ENHANCED BIODIVERSITY IN SUGAR BEET ROTATIONS

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FINAL REPORT

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CONTENTS

1.0 EXECUTIVE SUMMARY

1) A crucial part of the year for birds is winter, when resources are low, and survival difficult. Inclusion of a spring-sown crop such as sugar beet, predominantly preceded by cereals, can play an important role in supporting some farmland bird populations. Therefore this study by the British Trust for Ornithology and Broom's Barn Research Centre investigated the potential for beet, beet stubbles and cultivated and uncultivated cereals to provide food for birds. The project considered both plants and seeds (from volunteers or weeds) and invertebrates.

Manipulation of weeds in beet fields

2) Beet fields were selected to assess food resources available after the beet crop but also measures were made of the effects of autumn cultivations preceding beet on the potential food resources for birds. Assessments included weed biomass, weed seeds and invertebrates. In one season weeds and invertebrates were also monitored in sugar beet at four sites. No field counts were taken of birds, instead the BTO provided expert advice on the potential use of beet crops and stubbles by birds, according to measures of weed and invertebrate composition.

3) Densities of carabid beetles were highest in June and July. At this time of year they are available to parent birds feeding nestlings of species such as skylark. Weed seed densities peaked toward the autumn and winter when they are an important resource for juvenile birds. In most cases gastropods were poorly represented in samples except at the Broom's Barn site in autumn where both gastropods and earthworms were conspicuously abundant relative to the other sites. At such sites these prey species would be valuable food for juvenile song thrushes and for lapwings.

4) At two sites invertebrate samples indicated a June/July peak that would benefit breeding species. At the other two sites most invertebrates were caught later, from July onwards, when the value to birds would be in increasing post-fledging and juvenile survival and hence breeding recruitment into the following year.

5) Whilst weedy crops are ideal as a source of seeds for birds, these are seldom economically feasible. However, growing beet does offer opportunities to help birds through the difficult winter period when food is short in January and February. At this time of the year freshly harvested beet will not only have chopped beet tops present for large birds such as Canada geese, but the soil disturbance will leave many freshly shed and previously buried weed seeds available on or near to the soil surface for a range of bird species.

Main points

- In all crops, weed and invertebrate populations of desirable species, in terms of their value as bird food, were found.

- In some cases, weed seed densities in particular were exceptionally high.

Effects of stubble cultivations preceding beet

6) Tined cultivations were made as soon as possible after cereal harvest and were intended to disturb rather than invert the soil. By the end of the cultivation versus uncultivated stubbles trials in 2007/08, weed biomass was consistently, significantly higher on uncultivated treatments both within and between sites. The difference was usually of the order of two to three times higher in favour of uncultivated treatments (although the values are highly variable), and included important plant species for birds, such as lapwing, skylark, yellow hammer, turtle dove, tree sparrow, reed bunting, yellow wagtail and grey partridge.

7) In contrast, there were no consistent, significant differences between the treatments for other variables: i.e., weed-seed rain, the seed soil bank or invertebrate abundance. The amount of seed rain was not always consistent with the difference in weed biomass, so making the interpretation of the data more difficult to summarise. That said, the abundance of viable seeds tended to be higher in uncultivated treatments than in cultivated stubbles treatments. This can also be important although the differences were not necessarily statistically distinct. Viable seeds are likely to be of greater calorific value to birds than non-viable, soft or damaged seeds, potentially improving the physiological condition, over-winter survival and recruitment into breeding populations.

8) Most effects on invertebrates were non-significant and, generally, the results were highly inconsistent or equivocal between treatments, both within and between sites.

Beet aftermath

9) Beet aftermath certainly has the potential to provide important winter-feeding resources for farmland birds due to the presence of the remains of leaves and tops or the invertebrates that feed on them (**Ref. 9**). The assessments demonstrated that aftermath may also have high densities of the broad-leaved weed seeds such as fat-hen that are common in the diet of many granivorous bird species.

10) Upon harvesting, a large volume of organic matter (leaves, tops) is ploughed into the soil, increasing the organic matter content of the soil and providing a more favourable environment for invertebrates such as earthworms. Furthermore, the addition of farmyard manure as part of the sugar beet rotation will also benefit soil invertebrates with potential benefits for invertebrate-feeding birds such as plovers and thrushes. However, a qualitative assessment of the potential of aftermath to support birds is much more difficult to make. At times aftermath can attract high densities of birds (**Ref. 5**).

Suggestions for future investigations

11) The strong variability between sites in the densities of weed seeds and invertebrates recorded suggested that exceptional and valuable populations of these food groups do not always exist in all sugar beet crops. So which sites are most representative of the majority of sugar beet crops grown?

12) Patches of grass weeds, such as low-growing meadow grasses and fescues are recognised as food resources for birds for their seeds and for harbouring insects such as carabids and caterpillars. Is there scope to encourage tolerable levels of such grass-weed cover in sugar beet?

13) The main limitation to benefits from aftermaths in early and mid winter is the short period during which they are available to birds. However, later harvested beet may be left for longer periods before cultivation in these cases it could provide important resources during the late winter period, or the so-called “hungry gap” for birds when other resources are also low.

14) Potentially, cultivation after beet could improve the weed seed foraging resource for birds by bringing new seed to the surface from the seed bank below. If this practice operated over the protracted period of harvest, from early to late winter, then the value of beet fields for birds might be extended. Unfortunately, the results from the present study were rather equivocal with respect to the seed bank’s provision of viable seeds even following cultivation. Nevertheless, given the enormous potential source of food present in the seed bank and particularly after a period of winter depletion of surface resources, any subsequent levels of soil disturbance could rejuvenate the soil seed resource by exposing buried seeds.

15) Another route might be to address the period before beet and to perhaps lightly cultivate preceding cereal stubbles in late winter to bring seed to or near the soil surface. Exploring cultivation during the transition between cereal harvest and beet sowing and between beet harvest and the following crop would be an interesting and potentially beneficial area of research, aimed specifically at the mid- to late-winter period.

2.0 OBJECTIVES

The general objectives of the project were to determine whether simple changes to the management of cereal stubbles and to weeds in sugar beet could increase food and feeding opportunities for farmland birds.

There were three specific areas of research:

1) To determine whether reduced weed control in sugar beet could increase the number of invertebrates, weeds and weed seeds available for farmland birds. [This part of the project was curtailed during its second year owing to a reduction in the overall funding available for the project.]

2) To compare the ability of simple, early-tined cultivations of cereals post-harvest to improve the food and shelter resources for farmland birds in the stubbles.

3) To determine the availability of seeds and green material as bird food post-harvest of sugar beet. [This part of the project was not started owing to the reduction in funding available for the project.]

3.0 INTRODUCTION

Bird populations have declined on arable farmland largely because of losses of breeding habitat and reduced food availability in summer and winter. Protein-rich food, such as invertebrates, is important for raising chicks in summer, whilst over-winter survival requires plant food, like weed seeds and some invertebrates (**Ref. 1**). Reduced over-winter survival explains patterns of decline for several granivorous species (**Ref. 2**) whose preferred winter feeding habitat is stubble fields (**Ref. 3**). Many modern stubble fields now provide poor resources as a result of more efficient harvesting and weed control depleting seed banks and reducing the abundance of the broad-leaved weeds that are important in the diet of many farmland passerines (**Ref. 4**).

An intensive field study, (**Ref. 5**) showed that most stubble fields contained very low densities of weed seeds, and only a small proportion of fields held high densities of seeds. Exactly the same pattern was evident in the frequency distribution of granivorous species densities in individual stubble fields and, crucially, the density of weed seeds was a strong predictor of the abundance of granivorous passerines at the field scale. Where weeds develop within crops or stubbles, the crop's value to birds is enhanced (**Ref. 6**).

Structural and botanical variation in a field encourages birds to exploit it as the gaps in the vegetation aid access for foraging (**Ref. 7**). Field composition also affects invertebrate-feeding bird species, such as song thrush, since research (**Ref. 6**) found that song thrushes preferred weedy stubbles to crops or grassland, especially where annual weeds such as fumitory and field pansies, thrived on worked ground. Grasses and broadleaved weeds are also a reservoir of invertebrate food for finches, buntings and grey partridge.

Over 50% of granivorous birds (sparrows, finches and buntings) occur on stubbles in winter (though stubbles only represent 10% of the available habitat) relative to nearby cereals and non-cereal crops (**Ref. 8**). The availability of overwinter stubbles can explain some of the variation in breeding population trends for several declining farmland birds.

The general pattern is that stubbles can provide very important food for birds in winter, potentially (and demonstrably in a few cases) with positive effects on their survival and recruitment into the breeding population (**Ref. 8**). If the food quality of stubbles for birds, particularly in late winter (February), can be raised on average, this should greatly enhance survival. Commercially productive crops may be able to contribute directly to the provision of food resources for birds if weed populations can be manipulated without significant damage to the crop. The potential for crops to do this varies widely between different field/crop types and between crop management regimes but, compared to cereal crops, sugar beet is often relatively rich in weeds, particularly broad-leaved weeds that form an important part of the diet of many farmland birds (**Ref. 9**).

In addition, the sugar beet stubble becomes available to birds relatively late in the mid winter, for a short period of time, but this is when food elsewhere on farmland is becoming scarce and birds have difficulty meeting their energy demands (**Ref. 9**). Therefore, delayed harvesting of beet should provide food late in winter for birds.

Stubble fields that are used by large numbers of birds are rich in weed seeds. Weed seeds on the soil surface are generally most abundant in broad-leaved crops – sugar beet and oilseed rape (**Ref. 5**). It is these seeds on or near the soil surface that are important for granivorous birds feeding in beet or cereal stubbles.

Therefore this study by the British Trust for Ornithology and Broom's Barn Research Centre investigated the potential for beet, beet stubbles and cultivated and uncultivated cereals to provide food for birds. The project considered both plants and seeds (from volunteers or weeds) and invertebrates.

4.0 WEED MANIPULATION IN SUGAR BEET

4.1 Methods – year 1 (2005)

Trial sites

Three sites with different soil types, which also gave a different spectrum of weed numbers and species were selected to compare the effects of different herbicide regimes on weed development, biomass and seed production. In addition, a larger trial was set up at Broom's Barn to examine the interaction between the herbicide treatments and commonly-used insecticide seed and granule treatments. Details of husbandry applied to each site are listed in Table A1. [Note A denotes Appendix A.]

Treatments

Herbicides treatments

At the three outside trials, specific herbicide treatments were devised to give optimum control of the weed spectra prevalent at each site. Reduced herbicide regimes were designed around that core programme to give target weed biomasses of 50, 100 and 150 g dry matter/m^2 respectively in mid-late July. 100g DM/m^2 had been shown in previous experiments with GMHT glyphosate-tolerant sugar beet to give environmental benefits without loss of yield. Details of the herbicides applied to each site are listed in Tables 2 and 3.

Sprays were applied with a one-man operated 3m Oxford precision sprayer, delivering 100 l/ha through F110/01 Tee-Jet nozzles.

At Broom's Barn, only two herbicide regimes were compared – a full conventional programme and the reduced programme targeting 150 g DM/m^2.

Insecticide treatments

At the three outside sites, untreated seed was used to provide the range of weed biomasses described above. In addition the imidacloprid-treated seed (Gaucho) was also subject to the two extreme herbicide treatments – a full herbicide programme to give maximum economic weed control and a reduced regime targeting 150 g DM/m^2.

At Broom's Barn, an untreated control was compared with the standard imidacloprid at 90 g a.i./unit (Gaucho from Bayer), the newly introduced clothianidin plus betacyfluthrin at 60 + 8 g a.i./unit (PonchoBeta from Bayer), the soon to be registered thiamethoxam plus tefluthrin at 60 + 8 g a.i./unit (proposed name Cruiser Force from Syngenta) and a carbamate granule, carbosulfan at 600 g a.i./unit (Posse from Belchim).

Design / layout

At all outside three sites, the six treatments were replicated five times in randomised blocks. Plots were 24 rows wide (12m) and 12m long to reduce the impact of neighbouring plots on the activity of invertebrates within each plot.

At Broom’s Barn, a factorial arrangement comparing the interaction between two widely different herbicide regimes with the untreated control, the three neonicotinoid seed treatments and the carbamate granule was set up; i.e. five insecticide treatments x two herbicide regimes, giving 10 treatments replicated four times (= 40 plots) in randomised blocks. Plot size was the same as in the outside sites.

Observations

Emergence and establishment of beet

At all four sites, the number of plants present in the central 6 rows by 10 m were counted in each plot on two or three occasions, the first at cotyledon stage when plants were just coming through the soil surface, and the second and third when plants were well established (2-4 or 6 leaf stage).

Crop vigour

At all sites the vigour of growing plants was scored on two or three occasions, usually at the time of the plant counts. The vigour score of complete plots was made on a linear scale of 0-10, with 0 = no plants and 10 = a full healthy canopy.

Weed numbers and biomass

In late June/early July, the number and species of weeds present within the beet crop in each plot were counted in ten 50 x 50 cm quadrats (total 2.5 m^2) placed in the centre of each outside drill width to the side of the wheelings made by the tractor, on two occasions. The percent weed cover, and that and of beet were also estimated on each occasion using visual scores (0 – 10 linear scale where 0 = no cover and 10 = complete canopy).

Weed and beet foliar biomass was measured in late July by cutting all plants at ground level within two 1 x 1 m quadrats. Plant material, both live and dead, was weighed fresh, and again after drying until constant weight at 85^{o}C. Live material was identified to species and weighed separately before drying.

Seed rain

Weed seed rain was collected using three seed rain traps (9.5cm in diam) per plot (Heard e*t al*., *2003)*, placed in the centre of the drill width to the right of centre, from June – harvest in October/November depending on site. Seeds were identified to species where possible, or at least to genera.

Vortis samples.

Seeds lying on the ground after harvest were sampled by using a Vortis suction sampler to take 10 sub-samples of 10 second duration from two diagonals across the right hand side of the plots (avoiding the harvest area). Samples were stored in a freezer prior to sorting and identification at a later date.

Soil seed bank

Four soil cores, 30 cm long by 2 cm diameter, were taken at the beginning of the experiment just after sowing, and again at the end after harvest but before soil cultivation. Samples from a selection of the plots across the trial were sorted and seeds identified to give a baseline measurement of the initial seed bank, and to determine if there was much variation between blocks. Seeds from all plots were sorted and identified from the final sample from a sub-sample of 500g soil. Seeds were extracted using a system of sieves as per Bright project (**Ref 10**).

Soil invertebrates

Surface–active invertebrates

Surface-active invertebrates were caught in pitfall traps, consisting of 65 mm diameter plastic cups 80 mm deep, 2/3 filled with a mixture of ethyl alcohol, glycerol and water in the ratio 50: 5: 45, placed within 7 cm diameter, 15 cm deep plastic sleeves (drain pipe), set between the rows down the middle of each plot with the tops flush with the soil surface. One trap was place in the centre and the other two 3 m from each end of each plot. Traps were set for two weeks in each month from June-October in each trial.

All arthropods were sorted and identified as far as possible. Carabid beetles were identified to species. The biomass of invertebrates was measured in each plot by drying the samples after identification.

Vortis samples

Invertebrates present on the foliage and soil surface at the time of sampling for weed biomass were sampled using a Vortis suction sampler. In each plot samples were taken from ten locations, five each in diagonals across the right hand side of each plot (i.e. not in the harvest area), comprising a total of $0.18m^2$ per plot. Samples were stored in the freezer prior to sorting and identification at a later date. Samples were identified as far as possible.

Yield

The trials at Ramsey and Stetchworth were harvested by hand due to restrictions placed on the use of the machine harvester following the discovery of rhizomania at Broom’s Barn in 2004. Beet was lifted from four rows by 8 m long from the drill width immediately to the left of centre in each plot. The trials at Ixworth and Broom’s Barn were harvested by machine, an Edenhall two-row harvester, which lifted beet from four rows by 9.7 m from the drill width immediately to the left of centre. Clean beet weights, sugar concentration and level of Na, K and amino N were determined in the Broom’s Barn tarehouse.

Analyses

Data were analysed by analysis of variance using GENSTAT V.

4.2 Methods year 2 (2006)

Treatments were similar to those used in year 1 – namely

Ten treatments used at Broom's Barn were

Six treatments used at the other 3 sites were

Application and assessments used the same methodology as in year 1 but for only a limited range of assessments owing to a reduction in funding:-

- crop and weed vigour and biomass were scored during the weed control season and in September / October. Vigour scores of the individual main species were also taken.

5.3 Results 2005

Effect of herbicide treatments on weeds

Ixworth

- Full programme had 6 sprays (5 a.i.'s), reduced 50g had five sprays (8 a.i.'s); reduced 100g had 5 sprays (6 a.i.'s); reduced 150 g had 5 sprays (6 a.i.'s). Where five sprays were used, the third was omitted (Table A2).
- There was no effect of treatments on emergence or establishment (Table A3). Crop populations were good.
- 14 species of weeds were recorded in all treatments; field pansy, small nettle, fat hen, black bindweed and annual meadow grass were the most prevalent (Table A4)
- 13 species of weed were recorded in biomass samples in all treatments. The highest biomass was produced by field pansy, small nettle and fat hen (Table A5)
- The number of weeds in full programmes and reduced 50g were between 13-16/m^2. The number in the two other reduced treatments (100 and 150 g targets) were 2.5-3 times more. There was no difference between these (Table A6). Weed cover was four times greater in reduced 100 and 150 g target treatments. Significant effects were recorded on only two of top five weeds, especially field pansy and black bindweed. Field pansy was the main species driving differences. There was no effect from the use of Gaucho.
- The total biomass of weeds was significantly greater (x 5-7 greater) in reduced 100 and 150 regimes compared to the full weed control programme, though this was mostly due to field pansy and small nettle, although the latter was not significant (Table A7). There was no difference between 100 and 150 g treatments, or between full and reduced 50 programmes. There was no effect of Gaucho on weed biomass.

Stetchworth

- The full weed control programmes had 5 sprays (4 a.i.'s), reduced 50 g 4 sprays (3 a.i.'s); reduced 100 g 3 sprays (4 a.i.'s) and reduced 150 g 3 sprays (4 a.i.'s) (Table A2).
- There was no effect of treatments on emergence 30 DAS, but some effect on establishment 45 and 56 DAS. There were fewer plants in the full programme treatment with untreated seed (Table A3).
- 11 weed species were recorded on 30 June; field pansy, knotgrass, black bindweed, fat hen and ivy-leaved speedwell were the most prevalent (Table A4).
- 9 species were recorded in biomass samples; knotgrass, field pansy, black bindweed, mayweed and fat hen were the most prevalent (Table A5).

- The number of weeds in the full programme treatments was significantly less than all reduced treatments; weed cover was only 5-6%, 3 times more than this in the reduced 50 g, and 6-7 times more in the reduced 100 and 150 g treatments. Effects were significant on knotgrass and field pansy only. The reduced 100 and 150 g treatments had more weeds than reduced 50 g, but there was no difference between reduced 100 and 150 g treatments (Table A8). There was no effect of Gaucho on weed numbers.
- Total biomass was very low following the full herbicide programmes (5 g /m^2). There was significantly more in the reduced 100 and 150 g treatments, with the reduced 50 g treatment intermediate. Most differences were due to field pansy and knotgrass, with a small contribution from black bindweed. There was no effect of Gaucho on weed biomass (Table A9).

Ramsey

- The full weed control programmes had 2 sprays (4 a.i.'s). The reduced 50 g treatment had 2 sprays (3 a.i.'s), reduced 100 g 2 sprays (2 a.i.'s), reduced 150 g 2 sprays (2 a.i.'s) (Table A2).
- There were significantly more plants in the reduced 100 g treatment at emergence, but there was no difference at establishment (Table A3).
- 18 weed species were recorded in all treatments on 1 July but numbers per m^2 were much lower than for the other two outside sites. Prickly sowthistle, creeping thistle, common chickweed, annual meadow grass and common field-speedwell were the most prevalent (Table A4).
- The mean biomass was also much lower (five-fold) than at the other two outside sites. 18 species were recorded in the samples at end July. Creeping thistle, common chickweed, mayweed, bristly ox-tongue and weed beet were the most prevalent (Table 5).
- Effects on weed cover were significant but not great. Weed cover was only 5% in the full programmes and reduced 50 g, but double in reduced 100 and 150 g treatments. Weed numbers doubled from *circa* 5/m^2 in full and reduced 50 g programmes, to *circa* 12/m^2 in reduced 100 and 150 g regimes. Differences were due to common chickweed and prickly sowthistle. There was no effect of Gaucho on weed cover (Table A10).
- There was no significant effect of treatments on weed biomass. The distribution of weeds was very erratic and ranged from 6-37 g DM/m^2. Biomass in reduced 100 and 150 g treatments was much less than at the other two sites (Table A11).

Broom's Barn

- The full weed control programme had 3 sprays (5 a.i.'s) and the reduced 150 g programme had 2 sprays (4 a.i.'s) (Table A2).
- There was no effect of treatments on emergence, but there were fewer plants in the full programme with PonchoBeta seed treatment and the reduced programme with Cruiser Force seed treatment (Table A12).

- This site had the fewest weed numbers (4.5/m^2), but the largest number of species (21). Fat hen, creeping thistle, field pansy, black bindweed and volunteer barley were the most prevalent (Table A4).
- Weed biomass in late July recorded 17 species but was as low as Ramsey. Creeping thistle, fat hen, common orache and smooth sowthistle were the most prevalent (Table A5).
- Weed cover increased from *circa* 2.5% in the full programme to 5% in the reduced weed control regime. Significant effects on total weed numbers of reduced regime, Whilst weed numbers on the reduced regime were 6/m^2 compared to *circa* 2.5/m^2, this effect was statistically significant The effects were on black bindweed and fat hen only (Table A13). There was no effect of insecticide treatments on weed number or cover.
- Although the biomass in reduced regime was 5-14 times that of full programme, weed distribution was very erratic and the differences were not significant. There were some effects of treatments on the biomass of fat hen and field pansy (Table A14). Insecticide treatments had no effect.

Effect of herbicide regimes on weed seeds

Ixworth

- Seedbank samples at the beginning of the trial recorded 12 species; fat hen, field pansy, common chickweed and small nettle being the most prevalent (Table A15).
- Seedbank samples at harvest recorded 13 species with numbers per plot doubled from those recorded in the spring. The same species were prevalent at the end as at the start (Table A16).
- There were significant effects on total seeds extracted at the beginning of the experiment with more non-viable seeds collected in Gaucho plots due to be treated with a full herbicide programme or the reduced 150 g treatment. The differences were mostly due to fat hen and common chickweed (Table A17). The proportion of non-viable seed was quite high (over 80%).
- No significant difference was recorded between treatments in December but the number of seeds was much higher in all treatments with approximately 50% viable. Effects were significant on viable field pansy seeds (Table A18).
- Very large numbers (>29,000) of seed were caught in seed rain traps from July-December (none were caught in June). Of the 23 species recorded, field pansy, small nettle, fat hen and annual meadow grass were the most prevalent (Table A19).
- There was a significant increase in total weed seed numbers from *circa* 19,000- 27,000 /m^2 after the full herbicide programmes, to >75,000 /m^2 in reduced 150 g regimes. There was no difference between full and reduced 50 and 100 g programmes but the reduced 150 g programme had significantly more than all others. Most differences were due to

annual meadow grass, field pansy and small nettle (Table A20). The majority of seeds (>85%) of the most prevalent species were viable.

- Few seeds were collected in the Vortis samples taken after harvest but field pansy, fat hen and small nettle were the most prevalent (Table A21).
- There was no significant effect of any treatment on seeds collected by Vortis. Numbers ranged from 36-59/m^2, much less than recorded by seed rain traps (Table A22).

Stetchworth

- The number of seeds at recorded at the start were <one fifth per plot of those at Ixworth. Six species were recorded, field pansy, fat hen and knotgrass were the most prevalent (Table A15).
- 9 species were recorded in the samples taken at harvest with numbers 6 times greater than at the beginning. The same species dominated (Table A16).
- Significantly more seeds in soil were recorded in untreated plots with reduced 150 g regime having three times more than the full regime. There were more of all the main species, fat hen, black bindweed, knotgrass and field pansy (Table A23). 68% were viable.
- Large numbers of seeds were collected in the seed rain traps (>13,000). Of the 17 species recorded, field pansy, knotgrass, black bindweed, mayweed and fat hen were the most prevalent (Table A24).
- Significantly more seed was collected in reduced (100 and 150 g) regimes (x25-40). These effects were due to black bindweed, knotgrass and field pansy. There was no significant difference in fat hen and mayweed numbers. Mean viability was 84% with the highest (96%) for field pansy and the lowest (63%) for knotgrass (63%) (Table A25).
- The numbers of seed in Vortis samples taken after harvest were about half those at Ixworth (123). Of the 9 species recorded, mayweed, field pansy and knotgrass were the most prevalent (Table A21).
- There were no significant differences between treatments for any weed species or totals as results appeared very variable. Their mean viability was 63%, with that of field pansy the highest 92% and mayweed the lowest at 34% (Table A26).

Ramsey

- The number of seeds at the start of the experiment was the lowest of all sites. Seven species were recorded, common chickweed and fat hen were the most prevalent (Table A15).
- Number of seeds recorded at harvest were similar to that at the start, but the number of species increased to 13, probably due to more samples being extracted. Common chickweed, fat hen, mayweed and field pansy most prevalent (Table A16).
- Full sorting and identification was not concluded at this site as there was no difference in the subsamples from the two treatments, full and reduced 150 g regimes (Table A27).

- Many fewer seeds were collected at Ramsey (2,458), reflecting lower weed numbers. Of 16 species recorded, mayweed, prickly sowthistle, common chickweed and bristly ox-tongue were the most prevalent (Table A28).
- There were no significant effects on total seed numbers, only on the individual species of prickly sowthistle. Mean viability was 85% (similar to Stetchworth) with the highest for common chickweed at 99% and the lowest prickly sowthistle at 54% (Table !29)
- Only 13 seeds collected by Vortis after harvest; mostly prickly sowthistle and chickweed (Table 21).
- No significant effects on any of the few species collected by this method (Table 30).

Broom's Barn

- Moderate numbers of seeds extracted at beginning; 8 species recorded, of which fat hen, chickweed and pansy most prevalent (Table 15).
- Numbers of weed seeds remained similar to beginning, therefore no further sorting done. 11 species recorded, same species prevalent (Table 16).
- Sig. more chickweed in reduced regime with untreated seed, more fat hen in full remine with Cruiser force; no other differences and no differences in total, results very variable (Table 31). Viability only 48% overall, highest in mayweed (80%) and lowest in fat hen (44%).
- Circa 2800 seeds collected in seed rain traps; 23 species recorded; fat hen by far most prevalent, followed by chickweed, black bindweed and perennial sowthistle (Table 32).
- Only one sig effect – more viable total seeds in reduced regime with Cruiser Force, due mainly to viable fat hen. Mean viability 87%, highest pansy at 95%, lowest perennial sowthistle at 48% (Table 33).
- Of 32 seeds collected by Vortis at harvest, only 3 species recirded; fat hen and creeping thistle most prevalent (Table 21).
- Only effect on non-viable seeds in reduced regime with Cruiser Force, due to creeping thistle. No. sig effect with any other species, results very variable (Table 34).

Effect of treatments on invertebrates

Ixworth

Pitfall traps

- > 5000 carabids caught from June-October; of 25 species recorded, *Pterostichus melanarius (38%), Harpalus rufies (35%), Calathus fuscipes(11%), C. cinctus (3%) and Nebria brevicollis (4%)* most prevalent (Table 35). Most were caught in August and September.
- No effect of treatments on any of these species, or on total carabids, staphylinids or spiders (Table 36). No effect of Gaucho.

- Of 1022 other invertebrates caught, flies, heteropteran bugs, parasitic wasps, sap beetles and sawfly larvae were the most prevalent (Table 37).
- No effect of herbicide regimes on numbers of any of these; no effect of Gaucho although most heteroptera were found on untreated reduced herbicides targeting 150 g (Table 38).
- Total biomass of invertebrates ranged from 6-11 g DM/m2; most caught in August; no significant difference between treatments; no effect of Gaucho (Table 39).

Vortis samples(July)

- >1200 specimens collected in July; flies, parasitic wasps, spiders, heteropteran bugs, aphids, staphylinids beetles, thrips and small carabids were the most prevalent (Table 40).
- Significantly more (3-fold) invertebrates were found in reduced 100 and 150 plots, due to more flies, parasitic wasps, total coleopteran and spiders (Table 41). No sig effect of Gaucho.

Stetchworth

Pitfall traps

- >40000 carabids caught, 8 times more than Ixworth. 25 species recorded; *P melanarius (65%), H. rufipes (30%), C. fuscipes (2%), P. madidus (1%) and C. cinctus (<1%)* were most prevalent (Table 42). Most caught in June and July.
- Sig increases in carabids in all reduced regimes, especially 100 and 150 g plots compared to full programmes due to effects on *P. mel, H. ruf, and C. fus.* No effect of tmnts on spiders or staphs. No effect of Gaucho (Table 43).
- Of 1146 other inverts caught, flies, burying beetles, millipedes, earthworms and woodlice most prevalent (Table 44).
- No effect of treatments on most of these or total; some effect on larvae; more in reduced 100g plus Gaucho and 150 g untreated plots (Table 45).
- Biomass ranged from 51-78 g DM/m2, much more than Ixworth; sig increases in reduced 100 and 150 regimes, especially in June, July August (one tmnt) and September (one tmnt) (Table 46).

Vortis samples (July)

- >2700 specimens caught, twice that of Ixworth. Flies, beetle larvae, parasitic wasps, spiders, staphs, heteroptera, aphids, and carabids most prevalent (Table 40).
- 3-5 times more inverts in reduced 100 and 150 regimes, reduced 50 regime intermediate; mostly due to flies, parasitic wasps, Chrysolmelid beetles (one tmnt), total coleopteran, heteroptera, spiders, and very significantly, coleopteran larvae (Table 47).

Ramsey

Pitfall traps

- >5200 carabids caught; *P. melanarius (69%), Trechus quadriastriatus(12%), H. rufipes (11%), N. brevicollis (3%) and P. cupreus (1%)* most prevalent (Table 48). Most caught in July.
- Sig fewer carabids in reduced 100 and 150 g plots, due to lower numbers of *P. mel and T. quad.* No effect on other species or carabid larvae, staphs or spiders (Table 49). No effect of Gaucho.
- Of *circa* 2000 specimens collected, flies, gastropods (mostly slugs), millipedes, harvestmen spiders, centipedes and earthworms were most prevalent (Table 50).
- No effect of any tmnt on any group. No effect of Gaucho (Table 51).
- Biomass ranged from 6-10 g DM/plot similar to Ixworth. No effect of tmnts; most caught in July, although slugs contributed a lot in October (Table 52).

Vortis samples (July)

- Of 1293 specimens collected, flies parasitic wasps, spiders, aphids, carabids, staphylinids and weevils were most prevalent (Table 40).
- Sig more Coleoptera in reduced 150 regimes, and Heteroptera in reduced 150 untreated plots; no effect on other inverts (Table 53).

Broom's Barn

Pitfall traps

- >26000 carabids caught; *P. melanarius (91%), H. rifipes(4%), T. qudristriatus (2%), N. brevicollis (0.5%) and Bembidion obtusum (0.4%)* most prevalent (Table 54). Most caught in June and July.
- No significant effect of treatments on any species of carabid, or on staphylinids or spiders (Table 55). No effect of any insecticide.
- Of 1738 other invertebrates caught, most were slugs, followed by flies, earthworms, centipedes, and burying beetles (Table 56).
- Gastropods made a significant contribution to numbers. However, no effect of any treatment on total numbers or any individual group (Table 57). No effect of insecticides.
- Biomass ranged from 25-36 g DM/m2; most caught in June and July. No effect of treatments on total or in any month (Table 58). No effect of insecticides.

Vortis samples (July)

- Of 743 specimens collected, flies, parasitic wasps, spiders, carabids, staphylinids, heteroptera and aphids most prevalent (Table 40).
- No significant effects of any treatment of numbers of any group or total ; no effect of insecticides (Table 59).

Effect of herbicide and insecticide treatments on sugar beet growth and yield

Ixworth

- Ground cover in late June was significantly less in reduced 100 and 150 g regimes (Table 60).
- In late July, there were significant effects of reduced 100 and 150 regimes on both top and root weights (Table 62).
- At harvest, best root yield from reduced 50 g; sig reduction in reduced 150 g and full programme untreated plots; sugar % only 15.32% (Table 63). Poor yield due to BCN infestation, maybe also rhizomania.

Stetchworth

- Ground cover sig less in reduced 100 and 150 g regimes (Table 60)
- Best biomass given by full herbicide regime plus Gaucho seed. Sig reduction in untreated; reduced 150 g regime significantly less than all other treatments (Table 62).
- Highest root weights from outside sites; reduced 150 regimes sig less than reduced 100 regime, which in turn was significantly less than reduced 50 g and full programme; sugar 17.82% (Table 63).

Ramsey

- Ground cover unaffected by weeds in any treatment (Table 60).
- Highest top and root weights of all outside sites in July; no significant differences of any treatments; no effect of Gaucho (Table 62).
- Root yields were less than at Stetchworth; no significant effect of treatments; no effect of Gaucho; sugar concentration was 17.41%, similar to Stetchworth (Table 63).

Broom’s Barn

- Ground cover was significantly less in reduced herb regimes treated with Gaucho, Poncho Beta and Cruiser Force (Table 61).
- There was no significant difference in either fresh or dry weight of tops or roots (Table 64), although Posse tended to be consistently higher than the other insecticide treatments.
- Highest root yields of all sites; there were significant reductions in root weight and sugar yield in reduced regimes with Gaucho, Poncho Beta and Cruiser Force treatments, but not Posse granules (Table 65).

4.4 Results 2006

Broom's Barn site (Table 1B)

There was no difference between treatments on the crop (biomass, vigour).

There was also no difference in effects on vigour of individual weeds (FALCO, ATRPA, VIOAR, CISAR, VERPE).

Throughout the season and in October weed biomass was generally higher on treatments 6 to 10 inclusive compared to the other four treatments.

Ixworth (Table 2B)
There was no difference between treatments on weed biomass (except on 22/5/06), crop vigour or vigour of individual weed species (FALCO, VIOAR, GALAP, ATRPA).

Weed biomass on 22/5/06 was significantly poorer on treatments 5 and 6 compared to the other four treatments.

On 8/05/06 crop biomass was higher on treatments 5 and 6. On 5/06/06 and 19/06/06 crop biomass was highest on treatment 5 and lowest on treatment 3. On 02/10/06 crop biomass was lowest on treatments 3 and 6.

Ramsey (Tables 3B and 4B)
There was no difference between treatments on vigour of FALCO, POLPE or ATRPA. Vigour of oilseed rape on 21/06/06 was highest on treatment 3 and lowest on treatment 2. Common field-speedwell vigour was generally highest on treatments 5 and 6 and lowest on treatment 2. Vigour of fat hen was greatest on treatments 5 and 6 and low to nil on the other four treatments.

Crop vigour was not affected at any assessment but vigour on 8/05/06 was generally slightly (but significantly) higher on treatments 5 and 6 compared to most other treatments.

Stetchworth (Tables 5B and 6B)

There was no difference between treatments on vigour of VIOAR. On 15/06/06 treatments 1 to 3 reduced vigour of FALCO compared to treatments 4 to 6. On 13/07/10 vigour of FALCO was reduced on treatment 2 whilst on treatments 4 to 6 it was unaffected. On 23/05/06 vigour of common orache was high on treatment 6 but the weed was not recorded on treatments 2 and 4. Small nettle was not recorded on treatment 1 on 7/06/06 whilst vigour was higher on treatment 4 than all treatments bar treatment 10.

None of the treatments affected weed or crop vigour.

Overall crop biomass on 1/06/06 was lowest on treatment 1 and on treatment 6 on 29/09/06.

Overall weed biomass on 1/06/06, 15/06/06 and 13/07/06 was generally significantly lower on treatments 1 to 3 compared to treatments 4 to 6.

5.0 Stubble trials

5.1 Method

An uncultivated and cultivated (immediately after cereal harvest) treatment were compared on cereal stubbles. Assessments included scores of weed species vigour and overall biomass, weed seed rain, weed seed bank and invertebrate numbers in pitfall traps. The final two assessments were carried out just before the primary cultivation was carried out for the following sugar beet crop. All others were carried out monthly between cultivation and the primary cultivation. Treatments were replicated six times in randomised blocks.000

A light power harrow cultivation was used on all sites as the cultivation treatment. This operation was carried out within 14 days of cereal harvest.

Five sites (all in close proximity to Broom's Barn) were used each year (but one was abandoned in the final season). These were:-
Broom's Barn, Ixworth, Ramsey, Stetchworth and a light land site.

The main features of the sites were:-

Broom's Barn – sandy loam; previous crops winter wheat

Ixworth – light loamy sand soil; previous crops winter barley

Ramsey – peaty clay loam; previous crops winter wheat

Stetchworth (2005 and 2006 only, site had to be abandoned owing to farm operations in 2007) – loamy sand; previous crops winter wheat (winter barley 2005)

Light land site (Thetford 2005/6: Lark Hall 2006/7: Tuddenham 2007/8) – Breckland sand; previous crops winter barley

5.4 Results (see Appendix D)

2005 cereal harvest
Broom's Barn site In August 2005, FALCO and SENVU were more vigorous on the cultivated than uncultivated plots but in the period August to November there was greater weed biomass on uncultivated plots but no difference in December and January.

There was no significant difference between treatments on seed rain.

Spiders were more prevalent on cultivated plots whereas Staphilinid beetles, diptera and gastropods were less so. There was no difference in total pitfall catches between the two treatments.

Ixworth site VERPE was more vigorous in September in uncultivated plots and greater overall weed biomass in September and October on uncultivated plots compared to cultivated ones.

Gastropod pitfall catches were greater in the uncultivated than cultivated plots but there were no other differences in the catches.

Ramsey site SENVE and BETVU were more vigorous in September on the cultivated compared to uncultivated plots. There was no other significant difference.

Seed rain was not recorded owing to destruction of the traps by animals. There was no difference in the seed banks of the two treatments.

There were more *Pterostichus melanarius*, staphilinids and diptera caught in pitfall traps on uncultivated than cultivated plots.

Stetchworth site Vigour of VERPE was greater on uncultivated in August whereas that of SENVE and SONAS was greater on cultivated plots in November. Overall weed biomass was also higher on uncultivated in November than on cultivated.

There was no difference between treatments on seed rain or seed banks.

More carabids and spiders but fewer staphilinids were caught in pitfall traps on cultivated compared to uncultivated treatments.

Light land site Vigour of VERPE in August and of CHEAL in December were greater on uncultivated plots and overall biomass was greater on this treatment in August and September.

There was greater seed rain from FALCO, POLAV, VIOAR and total species in uncultivated compared to cultivated plots. There was no difference between treatments on the weed seed bank.

More *Nebria brevicollis* was greater in pitfall traps in cultivated compared to uncultivated plots but there was no difference with other species or total individuals.

2006 cereal harvest
Broom's Barn site Total weed biomass in August, September and October were greater on uncultivated plots but there was no difference in November.

There was no significant difference between treatments on seed rain.

Trechus quaristriatus were present in greater numbers on the cultivated plots whereas *Calathus fuscipes* were lower in number. There was no other or overall difference between pitfall trap catches.

Ixworth site In September, October and November there was greater overall weed biomass on the uncultivated plots but numbers of URTUR were greater on the cultivated plots in January.

More CHEAL seeds were shed on cultivated compared to uncultivated plots but there was no other difference in individual species or overall. There was a greater abundance of STEME in the seed bank on uncultivated plots but there was no other difference in the seed bank.

Gastropod pitfall catches were greater in the uncultivated than cultivated plots whereas numbers of *Nevia brevicollis* were greater on the cultivated plots. There was no other difference in the catches.

Ramsey site In August vigour of TRIAE and overall biomass were significantly greater on the uncultivated plots than the cultivated whilst in October vigour of VIOAR was greater on cultivated than uncultivated. There were no other significant differences.

There was no difference in seed rain catches or seed bank between treatments.

There were more *T. quadristriatus* in pitfalls on cultivated compared to uncultivated plots but no other significant difference.

Stetchworth site There was significantly greater weed biomass on uncultivated plots in November but differences were not significant at other times.

There were more non-viable seeds in the seed rain on uncultivated compared to cultivated plots. There was no difference in seed banks on the two treatments.

There was no difference in pitfall catches in either treatment.

Light land site SENVE vigour was greater on cultivated than uncultivated plots in November whilst overall weed biomass was greater in uncultivated plots from September to December inclusive.

There was greater seed rain (non-viable seeds only) from CHEAL and total species on cultivated compared to uncultivated plots. There were more CHEAL and total weed seeds in uncultivated compared to cultivated treatments. The seed bank at this site was very large (>170k m^{-2}).

Numbers of *Calathus cinctus, Nebria salina* and *Trechus quadristriatus* were greater in cultivated than uncultivated treatments.

2007 cereal harvest
Broom's Barn site Overall weed biomass and vigour of some species such as SONAS were greater on uncultivated compared to cultivated plots in August and September but there were no differences in later months.

There was no significant difference between treatments on seed rain or seed banks.

Both *Nebria salina* and *T. quadristriatus* were more prevalent on cultivated compared to non-cultivated plots but there was no other or overall difference between pitfall catches.

Ixworth site There was no significant difference between treatments on weed numbers or biomass.

There was no difference in seed rain catches between treatments. Greater numbers of VIOAR were found in the seed bank of the cultivated to uncultivated treatment.

There were more spiders in pitfall traps on the uncultivated plots but there was no other or overall difference between pitfall catches.

Ramsey site There was greater overall weed biomass on uncultivated compared to cultivated plots in August, but no other significant difference on weeds.

There was no difference in seed rain catches or seed rain between treatments.

There were more staphilinids in pitfall traps on cultivated compared to uncultivated plots but no other significant difference on weeds.

Light land site Vigour of *Epilobium* spp. was greater on uncultivated plots in August and September and overall weed biomass was greater on this treatment in October and November.00000

More seeds of CHEAL and URTUR (non-viable and viable + non-viable of each) and total species were recorded in seed rain in cultivated compared to uncultivated treatments. There was no difference in weed seed banks between treatments.

Nebria brevicollus, Nebria salina were found in greater numbers in pitfall traps on uncultivated plots whereas there were fewer spiders.

6.0 References

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