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Non-inversion tillage and farmland birds in winter

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ABSTRACT

This study investigated the effects of non-inversion tillage and ploughing establishment methods of winter wheat and barley crops on field use by wintering farmland birds. Birds were censused on 121 fields during winters 2000 to 2003, using standard whole-field count methodologies. The data were analysed using multivariate logistic regression methods, to assess the differences in bird occupancy between fields with the two crop establishment methods, whilst controlling and testing for effects of a variety of other variables. Skylarks, granivorous passerines and gamebirds were found more regularly on fields established by non-inversion tillage than conventional tillage.

INTRODUCTION

The populations of many UK farmland birds have declined substantially in recent decades (Gregory *et al*., 2003). In Europe, the extent of national population decline is correlated with various indices of intensification of agricultural production (Donald *et al*., 2002). These declines are of so much concern within the UK, that a wildlife 'indicator' based on farmland bird population trends is now used as one of fourteen 'headline' indicators of sustainability (Gregory *et al*., 2003).

Three major factors that have contributed to farmland bird decline are the loss of nest sites, reduction of invertebrates for nestling food and reduced availability of seeds for winter food (Evans *et al*., 1995). For many granivorous species, reduced survival seems to be the current most limiting factor (Peach *et al*., 1999, Siriwardina *et al*., 1999). Possible reasons for changes in survival include lack of winter seed food, caused by increased pesticide use, improved harvesting efficiency, bird-proofing of food stores, and the loss of winter stubbles with the switch from spring to autumn sowing of cereals.

Non-inversion tillage (NIT) is a method of preparing a seedbed to establish a crop from the stubble of the previous crop, and is a potential means of enhancing winter food for farmland birds. NIT is a broad term that encompasses different methods that use a combination of tines and discs, rather than the conventional mouldboard plough. It is referred to as reduced tillage, no-till, ECOtillage, minimum tillage (min till) and conservation tillage. The NIT system offers significant potential savings in terms of labour, fuel and time compared to conventional mouldboard ploughing (Ball, 1989). It is therefore likely that NIT will become a more widespread practice in Europe, independent of any need for additional financial incentive for helping biodiversity.

Reduced tillage methods have been shown to have benefits for biodiversity outside the UK. In North America, greater productivity of some farmland bird species has been observed on arable land established by minimum tillage compared with conventionally ploughed fields (Martin & Forsyth, 2003). In winter, granivorous birds could benefit from lack of burial of split grain and weed seeds that might be expected with NIT. In the UK, there has been little work to evaluate the effects of NIT on farmland biodiversity. The results of a three-year study to investigate the relative occupancy of birds on winter wheat and barley fields established by non-inversion tillage and conventional ploughing are presented here.

STUDY AREA AND METHODS

Study area

Winter wheat and barley fields established by either non-inversion tillage (NIT) or conventional tillage (CT) were surveyed on commercial farms in Oxfordshire, Leicestershire and Shropshire. Monthly surveys took place between October and March in 2000- 2003 (Oxfordshire was only surveyed in winter 2000/1, due to logistical constraints). In each year, between seven and nine farms were surveyed (121 different fields in all). Previous crop types included winter wheat, winter barley, oilseed rape, peas, beans, maize, carrots, grass, oats, and set aside. Field area, excluding field boundaries and margins, ranged from 1.6 to 22.2 hectares.

Survey method

Birds were counted using line transects 60m apart, to flush all the birds present in each field (Perkins *et al.*, 2000). Detailed methods have been described in Cunningham *et al.* (2002).

Statistical analysis

Bird counts were collated for two periods over the winter for all three years. These were defined as the early winter period, during October to December, and late winter period, during January to March. Data were simplified to presence or absence of each species in each field, on any visit within the specified time interval. Splitting the data into two temporal periods allowed comparisons to be made between early and late winter when food resources may change. The bird species recorded were divided into five groups for the analysis (Table 1).

Table 1. Bird groups used in analysis.

Group:	Bird species included in group:
Skylarks	Skylarks (*Alauda arvensis*)
Game birds	Grey Partridge (*Perdix perdix*), Red-legged Partridge (*Alectoris rufa*) and Pheasant (*Phasianus colchicus*).
Insectivores	Blackbird (*Turdus merula*), Fieldfare (*Turdus pilaris*), Lapwing (*Vanellus vanellus*), Meadow Pipit (*Anthus pratensis*), Mistle Thrush (*Turdus viscivorus*), Pied Wagtail (*Motacilla alba*), Redwing (*Turdus iliacus*), Robin (*Erithacus rubecula*) and Starling (*Sturnus vulgaris*).
Granivorous passerines	Chaffinch (*Fringilla coelebs*), Goldfinch (*Carduelis carduelis*), Greenfinch (*Carduelis chloris*), Linnet (*Carduelis cannabina*) and Yellowhammer (*Emberiza citrinella*).
Corvids and pigeons	Carrion Crow (*Corvus corone*), Rook (*Corvus frugilegus*), Magpies (*Pica pica*), Jays (*Garrulus glandarius*) and Pigeons (*Columba* species).

The effect of tillage (a two-level fixed factor) on field occupancy (i.e. presence or absence) was tested whilst controlling for the following factors, where they were significant: year (a three-level fixed factor), crop type (a two-level fixed factor), previous crop type (a ten-level fixed factor), farm identity and field size. Farm identity was included as a random factor, as the fields were nested within farms (a seven, seven and nine-level factor in year 1, 2 and 3 respectively). This was achieved by fitting a generalised linear mixed model, procedure GLMM (Genstat 4.2 5th Eds. Lawes Agricultural Trust, 2000). Significance testing was achieved by calculating the Wald statistic, and comparing this with the χ^2-distribution (α = 0.05).

RESULTS

Tillage method had no significant effect on any of the bird groups in the early winter period. In the late winter period, tillage method was a significant explanatory factor for three groups. Skylarks, granivorous passerines and gamebirds occupied a significantly greater proportion of fields established by non-inversion tillage than conventional tillage (Figure 1).

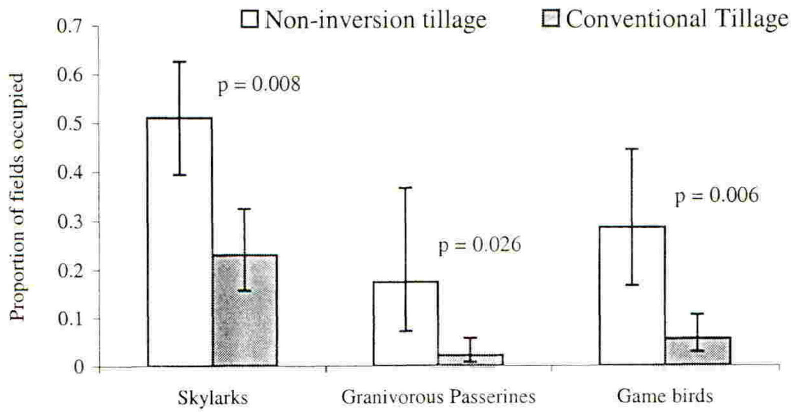

Figure 1. Mean probability of occupancy of non-inversion tillage and conventionally tilled fields by Skylarks, granivorous passerines and game birds in the late winter period (i.e. January - March inclusive).

DISCUSSION

In the late winter period, several bird groups occupied a greater number of fields established by non-inversion tillage (NIT) than conventional tillage (CT). These bird groups (Skylarks, granivorous passerines and game birds) are mainly seed feeders in winter (Wilson *et al.*, 1999). This would suggest a greater abundance of seed food resources in NIT fields in late winter. The insectivores, which include Lapwing, Robins and Mistle Thrushes, is an eclectic group with a wide range of feeding strategies and this could explain the lack of differences in the occupancy of NIT and CT fields. Corvids and pigeons are generalist feeders and consequently may not be expected to show any differences, as seen here. All the differences in field occupancy were seen only in the late winter period, which suggests that food resources became scarcer over the course of the winter. Further work will aim to identify possible reasons behind these bird responses, particularly with respect to abundance of 'food' groups, such as earthworms, epigeal arthropods and seeds.

UK agricultural systems are shifting from intensive crop production towards more sustainable agriculture. In addition to sustaining biodiversity, this integrated approach to crop production involves soil conservation, water conservation and carbon sequestration; factors that have been shown to benefit from NIT. This study shows that NIT also seems to have a positive impact on biodiversity, in terms of birds, in the UK. It is therefore encouraging that reduced tillage options have been included in the new pilot Entry Level Agri-environment scheme.

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Managing weeds for environmental benefit in GMHT sugar beet

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ABSTRACT

Two weed management strategies were tested using GM herbicide tolerant (GMHT) sugar beet. One examined the effect of delaying weed control and the second compared overall sprays with banded treatments. Data from two trials in a series of five are presented for weed density, weed biomass score and sugar yield. These are used to relate current weed management practices with options which might be possible if GMHT sugar beet were grown. The implications of weed presence during the crop life cycle are discussed and suggestions made of the ways in which farmers might be prepared to manage weeds to benefit invertebrates, and ultimately birds, in the farmed environment.

INTRODUCTION

Beet is a spring-sown crop, which is usually harvested in the autumn but in some fields may not be harvested until January/ February of the following year. It has several potential benefits for wildlife compared to winter sown crops such as cereals; being spring sown the weed species that commonly germinate in it are different to those in autumn sown crops. Some spring germinators, e.g. the *Polygonaceae* and *Chenopodiaceae* families, are important seed components in the diet of granivorous birds. Beet is grown in wide rows which can favour birds that prefer to nest in field centres (provided mechanical weeding is not used), e.g. skylark and lapwing. Late harvesting can be particularly beneficial if the ground is not cultivated until late spring, or placed into set-aside.

Whilst its architecture has certain advantages to other species, beet generally contains low weed numbers to act as food resources. Classical weed removal studies in the 1970's showed that weed removal was necessary before beet reached the 6-8 true leaf stage if yield loss was to be avoided (Scott, *et al*., 1979). The herbicides commonly used in beet, tend to be of relatively low efficacy and must be applied to small weeds, usually cotyledon sized, to achieve effective weed control. Consequently complex herbicide programmes are used consisting of tank mixtures of a number of herbicides applied at short intervals of 7-14 days (May, 2001a). A residual pre-emergence herbicide is included in many of these programmes. These current programmes result in frequent spraying for much of the life of the growing crop. Missed or delayed sprays result in weeds growing beyond their susceptible stage and requiring more intensive and more expensive herbicides to control them later. This combined with the loss of yield associated with crop shading by weeds means that, to maintain profitability, most growers strive for relatively weed-free fields.

Weed beet are the same species as sugar beet but they have reverted to an annual habit and bolt (flower) in the first year. Weed beet are a serious problem in the UK occurring in 70%

of fields (May, 2001b). Being the same species as sugar beet it is also tolerant of the same herbicides and control by spraying is not an option. Weed beet is a problem because it competes with the crop and each plant produces as many as 19,000 seeds which are very long lived in the soil (Champion, 2000). Whilst these may be a food source for small mammals, high levels of control are necessary to prevent weed beet becoming a very serious problem. Control is currently achieved by inter-row cultivations and hand-pulling or weed wiping with glyphosate by selective height applicators-soaked wicks or cutting.

This paper presents work undertaken at Broom's Barn investigating weed management strategies for use in genetically modified herbicide tolerant (GMHT) beet and describes how these might be used for environmental benefit. Other aspects of the use of GMHT beet are discussed in relation to achieving environmental gain.

MATERIALS AND METHODS

Delayed weed control – when is control needed?

Five experiments were conducted at Broom's Barn between 1999 and 2000, examining delayed weed control in GMHT beet. Each was a randomised block design with four replicates. Plots (3mx12m) were sown with a GMHT variety of sugar beet tolerant to glyphosate. The conventionally treated plots received herbicides in programmes appropriate to the weeds at each site. The other plots were treated with glyphosate in two sprays at rates of 3 litres ha^{-1} (360 g a.i. $litre^{-1}$) but treatments differed in the timing of the first application between 200 and 860 accumulated day degrees (C°d) above a base temperature of 3°C.

Band spraying – where is control needed?

Certain treatments were applied as band sprays of glyphosate, approximately 20 cm wide, along the crop rows at a single timing equivalent to one of the overall spray timings and at an equivalent *pro rata* rate of glyphosate per unit area. These plots received a second spray overall, applied at a range of timings, between 400 and 750 C°d, to determine how late the weeds between the rows could be removed.

Assessments

Weed assessments were taken throughout the growing season. Weed biomass was visually scored on a 0-10 scale and weed densities recorded in ten 30x30 cm quadrats per plot. Plots were harvested in late August/early September which was unusually early, but necessary in order to comply with the sugar industry protocols designed to prevent GMHT beet accidentally being introduced into processing factories. All plots within an experiment were harvested on the same date. Roots were washed, weighed and analysed for sugar content.

RESULTS

A variety of responses were seen across the five experiments and details of two are presented to represent the two extremes. These were on peaty loam and sandy loam sites in 2000. Weed densities, weed biomass scores and sugar yields are plotted against the accumulated day degrees (°Cd) above a base temperature of 3°C, from sowing to first treatment for delayed treatments and from sowing to application of the second spray for band spray treatments (Figure 1). Data for the conventional treatments are presented as vertical bars. For sugar yields the data for the untreated plots was included to help model the yield response curve and are plotted at the harvest date.

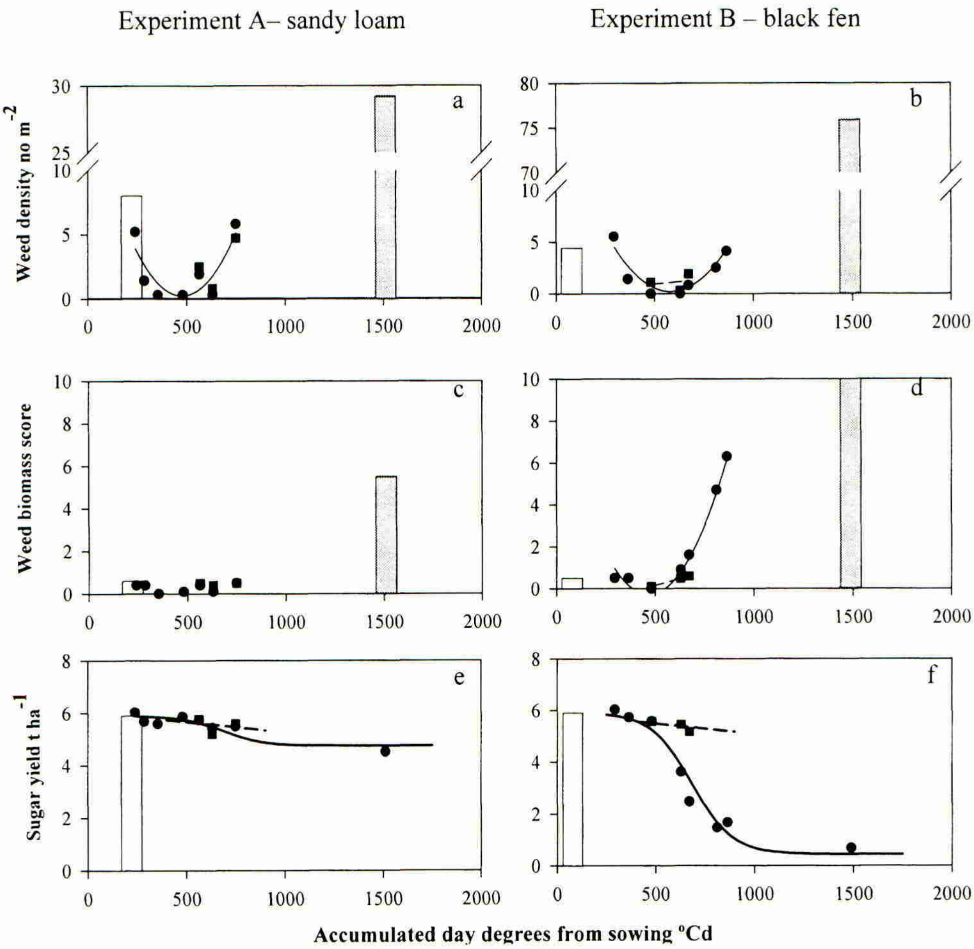

Figure 1. Weed density from quadrat counts in late July/ early August (a and b), weed biomass scores on 0-10 scale in early August (c and d) and sugar yield (e and f) plotted against °Cd from sowing to first application for delayed sprays (circles, solid lines) and second application for band sprays (squares, dashed lines) for experiments A and B. Conventional treatments are indicated by an open bar and untreated control by a shaded bar.

Weed density

The second (final) applications in the delayed treatments were applied on 18 and 20 July for experiments A and B respectively and all second overall treatments applied to band sprayed plots before these dates. Weed densities were recorded on 26 July and 3 August, experiment A Figure 1a and experiment B Figure 1b respectively. Weed densities on experiments A and B on conventional plots were 8.0 and 4.4 plants m^{-2} and for untreated plots 29.2 and 75.9 m^{-2} respectively. In both experiments the plots treated early and late with glyphosate had between 5 and 6 weeds m^{-2}. Intermediate timings of glyphosate resulted in very low weed densities. Weed densities of band sprayed plots were comparable with those for the delayed treatments.

Weed biomass

Visual scores of weed biomass carried out on 7 and 9 August, experiment A Figure 1c and experiment B Figure 1d respectively. A zero indicated absence of weed material, and a ten full cover comparable to that which might be expected for that site at that time of year. Scores for untreated plots in experiments A and B were 5.5 and 10.0 respectively. In experiment A weed biomass was less than 1 across all timings for both delayed and band sprayed treatments whilst in experiment B weed biomass reached a score of 6 at the final timings for delayed treatments.

Sugar yields

Yields across the experiments were relatively low, due to the imposition of the very early harvest. In experiment A (Figure 1e) late applications resulted in relatively small yield losses (9%) and untreated plots yielded 76% of the conventional plots. For experiment B (Figure 1f) the later the herbicide application, the lower the yield, and on untreated plots yield was only 11% (89% yield loss) of the conventional. Yields of band sprayed plots, were much less affected by later applications of herbicide with yields up to 95% and 88% of the conventional for experiments A and B respectively at the final overall spray timing.

DISCUSSION

These results suggest that weed density is a poor predictor of the eventual effect of weed presence in beet crops. Although the densities in untreated plots in these experiments were different, those in glyphosate treated plots were similar. Despite this similarity in weed density on glyphosate treated plots, the yield response in the two experiments was very different and not related to density. In common with other studies, this work shows that weed biomass is a better predictor of weed competition. Data from other experiments (not presented) confirms that visual scores of weed biomass and weight of weed biomass as g d.m. m^{-2} are closely correlated, although the exact relationship between scores and weight of d.m. varies from site to site and year to year. Sites with high weed densities of species having low biomass, should result in small reductions in yield and conversely high weed densities of species having high biomass, should result in large yield losses.

These data provide a snapshot of the position at the end of the season but it is important to consider the duration of crop and weed competition. Scott *et al.* 1979 suggested that competition when the crop was young was the most important and current weed management strategies are built around this. However, to some extent our work challenges this assumption. Optimum yields (greater than the conventional) across the five field trials were obtained when glyphosate applications were made at 275°Cd and significant yield loss was avoided where applications were made before 535°Cd (May, *et al.*, 2003). However, the conventional applications at these two sites were made at 79°Cd and 222°Cd. At site A the application at 79°Cd was pre-emergence but used non-residual products. Many farmers use residual pre-emergence herbicides as an insurance against late applications of subsequent post-emergence treatments, drastically restricting the length of time when weeds can grow in the beet.

The other aspect demonstrated by this work is that the application window for overall applications is relatively wide where the first treatment is a band spray. Removal of weeds immediately adjacent to the crop early in the season greatly extends the period during which weeds can be present between the rows before yield suffers. Weeds between the rows in plots treated with band sprays between 207 and 530°Cd could be left until between 586 and 725°Cd (average 656°Cd) before yields were significantly lower than the conventional (May *et al.,* 2003). Although levels of weed biomass at harvest were similar to those for two overall spray treatments weeds were present for much of the mid season. Another possible strategy could be to apply the first spray overall, followed by a band spray at the second timing. This may allow late germinating species and cohorts to emerge between the rows without affecting yield. Late emerging cohorts are smaller, less competitive and produce fewer seeds than early emerging ones (Mulugeta & Stoltenberg, 1998) and relative time of emergence is important in the balance of crop and weed competition (Kropff, *et al*., 1992).

Weed beet control is an area where the use of GMHT sugar beet may reduce the need for costly control measures (May, 2001b). Currently all the weed beet seed in UK fields is from conventional strains and is susceptible to glyphosate. Provided gene flow does not occur into these beet, the use of GMHT cultivars allows a quick and easy method of controlling weed beet without the need for inter-row cultivations, which are threatening to ground nesting birds.

The presence of weed material in crops is undesirable for farmers where it reduces yield through competition. It may also hinder harvest and cause problems in future crops if weed seed return is high. However, in many situations the presence of some weed material can be beneficial. At sites with moderate numbers of weeds, weed biomass is correlated with invertebrate presence (Dewar, *et al*., 2003) and this may include predators (beneficial insects) of invertebrate crop pests. Some of these species may be used by birds to feed their chicks.

Although ACRE (Advisory Committee on Releases to the Environment) have judged GMHT crops safe to the environment, so allowing them to be grown in trials, various groups have expressed concerns about the possible effects of using GMHT crops on the wider farming environment. In terms of weed control, the main concerns related to sugar beet refer to the relatively high efficacy of glyphosate, and that it may be too easy for farmers to have clean fields, reducing the availability of weeds and hence reducing the supply of seeds and invertebrates for birds. Ultimately this might reduce the number of weed seeds for autumn bird food and affect replenishment of the weed seedbank, contributing to a decline in the arable weed flora. However, it is possible to achieve very clean fields using any technology, including both conventional herbicides and even organic methods, if the aim of the field management is zero tolerance of weeds. Being applied to relatively mature weeds, the use of GMHT beet allows for decisions on the intensity of treatment to be taken at a relatively late stage in the life of weeds and crop. On sites with low weed biomass (such as experiment A) the emerged weeds may only warrant treatment with one overall low dose application of glyphosate, leading to a reduction in herbicide use.

The methods tested above suggest that the use of GMHT beet can be flexible. If the environmental objectives rather than the farming objectives are set as the most important criteria, then appropriate management systems can be developed to deliver these using GMHT beet but it would be very difficult to use the current conventional practice to achieve similar ends. Whether it is more important to have invertebrates in the spring or weed seed production in the autumn will determine the best management strategy to be adopted. Whilst many fear the use of GMHT, it is not the technology itself which will lead to clean fields, but how it is applied. Financial drivers may be necessary in some cases to persuade farmers to change their practices. Whilst some believe it will be difficult to change mind-sets, where farmer's pride themselves on clean fields, history has shown that farmers are willing to change practices, provided it is economically feasible. This study suggests that changes are technically feasible and other work suggests that adoption of GMHT (May, 2003) could provide large economic benefits for growers using the technology.

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