5RD.

K.W. JAGGARD

Institute of Arable Crops Research, Broom's Barn Experimental Station, Higham, Bury St. Edmunds, Suffolk IP28 6NP.

ABSTRACT

Headland yields were recorded by farmers on commercial cereal and sugar beet crops. The yield of the headland averaged 26% lower in the sugar beet crops and 11% lower in the winter wheat. One spring barley field was also monitored, and in this field the headland actually outyielded the midfield by 20%. Experimental work at Sutton Bonington indicated that yields of winter barley and sugar beet increased with distance into the field. When boundary strips of different widths around the crop were planted with grass no evidence for migration of the 'headland effect' into the field was found.

INTRODUCTION

The first set-aside scheme began in 1988. This was a voluntary programme which allowed farmers to take 20% or more of their land out of production for five years: for doing this farmers received a payment per hectare set aside. In 1991 a further voluntary scheme was introduced which allowed set-aside for one year only. The lower limit for this was set at 15%.

In 1992 the Common Agricultural Policy (C.A.P.) reforms introduced a new set-aside scheme across the European Community (E.C). The system of intervention payments was dropped, and replaced by Arable Area Payments. In order to qualify for these payments, farmers with more than 16 hectares of land in eligible crops had to set-aside 15% of their acreage on a rotational basis. From 1993, a non-rotational option is also available, set at the higher rate of 18%, making headland set-aside possible.

Depending on the size and shape of a field, the crop margin can be difficult to manage, and often yields poorly in comparison to the rest of the field (Boatman & Sotherton 1988, Speller, Cleal & Runham 1992). From studies on sugar beet headland yields, Jaggard (pers. comm.) estimated that headlands take up 15% of the area, require 20% of the effort, but only produce 10% of the yield of an average field. Headland set-aside would allow fields to be 'squared-off', and for all turning of sprayers, spreaders, hoes and harvesters to take place out of the crop.

At Bedfordia Farms, Bedfordshire where headland set-aside has operated for the past five years, it was estimated that taking 20% of the land out of production reduced yields by just 11% but reduced machinery and labour costs by 35%. These figures, were they repeated elsewhere, would make headland set-aside very attractive to the farmer.

The potential benefits of headland set-aside are not just economic. A grass strip between crop and boundary could act as a 'buffer zone', preventing nitrate and phosphate leaching into water courses. It could also provide nesting areas for game, hunting areas for owls and kestrels and, if wild flower species are encouraged, the diversity of flora will attract a wider range of fauna.

On-farm studies have been conducted to look at crop margin yields in comparison to field centre yields in cereals and sugar beet, the latter of which is more susceptible to soil compaction (Brereton 1986). Experiments at Sutton Bonington have been used to look at the yield profile of barley and sugar beet in detail. Various widths of grass strip were used to determine whether the 'headland effect' would be removed if a boundary strip were fallowed, or if it would migrate into the field.

METHOD

Data collection from commercial crops

Several farmers were asked to record, for one or more fields, the headland yield separately from the rest of the field. These data are not always directly comparable as 'headland' can be interpreted either to mean the crop margin all round the field, or just the at the turning ends of the field.

Sugar beet

Two farmers in East Anglia collected data on headland yields of sugar beet fields. At Upton Suffolk Farms, the two 'turning headlands' were recorded separately. At Weasenham Farms yield data were collected for four fields on the all-round headland as compared to the mainfield. Beet harvested from the headland was kept in a separate heap, and delivered separately to the factory in order to distinguish it from that lifted from the rest of the field.

Cereals

The Datavision system was used to record cereal yield on two fields at Moat House Farm, Sufolk. Combine harvesters with the Datavision system have a small radioactive source on one side of the grain elevator which emits low energy gamma rays. These are detected by a receiver on the other side. Yield is monitored as the grain passes up the elevator, interrupting emissions from the radioactive source. The headland was defined as twice around the field with the combine harvester, which had a cutter bar width of 5 metres. The on-board computer recorded yield and area harvested for the headland, and the whole field. Therefore, centre field yield was calculated by subtraction.

Experimental Methodology

An experiment was designed to investigate the effect of fallowing different widths of boundary strip on the yield of commercial crops. Three widths of grass strip (seed mixture of *Holcus lanatus, Phleum pratense* and *Dactylis glomerata*) were chosen to fit in with the farm machinery, e.g. drill, sprayer and fertiliser spreader. Due to the differences in the machinery used for the cereal and sugar beet, the widths are slightly different in each case. The three widths of boundary strip were compared with cropping up to the field boundary. Therefore, there were four treatments, each of which were replicated four times. Each plot was 18 metres long.

For practical reasons associated with the commercial use of crop protection chemicals by farm staff within the experiments, the treatments were arranged in a systematic design, within a block. The widths of grass strip were arranged as a progression 0, 5.4, 10.8, 18m: in the adjacent block this progression was reversed to produce a castellated effect. Each experiment had four replicates, therefore two of these 'castles'. (The grass strip widths given above are for the sugar beet experiment, in the barley crop, because of differences in machinery the widths were 0, 3, 9, 18m).

Crop cover measurements were taken throughout the growing season of both crops using a spectral-ratio meter. Measurements were made at 3 metre intervals from the field boundary to 36 metres into the field.

A cone penetrometer was used to measure soil compaction, also in a transect from the field boundary to 36 metres into the field, in the barley crop on 25 February. Equipment failure, followed by adverse weather conditions, prevented this from being repeated in the sugar beet crop.

Sugar beet

Sugar beet seed (cv. Celt) was drilled on 19 April 1993, at a within row spacing of 16.5cm and between row spacing of 45cm. Crop cover measurements were taken on 26 May, 23 June and 14 July. The crop was harvested on 1 and 4 October. Areas harvested were 6 rows by 2 metres in the headland, and 4 rows by 3 metres in the mainfield (because of the change in direction of the rows), thus 12 metres of row were harvested from each plot. The roots were pulled by hand and topped in the field. The samples were put through the tarehouse at Broom's Barn Experimental Station to determine clean root weight and sugar concentration.

Barley

Winter barley (cv. Pastoral) was drilled on 13 and 14 October 1992. Crop cover measurements were taken on 23 February, 21 April and 26 May.' The crop was harvested on 27 and 28 July with a Wintersteiger plot combine (cutter bar width 1.75 metres). Strips were cut from the plots at different distances from the field boundary. Moisture content of sub-samples was determined and the yield standardised to 85% dry matter. Once the samples had passed through a seed cleaner, 1000 grain weights were determined using a Decca Mastercount to count 200 grams of seed.

RESULTS

Studies in commercial crops

Sugar beet

Data collected from two farmers in East Anglia on headland beet yields showed significant reduction in yield compared with the field centres. On one field, 6.24 ha in size, only turning headlands were recorded separately, these yielded 34.6 t/ha, while the rest of the field averaged 63.4 t/ha. Four fields were measured with an all-round headland kept separately from the field centre. On these fields yield on the headland was 21.7 - 30.7 % lower than that on the centre. (Table 1.).

Table 1. Headland and centre field yields of sugar beet from four fields in 1992

Field name	Lamberts	Pottle	Bullrush	Chicory
Field area (ha)	31.13	21.01	15.87	16.32
Headland area (ha)	3.61	3.09	2.62	2.52
Centre yield (t/ha)	43.26	34.53	45.69	46.25
Headland yield (t/ha)	27.52	26.56	35.77	33.69

Cereal

Winter wheat (cv. Estica), harvested on 20 August from a 7.73 ha field, yielded 7.31 t/ha on the headland (1.43 ha) and 8.27 t/ha on the rest of the field. A 4.78 ha field of spring barley (cv. Alexis) harvested on 17 August, yielded 5.22 t/ha on the 0.9 ha headland and 4.08 t/ha on the field centre.

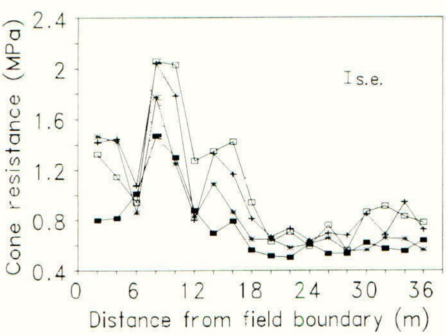
Replicated experiments

The crop cover measurements, made with the spectral-ratio meter, did not show any significant differences due to position in the field.

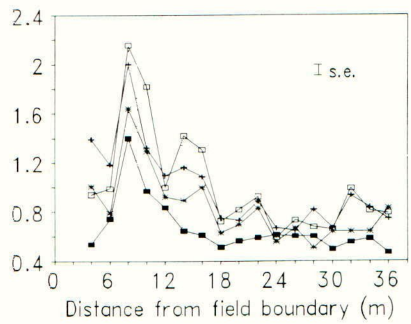
In general, the density of the soil in the barley crop, measured as the cone penetrometer resistance, was least near the surface and increased to a depth of about 25 cm (Fig. 1). The density was greatest 8 to 10m from the field boundary, corresponding with the positions of the tramlines. The resistance then decreased by about 0.5 MPa in the region 12 to 16m from the field boundary: this corresponds to the area where the sprayer turns around. The outer 4m of the field had a similar density, probably corresponding with the turning of cultivation machinery. Cone resistance 18 to 36m from the field boundary was consistently small. There was no evidence that the grass strip affected cone penetrometer resistance.

Figure 1. Cone resistance of soil in a transect from field boundary to 36m.

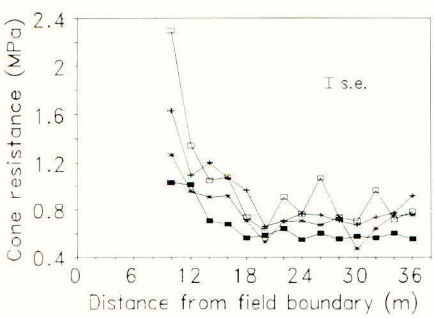
(i) Plot A, cropped to field boundary



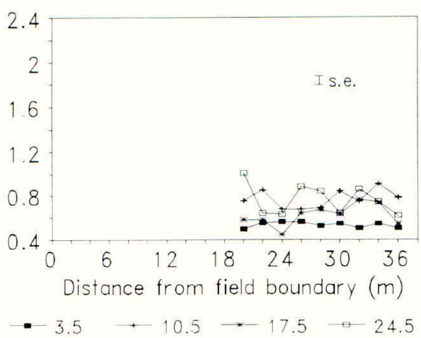
(ii) Plot B, 3m grass strip



(iii) Plot C, 9m grass strip



(iv) Plot D, 18m grass strip



The yields of barley are shown in Fig. 2. The position of the tramlines can be seen clearly, corresponding to a serious yield reduction. There was little evidence that yield was influenced by width of grass strip. The thousand grain weight averaged over all plots, was 36g. There were significantly larger thousand grain weights at 6-9 and 9-12m from the field edge, i.e. the position of the tramlines.

Fig. 3 shows sugar yield of the plots without a grass margin. Yield was small at the very edge of the field, and at about 10m from the boundary. Again, this corresponds to the tramlines. Overall, yield at the crop margin was smaller than in the main field. Sugar percentage was not affected by position in the field, but there was a clear trend in root weight.

Figure 2. Yield of barley from the field boundary to 36 metres into the field.

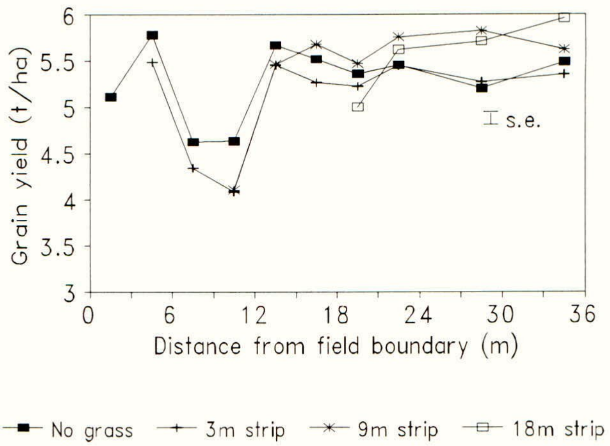
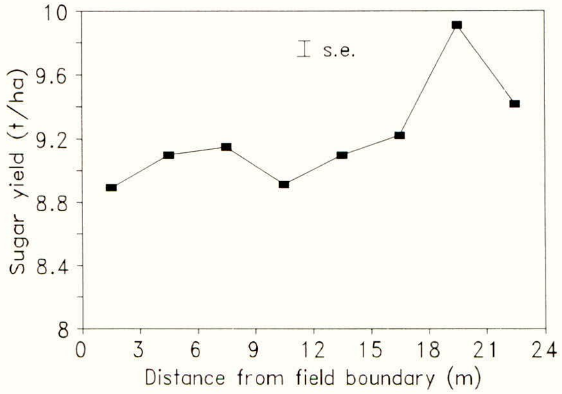


Figure 3. Yield of sugar from field boundary to 24m into the crop.



DISCUSSION

Studies in commercial crops, especially sugar beet, revealed the low yields of headlands. However, in one case, the spring barley field, the headland actually yielded more than the midfield. Boatman (1992), reported larger yields on headlands than the centre for two out of three spring barley fields. Boatman & Sotherton (1988), measured cereal headland yields over several years. Although, on average they yielded 18% less than the midfield, there was great variation, from 67% decrease to 24.9 % increase. All other on-farm measurements showed reduced yield on headlands, particularly evident in sugar beet crops.

As well as yielding poorly, the crop margin can be a difficult and time consuming area to manage. Therefore, even if the headlands were to yield as well as the midfield, it may be expensive to produce. The new set-aside rules provide an opportunity for farmers to create boundary strips around arable fields, which contribute towards their set-aside requirement. The experiments at Sutton Bonington showed no evidence for the headland effect moving into the field. However, the experiments so far have only tested one site for each crop in one year so firm conclusions cannot be drawn. The experiments will be repeated next year. It is interesting that thousand grain weights of the samples around the tramlines were significantly greater than those from the rest of the plot area. This may be due to the low plant population in this area, therefore less competition for light, water and nutrients, together contributing to more carbohydrate being produced and hence larger grains.

Neither field in these experiments had a hedge along the boundary where the trial plots were situated; this may mean that yield reduction at the crop margin was minimal. If there was an adjacent hedge, how would the results change? In 1993/4 an experiment has been designed to look at the various factors which together might cause small yields at crop margins, and attribute how much yield is lost due to each of these factors. It is a factorial experiment comparing yields with or without grass margins, with or without a hedge and with or without turning. There are also small fenced areas to prevent grazing by pheasants, rabbits etc.

Other benefits to be gained by setting aside the headlands are not easily quantifiable. If a hedge is already present, then an existing wildlife feature will be enhanced. There is also the possibility of a network of these headland strips providing wildlife corridors through arable England. Year-round access will allow crops to be monitored more easily, and hedge trimming / ditch cleaning timed to minimize disturbance to wildlife and when labour is not at a premium. 'Squaring off' fields will reduce overlapping of fertiliser and sprays.

The data accumulated from these experiments and studies will be used to calculate the cost of cropping the headlands, compared to setting them aside. The systems of whole field, rotational set-aside and headland set-aside will also be compared and their effects on the whole-farm budget studied.

ACKNOWLEDGEMENTS

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