SAFFIE – research into practice and policy

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Summary

SAFFIE is a five-year, joint industry, academic and government LINK project. The aim is to enhance biodiversity in and around winter wheat crops by integrating novel habitat management practices within the crop and field margins without compromising yields or profitability. The project has already produced results that are relevant to farmers entering the new Environmental Stewardship Scheme, and to Defra's policy objective to reverse the decline in farmland bird populations. The breeding success of skylarks in wheat crops with undrilled patches (skylark plots) was 49% greater than in the control crops. Novel margin management has improved the biodiversity value of cereal field margins. Work on 26 commercial farms aims to provide an understanding of the ecological interactions between margins and crops, so that sound, practical and scientifically-based advice on the best options for biodiversity can be given (www.saffie.info).

Introduction

By the nature of their work, farmers manage the environments in which they farm. Over the past 50 years, there has been strong pressure from both government and commercial sources to produce maximum yields from those environments. This has resulted in the decline in populations of some of our key farmland plant, bird and invertebrate species (Aebischer, 1991). With the launch of the Entry Level (ELS) component of the new Environmental Stewardship Scheme in the spring of 2005, all farmers now have the opportunity to help to redress the balance of wildlife and cropping on their farms, with compensation for land taken out of production for environmental benefits (Defra, 2005). Many arable farmers are now making management of the environment part of their farming businesses, through agri-environment schemes. Revenue from this source will increase in importance as the Single Payment Scheme funds are gradually diverted into the agri-environment schemes through the CAP reform measures. Choosing the best environmental options for the farm will become as important as choosing, for example, the best variety of a crop species.

The UK government regards birds as a primary quality of life indicator and is committed to several Biodiversity Action Plan (BAP) targets. Specifically, Defra has a public service agreement to reverse the decline in a suite of farmland bird species (including skylark, grey partridge, yellowhammer, corn bunting and reed bunting) by 2020, and a BAP target to increase the area of cereal field margin under conservation management to 15,000 ha by 2010. Although the BAP target for the area of margins has already been achieved, the diversity of wild plants is still in decline in fields and margins. So it is important to consider the quality of an environmental measure as well as the quantity (Vickery *et al.*, 2004).

The SAFFIE Project

The Sustainable Arable Farming For an Improved Environment (SAFFIE) project combines management of the crop and non-crop areas of winter wheat fields, with the objectives of profitable crop production and better conservation of biodiversity. The project aims to evaluate the most practical techniques to improve biodiversity in the cropping environment by quantifying the impact of the techniques on key species of birds, plants, bees, butterflies, beetles and spiders. Specific aims are to maximise the benefits from field margin and crop habitat management without compromising yields, to understand how various species use margins and crops for feeding and nesting, and to determine the best management techniques and their likely cost.

Experimental approaches

The SAFFIE project started in 2002 and will continue until the end of 2006. There are four experiments within the project, as follows:

1.1 – Crop management to increase biodiversity

Wide-spaced rows and undrilled patches (called Skylark plots in ELS) in crops with normal-spaced rows, were evaluated in fields of winter wheat on 10 farms in 2002 and 2003, to determine how these novel techniques increase abundance and availability of food and nest sites for birds. Invertebrates, plants and birds were monitored, with emphasis on the breeding success of skylarks. The techniques were compared with fields of winter wheat with normal row spacing.

1.2 – Weed management to increase beneficial weeds

Small-scale plot experiments, at three research sites, were established in harvest years 2003, 2004 and 2005, to look at combinations of herbicide treatments, row spacing and hoeing, to maximise the diversity of plant species and associated insects within wheat crops, without compromising yield.

2. – Margin management to maximise biodiversity

Three grass seed mixtures (Table 1), including a typical grass mix (a standard Countryside Stewardship mix), a mixture of tussock grass and flowers (to increase ground-dwelling invertebrates), and a mixture of fine-leaved grass and flowers (to increase insect diversity, including pollen and nectar feeders), were sown as randomised, 6 m wide margins, with five replicates, at three ADAS research sites (Boxworth, Gleadthorpe and High Mowthorpe) in autumn 2001. Three different spring management treatments (cutting, scarification and a low rate of a selective graminicide) started in 2003, and are applied annually to each margin type, to manipulate the architecture of the vegetation. The resulting vegetation, ground-dwelling invertebrates, bees, butterflies and birds are being monitored in detail.

3. – Integrated effects of 'best' crop and margin management

Results from the studies above are being evaluated in winter wheat crops on 26 commercial farms in England and Scotland, using a full factorial design. This work started in 2004. The four treatments include: (1) conventional wheat and no margins; (2) wheat with undrilled patches and margins; (3) conventional wheat and margins; (4) wheat with undrilled patches and no margins. Two margin types, tussock grass + flowers and fine grass + flowers (Table 1), are used on each site. The best margin management treatment from Experiment 2, scarification, was first tested in Experiment 3 in spring 2005.

Table 1. Species composition of margin seed mixes for experiments 2 and 3.

Seed mix	Grasses	Wild flowers	
Countryside Stewardship mix	Cocksfoot	None	
	Common bent		
	Crested dogstail		
Experiment 2	Meadow fescue		
	Sheep fescue		
Tussock grass & flower mix	Cocksfoot	Common knapweed	Tufted vetch
	Meadow fescue	Greater knapweed	Wild carrot
	Meadow foxtail	Hedge bedstraw	Wild teasel
Experiments 2 and 3	Red fescue	Meadow cranesbill	Yarrow
	Timothy	Meadow vetchling	
	Wavy hair grass	Oxeye daisy	
	Yorkshire fog	Red campion	
Fine grass & flower mix	Common bent[1,2,3]	Birdsfoot trefoil[1,2,3]	Meadow cranesbill[1]
	Crested dogstail[1,2,3]	Bladder campion[3]	Musk mallow[1,3]
Sites	Red fescue[1,2,3]	Bulbous buttercup[3]	Oxeye daisy[1,2,3]
[1] Boxworth experiment 2; all sites experiment 3		Burnet-saxifrage[2]	Ribwort plantain[1,2,3]
		Common knapweed[1,2,3]	Rough hawkbit[1,2]
[2] High Mowthorpe experiment 2		Common sorrel[1,3]	Salad burnet[2]
		Common toadflax[3]	Selfheal[1,2,3]
[3] Gleadthorpe experiment 2		Cowslip[1,2,3]	Tufted vetch[1]
		Field scabious[1,2]	Vipers bugloss[3]
		Greater knapweed[2]	Wild carrot[1,2,3]
		Hoary plantain[2,3]	Wild mignonette[2]
		Kidney vetch[2]	Yarrow[1,2,3]
		Lady's bedstraw[1,2,3]	Yellow rattle[1,2,3]
		Meadow buttercup[1,2,3]	

Results

Summary results are given for 2002, 2003 and 2004.

1.1: Crop management to increase biodiversity

Birds: Data on 159 skylark nests were collected over the two years of the study (2002 and 2003); 45% of the nests were found in fields with skylark plots. For skylarks, both undrilled patches and wide-spaced rows conferred significant advantages over conventional winter wheat. Undrilled patches were the most consistently beneficial option. Skylarks are able to breed more successfully, and for longer, in winter wheat with undrilled patches compared with a conventional autumn-sown crop. At the height of the breeding season, in June, fields with undrilled patches held 30% more skylarks and twice the density of nests, compared with fields without patches. During the early part of the breeding season, while winter wheat canopies were still open and accessible to birds, there appeared to be almost no difference in skylark breeding performance between fields with and without patches. However, in the important period from June onwards, when the great majority of skylark nesting attempts are made, birds nesting in cereal crops with patches did better than those in crops without patches (Figure 1). Across the whole breeding season, nests in crops with patches raised an average of 0.5 more chicks per breeding attempt (and 1.5 more later in the breeding season) than those in conventional crops. Results indicate that benefits mostly relate to the additional foraging opportunities in the patches (Morris *et al.*, 2004). Skylark chick faecal samples showed that flies, large carabids and smaller crop dwelling beetles dominated their diet.

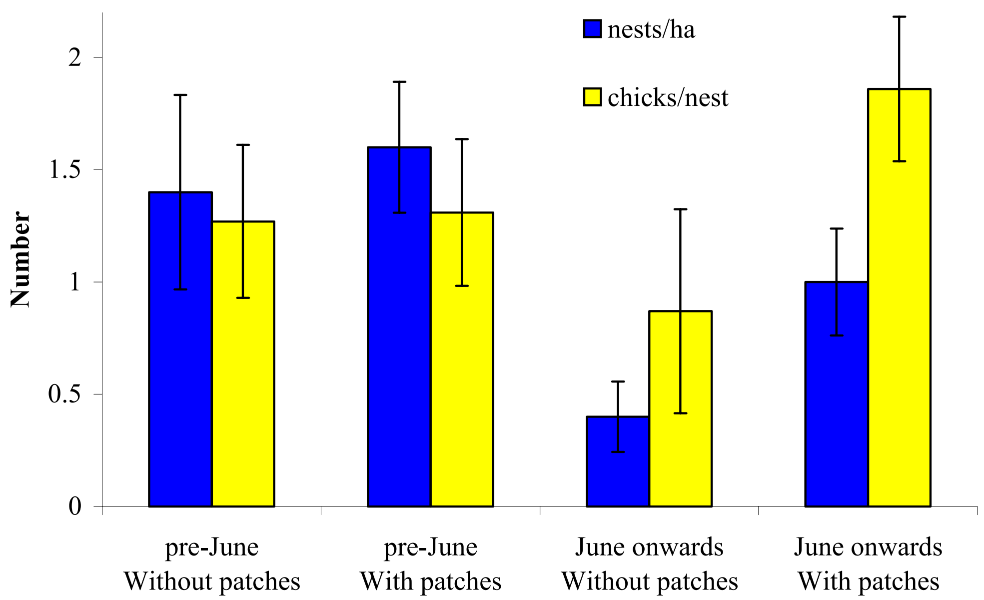

Figure 1. Numbers of skylark nests per ha and chicks per nest, 2002-2003.

Vegetation: Weed density and species composition in cropped areas and undrilled patches varied between sites and also between fields at some sites, but were similar in 2002 and 2003. Undesirable species were the most common, as might be expected in arable fields which had received routine herbicide treatments.

There were no differences in weed cover between conventional spacing and wide spaced rows. Significantly higher weed cover was found in the undrilled patches compared with the adjacent crop for all groups of species analysed, but there were differences between years. For example, cover of undesirable species (species that compete with the crop and have no biodiversity benefit) on patches was nearly 30% in 2002, but below 10% in 2003.

Although weed cover was higher in the patches themselves, they only represent a small area on the ground (two average-sized patches are equivalent to 0.0032 ha). Patches did not have a significant impact on weed cover for crop and patches averaged across the whole treatment area (Figure 2). The number of weed seeds produced in each treatment was also assessed. In 2002, a significantly greater number of seeds of beneficial species were found on plots with undrilled patches compared with conventional drilling.

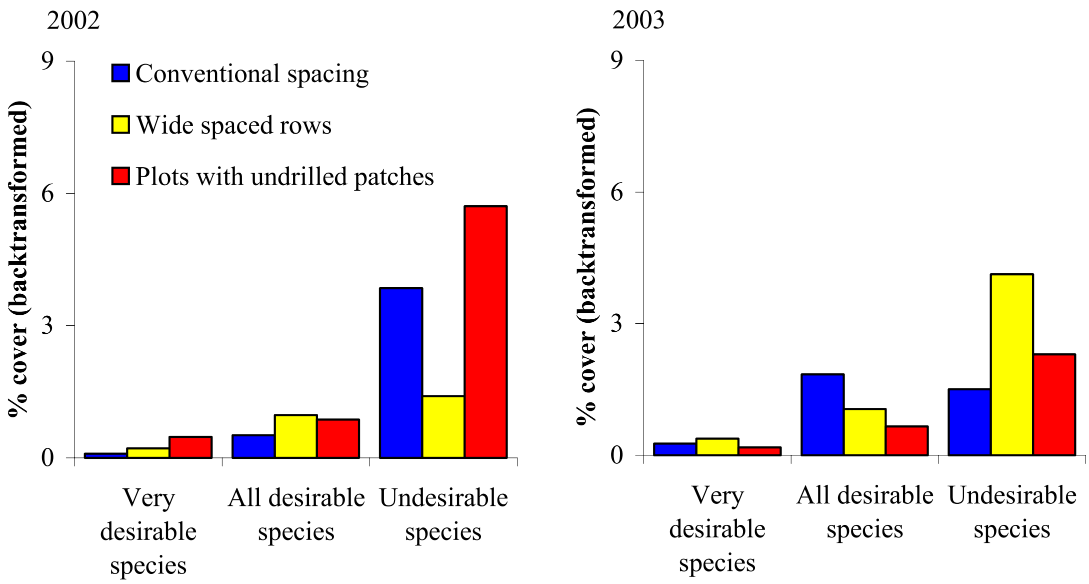

Figure 2. Percentage weed cover in wheat with conventional spacing, wide rows or with undrilled patches, averaged across the whole field area, for three weed species groups (based on biodiversity value), in 2002 and 2003.

Invertebrates: The effect of undrilled patches and wide-spaced rows on invertebrate abundance and diversity within wheat fields was also compared. The aim was to discover if there was any increase in non-pest invertebrates, both as a component of biodiversity and as a food source for farmland birds. In the first year (2002), the overall invertebrate species richness and, in particular, the abundance of rove beetles, was greater in fields with undrilled patches, whilst wolf spiders were more abundant in fields with wide-spaced rows. However, in the second year (2003) there were no differences between treatments. When the invertebrate abundance within the patches was compared with that in the surrounding crop, abundance and diversity was found to be higher in the crop. Overall numbers were low, because the conventional herbicides programme removed most of the weeds, leaving little cover compared with that provided by the crop. Although the undrilled patches did not consistently increase the abundance of invertebrates, they have may have provided access for birds so that foraging was more efficient.

The data were examined to determine whether the abundance of invertebrates was linked to abundance of weeds. There was some evidence that, within the patches, an increase in the abundance of broad-leaved weeds led to an increase in the number of invertebrates. This suggests that, if it were possible to encourage the less competitive weeds by reducing or changing the herbicide regime, then it may be possible to maximise the value of the undrilled patches for invertebrates in fields, as has been achieved in conservation headlands (Moreby and Southway, 1999). This is being examined in Experiment 1.2.

Effect on yields and costs: Wheat crops with wide-spaced rows or undrilled patches gave similar yields to conventional wheat in the two test years, on 15 sites, when assessed at the field scale. If the loss of yield from two 16-24 m^2 undrilled patches per hectare is calculated, the loss in revenue is £2/ha (based on 7.5 t/ha average wheat yield and £75/t). Problem weeds can be controlled by knapsack spray treatments, if needed, at an additional cost of £5/ha. Undrilled patches or skylark plots are worth 10 ELS points per hectare (option EF8). However, as the patches are over-sprayed by routine herbicide treatments, there is usually no need for additional weed control. Although herbicides generally restrict the growth of pernicious weeds, the lack of crop competition and a 'trickle-off' effect from shutting off the seed drill (giving the edges of the patches an intermediate structure of low-density cereal plants), result in most patches developing a low, sparse vegetation of grass, broad-leaved weeds and crop, ideal for nesting and feeding skylarks.

1.2: Weed management to increase beneficial weeds

Results from experiments in harvest years 2003 and 2004 showed that it is possible to leave desirable weeds with different herbicide programmes, but results varied between fields and years. Only a small selection of herbicide combinations has been tested.

Using wide rows and mechanical weeding had little effect on weed populations in comparison with herbicides. Of the products tested, the spring herbicide alone left the greatest variety of desirable weeds, including meadow-grasses, polygonums, chickweed and field pansy. Generally, single herbicide applications were more likely to leave beneficial weeds than sequences of herbicide applications. A difficulty where there were high population densities of undesirable weeds was that it was difficult to avoid control of desirable species.

This work is reported in more detail in Clarke, 2006. Full results will be consolidated when the data analysis is complete, including data collected in 2005.

2: Margin management to maximise biodiversity

Birds: From over 2500 records, there were few consistent patterns of habitat selection by birds using the different grass mixes and margin treatments: birds chose not to feed in the margins at all on 90% of foraging trips. However, within the margin data, there was a general preference for the tussock mix in 2003 and the fine grass mix in 2004. There were more birds associated with the scarified margins compared with the cut margin in July 2004.

Vegetation: The clustering of plots with similar vegetation compositions (Figure 3) shows that distinct plant communities, related to the seed mixes, were evident at all sites (Figure 3a), and distinct vegetation structures developed in relation to seed mix and management (Figure 3b). The scarification treatment opened up the vegetation by increasing the amount of bare ground, promoting species diversity, especially of unsown species, and a thinner, more mixed sward. The cutting treatment benefited the tussock grass species and maintained species diversity in the grass and flower mixes. It also increased sward density, whilst the application of the graminicide suppressed the productivity and flowering of the susceptible grass species in all three margin types, benefiting the finer grasses and flower species.

Invertebrates: The invertebrate communities have started to respond to the management treatments applied to the different margin seed mixes (Woodcock *et al.*, 2005). The diversity of beetles (Figure 4) and true bugs was enhanced by scarification at some sites. The response of invertebrate abundance to the management treatments was more complex, tending to be site and group specific. Cutting and graminicide treatments generally promoted true bug and planthopper numbers in both the tussock and fine grass mixes. Scarified plots often had higher numbers of beetles in the tussock grass mix. Spiders were more common in the fine grass mix when scarified, and in the tussock grass mix when cut or graminicide treated. Further trends are expected in future years.

a.

b.

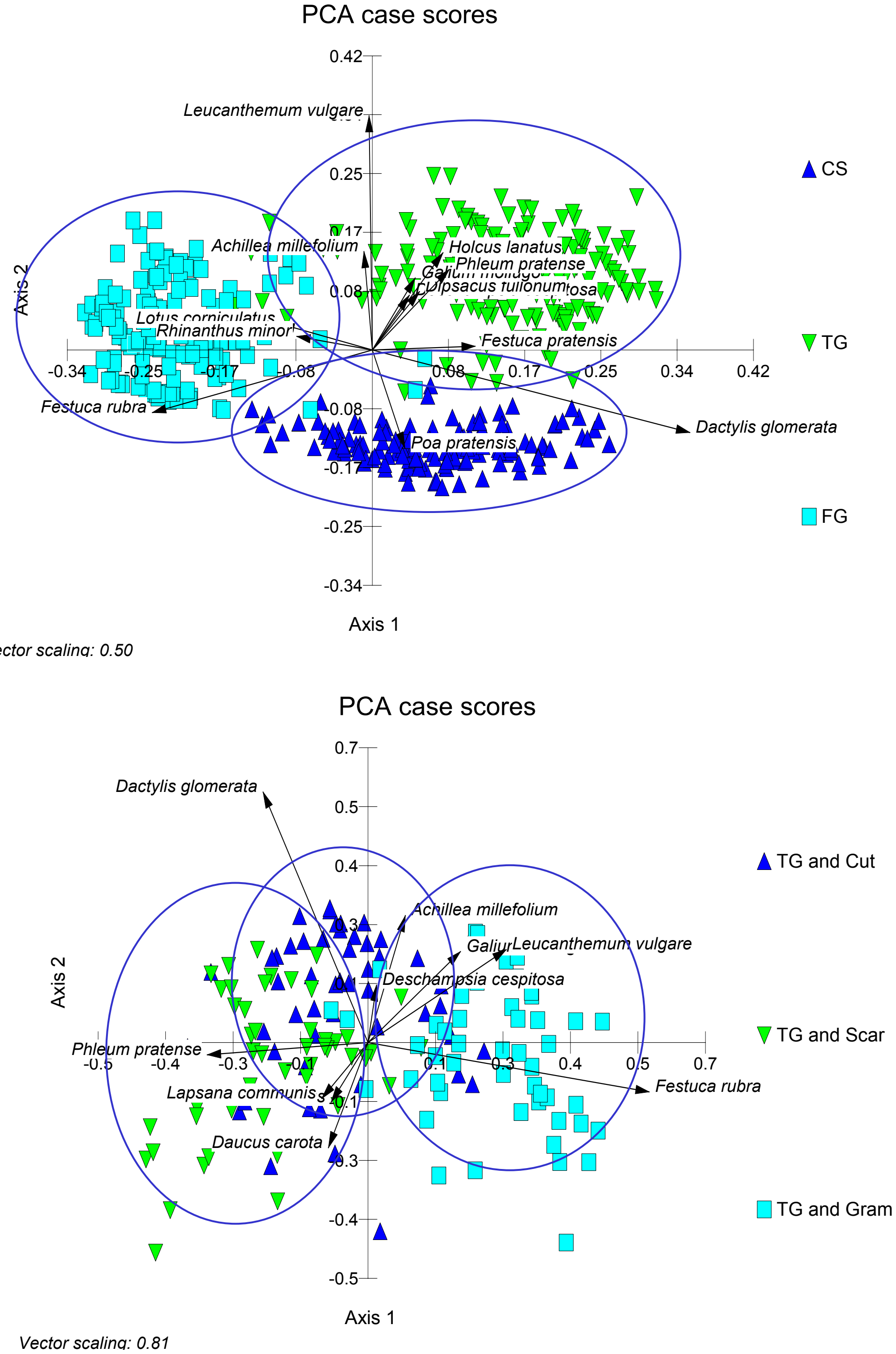

Figure 3. a. Seed mix plant communities, and b. effect of margin management, on plots sown with the tussock grass and flower mix at High Mowthorpe, June 2004.

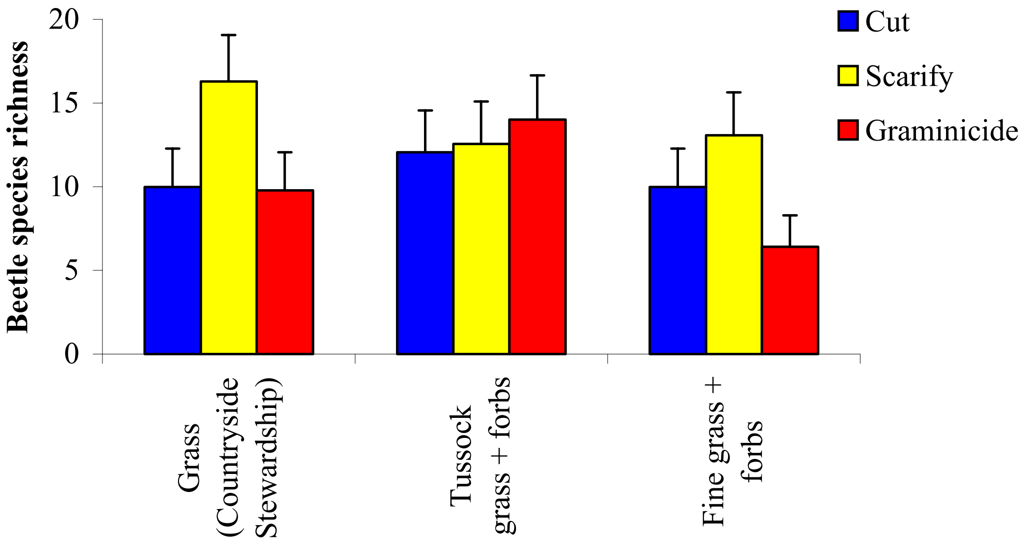

Figure 4. Effect of seed mix and margin management on beetle species richness.

Bumblebees and butterflies: Sowing seed mixtures containing wildflowers, either in a matrix of fine-leaved or tussocky grasses, was an effective means of increasing the abundance and number of broad-leaved flowers (forbs) species available to foraging bumblebees and butterflies on arable field margins (Figure 5a, b). After three years, the spring application of graminicide significantly increased the abundance of flowers compared with conventional management by cutting. This reflected the reduction in competition from tall grass species. In contrast, soil scarification significantly increased the number of broad-leaved species in flower due to the increase in bare soil providing gaps for germination. Bumblebee abundance and species richness responded strongly to these effects on the flower resource, with significantly more bees foraging on the margins sown with wildflowers and greater numbers of bee species on margins sprayed with graminicide (Figure 5c, d). There was a significant interaction between seed mixture and management on butterfly diversity: scarification was most beneficial in the simple tussock grass mix, whereas the graminicide had most benefit in the tussock grass/flower mix.

The rare BAP species of bumblebee, *Bombus ruderatus* was found on the margins at the Boxworth site.

Summary of biodiversity value: Scarification offered the most consistent beneficial effects, across the different biodiversity categories (Table 2). This treatment was selected for further evaluation on commercial farms in Experiment 3. However, other combinations of seed mix and management might also have value in certain situations.

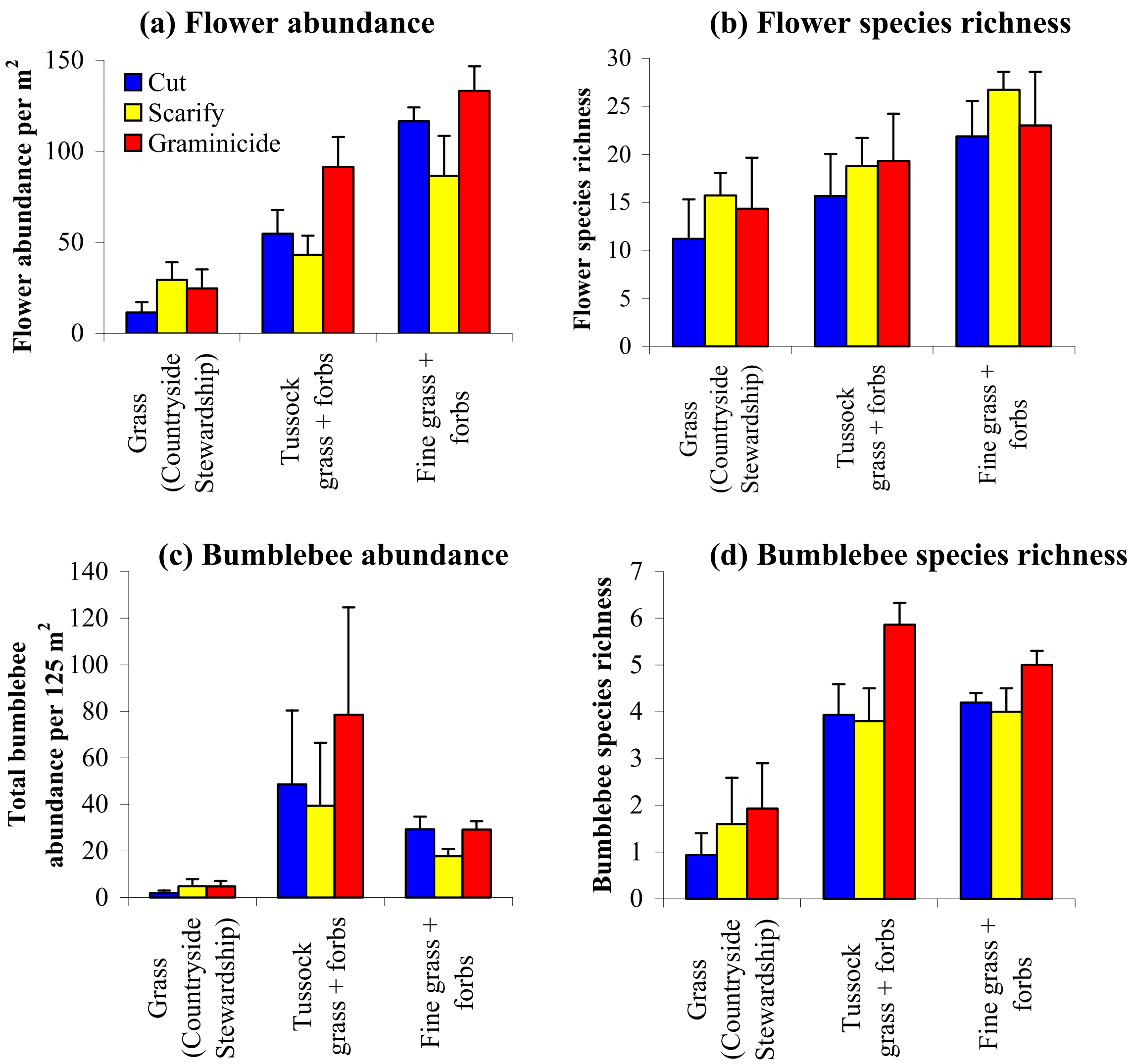

Figure 5. Field margin treatment effects on flower and bumblebee abundance and species richness. Bars represent standard errors of the means.

Table 2. Biodiversity scores (1-3, 3 = greatest benefit or response) for two margin seed mixes and three management techniques (Gramin = low rate of a graminicide).

	Biodiversity scores (1-3) for combinations of seed mix and management technique					
	Tussock grass mix			Fine grass mix		
Biodiversity categories	Cut	Scarify	Gramin	Cut	Scarify	Gramin
Invertebrate abundance	3	1	2	2	2	2
Invertebrate diversity	1.5	3	1.5	2	3	1
Pollinators	1.5	1.5	3	2	2	2
Unsown plant diversity	1.5	3	1.5	1.5	3	1.5
Sown plant diversity	3	1.5	1.5	2.5	2.5	1
Access for birds	1	3	2	1.5	3	1.5
Total (biodiversity	**11.5**	**13**	**11.5**	**11.5**	**15.5**	**9**

value)

Costs of margin establishment and maintenance: Costs will vary according to the mix of species chosen for inclusion in the margin seed. Wildflower seed is expensive and establishment can be very variable, especially if soil fertility is high. Seed mixes need to be selected carefully for site and location to avoid wasting money, but adding flowers to a margin mix does greatly enhance the biodiversity value of the margin. At the end of the SAFFIE project, guidance will be given on the best performing flower species, and costs of including them in seed mixtures for margins.

We have started a cost:benefit analysis for the margins treatments, although results to quantify biodiversity benefits are not yet all available. Taking account of lost yield, savings of input costs, fuel and labour, and the costs of margin establishment and management, the analysis shows that money received from Entry Level Schemes is sufficient to cover some expensive seed costs. Full experimental results will allow this budget to be adjusted to include costs of refined seed mixtures that omit plant species with little benefit.

3: Integrated effects of best crop and margin management

The 26 farm sites were selected and the margins were established in 2002 and 2003. Five Common Birds Census bird survey visits were carried out on all sites in 2003. Bird densities were low with around 35 birds recorded per site visit (approximately one bird per hectare). Baseline vegetation and invertebrate assessments were done at all sites. Establishment success of the seed mixes in the margins varied between sites. Undrilled patches were established in the wheat crops in autumn 2003. The sites were visited on eight occasions for bird monitoring in 2004, and data on a further 55 skylark nests, and 100 nests of other species, were collected. 2004 was a poor year for breeding, with skylarks fledging less than one chick per nesting attempt. Depredation and starvation of nestlings during spells of cool wet weather were the main causes of loss, in all treatments. However, although sample sizes were small, there were further indications that skylarks had larger clutch sizes and fewer nestling starvations on treatments with undrilled patches. Results from the vegetation and invertebrate monitoring will be reported when the field studies are completed in 2006.

Conclusions

The project is already giving practical guidance to farmers on conservation actions, which they can choose as options in the new Entry Level Scheme in 2005. Research from the SAFFIE project has confirmed that undrilled patches in wheat provide real benefits for skylarks, so that the number of points increased from eight per hectare in the pilot ELS scheme to 10 per hectare in the new, full scheme launched in 2005. This is a very good example of research providing practical solutions, which can be incorporated into policy.

Undrilled patches (skylark plots EF8) are now being actively promoted to farmers as a very positive means of improving skylark populations in winter cereals with minimal costs. If undrilled patches were created on just 15% of England's winter sown cereals, in conjunction with increased overwinter stubbles, the decline in skylark populations could be halted and possibly reversed (Donald & Morris, in press). Ongoing work on the field margins and the crop treatments aims to provide an understanding of the ecological interactions in these areas. The effects of the sown margins on weeds and invertebrates within the crop, including crop pests, are also being evaluated. The project is already showing that changes in margin management practice, like scarification, can benefit the abundance and diversity of plant and invertebrate species, above standard practices. Weeds and invertebrates are key parts of the food chain for birds, and the understanding to be gained from the SAFFIE field studies on crops and margins will lead to sound advice on the best options for biodiversity in the arable cropping environment. This will be combined with an understanding of the costs and benefits for farmers, so that they can incorporate the best schemes into their farming businesses.

Acknowledgements

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