Project title:	Perennial field margins with combined agronomical and ecological benefits for vegetable rotation schemes
Project number:	FV 334 / HortLINK HL019
Project leader:	Prof Felix Wäckers (Lancaster University)
Report:	Annual Report, Feb 2014 (overdue from Dec 2013)
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Location of project:	Lancaster University, Bailrigg, Lancaster, LA1 4YW STC Research Foundation, Stockbridge House, Cawood, Selby, North Yorkshire, YO8 3TZ Food and Environment Research Agency, Sand Hutton, York, YO41 1LZ (previously Central Science Laboratory)
Industry Representative:	Nathan Dellicott Barfoots of Botley
Date project commenced:	1 December 2008
Expected completion date:	30 November 2013

The following are members of the Consortium for LINK project HL0192:

Lancaster University
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STC Research Foundation
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Food and Environment Research Agency
•
Agriculture and Horticulture Development Board
•
AHDB-HGCA
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Processors and Growers Research Organisation
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Westhorpe Flowers and Plants Limited
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Produce World Limited
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National Farmers Union
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J.F.D. Hargreaves Limited
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Donald McIntyre (Emorsgate Seeds)
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Growing Wild Limited
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Syngenta Limited
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Dow AgroSciences Limited
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Koppert Biological Systems BV
•
BCP Certis

- Unilever U.K. Central Resources Limited
- Birds Eye Limited

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Prof Felix Wäckers
Project leader and overall Project Co-ordinator
Lancaster University

Signature .... Date ....

IMPORTANT TERMS

Whilst every effort has been made to ensure that this report is as jargon-free as possible, the reader should familiarise themselves with the following terms before reading the results as reported below. The terms and abbreviations have been retained from previous reports for the sake of brevity and clarity.

FM = Flowering Margin
CF1 = Crop Field sampling site 1 (5m into the crop from the FM)
CF1.5 = Crop Field sampling site 1.5 (mid-way between CF1 and CF2)
CF2 = Crop Field sampling site 2 (in the middle of the crop)
CF2.5 = Crop Field sampling site 2.5 (mid-way between CF2 and CF3)
CF3 = Crop Field trapping site 3 (5m into the crop from the CM)
CM = Control Margin

Sampling sites are shown diagrammatically to the right.

CONTENTS

GROWER SUMMARY

Headline

- The successful conclusion of 4 years of establishing perennial margins at the experimental field site has shown the superior nature of flowering field margins as a resource for multiple groups of beneficial insects.
- Yield increases adjacent to established margins were seen in some crops indicating the increased numbers of biocontrol agents and parasitism translated into increased pest control and improved crop yield.
- Nearer to flowering field margins good trends were seen for reduced pest incidence and increased natural enemy activity in all years of the study.
- Four individual seed mixes tailored to soil type and budget are recommended. Further options for growers are available through the Automated Margins project (HDC FV 334a) at http://www.stockbridgetechnology.co.uk/Automated_Margins/

Background

The horticultural industry faces a range of issues linked to crop protection. These include a reduction in the available products approved for use, the potential for increasing resistance in the target organisms, increasing pressures from consumers and retailers for residue-free produce and a need to comply with legislation and industry initiatives (e.g. Water Framework and Voluntary Initiative). These pressures have resulted in the need for a more considered approach to pesticide use and for the full exploitation of the range of alternative methods available for maintaining pest populations below economic damage thresholds.

The development of stewardship schemes that encourage the management of the farmed environment in a way that increases levels of biodiversity, provides an opportunity to combine conservation objectives with the benefit of enhanced pest control (either through conservation biological control or through other methods such as trap cropping). Current stewardship options include pollen and nectar mixes targeting bees and butterflies, as well as separate margin prescriptions to encourage farmland birds. Previous work by members of the research team involved in the current project has developed the concept of designing flowering field margins for the specific purpose of optimizing biological pest control. The current project looks to build upon the above research and seeks to combine the biodiversity and pest-control benefits of perennial field margins, providing growers with a direct economic benefit in addition to the expected subsidies from stewardship schemes.

The expected deliverables from this work included:

1. Development of a seed mixture for perennial field margins that has the potential to optimize joint pest control and conservation benefits while minimizing potential risks for vegetable rotation schemes.
2. Quantification of the impact of field margins on biological control agents, pests, pollinators and farmland birds.
3. Development of the use of flowering field margins as part of an insecticide assisted trap-cropping approach.
4. Development of field margins that support predator population build-up through provision of non-pest prey in field margins.
5. Assessment of the feasibility of using banker plants in field margins and development of these plants as sentinels to monitor levels of biological control agents.
6. Development of a database on the compatibility of available chemical control options with various biological control agents to optimize integrated pest management decisions.
7. Quantification of the impact of perennial field margins on pest levels, crop quantity/quality and pest management costs.
8. Communication of best practice to commercial growers in the form of ‘blueprints’ for margin establishment and management, drawing upon knowledge generated in the proposed project as well as in ongoing European biodiversity projects.

Summary of the project and main conclusions

Objective 1- Development of the seed mixture.

Despite harsh winter/spring conditions in the four successive years since their initial sowing, many of the flowering plants sown established and survived well in experimental margins at the project field site, STC. Year on year plant surveys at STC have shown increased overall flower coverage.

Commercial flowering margins sown in 2011/2012 established well in some cases, with weeds suppressed as margins developed. Sown forbs failed at one commercial site in 2013, despite good establishment in 2012. It appears that lack of mowing in 2012 combined with earlier sowing of this margin in the autumn of 2011 was the causal factor, supporting the importance of margin management, particularly in the first season. Flowering margins at other sites fared relatively well into their second year, maintaining or increasing their percentage cover of sown flowers despite a lack of management (though it is likely that management would be required in 2013 to prevent declines in margin quality in 2014). One flowering field margin was accidentally ploughed under at the end of 2012 and no further establishment data was collected from it. However, casual observation suggests that this margin recovered well with primarily annual species re-establishing themselves, presumably as a result of self-seeding.

Data collected throughout the project suggests that the selection of plants included in experimental flowering margins was capable of providing a diverse floral resource throughout the season, with selected species providing benefits when floral resources are otherwise notably scarce.

Based on data from experimental and commercial scale margins, four individual seed mixes have been recommended. These have been tailored for soil type and budget and indicate which of the included species are non-native (allowing growers to omit these if desired). Further details are provided in the Science Section.

Objective 2 – Establish field margins and quantify margin impact on selected target species

Both 2010 and 2011 crop surveys showed lower aphid occurrence nearer to flowering field margins in some crops at STC, in a number of instances in conjunction with increased predator/parasitoid numbers, indicating that predation/parasitism has been an underlying mechanism explaining these patterns. Though trends were not as apparent for 2012 data, which were compromised by low invertebrate counts following poor weather, 2013 data again supported a beneficial effect of field margins on in-crop natural enemies and aphid counts, at least in those crops where reasonable numbers of insects were recorded. Commercial counts could not be analysed statistically.

Visual surveys of flowering and control field margins at STC in all years of the project (2010-2013) clearly demonstrated the superior nature of flowering field margins as a resource for multiple groups of beneficial insects. Commercial counts (2012 and 2013) supported this result, though data could not be analysed statistically due to a lack of replication. Counts of target groups from pitfall and water traps suggest that 'activity-abundance' data do not necessarily match visual count (i.e. abundance) data, perhaps as a result of decreased insect movement in FMs for many groups.

The effect of flowering vs grassy margins on insect over-wintering groups varied throughout the project. By the end of the project in 2013 this was neutral for all groups considered, though the superior nature of margins *per se* as overwintering sites (vs crop fields) was confirmed in a number of cases.

Further details are provided in the Science Section.

Objective 3 - Development of the trap-cropping approach.

Two trap plant species, chervil (with carrots) and yellow mustard (with cabbage) were trialled in the field plots at STC in 2011 with varying success. Future work at STC will continue to investigate the benefits of a combined field margin / trap crop approach for *Brassica* pest insects.

Objective 4/5 – Development of banker plant species.

Banker plants are plants which harbour non-pest prey (primarily aphids) that can support pest natural enemies, e.g. when crop-based prey is scarce. In early years of the project teasel had been found to be the best banker plant / sentinel species, though this trend was not continued into 2013 when yarrow and tansy performed better. Inclusion of multiple banker plant species in field margin seed mixes can thus be recommended to insure against variation in aphid loads on any given banker plant between years. Based on the results of the current study, a combination of teasel, yarrow and tansy is suggested to boost the number, longevity and diversity of non-pest aphids in flowering margins. Of these, teasel appears to hold most promise as a sentinel species due to the ease of observing aphids and pest natural enemies on flowering stems.

Further details are provided in the Science Section.

Objective 6 – Development of a compatibility database of chemical control options.

Compatibility matrices have been developed for all crops. Updates to all matrices have been made as part of the project following identification of gaps.

Objective 7 - Quantification of margin impact on pests, crops and pest management costs.

Flowering margins at STC had no effect on crop yield and quality parameters in 2010, though the poor nature of the pea crop prevented reliable analysis. All crops performed relatively well in 2011, with substantial yield increases (up to 40%) adjacent to flowering margins in the case of peas, wheat and cabbages. This strongly indicates that the increased numbers of biocontrol agents and parasitism recorded in conjunction with the flowering margins translated into increased pest control and improved crop yield. 2012 data again demonstrated increased yield near to flowering margins for peas and cabbages. For 2013 data there were fewer effects of sampling site on yield, possibly as high mammalian herbivory had an over-riding effect. Unexpectedly, 2013 yield in carrots was lower nearer to flowering field margins than at other sites. That yield was never increased in carrots in previous years, unlike in the other three crops, perhaps suggests that either the FM seed mix was less well suited to this crop than others, or that the crop itself is less well suited to FMs (at least in terms of deriving yield benefits from it).
Further details are provided in the Science Section.

Objective 8 – Communicate best practice.

Delivery of information, primarily via platform presentations at appropriate events has featured strongly throughout the project. As part of the project a Communication Group was initiated, which has now met twice (12th March 2012 and 22nd April 2013), with at least one further meeting planned in 2014 soon after project completion. This group will continue to liaise in future years to ensure optimal uptake of project results.

Blueprints for growers have been drafted as part of the project. It is hoped that these will be further developed by relevant project partners to be of optimal use to end-users. Samples of the final seed mixes have also been made available to selected growers through the project's 'Farmers to Follow' initiative.

Further details are provided in the Technology Transfer section.

Why sow flowering field margins?

OVER-VIEW | PLANT/SITE SELECTION | MANAGING MARGINS | MARGIN MIXES | THE IPM APPROACH | PLANT SPOTTER | INSECT SPOTTER | FAQs

Non-crop vegetation in agricultural landscapes can provide a range of important ecological services, including conservation of native flora/fauna and the enhancement of pollination efficacy and biological pest control. Not only pollinators, but also many biological control agents depend on flowering vegetation as a source of nectar and pollen. The scarcity of floral resources in modern horticultural and arable systems severely constrains predator survival, limiting the effectiveness of biological pest control.

Flowering field margins can help to address the scarcity of floral resources in the farm-scape, but their effectiveness in delivering pest control services strongly depends on their botanical composition. Currently, these non-crop elements are typically designed for one particular ecosystem service, often rendering them suboptimal for other functions.

As part of Defra-funded HortLINK Project HL0192: 'Perennial field margins with combined agronomical and ecological benefits for vegetable rotation schemes', otherwise know as the Ecostac project, scientists at Lancaster University, Fera and Stockbridge Technology Centre, in collaboration with partners from industry, have shown that it is possible to stack and optimize conservation and agronomical benefits obtainable from flowering filed margins by adopting an informed selection of floral resources. This large scale project applies this multifunctional approach to focus on ecosystem services that are of direct benefit to UK agriculture, and conservation.

- Inclusion in AES.. ✓
- Qualification as 'Ecological Focus Areas'................. ✓
- Promotion of pollination.................................. ✓
- Promotion of pest control................................. ✓
- Increased yield / reduced pesticide costs................. ✓
- IPM amenable.. ✓

5 KEY FINDINGS FROM THE ECOSTAC PROJECT

1). The seed mix developed established well, despite unusually harsh weather conditions post-sowing, with the flowering component increasing year-on-year from 2010-2013.

2). Flowering field margins were capable of providing diverse floral resources from early spring to late autumn.

3). Observations on insect visitation demonstrated that the mix used 'stacked benefits' for beneficial insect groups, simultaneously attracting pollinators and pest natural enemies. Insect trapping in early spring found flowering margins at least as good as grassy counterparts for insect over-wintering.

4). Though pest and parasitism rates varied between and within the project's four target crops, data supported that flowering margins played a role in pest suppression by promoting parasitoids and predators.

5). Higher yields were achieved near to flowering margins in a third of cases. No differences in yield were seen in year 1, supporting that optimal benefit can only be gained from mature, perennial-based margins.

EcoSTAC

Financial benefits

In accordance with the Government's longstanding policy of minimizing the use of pesticides, the boosting of native biological control agents through functional field margins should make it possible to reduce pesticide inputs while maintaining crop yield and quality. In addition to financial savings associated with reduced pesticide use, economic benefits will also result from use of functional field margins that can count towards stewardship accreditation. Previous contacts with Natural England may have contributed toward recent modifications to ELS options. These should make it logistically and economically more beneficial to include flowering plants within future RPDE schemes such as NELMS.

Action Points

- Growers wishing to sow field margins with flowering seed mixes should use prescriptions that provide floral resources to a broad range of beneficial insects, whilst limiting flower associated pests from obtaining benefits. Four such seed mixes have been recommended for use by growers and are available from Stockbridge Technology Centre through our ‘Famers to Follow’ Programme, or for purchase.
- Growers should select seed mixes containing flowers that provide alternate prey for beneficial insects, as well as nectar and pollen.
- Growers should use the compendium provided to optimize returns from their flowering field margins, following guidelines therein for site preparation, sowing, aftercare and general management.
- Growers should appreciate that returns in terms of yield benefit may not be realised year-on-year through the use of FMs, but that such returns are achievable if appropriate seed mixes are properly selected, sown and maintained as managed field margins.

Milestones (primary)

Year	Milestone	Activity	Proposed target*	Revised target*	Further details of any change in target date	Implications of any change
1	1.1	Generate appropriate seed mixture	30.06.09 TR	30.08.09 TM	Delay in appointment of Research Associate due to late confirmation of project funding	None
1	4.1	Identify the most appropriate banker plant species for the various crops	30.06.09 TR	30.08.09 TM	As Milestone 1.1	None
1	6.1	Using data from LIAISON (CSL held database on approved products) generate a list of all active ingredients available for application to the crops relevant to the current project	31.09.09 TM	31.09.09 TM	NA	NA
1	2.1	Establish field margins at the four 2 acre sites	30.11.09 TR/TM**	20.04.10 TM	Whilst the proposed target was met with an initial sowing, a second sowing was deemed necessary to ensure adequate field margin establishment	None
2	6.2	Compile a compatibility matrix of control options and biological control agents relevant to the crops in the project and identify data gaps	30.02.10 TR	30.05.10 TM***	Proposed target delayed in order to gather the most up-to-date information	None
2	2.2	Compile and where necessary develop protocols for all monitoring methods and undertake 1st years monitoring of field margin plants and other relevant biota.	31.10.10 TM	31.10.10 TM	NA	NA
2	3.1	Establish and monitor effect of trap crops	31.09.10 TR	31.09.11 TM	Decision made to omit trap crops in 2010 to allow investigation of flowering margins only	None
2	4.2	Monitor and assess effects of banker plants	31.12.10 TM	31.12.10 TM	NA (*completed for all years*)	NA
3	2.3	Establish field margins at the four commercial scale sites	30.11.11 TR	30.04.12 TM	Decision made to sow 3 out of 4 FMs in Spring 2012 to better fit with growers existing practices	None
3	5.1	Develop banker plant monitoring tools to facilitate decisions on optional supplementary release of predators from commercial rearings	31.10.11 TM	31.10.11 TM	NA	NA

3	**2.4**	Undertake 2nd year monitoring of relevant biota	30.10.11 TM	30.10.11 TM	NA	NA
3	**8.1**	Draft guide document with 'blueprints' for the successful establishment, use and management of field margins	30.12.11 TM	30.12.11 TM	NA	NA
4	**2.5**	Undertake monitoring of relevant biota in both small and commercial scale sites	31.12.12 TM	31.12.12 TM	NA (*complete for all years*)	NA
4	**3.2**	**Establish and monitor effect of trap crops on commercial scale sites**	**31.12.12 NA**	**31.12.12 NA**	**Decision made to omit trap crops from commercial testing**	**Further study needed to reliably assess trap crops combined with FMs on a commercial scale**
4	**4.3**	Establish and monitor effect of banker plants on commercial scale sites	31.12.12 TM	31.12.12 TM	NA	NA
4	**5.2**	**Monitor effect of supplementary releases on the commercial scale sites**	**31.12.12 TR**	**31.12.13 NA**	**Releases not considered beneficial in 2012 and resources unavailable for monitoring in 2013**	**Further study needed to assess the effects of margins on releases**
5	**3.3**	**Complete recommendations on the use of trap crops for those pest species that aggregate around flowering margins (e.g. carrot fly; cabbage root fly).**	**30.11.13 NA**	**30.11.13 NA**	**Insufficient data are available to allow such recommendations (see MS 3.1 and 3.2)**	**Further study needed to reliably assess trap crops combined with FMs on a commercial scale**
5	**5.3**	Complete recommendations on the use of banker plants as monitoring tools for natural predator populations and potential release of commercially reared predators	30.11.13 TM	30.11.13 TM	NA, though further analysis planned as part of the longer term publication process	NA
5	7.1	Complete the quantification of the impact of field margins and the cost-benefit analysis	30.11.13 TR	30.01.14 TM	Additional time required to consider all available data	None
5	8.2	Finalise and distribute document on the establishment, use and management of field margins combining agronomical and ecological benefits	30.11.13 TR	30.01.14 TM	Additional time required to consider all available data	None

Lighter shaded Milestones in plain font have been achieved as proposed or otherwise without significant amendment to Milestone dates. Darker shaded Milestones in bold font have not been achieved as proposed resulting in significant amendment to Milestone dates. Darker shaded Milestones in plain font were not achieved as proposed, but have since been completed (albeit with significant amendment to Milestone dates). *TM = Target Met, TR = Target Revised. **TM by initial 2009 sowing, but TR for 2010 sowing. ***TM for *Brassica* crops, which were the only crop requiring treatment in 2010. NA = No longer Applicable.

Milestones (secondary)

Year	Milestone	Activity	Proposed target*	Revised target*	Further details of any change in target date	Implications of any change
1	**1.2**	Undertake a detailed desk study to generate a list of the plant species that will be considered for use in the project	30.06.09 TR	30.08.09 TM	Delay in appointment of Research Associate due to late confirmation of project funding	None
1	**1.3**	Consider tailoring of seed mixtures to soil types	30.07.09 TR	30.08.09 TM	As Milestone 1.2	None
1	**1.4**	Consider tailoring of seed mixtures to crop types	30.07.09 TR	30.08.09 TM	As Milestone 1.2	None
1	**1.5**	Discuss with seed companies and produce optimum seed mixtures	30.07.09 TR	30.08.09 TM	As Milestone 1.2	None
1	**1.6**	Where necessary, scale up production of seeds for establishment of margins at commercial scale sites (in 2010)	30.09.09 TR	30.09.10 TM	NA	None
1	**1.7**	Identify additional sources of seeds should partner seed companies not be able to produce spp identified under 1.1	30.09.09 TM	30.09.09 TM	NA	NA
1/2	**1.8**	Visit seed companies to monitor their crops of wild flowers and grasses for pests, diseases and beneficial insects	30.09.09 TR	30.10.10 TM	NA	None
3	**1.9**	Using data from 1.8, 4.6, and 8.1 to amend seed mixtures as appropriate for the commercial scale sites	30.08.11 TM	30.08.11 TM	NA	NA
5	**1.10**	Finalise detailed seed mixtures and management processes for different soil types and crops	30.11.13 TM	30.11.13 TM	NA	NA
1	**2.6**	Design cages for capturing invertebrates emerging from field margins	30.03.09 TR	30.11.09 TM	As Milestone 1.2	None
2/3	**2.7**	Monitor and assess impact of field margins on overwintering insects	30.04.10 TR 30.04.11 TR	01.02.11 TM 01.02.12 TM	NA (*completed for all years*)	None
1	3.4	Develop protocols for decision making for applying insecticides into the trap crops	30.12.09 TR	30.12.11 TM	NA	None
1	**3.5**	Investigate use of carrot fly predictive model (HDC product in Morph) as guide to pest activity	30.12.09 TM	30.12.09 TM	NA	NA

1	4.4	Develop protocols for monitoring non-pest prey and associated predators in banker plants	31.12.09 TM	31.12.09 TM	NA	NA
2-5	4.5	Determine the timing and extent of non-pest species populations on the banker plants	30.09.10 30.09.11 30.09.12 30.09.13 TM (ALL)	30.09.10 30.09.11 30.09.12 30.09.13 TM (ALL)	NA	NA
3	4.6	Review inclusion of banker plant species in light of 4.2 and 4.5	30.08.11 TM	30.08.11 TM	NA	NA
2	**5.4**	**Determine appropriate times of season when supplementary releases could be needed and develop protocols for their release**	**31.12.10 TR**	**30.11.13 TNM**	**Target not met as stored sample data were only available at the end of the project**	**This MS will now be addressed as part of the longer-term publication process**
3	**5.5**	**Establish relationship between predator counts on banker plants and population densities of those species**	**31.10.11 TR**	**30.11.13 TNM**	**Target not met as stored sample data were only available at the end of the project**	**This MS will now be addressed as part of the longer-term publication process**
3	6.3	Undertake discussions with chemical and biocontrol companies to ascertain the effect of each active on the natural predators	30.08.11 TM	30.08.11 TM	NA	NA
5	6.4	In instances where 6.2 has revealed gaps, the matrix will be updated. Where this is vital, additional bioassays will be conducted by Koppert and or other industry partners.	30.11.13 TM	30.11.13 TM	NA, though some gaps remain and warrant further study	NA
2	7.2	Establish structure of cost-benefit analysis for quantification of the impact of field margins	31.12.10 TM	31.12.10 TM	NA	NA
1	8.3	Create database compiling experience from functional biodiversity projects	31.12.09 TM	31.12.09 TM	NA	NA

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*TM = Target Met, TR = Target Revised, TNM = Target Not Met

SCIENCE SECTION

Please note that whilst the project consortium for HortLink HL0192 are keen to release results of the work to keep interested parties informed of project progress, it is also the case that for the overall benefit of the project much of the actual data generated must remain confidential at this stage. This is necessary for several reasons, the most prominent being protection of any potential IP and retention of data for later publication in the scientific press (which may be prevented by prior release). Thus, the following sections tend to provide an overview of results so far, whilst only providing data in a limited number of cases.

Introduction

The horticultural industry faces a range of issues linked to crop protection. These include a reduction in the available products approved for use, the potential for increasing resistance in the target organisms, increasing pressures from consumers and retailers for residue-free produce and a need to comply with legislation and industry initiatives (e.g. Water Framework and Voluntary Initiative). These pressures have resulted in the need for a more considered approach to pesticide use and for the full exploitation of the range of alternative methods available for maintaining pest populations below economic damage thresholds.

Non-crop vegetation in agricultural landscapes can provide a range of important ecological services, including conservation of native flora/fauna and the enhancement of pollination efficacy and biological pest control (Gurr et al 2003). Field margins can be used to harbour such vegetation and margin seed mixes have been developed that target bees (Carvell et al 2006), butterflies (Pywell et al 2004) and farmland birds (Vickery et al 2009). However, the effectiveness of field margins in boosting pest control strongly depends on their botanical composition (Wäckers 2005). A broad range of biological control agents depend on flowering vegetation as a source of nectar and pollen (Wäckers et al 2005) and often non-crop elements that are typically designed for bird or pollinator conservation are unsuitable for supporting biological control (Olsen & Wäckers 2007). In related work by the research team involved in the current project, the concept of designing flowering field margins for the specific purpose of optimizing pest control has been developed (Wäckers 2004; Wäckers and van Rijn 2012). The current project seeks to combine biodiversity and agronomical benefits from field margins, providing growers with a direct economic benefit in addition to expected subsidies from stewardship schemes.

As an alternative to ‘standard’ margin mixes, the current project proposes a multifunctional focus in composing perennial field margins, allowing joint optimization of pest control, pollination and conservation benefits across a crop rotation (brassica; carrots; peas; cereals). To achieve these broader benefits the project has selected non-crop vegetation based on the ecological requirements of a range of target species including biological control agents, key pest species, pollinators and farmland birds. Pest control will also be encouraged through the use of so-called “trap plants”, which are specific crop elements to attract and arrest nectar feeding pests, such as the carrot fly and the cabbage root fly, in designated border rows where they can be controlled by targeted insecticide sprays or other management methods. By combining the leading UK expertise on the use of non-crop elements for the conservation of birds and pollinators with our international experience in the use of field margins for conservation biological control, this project leads the way in this increasingly important area.

Objectives

The project was conducted in two phases:

1. During the first 2.5 years the establishment and impact of perennial field margins on functional agro-biodiversity in the four selected crops was assessed in a set of field trials on a relatively small scale. Four plots of around 2 acres were used, where in each a margin strip of 61.2 x 2 m bordered the plot at one end (where a control ‘margin’ consisting of naturally regenerated vegetation was sited at the other). Each plot contained all of the four crop species used, giving four replicates in total.
2. Building on results from this first phase, during the second phase of the project (2.5 years) field margins were established and their impact assessed on commercial fields (5-20 ha). Assessment of the small scale plots continued during the second phase to enable longer-term data to be generated.

The objectives of the project were as follows:

1 Development of a seed mixture for perennial field margins that has the potential to optimize joint pest control as well as pollinator and bird conservation benefits while minimizing potential risks for vegetable rotation schemes.

2 Quantification of the impact of field margins on biological control agents, pests, pollinators and farmland birds.

3 Development of the use of flowering field margins as part of an insecticide assisted trap-cropping approach.

4 Development of field margins that support predator population build-up through provision of non-pest prey in field margins.

5 Assessment of the feasibility of using banker plants in field margins and development of these plants as sentinels to monitor levels of biological control agents.

6 Development of a database on the compatibility of available chemical control options with various biological control agents to optimize integrated pest management decisions.

7 Quantification of the impact of perennial field margins on pest levels, crop quantity/quality and pest management costs.

8 Communication of best practice to commercial growers in the form of 'blueprints' for margin establishment and management, drawing upon knowledge generated in the proposed project as well as in ongoing European biodiversity projects.

<u>**OBJECTIVE 1: Development of a seed mixture for perennial field margins that has the potential to optimize pest control and conservation benefits while minimizing potential risks for vegetable rotation schemes**</u>

Materials and methods

See previous reports for details of the seed mix, sowing and sampling methodology.

Results and Discussion

ESTABLISHMENT AT STC: FMs established well during the project (see Fig 1), increasing in their coverage of sown forbs year-on-year between 2010 and 2013. Roughly annual management was implemented to minimise grass dominance. Conditions on site are likely to have favoured grass growth – particularly as FMs were sown on recently cropped and relatively fertile agricultural soil – and thus a need to control grasses in experimental FMs was not unexpected.

Barring 2010, perennial species dominated in FMs, with yarrow, birds foot trefoil, white clover, red clover, perennial cornflower, sorrel, bush vetch and oxeye daisy all performing well. Fennel also performed well in some FMs at STC, as did annual species able to re-seed within the sward (i.e. common vetch). Tansy, teasel, viper's bugloss, yellow rattle, cornflower, red dead nettle and borage were also observed in FMs on site. It is suspected that yellow rattle may have performed better had plants not been adversely affected by the spring drought in 2011.

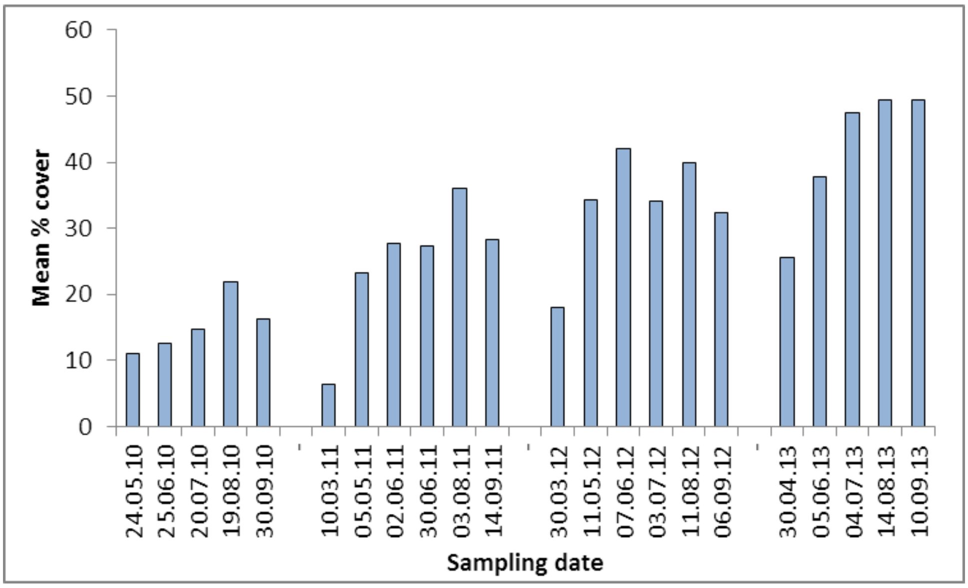

Figure 1. Mean percentage cover of sown flowers in FMs at STC throughout 2010-2013. n = 4 for all means.

ESTABLISHMENT AT COMMERCIAL SITES: Commercial FMs established well in some cases, with non-grass weeds naturally suppressed in their second year as hoped. Sown forbs failed at one commercial site in 2013, despite relatively good establishment in 2012 (Produce World). It appears that lack of mowing in 2012, combined with earlier sowing of this FM in the autumn of 2011 (as compared to spring 2012 at other sites), was the causal factor, supporting the importance of margin management, particularly in the first season.

FMs at other commercial sites fared relatively well into their second year, maintaining or increasing their percentage cover of sown flowers despite a lack of management (though it is likely that management would be required this year to prevent declines in margin quality in 2014). One commercial FM at Poskitt's was accidentally ploughed under at the end of 2012 and no further establishment data was collected from it as a result. However, casual observation suggests that this margin recovered well with primarily annual species re-establishing themselves, presumably as a result of self-seeding. The effect of this accidental ploughing on perennial species is unknown.

Commercial surveys confirmed good establishment of most annual forbs, as well as fennel, tansy, clovers, perennial cornflower, yarrow and oxeye daisy. Teasel seemed not to establish well in commercial FMs, though based on good establishment at STC it is suspected that this resulted from a ‘bad batch’ of seed, rather than any innate unsuitability for FM sowing (as supported by the widespread use of teasel in FM seed mixes *per se*). Wild marjoram and greater burnet saxifrage both failed to establish at STC, with neither plant noted in commercial surveys. Sunflower established at low levels at STC in 2010, but failed to re-establish in 2011 (and was excluded from commercial sowings as a result).

FLOWERING AT STC: Flowering times varied throughout the project according to species dominance (i.e. annuals in year 1 followed by perennials thereafter) and prevailing conditions. Nevertheless, in all years of the project a diverse selection of flowers were present in FMs at STC from early-late in the season.

In summary, despite harsh conditions in the four successive years since their initial sowing (Fig. 2), many of the selected flowering plants survived and established well in FMs at STC and most commercial sites. Based on data from experimental and commercial scale margins four individual seed mixes have been developed (see Table 1). These are tailored for soil type and budget and indicate which of the included species are non-native (allowing growers to omit these if desired). Further options for tailored seed mixes have been made available through the Automated Margins project (HDC FV 334a) and resulting website (http://www. stockbridgetechnology.co.uk/Automated_Margins/).

Table 1. Suggested premium and budget seed mixes (flowering component only) for heavy and light soils based on data obtained from HortLINK project HL0192. PER = Perennial; ANN = Annual; BI = Biennial. NATIVE = Native; NATURAL = Naturalised (introduced pre-1500); NonNATIVE = Non-native (introduced post 1500). Suggested sowing rate = 20-30kg/ha (5-10kg flowers: 15-20kg/ha grasses)*. Suggested grass component = 1:1:1 common bent:crested dogs tail:cats tail. Use of fescues are not recommended due to gramicide tolerance.

			Percentage of seed mix floral component by weight			
Common name	**Family name**	**Latin bi-nomial**	**Heavy-Premium**	**Heavy-Budget**	**Light-Premium**	**Light-Budget**
Fennel PER NATURAL	Apiaceae	*Foeniculum vulgare*	6.20	9.67	5.97	8.96
Tansy PER NATIVE	Asteraceae	*Tanacetum vulgare*	0.54	0.85	0.52	0.78
Yarrow PER NATIVE	Asteraceae	*Achillea millefolium*	0.18	0.20	0.12	0.13
Perennial cornflower PER NonNATIVE	Asteraceae	*Centaurea montana*	11.63	4.23	9.32	3.92
Oxeye daisy PER NATIVE	Asteraceae	*Leucanthemum vulgare*	0.23	0.59	0.15	0.39
Bird's foot trefoil PER NATIVE	Fabaceae	*Lotus corniculatus*	0.93	1.69	0.89	1.57
Red clover PER NATIVE	Fabaceae	*Trifolium pratense*	0.83	0.68	0.80	0.42
White clover PER NATIVE	Fabaceae	*Trifolium repens*	0.71	0.96	0.85	1.07
Bush vetch PER NATIVE	Fabaceae	*Vicia sepium*	18.10	14.10	17.40	13.07
Cornflower ANN NATURAL	Asteraceae	*Centaurea cyanus*	7.76	8.46	5.22	6.28
Borage ANN NonNATIVE	Boraginaceae	*Borago officinalis*	5.17	5.64	4.97	5.23
Scorpion weed ANN NonNATIVE	Boraginaceae	*Phacelia tanacetifolia*	0.59	1.29	0.57	1.20
Common vetch ANN NATURAL	Fabaceae	*Vicia sativa*	15.51	13.53	14.91	12.55
Red dead nettle ANN NATURAL	Lamiaceae	*Lamium purpureum*	0.44	0.00	0.71	0.00
Yellow rattle ANN NATIVE	Orobanchaceae	*Rhinanthus minor*	3.62	0.56	3.48	0.52
Buckwheat ANN NonNATIVE	Polygonaceae	*Fagopyrum esculentum*	20.68	30.07	26.51	34.86
Bishopsweed ANN NATURAL	Apiaceae	*Ammi majus*	0.52	0.56	0.50	0.52
Viper's bugloss BI NATIVE	Boraginaceae	*Echium vulgare*	2.22	2.42	2.13	2.24
Teasel BI NATIVE	Dipsacaceae	*Dipsacus fullonum*	4.14	4.51	4.97	6.28
ESTIMATED COST PER KG (£ STERLING)			**£134**	**£96**	**£126**	**£92**

Prices were preferentially obtained from project partners Emorsgate Seeds where possible. For species not stocked by Emorsgate, alternative on-line prices were sought. All prices were obtained on the 13.11.13. *Sowing rates at the lower end of this scale may produce good results depending upon land management pre-seeding and conditions post-sowing.

An estimate of the overall cost of the floral components of the above mixes has been calculated as being between £92 and £134 per kg, depending upon the prescription selected. At the lower end of the scale this compares well with comparable mixes, with the cost of both budget mixes being slightly under that of Emorsgate’s nectar and pollen mix (ESF2) at £110/kg. Premium seed mixes are relatively more expensive due to the inclusion of still relatively ‘novel’ species, though are still competitively priced when their ‘added value’ is taken into account. Furthermore, prices for ‘novel’ species may fall should increased demand drive larger-scale production, and for all species more thorough searches of seed suppliers may yield more competitive prices. Details on recommended site preparation, sowing and margin management (amongst other aspects) are provided in the ‘blueprints’ produced under Objective 8 and featured in full in Appendix 2

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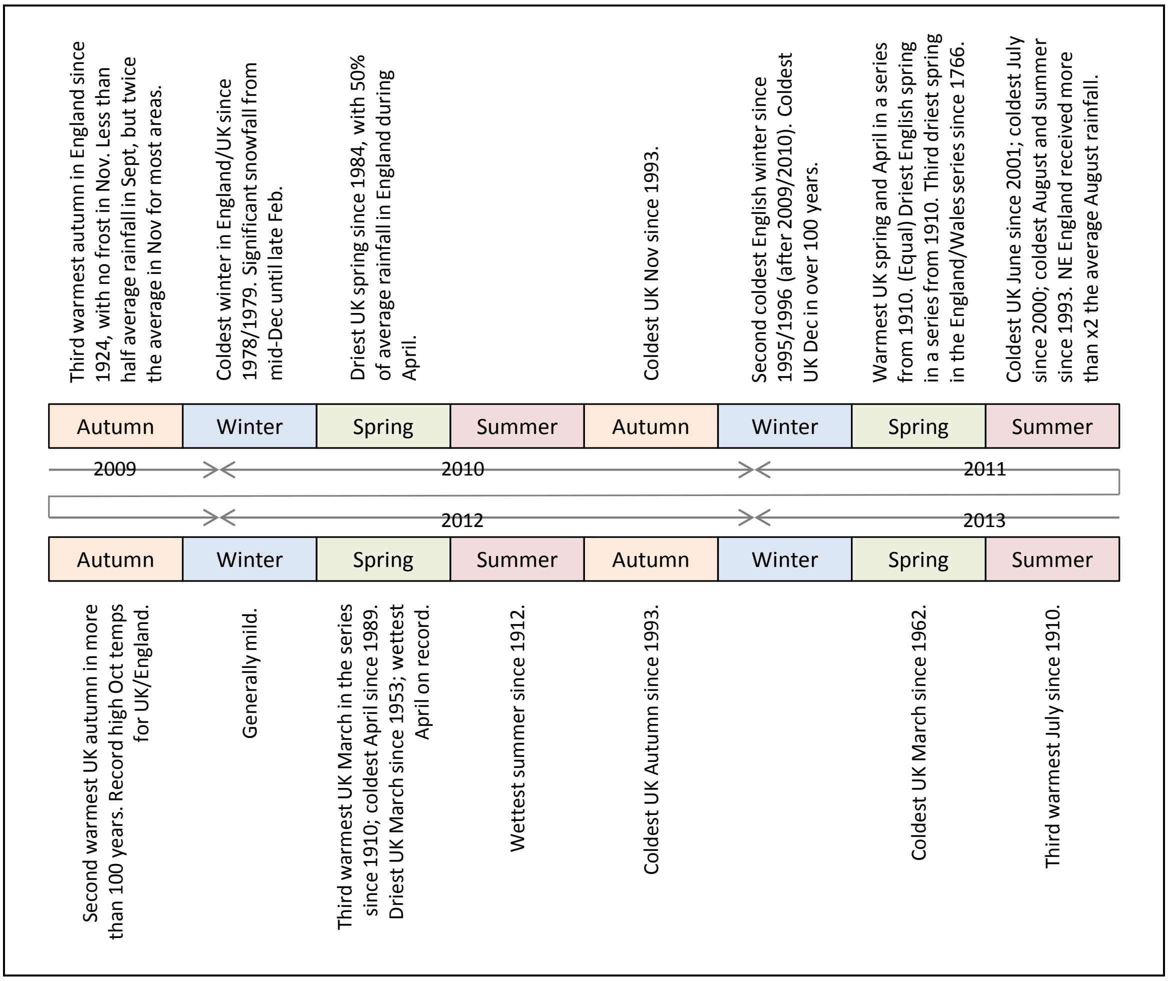

Figure 2. Climate trends experienced during HortLINK Project HL0192 since initial sowing (Autumn 2009) through to the end of the summer in the final field season (2013). All data obtained through the Met Office.

Conclusions

- Despite harsh winter/spring conditions in the four successive years since their initial sowing, several of the flowering plants sown have survived and established well in FMs at STC. Results from commercial sites suggest similarly good establishment thus far (with improved conditions post-sowing), though with one notable exception highlighting the importance of good management.
- Data collected throughout the project suggests that the selection of plants included in experimental FMs is capable of providing a diverse floral resource throughout the season, with selected species providing benefits when floral resources are otherwise notably scarce.
- Based on data from experimental and commercial scale margins four individual seed mixes have been recommended. These have been tailored to soil type and budget and indicate which of the included species are native, naturalised and non-native (allowing growers to include only certain groups if desired). Further options for growers, including a

range of mixes containing only native species, have been made available through the Automated Margins project (HDC FV 334a) (http://www.stockbridgetechnology.co.uk/Automated_ Margins/).

OBJECTIVE 2: Quantification of the impact of field margins on biological control agents, pests, pollinators and farmland birds

Materials and methods

INVERTEBRATE OVER-WINTERING

See previous reports for details of the methodology used.

INVERTEBRATE SUMMER SAMPLING

See previous reports for details of the methodology used for visual observations and 'stored sample' collection from pitfall and water traps. Processing of stored samples from combined pitfall and water traps collected at STC was undertaken as follows:

Samples were stored in ethanol and the invertebrates present were identified according to the scheme shown in Table 2. In some cases the insects were identified to the level of family, whilst others were identified to the species level. Samples collected on 17th June, 8th July, 29th July, 19th August and 9th September were examined for the 2010 season. Samples collected on 28th June, 13th July, 27th July, 11th August, 24th August and 7th September were examined for the 2011 season. For the 2012 season, samples collected on 14th June, 28th June, 12th July, 26th July, 9th August, 23rd August, 6th September and 20th September were examined.

Statistical analysis was carried out for the major groups found. Due to the high number of zero values for individual genera or species, the analysis was done on the total number of Carabidae, Staphylinidae, Coccinellid adults, Nitidulidae, Nematocera, Brachycera, Aphidae and Parasitica found. Results were analysed for differences between crops, between trap sites and the interaction of these factors using a generalized linear mixed model analysis (using the plots as the random term) with a Poisson distribution and a logarithm link function.

POLLINATOR AND BIRD SURVEYS

POLLINATOR SURVEY: See previous reports for details of the methodology used.

BIRD SURVEYS: See previous reports for details of the methodology used pre-late 2012/2013. Bird surveys were conducted at the three commercial sites during late 2012/2013, though following failure of the FM at Produce World data from this site were discarded. Data from the FM that had been ploughed under at Poskitts are shown as annual forbs re-established well, though it must be borne in mind that the structure of this FM differed from that at other sites. As only two true replicates (of FMs in their second year) existed, no analysis was run on this data. At each site bird presence in and around the field with the flowering margin and also in a nearby field that acted as a 'control' was recorded.

Table 2. Scheme used for identification of insects found in pitfall and water traps for summer sampling.

1	INSECTA NON-INSECTA	Go to 2 ID to Order
2	COLEOPTERA DIPTERA HEMIPTERA HYMENOPTERA LEPIDOPTERA NEUROPTERA OTHER	Go to 3 Go to 4 Go to 5 Go to 6 Go to 7 ID to Crysopidae, Hemerobiidae or Other ID to Order
3	Carabidae Cantharidae Staphylinidae Curculionidae Coccinellidae Chrysomelidae Elateridae Nitidulidae Other	ID to Genus (especially note *Zabrus spp*) ID to family ID to family *ID Sitona spp, Ceutorhynchus spp or Other* ID all common species *ID Phyllotreta sp., Psylloides sp., Oulema melanopus or Other* *ID Agriotes sp., or Other* *ID Meligethes sp. or Other* ID to Family or unknown
4	NEMATOCERA: Tipulidae NEMATOCERA: Cecidomyiidae NEMATOCERA: Other BRACHYCERA: Syrphidae BRACHYCERA: Asilidae BRACHYCERA: Empididae BRACHYCERA: Psilidae BRACHYCERA: Anthomyidae BRACHYCERA: Choropidae BRACHYCERA: Opomyzidae BRACHYCERA: Phoridae BRACHYCERA: Other	ID to family ID to family ID to 'Other Nematocera' ID to family ID to family ID to family *ID Psila rosae or Other* *ID Delia spp or Other* *ID Oscinella frit, Chlorops pumilionis or Other* *ID Opomyza florum or Other* ID to family ID to 'Other Brachycera'
5	Aphididae Alerodidae Miridae Anthocoridae Nabidae Other	ID all common species ID to family *ID to Lygus spp or Other* *ID to Orius spp or Other* ID to family ID to Family or unknown
6	Apidae Parasitoid wasps Formicidae Sphecidae Vespidae Symphata	ID to Bumblebees, solitary bees, and honey bees Go to 8 ID to family ID to family ID to family ID to family
7	Lepidoptera	ID to family or species
8	ICHNEUMONIDAE: Brachonidae ICHNEUMONIDAE: Ichneumonidae CHALCIDIODEA PROCTOTRUPOIDEA CERAPHRONOIDEA Other/Unknown	ID to Brachonidae ID to Ichneumonidae ID to Chalcidiodea ID to Proctotrupoidea ID to Ceraphronoidea ID to Other

Results and Discussion

INVERTEBRATE OVER-WINTERING

Full results of overwintering surveys run in 2010, 2011, 2012 and 2013 are provided in previous reports, with an overview of these given in Table 3. Data collected in 2013 showed comparably few statistical differences between trapping sites as compared to previous years, where these were only found to exist for rove beetles, springtails and spiders. Even in these instances, differences were only recorded between FM/CM and CFs, and not between FMs and CMs as in previous years. It is possible that any dry undisturbed site was viewed favourably by overwintering insects at the end of a wet 2012. The relatively low numbers of insects recorded as emerging for most groups in 2013 support that fewer invertebrates overwintered *per se* in 2013/2013 than in previous years. However, it is also plausible that the reason for CMs becoming more comparable to FMs as overwintering sites in 2012/2013 was the continued maturation of CMs relative to FMs, where the former had been ploughed under in Spring 2010. Though it is not possible to determine which of prevailing weather or maturation served to make CMs statistically comparable to FMs as overwintering sites in 2012/2013, it can be concluded that in no case were FMs inferior to CMs as overwintering sites in 2013, this being an improvement over newly established FMs which supported fewer carabids in 2010 (and to a lesser extent in 2011, though only for a group known to prefer disturbed habitats). Consequently, with their improved ability to provide floral resources during the growing season, it can be concluded that FMs present a more attractive option for growers to encourage year-round ecosystem service provision than CMs, particularly when mature.

Table 3. Results from overwintering trials displaying trends (arrows) and significant differences (colours) in mean catch of target insect groups from combined emergence/pitfall traps in Flowering Margins (FM) and Control Margins (CM). Arrows codes: ↑ = >twice as many individuals trapped in FMs than CMs, ↓ = >twice as many individuals trapped in CMs than FMs, ↔ = FM and CM catches similar (i.e. between ↓ and ↑). Colour codes: cells shaded to depict statistically significant (*P*<0.05) differences (white = no data available; red = negative effect; yellow = neutral effect; green = positive effect).

	Effect of FM *vs* CM			
TARGET GROUP	**2010**	**2011**	**2012**	**2013**
CARABID BEETLES (ADULTS)		↔	↑	↔
CARABID (ADULTS) EXCL. BEMBIDION SPP	↔			↓
BEMBIDION SPP (ADULTS) ONLY			↓	↔
ROVE BEETLES (ADULTS)		↔		↔
APHIDS*			↓	↔
HOPPERS				↔
TIPULIDS		↔	↓	↔
ALL NEMATOCERAN FLIES			↔	↑
ALL BRACHYCERAN FLIES			↔	↔
ANTS		↑	↑	↓
PARASITOID WASPS (ADULTS)	↔		↑	↔
SPRINGTAILS (ADULTS AND NYMPHS)	↔	↔	↔	↔
THRIPS		↔	↔	↔
SPIDERS (ADULTS AND NYMPHS)	↔			↔
MILLIPEDES		↑	↔	↓

*primarily fescue aphid, *Metopolophium festucae.*

INVERTEBRATE SUMMER SAMPLING

VISUAL PLANT INSPECTION – MARGINS:

Full results of margin visual plant inspections run at STC in 2010, 2011, 2012 and 2013 are provided in previous reports. Visual inspection of FMs and CMs at STC throughout the project has consistently provided good data for selected target assemblages of invertebrates, with results for the most commonly observed groups summarised by year in Fig 3.

For the majority of these groups significantly more individuals were always observed in FMs, supporting both the superior nature of the FM as a resource, and the ability of FMs to 'stack benefits' for multiple beneficial target groups. Ladybirds, however, were only observed in significantly greater numbers in FMs in the final year of the study. In 2010 and 2011 weed pressure from fat hen was notable in CMs which, with high aphid loads on these plants, may have promoted ladybirds in CMs. As compared to other groups in Fig 3, ladybirds also have a reduced requirement for floral resources. This may also at least partially explain higher counts for ladybirds seen in combined pitfall/water traps nearer to CMs (see later in this section), though visual observations did not support higher counts in CMs *per se*.

Several other key groups of invertebrates were recorded from margin visual surveys, albeit in reduced or more variable numbers than for those groups in Fig 3. Counts were typically higher in FMs for all of these groups, with previously reported analysis on weekly or combined annual counts finding significantly more of the following groups in FMs:

Pest natural enemies:	Soldier beetles; pirate bugs; Tachinid/Sacrophagid (decomposer) flies.
Pollinators:	Honeybees; Solitary bees.
Conservation value groups:	Moths; Tipulids (bird food); leafhoppers (bird food); mirid bugs (bird food).

Though visitation to plants by species was not recorded, once established, fennel was noted to be of particular importance to multiple pest natural enemy groups on late-season sampling dates (i.e. into Sept), with the majority of all wasps (vespid and parasitoid), hoverflies and ladybirds observed were on fennel plants. This may reflect an innate preference for fennel flowers in these groups, though such a pattern could also be explained by fennel being the only remaining ‘vigorous’ plant at this stage in the season. In either case, this observation supports that fennel may play a key role in promoting biocontrol providers later into the season, benefitting pest control on late-harvest crops and potentially optimising natural enemy fitness prior to over-wintering. Yarrow also appeared to be somewhat important in this regard, at least for hoverflies and ladybirds, though late season visitation on remaining yarrow flowers by these groups was lower than on fennel. Other (casually) observed insect-plant relationships included hoverflies/bees and borage/phacelia, parasitoid wasps and vetches/tansy, hoverflies and yarrow/bishops weed/oxeye daisy/tansy and bees and clovers. Cornflowers were, as expected, attractive to many groups.

It is likely that the diverse range of specialist and more generalist flowers included the seed mix allowed for their exploitation by multiple invertebrate groups simultaneously, allowing benefits for multiple groups to be ‘stacked’ within a single margin. Though the relative importance of including both specialist and generalist flowers to achieve a ‘multi-functional margin’ is not yet known, providing both likely acts as an insurance policy, promoting optimum resource exploitation by the maximum diversity of beneficial insects.

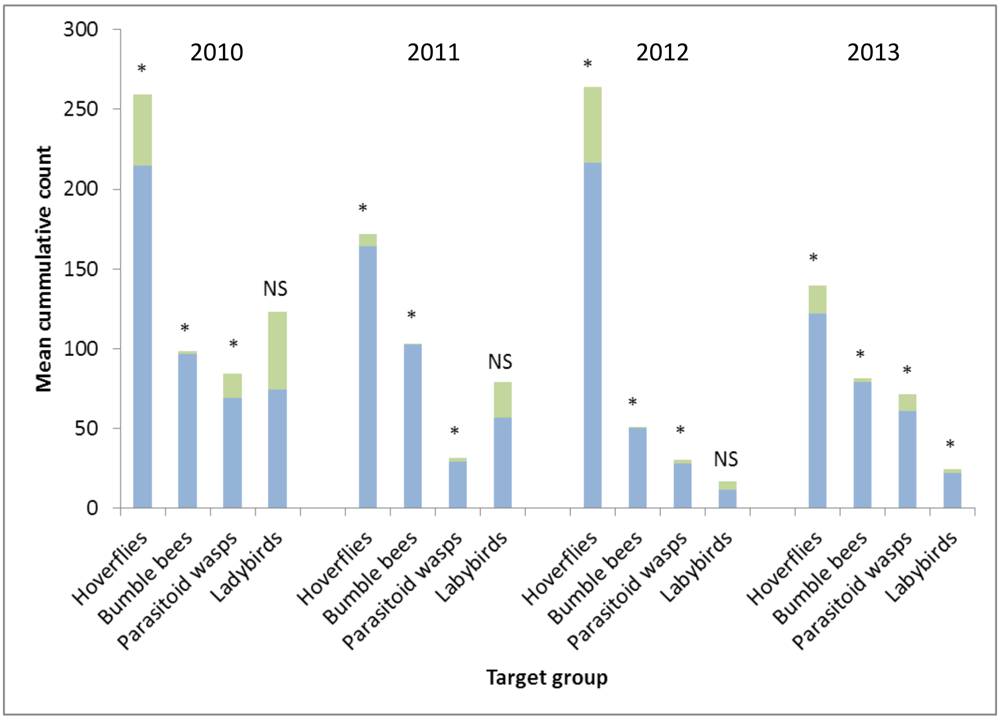

Figure 3. Mean counts of target insect assemblages from visual observation of flowering and control margins at STC in 2013. Means are displayed with SEs. N = 4 for all means. Data analysis was run considering each observation date independently using Mann-Whitney U Tests where NS = No Significant difference and * = $P < 0.05$. For hoverflies and ladybirds only adults were observed during surveys.

VISUAL PLANT INSPECTION – CROPS:

In most project years, and multiple crops, consistent trends have been observed for lowered aphid occurrence on crop plants nearer to FMs. Data are shown below (Fig 4) for cabbages in 2013, where these trends were well supported statistically. It is hoped that further analysis of past data for future publication (i.e. by combining data across years) will result in similar statistical support being generated for other crops. Statistical differences in % parasitism were less abundant in 2013 cabbage data, though trends were evident for more rapid increases in parasitism nearer to FMs, this potentially explaining reduced aphid counts at these sites. Again, this pattern has been repeatedly observed throughout the project in multiple crops and may become more apparent with future analysis planned as part of a long-term publication process.

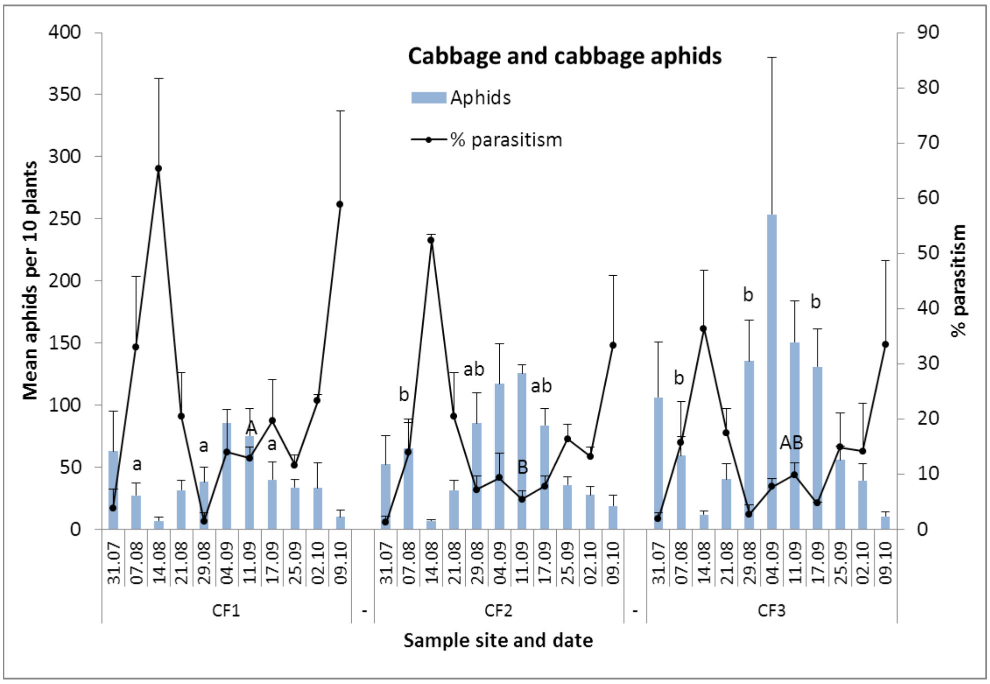

Figure 4. Mean aphid counts and percentage (%) parasitism rates from visual observation at different sites in cabbage crops the growing season at STC. Means are displayed with SEs. n = 4 for all means, except at all Sites on the 14.08 and the 21.08 where n = 3 for all data (due to crops being fleeced in Plot 2 during this time). Upon a given date, means not sharing a common letter are significantly different, where differences between aphid data are shown in lower case font, and differences between % parasitism data are shown in upper case font. CF1 = Crop Field 1 (5m from the FM), CF2 = Crop Field 2 (in the crop center), CF3 = Crop Field 3 (5m from the CM).

STORED SAMPLES FROM PITFALL AND WATER TRAPS:

Due to the lag time experienced between sample collection and processing, data collected from combined pitfall and water traps during summer seasons at STC has not previously been included in any project report. Consequently, data are presented in full for the 2010-2012 seasons for the first time. Data for 2013 will not be processed as part of this project, though samples have been collected, filtered and placed into ethanol for long-term storage in case the opportunity arises to process these at a later date.

2010 SAMPLES: For half of the target groups, no significant effect of trapping site was recorded in 2010. For ladybirds counts were lower overall in the FM *vs* the CM, with lower counts of Nematocera and Brachycera (flies) also recorded in the FM *vs* the CM for certain crops. Conversely, counts of parasitoid wasps were significantly higher in the FM vs the CM, though only in brassicas and cereals.

2011 SAMPLES: The statistical analysis could not separate means for counts of Nitulids at the different trapping locations, although a significant interaction was observed. For Nematocera there was no significance in numbers between sample sites. For all other groups, however, differences were detected. Ladybirds counts were again generally lower in the FM vs the CM, with the same being true of carabids, staphylinids, aphids and parasitoid wasps, though in 50% of cases differences were only detected in one of the four crops. Brachycerans were the only group whose numbers were significantly increased in the FM vs the CM, though this was only true in brassicas.

2012 SAMPLES: The statistical analysis could not separate means for counts of Nitulids and ladybirds at the different trapping locations, although a significant interaction was observed. Data for Nematocera could not be analysed as the statistical model failed to converge. For all other groups, however, differences were detected. Counts were lower in the FM vs the CM for carabids, staphylinids and parasitoid wasps, in 1, 3 and 2 of the four crops, respectively. Brachyceran numbers were again significantly increased in the FM vs the CM, in both brassicas and cereals, with aphid numbers generally higher in the FMs vs CMs.

GENERAL OVERVIEW: When FMs were shown to have an effect on target insect groups, this was generally found to be negative, with higher counts for these groups recorded in CMs. Indeed, FMs were only shown to have benefited insect counts in the case of parasitoids (in brassicas and cereals in 2010), brachyceran flies (in brassicas in 2011 and brassicas and cereals in 2012) and aphids (in general in 2012). Cases of FMs negatively affecting groups were more numerous, though in no case were any differences seen consistent across sampling years/crops.

That the patterns seen for certain groups (e.g. parasitoid wasps) failed to match those found during visual assessment of these groups is not necessarily surprising. Whilst visual observation records the ‘actual’ number (i.e. abundance) of insects of a given target group during counts, the same is not true of pitfall and water trapping; these latter methods instead determine ‘activity-abundance’, being dependant on insect movement as much as presence. Consequently, pitfall and water trapping cannot be used to provide a reliable assessment of abundance alone, or compare abundance between sites where insect activity is likely to differ, though these data do provide useful information on activity-abundance levels.

In terms of within crop counts, those of all target groups varied by year and crop. Higher counts of some groups at CF1 *vs* CF2 and CF3, even where counts of these groups were similar or lower in FMs than CMs (parasitoids in peas in 2011 and carabids in multiple crops in 2011/2012), are suggestive of overspill from the FM and support that low catches of these groups in FMs do not correlate with low abundance *per se*. This is further supported by homogenous ladybird distributions within crops in 2010 and 2011, despite lower catches of this group in FMs *vs* CMs in these years. Aphid counts were generally higher within crops than in margins, as to be expected in light of the fact that many aphids would have been resident on crop plants as pest species. Interestingly, however, in 2012 aphid counts were generally higher in margins, and especially FMs. This may have resulted from 2012 being a very poor year for crop aphids (on account of prevailing weather conditions) and supports that FMs may be important for harbouring aphid hosts/prey for those beneficial insects that use them when pest aphids are scarce. Ladybird numbers were generally higher within crops than in FMs, though with distributions being more homogenous in 2012, perhaps reflecting patterns in their aphid prey. Parasitoid wasps were generally trapped less often within crops *vs* margins, perhaps due to their increased requirement for floral resources, though again this pattern failed to hold in all years, with counts across sites being similar in 2012.

In the majority of cases it is difficult to draw specific conclusions from the data obtained during pitfall/water trapping, as analysis was only possible on broad target groups and statistical differences were inconsistent between crops and/or years. Nevertheless, it can be tentatively concluded that, in the system used here, low activity-abundance of many target groups in FMs *vs* CMs may reflect the fact that insects moved less in FM habitats, not that there were fewer of them *per se* in FMs. Increased movement in CMs could be logically expected for many target groups, where CMs were structurally and vegetatively simpler habitats, potentially forcing increased movement as a response to resource scarcity / increased resource searching. The structural complexity of FMs may have also reduced trap catches relative to CMs for some groups, particularly for flying insects to which water traps may have been a more easily ‘accessible’ target in CMs.

COMMERCIAL SAMPLING

VISUAL PLANT INSPECTION – MARGINS:

Though 2013 data was insufficiently replicated to permit statistical analysis, FM and CM counts of target invertebrates at commercial sites support that FMs are visited more frequently by numerous groups, including beneficial groups such as hoverflies, other beneficial Diptera (tachinids and sarcophagids) and bumblebees (Fig 5). This supports data from the previous year (Fig 5 insert) which included an additional replicate and thus permitted analysis (albeit with a n-value of only 3).

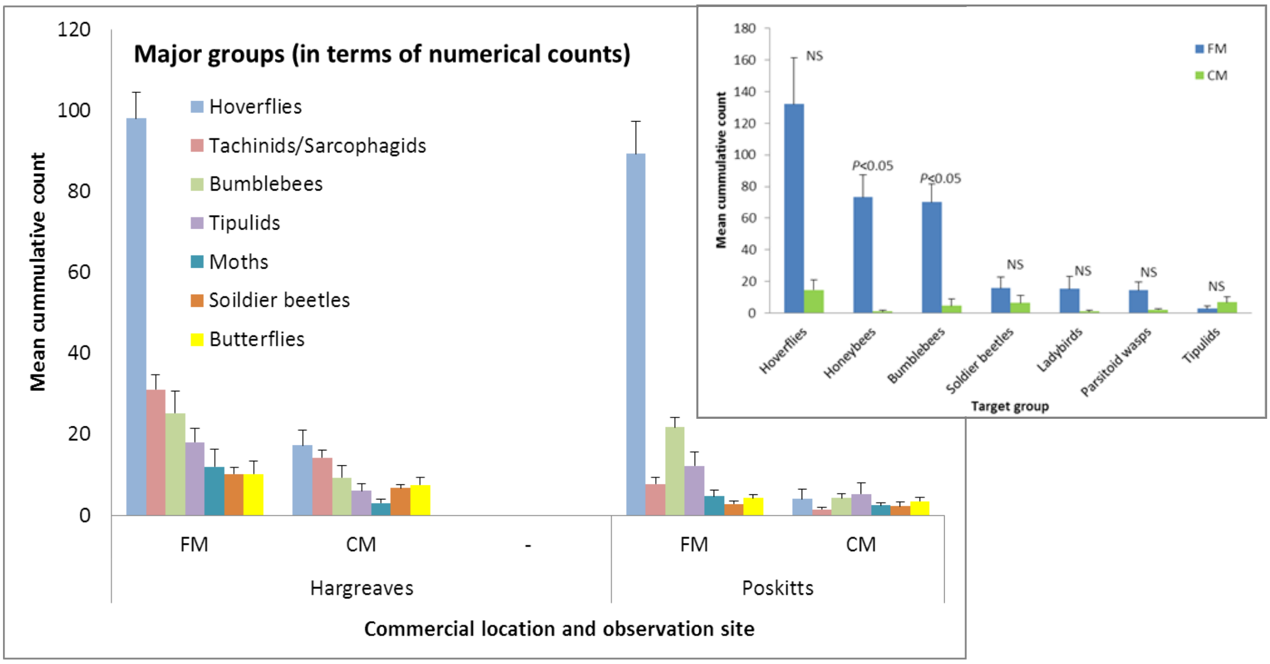

Figure 5. Mean cumulative counts of target insect assemblages from visual observation of flowering and control field margins at two commercial sites in 2013. Data combined across all sampling dates. Means are displayed with SEs. n = 4 for all means. Only those groups with a mean cumulative count above 10 in either or both of the FM and CM (at one or both sites) are shown. **Insert:** Mean cumulative counts of target insect groups at commercial sites in 2012. Means are displayed with ± SEs. n = 3 for all means. NS = not statistically significant.

POLLINATOR AND BIRD SURVEYS

POLLINATOR SURVEY

In all years, the diversity of *Bombus* species visiting FMs at STC was good, and included rare unidentified species. *Bombus* were only rarely observed in CMs on site. Data for FM visitation by *Bombus* species at STC are shown in Fig 6.

In most cases *Bombus* counts/diversity were also positive at commercial FMs sampled in 2012 and 2013 (Fig 7), though visitation to the FM at Produce World in 2013 was greatly reduced, even once increased sampling effort in 2012 was accounted for. This FM failed in 2013 as a suspected result of a lack of management with the paucity of flowers present almost certainly explaining poor visitation.

That both experimental and commercial FMs supported a diverse range of *Bombus* species in all project years, and at both STC and commercial sites (albeit with some species being more dominant than others), supports that the seed mix used can stack benefits within as well as between target beneficial insect groups.

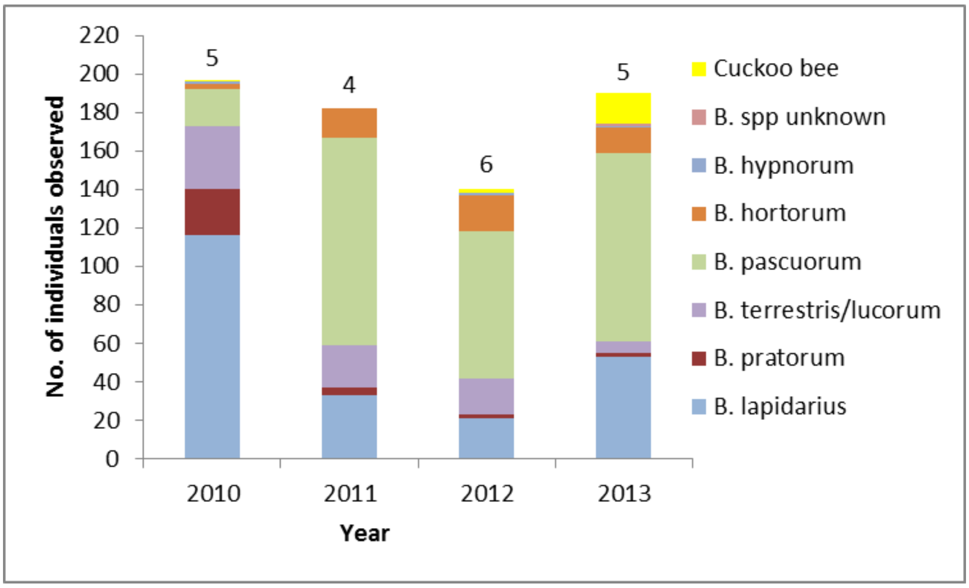

Figure 6. Total annual counts of *Bombus* species observed across all flowering margins at STC. Figures above bars represent the total number of sampling visits made that year.

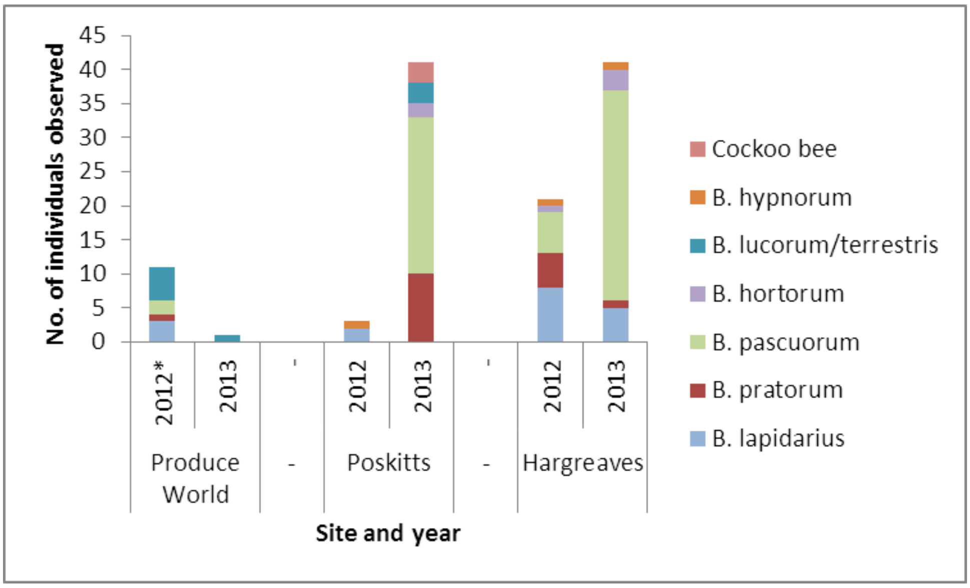

Figure 7. Total counts of *Bombus* species observed in commercial flowering margins in 2012 and 2013. FMs were sampled on two separate dates in any given year, *except for at Produce World in 2012 where four visits/assessments were made.

BIRD SURVEYS

The number of species and number of individuals recorded at each site on two occasions over the winter and over the course of the growing season are shown below in an extended Table 4. Species lists for the sites below are provided in Appendix 1. Though data were not subject to statistical analysis there appeared to be a consistent trend for increased species and greater numbers of individuals of farmland birds around plots with FMs.

Table 4. The number of farmland bird species and individuals recorded from commercial control field and fields with FMs during late 2012/2013.

Site 1 Julian Hargreaves: Control field

Date	No. of species recorded	No. of individuals recorded
30/11/2012	5	24
13/02/2013	3	78
23/05/2013	5	5
04/06/2013	5	5
18/07/2013	7	12
15/08/2013	5	6
04/09/2013	2	17
	Mean = 4.57	Total = 147

Site 1 Julian Hargreaves: Margin field

Date	No. of species recorded	No. of individuals recorded
30/11/2012	9	59
13/02/2013	3	5
23/05/2013	5	10
04/06/2013	10	12
18/07/2013	14	60
15/08/2013	3	4
04/09/2013	3	7
	Mean = 6.71	Total = 157

Site 2 Guy Poskitt: Control field

Date	No. of species recorded	No. of individuals recorded
29/11/2012	7	12
11/02/2013	1	9
02/04/2013	4	8
22/05/2013	2	2
03/06/2013	3	3
16/07/2013	6	12
13/08/2013	1	2
05/09/2013	2	4
	Mean = 3.25	Total = 52

Site 2 Guy Poskitt: Margin field 1

Date	No. of species recorded	No. of individuals recorded
29/11/2012	8	105
11/02/2013	8	88
02/04/2013	12	20
22/05/2013	5	10
03/06/2013	10	11
16/07/2013	12	20
13/08/2013	10	25
05/09/2013	9	34
	Mean = 9.25	Total = 313

Site 2 Guy Poskitt: Margin field 2 (margin accidently ploughed under in 2012)

Date	No. of species recorded	No. of individuals recorded
29/11/2012	5	12
11/02/2013	4	44
02/04/2013	4	22
22/05/2013	5	5
03/06/2013	3	3
16/07/2013	8	11
13/08/2013	4	10
05/09/2013	5	5
	Mean = 4.75	Total = 112

Conclusions

- The effect of FMs *vs* CMs on insect over-wintering has varied throughout the project, being neutral for all groups considered by the final year of the project. Nevertheless, for many invertebrate groups this work has confirmed the superior nature of margins *per se* as overwintering sites (*vs* crop fields).
- According to visual observations, the presence of experimental FMs promoted visitation by certain groups of beneficial insects in all four project years at STC, with commercial counts supporting increased insect visitation to FMs. Significantly increased visitation to FMs was recorded for a diverse range of pollinators, pest predators, pest natural enemies and groups of conservation interest. Thus, data have conclusively shown that the seed mix used is capable of stacking benefits for multiple invertebrate groups, this being true in every project field season from 2010-2013.
- According to pitfall and water trapping data, insect 'activity-abundance' patterns do not necessarily match those for abundance, perhaps as a result of decreased insect movement in FMs for many groups.
- The ability of FMs to stack benefits within a target group has been confirmed through bumblebee counts, which showed FMs were utilised by a diverse range of *Bombus* species.
- With the exception of tipulids, and to a lesser extent mirid bugs, FMs did not attract potential pest species, this being testament to the process used in developing the seed mix (which excluded flowers associated with pests of the four crops used).
- Throughout the project, counts of aphids and other above and below ground pest groups have supported a suppressive effect of the FMs on pest numbers, these being reduced nearer to FMs (albeit not significantly so in all cases with the analysis run to date), at least in those crops where reasonable numbers were recorded.
- Links between pest numbers and numbers of beneficial insects in and around FMs have yet to be fully disentangled, though it seems reasonable to assume that FMs exerted an effect on pests through promotion of beneficials. Data collected on in-crop percentage parasitism and distribution of adult predators and parasitoids support this in many cases.
- Though data were not subject to statistical analysis there appeared to be a consistent trend for increased species and greater numbers of individuals of farmland birds around plots with FMs.

OBJECTIVE 3: Development of the use of flowering field margins as part of a trap-cropping approach

Materials and methods

See previous reports for details of the methodology used.

Results and discussion

Field data from 2011, when traps crops where trialed *in vivo* with FMs in cabbage and carrot plots at STC, showed that chervil (used with carrots) largely failed to establish at all. By contrast, yellow mustard (with cabbage) grew into large, robust plants. Though these appeared not to attract cabbage fly oviposition based on egg counts in and around the mustard roots vs those in the crop, there was some suggestion that yellow mustard served as a barrier plant. The overall results from CRF pupal sampling in the absence (see Objective 2) and presence (see previous reports) of trap crops, and trap plant data, support that yellow mustard operates as a barrier plant within the field, restricting movement of adult CRF located between the flowering margin and the trap crop and resulting in increased oviposition to one side of the barrier plant. The numbers of pupae actually in the soil under the trap crop in 2011 were significantly lower than numbers recorded in the cabbages. The actual role of this trap crop in a field situation has still to be further evaluated in order to provide recommendations for use with commercial growers. By contrast, in potted trials in 2012 more cabbage root fly oviposited in pots with yellow mustard than cabbage, though this difference was not statistically significant and overall numbers recorded were relatively low (0-18). Nevertheless, this suggests an additional possible role of yellow mustard as a dead-end trap crop for this pest. It follows that the actual role of yellow mustard as a trap/border crop in a field situation has still be to be further evaluated in order to provide recommendations for use with commercial growers.

Conclusions

- Yellow mustard performed well as a trap crop physically (i.e. large, healthy plants) in 2011.
- Numbers of cabbage root fly pupae in trap crops in 2011 suggested that either very few adults oviposited in the trap crop relative to the cabbage, or relatively few larvae developed to the pupal stage in the trap crop. 2012 data support that adults do oviposit in yellow mustard, suggesting its potential as a dead-end trap crop. Nevertheless, further study is required to better assess this species as a trap plant. Based on the results of the current study it remains unclear if yellow mustard will function more as a trap crop or barrier plant at field edges for cabbage root fly.

- Further research needs to be undertaken to fully evaluate combined benefits of trap crops and FMs at field edges. Such work is planned at STC in 2014 as part of a separate project (using brassicas) funded by the Soil Association.

OBJECTIVE 4: Development of field margins that support predator population build-up through provision of non-pest prey in field margins

Materials and methods

See reports for details of the methodology used in caged studies and field assessments.

Results and discussion

In 2010 aphids were only rarely and inconsistently observed on FM forbs. The inconsistent occurrence of aphids across plots, and unexpectedly low infestation rate of plants such as cornflower and yarrow, may have resulted from the early developmental stage of the FM having allowed insufficient time for aphid populations to locate and establish themselves on FM plants. The short-lived nature of any aphid populations that did establish on FM plants probably resulted from these plants becoming less attractive as hosts over time (though the role of natural enemies in the margins or weather extremes, where the end of July was notably wet with periods of heavy rain, cannot be discounted). For the leguminous FM species, the aphids present were recorded as the pest species *Acyrthosiphon pisum*. However, the absence of aphids on these plants earlier in the season suggests that *A. pisum* moved from peas to the FM and not *visa versa*.

Increased numbers of aphids on FM plants were observed in 2011, with aphids recorded over a much longer duration. Fewer pea aphid were observed on leguminous species, supporting that high occurrence of pea aphid on these plants in 2010 resulted from overspill of pests from the heavily infested crop that year. Aphids observed on non-leguminous plant species were not noted as pest species. Yarrow and teasel attracted most aphids in 2011, with observation of teasel plants demonstrated that aphids present on this species suffered a relatively high rate of parasitism (up to 95% in extreme cases). Adult parasitoid wasps and aphid-associated predators (hoverflies and ladybirds) were also commonly observed on teasel during peak periods of aphid infestation in 2011.

2012 aphid (and associated beneficial insect) counts on FM forbs were low due to adverse weather, which also resulted in low in-crop aphid counts. Aphid numbers on teasel were most consistent during sampling, with relatively high levels also observed on common vetch, but over a shorter period. Aphids observed were not noted as being pest species.

Increased numbers of aphids on FM plants were observed in 2013 as compared to 2012, as a probable result of much improved weather conditions from late spring onwards. As in 2011 and 2012, pea aphids were not observed on leguminous species, largely confirming that high occurrence of pea aphid on these plants in 2010 resulted from overspill of pests from the heavily infested crop that year. Aphids observed on non-leguminous plant species were not noted as pest species. In contrast to previous years, teasel attracted relatively few aphids in 2013. However, as seen previously, yarrow remained a reliable banker plant attracting high levels of aphids throughout the entire sampling period. Both tansy and fennel also performed well as banker plants in 2013, with fennel attracting low-moderate levels of aphids throughout the whole season and tansy attracting higher levels, but being free from aphids in Sept.

Observation of plants demonstrated that aphids present on fennel and yarrow suffered a relatively high rate of parasitism, with those on teasel also being highly parasitized. Adult parasitoid wasps engaged in apparent aphid-associated activity and aphid-associated predators (hoverflies and ladybirds) engaged in similar behaviour were repeatedly observed on yarrow, teasel and tansy, with other natural enemies (i.e. pirate bugs, soldier beetles and *Aphidoletes* larvae) also observed on yarrow.

The results suggest that certain flowering plants may serve as effective banker plants, providing prey resources throughout much, if not all of the growing season. In contrast to previous years, teasel was less effective as a banker plant as 2013, possibly as the aphid species previously present on this plant recovered less well than others following the generally poor insect year in 2012. This supports that wherever possible a diversity of banker plants in FMs can be recommended to provide resilience to natural fluctuations in non-pest aphid populations. Taken as a whole, the results of this study support inclusion of teasel, yarrow and tansy to boost the number, longevity and diversity of non-pest aphids (and associated natural enemies) in FMs.

Conclusions

- Inclusion of multiple banker plant species in FM seed mixes can be recommended to insure against variation in aphid loads on any given banker plant between years.
- A combination of teasel, yarrow and tansy is suggested to boost the number, longevity and diversity of non-pest aphids in FMs.

OBJECTIVE 5: Assessment of the feasibility of using banker plants in field margins and development of these plants as sentinels to monitor levels of biological control agents

Materials and methods

See previous reports for details of the methodology used.

Results and discussion

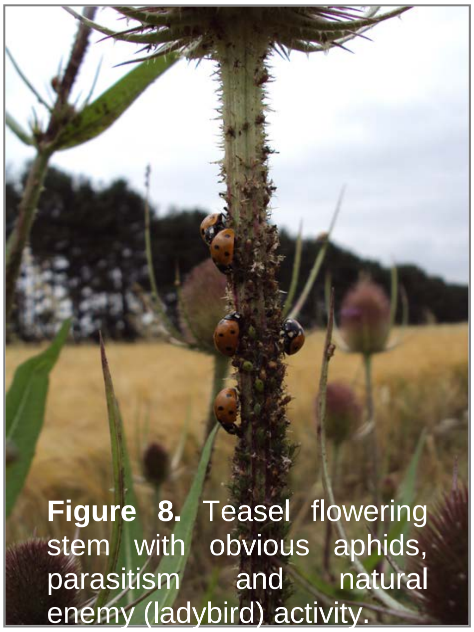

Figure 8. Teasel flowering stem with obvious aphids, parasitism and natural enemy (ladybird) activity.

Visual observation of FM forbs for aphids and associated natural enemies (see Objective 4) reported that several species were notable for their ability to act as banker plants. Of these, natural enemy activity was most easily observed on teasel, where both aphids and natural enemies were visually obvious on flowering stems (Fig 8). This is in contrast to observations on tansy and yarrow, where although both groups were present they were typically harder to observe being located within the compound heads of flowering plants. It is therefore logical to recommend that teasel is best suited as a sentinel species, allowing rapid visual assessment of non-pest FM aphid loads and associated natural enemy activity.

Due to the long lag time required to process samples from pitfall and water traps (see Objective 2), it was not possible to relate these data to banker plant surveys (Objective 4) to determine any relationship between in-crop natural enemy activity and that seen on teasel. Such analysis is, however, anticipated as part of the longer-term publication process.

Conclusions

- Results suggest that teasel may prove useful as a sentinel to monitor levels of biological control agents.

OBJECTIVE 6: Development of a database on the compatibility of available chemical control options with various biological control agents to optimize integrated pest management decisions

Materials and methods

See previous reports for details of the methodology used.

Results and discussion

Matrices were first compiled at the beginning of the project using data on active ingredients obtained from Fera. Updated compatibility matrices (with gaps addressed by Koppert) for all crops have since been developed and uploaded to the confidential page of the project website. These can currently be viewed using the consortium username and password, though will become freely available after the conclusion of the project when the website format will change (see 'Knowledge and Technology Transfer').

Though gaps have been filled, some do still exist. In short, the information on insecticide side effects is available for common aphid parasitoids (*Aphidius colemani* and *A. ervi*), but for non-aphid parasitoids (such as *Cotesia glomerata*) there is currently a paucity of information on the effect of insecticides used in the four crops. Similarly, there is no information on these same active ingredients against carabid beetles and ladybirds. Other predatory groups such as hoverflies (*Episyrphus balteatus*), lacewings (*Chrysoperla carnea*) and true bugs (*Orius majusculus*) have some information available regarding some of the insecticides, but lacunae are still present, especially for older actives ingredients (e.g. chlorpyrofos), though Koppert have provided updated information on the relatively new active thiacloprid. Addressing these outstanding gaps has not been possible as part of the current study, though it is hoped that in highlighting them the project will encourage future work in this area.

Conclusions

- Compatibility matrices of chemical control options have been generated for all crops being used in the study and can be used to make decisions on which treatments to apply/avoid in commercial crops to best integrate production and fully-functional FMs.
- Gaps have been identified and in some cases these have been addressed by Koppert.

<u>OBJECTIVE 7: Quantification of the impact of perennial field margins on pest levels, crop quantity/quality and pest management costs</u>

Materials and methods

Quantification of the impact of FMs on pest levels is reported under Objective 2. An overview of yield results for all years of the project is provided below, though a cost:benefit analysis could not be run with the available data and budget.

Results and discussion

Overall, yield results throughout the project have been encouraging. Though no differences in yield between sampling sites in any crop were seen in the first field season (2010), in the two years that followed increases were repeatedly recorded at sites nearer to FMs at STC (Table 5). This data may represent the cumulative effect of FM pest insect suppression over a season, though it is important to note that other factors could also be playing a role. In 2012, for example, flooding and (vertebrate) herbivory at field plot edges was evident. As pest insects were extremely low in 2012, effects of FMs/CMs (and their associated management) on these factors may have been more important in determining yield. 2011 and 2013 were less extreme years in terms of weather and yield benefits observed during 2011 may better reflect effects of FMs on pests. 2013 was, even more so than 2012, notable for vertebrate herbivory. As a possible result no yield increases were seen nearer to FMs in 2013.

In one instance (carrots, 2013) yield was found to be significantly lower nearer to the FM. Data obtained for carrot fly damage during yield sampling show that this was high at CF1 and potentially responsible for lowered yield at this sampling site. Increased carrot fly larval damage to carrots was, however, not recorded when separate sampling was undertaken under Objective 2. This inconsistency in results probably reflects the different sampling procedures used, where under Objective 2 damage was assessed at each sampling site from a set number of carrots, and under the current Objective damage was assessed per quadrat. As carrot yield was reduced at CF1 in 2013 it follows that less carrot material would have been present per quadrat at this sampling site, potentially concentrating damage per spatial unit whilst damage per capita remained relatively constant. In this instance it would perhaps be more likely that other factors, such as mammalian herbivory (which was noted as high in 2013), were the primary cause of reduced carrot yield at CF1.

Though in 1/3 of cases yields were increased nearer to FMs, suggesting an overall beneficial effect of FMs (especially when ‘mature’), this result does highlight that unexpected results can occur when dealing with variable biological systems. That yield was never increased in carrots in previous years, unlike in the other three crops, perhaps also suggests that either the FM seed mix was less well suited to this crop than others, or that the crop itself is less well suited to FMs (at least in terms of deriving yield benefits from it).

Table 5. Summary of yield data from crops at STC in 2010, 2011 and 2012.

	YIELD			
YEAR	**Carrots**	**Cereals**	**Peas**	**Cabbages**
2010	No difference	No difference	Could not be analysed: poor crop	No difference
2011	No difference	Yield increased at CF1 by 22.5%$_{max}$	Yield increased at CF1 by 41.1%$_{max*}$	Yield increased at CF1 by 15.8%$_{max*}$
2012	No difference	No difference	Yield higher at CF1 & CF2 by 74.2%$_{max**}$	Yield increased at CF1 by 29.9%$_{max*}$
2013	Yield decreased at CF1 by 25.4%$_{max*}$	No difference	No difference	No difference

*vs CF3 where lowest/highest yield was recorded. **For CF2 vs CF3, where at CF1 yield was 45.5% increased vs CF3.

Conclusions

- Data from years 2 and 3 of the project support that mature FMs benefitted yield in at least one field season in cereals, peas and cabbage.
- Positive effects of the projects FMs on yield may be crop dependant and, due to the variable nature of biological systems, should not be expected every year.

OBJECTIVE 8: Communication of best practice to commercial growers in the form of 'blueprints' for margin establishment and management, drawing upon knowledge generated in the proposed project as well as in ongoing European biodiversity projects

Materials and methods

A project Communications Group was established to inform Technology Transfer to the industry and advise on production of a growers handbook to include 'blueprints'. The group met for the first time on the 12th March 2012 and again on the 22nd April 2013.

A meeting was held with Natural England in 2012 to discuss whether changes to the ELS options will allow growers to apply results from this HortLINK project to their margins, buffer strips and rotational land. Proposed new options and changes to existing options reflect the discussions we had earlier-on with Natural England. Should these changes be approved by the EC, this will give growers the opportunity to better utilize flower mix prescriptions as part of ELS and to receive extra points for flower-rich margins to compensate for (at least some of) the cost for the seed mix.

Results and discussion

A compendium has been produced following comments/suggestions made at the first meeting of the Communications Group supporting this as the preferred format for the required 'blueprints'. This compendium is available in Appendix 2 with a total of eight sections included as below. Following discussion at previous meetings, it is anticipated that this document will be further developed by the relevant project partners to ensure that it is of optimal benefit to end users. A usb drive containing all project images is being made available to these partners to facilitate this process.

Compendium Sections

- Overview
- Plant / Site selection
- Managing margins
- Margin mixes
- The IPM approach
- Plant spotter
- Insect spotter
- FAQs

‘Farmers to Follow’ was discussed as a potential project outreach activity at the first Communications Group meeting and subsequently approved by the project consortium. Although resources were only initially available to provide seed to limited participants (two ‘Farmers to Follow’ in Scotland), further resources have been made available for this initiative which will now continue post-project completion through STC.

Conclusions

There are no conclusions to be drawn on this Objective at this stage, where its success can only be gauged by uptake after the project end.

Overall conclusions

- Despite harsh winter/spring conditions in the four successive years since their initial sowing, several of the flowering plants sown have survived and established well in FMs at STC. Results from commercial sites suggest similarly good establishment thus far (with improved conditions post-sowing), though with one notable exception highlighting the importance of good management.
- Data collected throughout the project suggests that the selection of plants included in experimental FMs is capable of providing a diverse floral resource throughout the season, with selected species providing benefits when floral resources are otherwise notably scarce.
- Based on data from experimental and commercial scale margins four individual seed mixes have been recommended. These have been tailored to soil type and budget and indicate which of the included species are native, naturalised and non-native (allowing growers to include only certain groups if desired). Further options for growers, including a range of mixes containing only native species, have been made available through the Automated Margins project (HDC FV 334a) (http://www.stockbridgetechnology.co.uk/Automated_ Margins/).
- The effect of FMs *vs* CMs on insect over-wintering has varied throughout the project, being neutral for all groups considered by the final year of the project. Nevertheless, for many invertebrate groups this work has confirmed the superior nature of margins *per se* as overwintering sites (*vs* crop fields).
- The presence of experimental FMs promoted visitation by certain groups of beneficial insects in all four project years at STC, with commercial counts supporting increased insect visitation to FMs. Significantly increased visitation to FMs was recorded for a diverse range of pollinators, pest predators, pest natural enemies and groups of conservation interest. Thus, data have conclusively show that the seed mix used is capable of stacking benefits for multiple invertebrate groups, this being true in every project field season from 2010-2013.

- The ability of FMs to stack benefits within a target group has been confirmed through bumblebee counts, which showed FMs were utilised by a diverse range of *Bombus* species.
- With the exception of tipulids, and to a lesser extent mirid bugs, FMs did not attract potential pest species, this being testament to the process used in developing the seed mix (which excluded flowers associated with pests of the four crops used).
- Throughout the project, counts of aphids and other above and below ground pest groups have supported a suppressive effect of the projects FMs on pest numbers, these being reduced nearer to FMs (albeit not significantly so from a statistical perspective in all cases with the analysis run to date), at least in those crops where reasonable numbers were recorded.
- Links between pest numbers and numbers of beneficial insects in and around FMs have yet to be fully disentangled, though it seems reasonable to assume that FMs exerted an effect on pests through promotion of beneficials. Data collected on in-crop percentage parasitism and distribution of adult predators and parasitoids support this in many cases.
- According to pitfall and water trapping data, insect 'activity-abundance' patterns do not necessarily match those for abundance, perhaps as a result of decreased insect movement in FMs for many groups.
- Though data were not subject to statistical analysis there appeared to be a consistent trend for increased species and greater numbers of individuals of farmland birds around plots with FMs.
- Yellow mustard performed well as a trap crop physically (i.e. large, healthy plants) in 2011.
- Numbers of cabbage root fly pupae in trap crops in 2011 suggested that either very few adults oviposited in the trap crop relative to the cabbage, or relatively few larvae developed to the pupal stage in the trap crop. 2012 data support that adults do oviposit in yellow mustard, suggesting its potential as a dead-end trap crop. Nevertheless, further study is required to better assess this species as a trap plant. Based on the results of the current study it remains unclear if yellow mustard will function more as a trap crop or barrier plant at field edges for cabbage root fly.
- Further research needs to be undertaken to fully evaluate combined benefits of trap crops and FMs at field edges. Such work is planned at STC in 2014 as part of a separate project (using brassicas) funded by the Soil Association.
- Inclusion of multiple banker plant species in FM seed mixes can be recommended to insure against variation in aphid loads on any given banker plant between years.
- A combination of teasel, yarrow and tansy is suggested to boost the number, longevity and diversity of non-pest aphids in FMs.
- Results suggest that teasel may prove useful as a sentinel to monitor levels of biological control agents.

- Compatibility matrices of chemical control options have been generated for all crops being used in the study and can be used to make decisions on which treatments to apply/avoid in commercial crops to best integrate production and fully-functional FMs.
- Gaps have been identified and in some cases these have been addressed by Koppert.
- Data from years 2 and 3 of the project support that mature FMs benefitted yield in at least one field season in cereals, peas and cabbage.
- Data for carrot yield were less positive, typically showing no effect of FMs on yield, and even exerting a negative effect on yield in the final project year. This appears to have resulted from increased carrot fly damage occurring nearer to the FM in 2013.
- Positive effects of the projects FMs on yield may be crop dependant and, due to the variable nature of biological systems, should not be expected every year.
- Delivery of information, primarily via platform presentations at appropriate events has occurred throughout the project and will continue after the official project end. Further details provided in the Technology Transfer section.
- Multiple meetings of the projects Communication Group have been held with a further meeting planned after the project end to optimise dissemination of the complete project.
- Blueprints in the form of a compendium have been produced. These are expected to be further developed by relevant project partners.

Knowledge and Technology Transfer

The major pieces of intellectual property to arise from the project were the seed mixes. However, these could not be patent protected for two reasons: (1) On speaking to the project partners it was identified that patent costs cannot be justified on seed mixes and thus patents are not normally used. (2) A patent would require full disclosure of the seed mix, making it simple to copy and very difficult to police such copying, hence making a patent a self-defeating approach. Instead, we considered publishing the seed mix to aid communication of the benefits of the projects FMs, but keeping the exact proportions of each species used confidential. Again, on the advice of project partners it became apparent this was not possible - marketing a seed mix requires information on the relative proportions of each species to be included. Therefore, we were left with not being able to protect the seed mix, other than perhaps by supplying it under a registered brand name with trademark protection.

Our exploitation strategy therefore became to make the seed mixes available to all by releasing the full details of each mix. However, to satisfy our commitment to commercialising the results of the project it was agreed that Stockbridge Technology Centre would commercially market and supply the seed mixes to growers from the end of the project on behalf of the project partners. Due to the issues in protecting the seed mix and ease with which it could be copied by others, it was agreed this would be done at or just above cost without a royally payment being due to the project partners. To initially support this initiative and spread the word about the seed mixes our Farmers to Follow programme was established to support interested growers in using the seed mixes, while confidence is developed in their performance. Further measures undertaken to encourage growers to use the seed mixes supplied by STC include extensive lobbying of Natural England to ensure FMs are included and further rewarded within their Environmental Stewardship Scheme and the development of grower blueprints on how to use the seed mixes to supplement the advice STC will be able to provide going forward.

A project website has been developed (www.ecostac.co.uk). This will continue to exist after completion of the project, with changes to the current format being implemented to reflect the changing aim of the website at this stage (i.e. with more emphasis placed on dissemination of relevant information to industry). Details of the project are also featured on the Project Database section of the European Learning Network on Functional AgroBiodiversity (ELN-FAB) website.

Overviews of the project have been presented at the following:

- Open Horticultural and Potato Board Meeting, 26th August 2009, STC, York, UK (platform pres).
- HDC Members Meeting, 5th October 2009, STC, York, UK (platform pres).
- Waitrose Innovation Forum, 16th February 2010, Harper Adams, Newport, UK (invited lecture).
- IOBC Meeting – BioControl in the Americas, 11th - 13th May 2010, Niagara Falls, Canada (platform pres).
- IOBC/WPRS Working Group for Landscape Management and Functional Biodiversity, 29th June - 1st July 2010, Cambridge, UK (platform pres).
- European Congress of Entomology, 22nd - 27th August 2010, Budapest, Hungary (plenary lecture).
- Sustainable Agriculture Initiative Platform Meeting, Berlin, 27th Sept (platform pres)
- VLM International Biodiversity Meeting, 13th October 2010, Bruges, Belgium (plenary lecture).
- Waitrose Agronomy Meeting, 1st – 5th Nov 2010, Cumbria, UK (invited lecture).
- AAB Conference – Advances in Biocontrol and Related Topics, 17th Nov 2010. Grantham, Leicester, UK (platform pres).
- Functional Agro-biodiversity Meeting, 11th -12th Nov 2010, Slovenia (platform pres).
- Greening the CAP, 12th Nov 2010, Bled, Slovenia (platform pres).
- VAA Members Meeting, 20th January 2011, PGRO, Peterborough, UK (platform pres).

- HGCA Crop Management Monitoring Meeting, 15th March 2011, NIAB, UK (platform pres).
- BOKU, 12th April 2011, Vienna, Germany (platform pres).
- Waitrose Innovation Forum, 9th – 10th June 2011, Aylesford, UK (invited lecture).
- AAB/BES Meeting, 15th – 16th June 2011. Dundee University, UK (platform pres).
- HDC Growers Meeting, 30th June 2011, STC, York, UK (invited lecture).
- Syngenta Biological Sciences and Product Safety Research Days, 19th–20th Sept 2011, Jealott's Hill, UK (platform pres).
- AAB Conference – Advances in Biocontrol and Related Topics, 30th Nov 2010. Grantham, Leicester, UK (platform pres).
- University of York, 31st Jan 2012 (invited lecture).
- Kettle Produce, 16th Feb 2012, Ladybank, Scotland (invited seminar).
- HGCA Crop Management Monitoring Meeting, 6th Feb 2012, NIAB, UK (platform pres).
- Informed Landscape Management to Maximize Ecosystem Services. 5th SETAC Europe Special Science Symposium 'Ecosystem Services: From Practice to Policy'. 13th Feb 2012, Brussels, Belgium (invited seminar).
- Fera Entomology SIG, 18th April 2012, Sand Hutton, UK (invited seminar).
- Opportunities and Challenges for Biological Control. Inauguration Symposium for the Centre for Biological Control, Uppsala 'Towards Integrated Biological Control'. Uppsala, Sweden, 19th – 20th April 2012 (invited plenary talk).
- IOBC/WPRS Working Group for Landscape Management and Functional Biodiversity, 7th – 10th May 2012, Leida, Spain (platform pres).
- The ELN-FAB Initiative. ELN-FAB European Seminar – 14th – 15th June 2012, Avignon, France.
- Biodiversity, Quo Vadis. Baltic State Region conference on agro-biodiversity. Tartu, Estonia 14-16 Nov 2012 (invited pres.)
- RES Insect Parasitoid SIG, 12th April 2013, York, UK (platform pres.).
- RES Northern Meeting, 5th Dec 2013, Newcastle upon Tyne (platform pres.).

The Project was also presented and discussed at a meeting of the ELN-FAB, May 2010, Copenhagen, Denmark.

Poster presentations providing an overview of the project have been displayed at:

- Lancaster University's Faculty Christmas Conference (Dec 2009).
- A Growers Meeting at STC on the 18.05.10.
- A Bayer Open Day at STC on the 22.06.10.
- A HGCA Cereals Event in July 2010.

- RES Insect Parasitoid SIG, 26th November 2010, York, UK.
- RES York Insect Festival, 3rd July 2011, York, UK.
- IOBC/WPRS Working Group for Landscape Management and Functional Biodiversity, 7th – 10th May 2012, Leida, Spain.
- Syngenta Biological Sciences and Product Safety Research Days, 10th–11th Sept 2012, Jealott's Hill, UK.

Three scientific publications outlining the project and detailing various results have appeared in the 'Bulletin of the IOBC/wprs' (one in 2010 and two in 2012) and details of the project featured in the July 2010 and Feb 2012 issues of HDC News as well as the 2013 edition of PGROs The Vegetable Magazine. A Short Communication based on sampling of flowering crops at Emorsgate has been published the Journal of Insect Conservation and a full paper featuring 2010 caged experiments on banker plants is in preparation for Biological Control. A further full paper outlining selected results is in the early stages of production.

The project was featured as part of STC open days on the 18.06.10, 17.10.10 and 25.09.11 and received mention on BBC1s Look North (Yorkshire) on the 13.07.10. The projects field margins and Research Associate also featured in the first episode of the BBC2 documentary 'Bees, butterflies and blooms' which aired on the 8th Feb 2012.

Press Releases outlining the project were sent to all project partners, as well as Lancaster University's Press Office, on the 06.09.10, the 17.02.12 and the 26.07.12. The latter was circulated to a readership of some 7,000 through LEAF's August 2012 EBrief.

A project 'Friends List' has been initiated where interested parties may provide their contact details and receive non-confidential project reports, notice of project open-days, etc. To date this list features a number of notable contacts including growers, seed companies, the RSPB, Natural England and Conservation Grade.

In order to increase public awareness of the project, a public-participatory study was run at the Royal Entomological Society's Insect Festival 2011 and project information cards were disseminated at the 2012 Harrogate Flower Show (as part of a stand run by STC). Details of the project were also disseminated at the RES's 2013 Insect Festival in York.

Led by Prof Felix Wäckers, a project Communications Group has been established to inform Technology Transfer to the industry and advise on production of a growers compendium (under Milestone 8).

Glossary

FM = Flowering Margin

CM = Control Margin

CF1 = Crop Field trapping site 1 (5m into the crop from the FM)

CF1a = Crop Field trapping site 1a (27.5m into the crop from the FM)

CF2 = Crop Field trapping site 2 (in the middle of the crop, 50m into the crop from the FM)

CF2a = Crop Field trapping site 2a (72.5m into the crop from the FM)

CF3 = Crop Field trapping site 3 (95m into the crop from the FM)

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Appendix

Appendix 1: Farmland bird species lists

Julian Hargreaves – Control field

Date	30/11/2012	13/02/2013	23/05/2013	04/06/2013	18/07/2013	15/08/2013	04/09/2013	Total
Blue tit					1			1
Carrion crow			1					1
Chaffinch				1				1
Goldfinch					5			5
Great tit						1		1
Grey partridge	5						16	21
Linnet			1			1		2
Magpie					2	1		3
Pheasant	3	2			1			6
Robin	1				1			2
Skylark			1	1				2
Tree sparrow	14			1				15
Whitethroat			1	1	1			3
Wood pigeon	1	75			1	1	1	79
Yellowhammer		1	1			2		4
Yellow wagtail				1				1
Total	24	78	5	5	12	6	17	147

Julian Hargreaves – Margin field

Date	30/11/2012	13/02/2013	23/05/2013	04/06/2013	18/07/2013	15/08/2013	04/09/2013	Total
Blackbird	5	2		1	2			10
Blue tit							1	1
Buzzard	1							1
Chaffinch	1		1	1				3
Dunnock					1			1
Golden pheasant					1			1
Goldfinch					4			4
Great tit	1							1
Kestrel	1							1
Linnet				1	2			3
Pheasant	2	1		2			1	6
Redwing	2							2
Reed bunting				1	1			2
Robin	1			1				2
Skylark			1	1	2	1		5
Sparrowhawk						1		1
Stock dove				2	1			3
Tree sparrow					35	2		37
Whitethroat			2	1	2			5
Wood pigeon			4		2			6
Wren					2			2
Yellowhammer	45	2		1	2		5	55
Yellow wagtail			2		3			5
Total	59	5	10	12	60	4	7	157

Guy Poskitt – Control field

Date	29/11/2012	11/02/2013	02/04/2013	22/05/2013	03/06/2103	16/07/2013	13/08/2013	05/09/2013	Total
Blackbird	3			1		1			5
Carrion crow			2						2
Dunnock	1								1
Goldfinch	1								1
Great tit			1						1
Linnet						1			1
Magpie	3								3
Pheasant	2		1						3
Rook		9							9
Skylark				1		2			3
Song thrush	1								1
Stock dove			4		1			2	7
Tree sparrow						5			5
Whitethroat						1			1
Wood pigeon								2	2
Wren	1								1
Yellowhammer					1	2	2		5
Yellow wagtail					1				1
Total	12	9	8	2	3	12	2	4	52

Guy Poskitt – Margin field 1

Date	29/11/2012	11/02/2013	02/04/2013	22/05/2013	03/06/2013	16/07/2013	13/08/2013	05/09/2013	Total
Blackbird	2						2		4
Blue tit				1			1	11	13
Blackcap					1				1
Chaffinch	2		1		2	1		1	7
Coot			3			4	6	4	17
Dunnock	2				1	2			5
Fieldfare	8								8
Goldfinch			1						1
Great spotted woodpecker	1	1							2
Great tit			1						1
Green woodpecker			1			1			2
Kingfisher					1		1		2
Lapwing				4					4
Long tailed tit	16	4	1		1			8	30
Magpie			2				7		9
Mallard		65							65
Marsh tit		2	1						3
Moorhen						4	4		8
Mute swan		2	1		1	1		2	7
Red legged partridge				2	1				3
Robin			1			1		2	4
Skylark						2			2
Sparrowhawk		1							1
Stock dove	1		5		1	1			8
Swallow								4	4
Tawny owl					1				1
Tree creeper			2				1		3
Tufted duck		5							5
Water rail								1	1
Whitethroat				2	1	1			4
Wood pigeon	73	8				1	1		83
Wren						1			1
Yellowhammer							1		1
Yellow wagtail				1			1	1	3
Total	105	88	20	10	11	20	25	34	313

Guy Poskitt – Margin field 2

Date	29/11/2012	11/02/2013	02/04/2013	22/05/2013	03/06/2013	16/07/2013	13/08/2013	05/09/2013	Total
Blackbird				1		1			2
Blackcap				1	1				2
Carrion crow			2				3		5
Chaffinch	6			1	1				8
Green woodpecker						1			1
Linnet			1						1
Magpie		2	18					1	21
Robin				1	1				2
Rook		40							40
Sedge warbler								1	1
Skylark	1		1			1			3
Sparrowhawk								1	1
Whitethroat						3			3
Woodcock	1								1
Wood pigeon	2					1	4	1	8
Wren		1				1	1		3
Yellowhammer	2	1				2	2		7
Yellow wagtail				1		1		1	3
Total	12	44	22	5	3	11	10	5	112

Appendix 2: Growers Compendium

In line with discussion at meetings of project Communications Group and full consortium, the following compendium has been produced as a draft document for further development by relevant project partners.

Why sow flowering field margins?

OVER-VIEW
PLANT/SITE SELECTION
MANAGING MARGINS
MARGIN MIXES
THE IPM APPROACH
PLANT SPOTTER
INSECT SPOTTER
FAQs

Non-crop vegetation in agricultural landscapes can provide a range of important ecological services, including conservation of native flora/fauna and the enhancement of pollination efficacy and biological pest control. Not only pollinators, but also many biological control agents depend on flowering vegetation as a source of nectar and pollen. The scarcity of floral resources in modern horticultural and arable systems severely constrains predator survival, limiting the effectiveness of biological pest control.

Flowering field margins can help to address the scarcity of floral resources in the farm-scape, but their effectiveness in delivering pest control services strongly depends on their botanical composition. Currently, these non-crop elements are typically designed for one particular ecosystem service, often rendering them suboptimal for other functions.

As part of Defra-funded HortLINK Project HL0192: **'Perennial field margins with combined agronomical and ecological benefits for vegetable rotation schemes**', otherwise know as the Ecostac project, scientists at Lancaster University, Fera and Stockbridge Technology Centre, in collaboration with partners from industry, have shown that it is possible to stack and optimize conservation and agronomical benefits obtainable from flowering filed margins by adopting an informed selection of floral resources. This large scale project applies this multifunctional approach to focus on ecosystem services that are of direct benefit to UK agriculture, and conservation.

Inclusion in AES and contribution towards 'Sustainable Use'……

Qualification as 'Ecological Focus Areas'……………………………………

Promotion of pollinators………………………………………………………………

Promotion of pest natural enemies……………………………………………

Potentially increased yield / reduced pesticide costs………………

IPM amenable……………………………………………………………………………………

5 KEY FINDINGS FROM THE ECOSTAC PROJECT

1). The seed mix developed established well, despite unusually harsh weather conditions post-sowing, with the flowering component increasing year-on-year from 2010-2013.

2). Flowering field margins were capable of providing diverse floral resources from early spring to late autumn .

3). Observations on insect visitation demonstrated that the mix used 'stacked benefits' for beneficial insect groups, simultaneously attracting pollinators and pest natural enemies. Insect trapping in early spring found flowering margins at least as good as grassy counterparts for insect over-wintering.

4). Though pest and parasitism rates varied between and within the project's four target crops, data supported that flowering margins played a role in pest suppression by promoting parasitoids and predators.

5). Higher yields were achieved near to flowering margins in a third of cases. No differences in yield were seen in year 1, supporting that optimal benefit can only be gained from mature, perennial-based margins.

Will any flowering seed mix do?

Though all flowering seed mixes may contain seed from a range of flowering plants, we do not believe that selecting your mix 'at random' from the many options available is the most cost-effective path to take. Here's why...

- 'Generalist' seed mixes do not always contain species that are best suited to agricultural settings. Picking the wrong mix may consequently result in disappointing establishment. The HortLINK mixes contains only seed that has proven itself to perform well when sown in agricultural soil.
- Most nectar and pollen mixes have been designed specifically with bees and butterflies in mind. These mixes do not always cater well for pest natural enemies, such as hoverflies and parasitoid wasps. HortLINK mixes are designed to be 'multi-functional' and include flowers to promote multiple beneficial insect groups and pollinators alike. This allows HortLINK mixes to make the most of the combined pollination and pest control potential that these groups can offer.
- 'Generalist' seed mixes often contain seed of flowering plants that could promote pests of certain crops. HortLINK mixes have been designed to minimise benefits to pests across the projects target crops, tipping the balance in favour of beneficial, not detrimental insects.

What's the best site and size for sowing?

In terms of site selection, flowering seed mixes are typically sown along field edges. Positioned in this way they may serve as buffer strips and add to existing barrier features, such as hedgerows, to create extended habitat for insects. Sowing flowering mixes as field margins will also ensure that beneficial insects using them are in close proximity to crop plants. However, flowering seed mixes are also useful for filling unused and unproductive areas, such as awkward field corners (see 'The IPM Approach'). For best establishment flowering mixes should be sown on nutrient poor soil wherever possible. Where this is not possible measures may be taken to reduce soil fertility (see 'Managing Margins'), limiting issues post-sowing, particularly with weeds.

In terms of optimal sizes for flowering margins, work still needs to be done to allow minimum effective sizes to be recommended. In many cases sizes will be dictated by existing field lengths and regulations governing minimum widths/areas (at least where margins are to be included as ES options). The HortLINK project has shown that benefits may be derived from flowering margins measuring a mere 65m in length, and being only 2m wide. These dimensions will almost certainly be exceeded when mixes are sown at industry scales, with increased benefits to beneficial insects expected as a result.

How do I manage a flowering margin?

Step 1: Site selection

It is generally accepted that wild-flower seed mixes perform best in nutrient-poor soil where they have a competitive advantage over undesirable weed species and grasses. As such, we recommend sowing your field margin on nutrient-poor soil for optimum results. Should you wish to sow on recently used agricultural soil, which is typically nutrient rich, measures to reduce soil fertility prior to sowing may be used. The most common of these is to sow a non-leguminous 'green manure' crop such as phacelia or buckwheat. This will grow quickly and as long as cuttings are removed after mowing soil fertility should be reduced with each 'sow and mow' cycle.

Step 2: Site clearance and weed control

For the purposes of the AFM project we recommend the 'stale seedbed technique' where possible. This involves preparing a seedbed by initially clearing your chosen area, for example by herbicide treatment or cultivation, and then allowing a flush of weed seed germination from the surface layers. This flush of weeds can then be killed-off by spraying (or cultivation) to produce a cleaned 'stale' seedbed - the surface of which should now have a reduced weed seed burden.

Step 3: Seed bed cultivation

Cultivate the soil to sufficient depth to bury any trash and to alleviate compaction. Next rake or harrow and roll the seedbed to produce a fairly fine, firm surface. The finished seedbed should be firm enough to walk on without leaving impressions.

Step 4: Seed sowing

Sow seed mixtures evenly onto the prepared soil surface by hand-broadcasting, seed fiddle, seed/fertilizer distributor, hydra-seeding or any other recommended method that suits. Bulking with an inert carrier such as sand, potting compost, sawdust or cornmeal may help achieve an even sowing. Hand-sown seed beds may benefit from being lightly raked post-sowing to better ensure even seed distribution, though care should be taken not to bury seed (see below). Seed can be drilled, but as most wild-flower seeds are very fine and cannot germinate if buried, drills must be set as shallow as possible and to a maximum depth of 7mm. Roll or tread after sowing, particularly in dry weather and with freshly worked loose soil. This will press the seed into contact with the soil and bring moisture to the surface, maximizing germination rates as a result.

It is generally recommended that seeds are sown in either autumn (August-Sept) or spring (March-April) for best results. Timing is dependent on the weather, however, where the over-riding aim is to sow when warm and moist conditions predominate, but remembering that some seeds, such as those of yellow rattle, require a period of cold weather to germinate (and are therefore likely to perform better if autumn sown). A sowing rate of 2-4g/m² is the norm for combined flower/grass field margin seed mixes.

Aftercare

The level of aftercare required will depend on conditions specific to each site, which will determine the flower establishment and grass growth characteristics of any margin. All margins will require management at some point, especially in their early years for perennial options. This is necessary to restrict grass growth and maintain a diverse sward. In the absence of grazing, mowing is the primary means of managing grasses (and some weeds). However, depending upon site conditions and other restrictions, gramicide application may also be considered.

For 'blanket mowing' we suggest that management is best avoided at times when margin flowers are likely to be in 'heavy' use by insects. Consequently, we recommend mowing in either late autumn or early spring, though winter mowing can also be effective. Depending upon site conditions, however, mowing may be needed more frequently to keep grasses at bay. This is especially true on high nutrient sites (which favour grass growth) and in the first year post-sowing for perennial margins (whilst perennials become established).

Where possible staggering mowing regimes (e.g. by only mowing sections of your margin at any one time) is a good way to ensure that floral resources for insect are always present, even where regular cutting is necessary. Staggered mowing has the added advantage of introducing structural variation in terms of sward height, which has been shown to benefit both beneficial invertebrates and some farmland birds. Where staggered mowing can be adopted, varying mowing times and introducing a summer cut can also be recommended and can be an effective way to maximize plant diversity and extend the working life of your margin.

Whatever your mowing regime, it is recommended that the sward is cut to around 10cm. Cuttings are best removed post-mowing to keep soil fertility down, especially where large quantities of clippings have been generated.

How do I choose the best seed mix for me?

The HortLINK project (HL0192)
The Defra funded HortLINK project 'Perennial field margins with combined agronomical and ecological benefits for vegetable rotation schemes' (HL0192) established a list of flowers that have been selected to provide a food source and habitat for pollinators/predators/parasitoids. The list excludes flowers that may provide a food source for the key pests associated with the four crops; cabbage, peas, carrots and wheat. The seed list is available on the following link http://www.ecostac.co.uk/seed_list.php

Automated Margin Design (FV334a)
HDC funded a small project (FV334a) which developed a database to identify lists of suitable flowers for brassicas, peas, carrots and potatoes. After a review of the literature, the database contains 109 species that are described using many criteria relating to the agronomy, benefit and general attributes of each species. To create an easy-to-use tool for growers, five criteria from the database were selected as most relevant. These relate directly to questions on the website:

- Lifespan (annual only or perennial)
- Provenance (to include naturalised non-native species or not)
- Soil type (clay, loam or sand)
- Cost of seed
- Pest associations (relating to the accompanying crop).

There is a welcome page, explaining the background behind the project and the rationale for the website and the top of the page has tabs relating to:
Home – returns the user to the welcome page
Establishment – contains notes on land preparation and margin establishment.
Management – contains notes on how best to manage the margin once established. Particularly relevant for mixes with perennial species included.
FAQ – contains 'frequently asked questions' relating to margins generally and this project more specifically.
Links – will contain links to appropriate seed producers and information on field margins. Also included will be links to the AHDB, HDC, STC and ecostac (FV334 – Hortlink project HL0192) websites.

The website is housed on the STC website:
http://www.stockbridgetechnology.co.uk/horticultural_research/technology_centre/find_us.php
and can also be accessed with the following link http://www.stockbridgetechnology.co.uk/Automated_Margins/ (password entomos).

This database is an initial design, it will need to be further developed as additional information becomes available, and as knowledge gaps, in the original databases sourced, become addressed.

EcoSTAC

Can margins fit within an integrated approach?

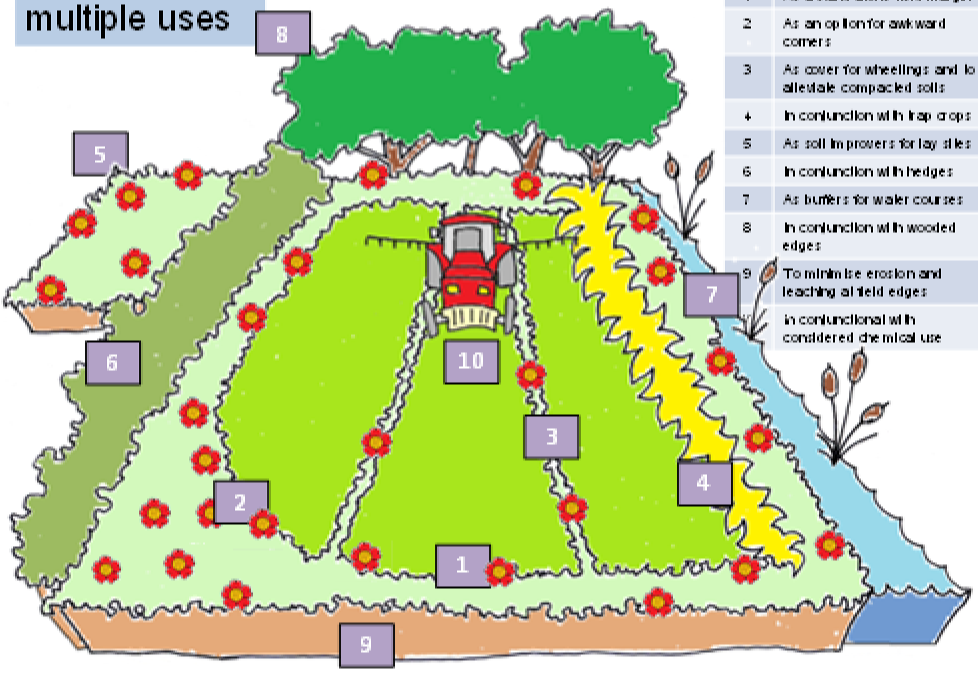
One of the most attractive features of flowering field margins is their compatibility within an IPM approach. Work on both the HortLINK and similar projects has shown that whilst flowering field margins can be employed as a 'stand-alone' option for boosting pollination and pest control (1), they can also be used alongside other techniques, and to serve a range of different purposes. This is especially true when considering potential benefits that can be derived by sowing seed mixes in other areas aside from field margins.

INTEGRATED MARGIN APPROACH: Flowering margins may be especially useful when combined with other perimeter features to provide extended habitat for the beneficial insects that use them. Such features include hedgerows (6) and wooded areas (8) that may be important over-wintering sites for pest predators and parasitoids. Combining flowering margins with border trap cropping (4) may improve the pest control efficacy of both techniques, bringing pests and their natural enemies into closer proximity to one another. Flowering margins can also be used as buffers to protect sensitive landscape features such as watercourses (7) or to minimise leaching and soil erosion from field edges (9), but with the added benefit of better provision for beneficial insects than standard cross-compliance strips.

BEYOND FIELD MARGINS: Floral mixes per se may be sown as cover for lay sites (5), potentially improving soils whilst boosting on-farm beneficial insects. They are also a good option for awkward corners (2) that might otherwise contribute little to farm productivity. Some scientists have also suggested that, if appropriate plants are used, flowering seed mixes could be sown as cover for wheelings to alleviate compaction whilst providing floral corridors into the crop for pollinators and pest natural enemies (3).

USE WITH AGRO-CHEMICALS: As long as products are selected and deployed in a considered manner, many should be compatible with a flowering field margin approach. A compatibility matrix of products and beneficial insects has been developed as part of the HortLINK project to help guide decisions on product use. This can be accessed at www.ecostac.co.uk

Floral mixes & multiple uses



No.	Floral mixes can be used...
1	As a stand alone field margin
2	As an option for awkward corners
3	As cover for wheelings and to alleviate compacted soils
4	In conjunction with trap crops
5	As soil improvers for lay sites
6	In conjunction with hedges
7	As buffers for water courses
8	In conjunction with wooded edges
9	To minimise erosion and leaching at field edges
	In conjunctional with considered chemical use

Plant spotter

PERENNIAL CORNFLOWER

PERENNIAL

OXEYE DAISY

PERENNIAL

RED CLOVER

PERENNIAL

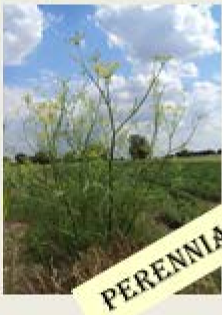
BIRDS FOOT TREFOIL

PERENNIAL

EcoSTAC

Plant spotter

FENNEL

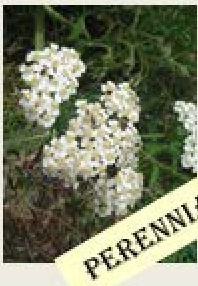


PERENNIAL

WHITE CLOVER

PERENNIAL

YARROW



PERENNIAL

BUSH VETCH

PERENNIAL

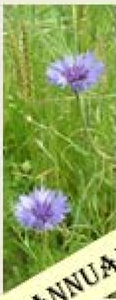
OVER-VIEW
PLANT/SITE SELECTION
MANAGING MARGINS
MARGIN MIXES
THE IPM APPROACH
PLANT SPOTTER
INSECT SPOTTER
FAQs

EcoSTAC

Plant spotter

ANNUAL CORNFLOWER





ANNUAL

BORAGE



ANNUAL

COMMON VETCH



ANNUAL

RED DEAD NETTLE



ANNUAL

EcoSTAC

Plant spotter

BUCKWHEAT

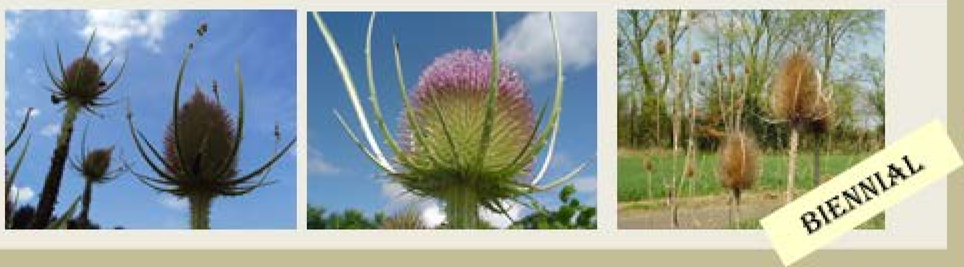
PHACELIA

BISHOP'S WEED

YELLOW RATTLE

VIPER'S BUGLOSS

TEASEL

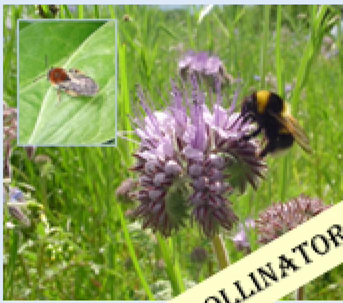


Insect spotter

BEES

Honeybees, bumblebees and solitary bees all provide pollination services, though they are not alone in doing so. Though there is only one species of honeybee in the UK, there are 24 species of bumblebee and more than 200 solitary bee species.

Images: Bumblebee (main); solitary bee (insert)



POLLINATORS

Hoverflies

Hoverflies also provide pollination benefits, requiring both nectar and pollen. The larvae of many species eagerly devour aphids making them a useful PNE (Pest Natural Enemy) . More than 250 species are present in the UK.

Images: Hoverfly resting on teasel

POLLINATORS & PNE

Parasitoid wasps

Parasitoid wasps are an extremely diverse group, with some 6,000 British species. Many are efficient PNEs, using crop pests as hosts for their young, and require floral resources for energy and reproduction. Selected species are commonly released in protected horticulture for biological control of aphids.

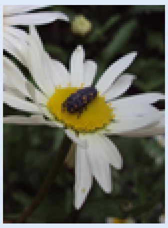
Images: Parasitoid wasp feeding upon a flower

PNE

Ladybirds

Most ladybirds are efficient pest predators as both adults and larvae. There are 46 species in Britain, though only around half are easily recognisable as ladybirds.

Images:7-spot larvae (left) and adult (right)



PNE

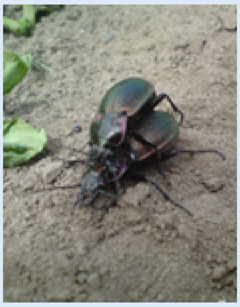
OVER-VIEW
PLANT/SITE SELECTION
MANAGING MARGINS
MARG MIXES
THE IPM APPROACH
PLANT SPOTTER
INSECT SPOTTER
FAQs

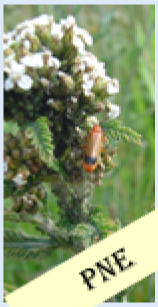
EcoSTAC

Insect spotter

Other predatory beetles

Numerous other species of beetle are, like ladybirds, generalist predators as adults and larvae. Species of particular benefit as PNEs include various ground beetles (Carabids), soldier beetles (Cantharids), and rove beetles (Staphylinids).

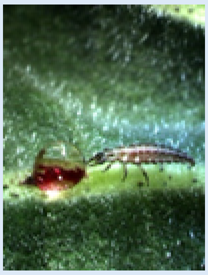


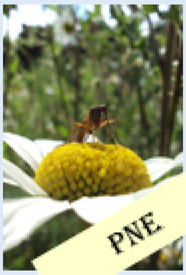


Images: Ground beetles (left); soldier beetle (right)

Other predator groups

A great many other species are also useful PNEs on account of their predatory nature. Classic examples include minute pirate bugs (hemipterans), lacewings (neuropterans) and predatory flies (dipterans)





Images: Lacewing larva (left); predatory fly (right)

Other pollinator groups

In addition to bees and hoverflies, pollination services are also provided by butterflies, moths and many other insect species. A number of these groups are also of significant conservation interest.

Images: Tortoiseshell butterfly feeding

Pest species

Many pests as well as PNEs will flower feed, and will do so from field margins if seed mixes are not carefully designed to exclude pest-friendly flower species.

Images: Cabbage white butterfly

OVER-VIEW
PLANT/SITE SELECTION
MANAGING MARGINS
MARGIN MIXES
THE IPM APPROACH
PLANT SPOTTER
INSECT SPOTTER
FAQs

Frequently Asked Questions

What's the benefit in sowing a flowering, rather than a grassy margin?
Though grassy margins can provide benefits to some insect groups, many insect pollinators and pest natural enemies require (or at least benefit greatly from) access to floral resources at some point in their life-cycle. Providing appropriate flowers in agricultural landscapes can greatly improve how well these beneficial insects perform to pollinate crops and manage pests. It follows that to get optimum returns from beneficial insects in terms of these 'ecosystem services', flowering margins are generally considered the best option.

What's wrong with a standard nectar/pollen mix?
In short, nothing at all. Most nectar and pollen mixes have been designed specifically with bees and butterflies in mind and they often do a very good job in promoting these insect groups. As different insects require different types of flowers, however, these mixes do not always cater well for pest natural enemies such as hoverflies and parasitoid wasps. Similarly, seed mixes designed specifically to promote biological control providers are not always beneficial for pollinators. A 'multi-functional' seed mix will take into account the needs of pollinators and pest natural enemies alike. By including flowers to promote multiple beneficial insect groups, a 'multi-functional' margin makes the most of the combined pollination and pest control potential these groups can offer.

Would a 'multi-functional' seed mix still count as an ES nectar mix option?
Indeed it would. Under current ELS the requirement for a nectar mixture (EF4, as of Jan 2013) is to sow at least four nectar-rich plants, with no one alone making up more than half the mix by weight. All of our recommended mixes comply with this requirement, though it's worth noting that to qualify for inclusion in ELS other criteria must also be met relating to margin size and management.

Is there any evidence that 'multi-functional' margins actually work to combine conservation and pest control benefits?
Tailoring field margin seed mixes to provide multiple benefits of pollination, conservation and pest control is a relatively new concept. Nevertheless, evidence is mounting to suggest that 'multi-functional' margins can and do work well. For further information we recommend a visit to the 'Ecostac' website which can be accessed through the links section.

What's the benefit to selecting a premium rather than a budget seed mix?
In general a premium mix will contain a greater range of flowering species. This will increase the chances of your margin establishing well, offering some insurance against factors such as bad weather post sowing and bad batches of seed for any given species. The increased diversity of seed in a premium mix is also more likely to promote a greater range of beneficial insects and the services they provide. Premium mixes are also more likely to offer extended and over-lapping flowering periods throughout the season to ensure that these beneficial insects stay well fed and optimally productive.

Can you guarantee establishment rates, and benefits such as reduced pesticide use and increased crop yield?
Unfortunately not. As establishment depends upon a number of factors outside of our control, such as seed quality, land preparation and weather conditions, we cannot guarantee establishment rates. However, by using our system to generate site-specific seed lists, the margin mixes we recommend should have the optimum potential to establish well. Unfortunately, we can't guarantee reduced pesticide use or increased crop yield either. Though the HortLINK project and related work in Europe have reported such benefits, biological systems and interactions can be highly variable between crops, sites and years. In the HortLINK project, for example, yield benefits were never recorded in carrots, and only recorded in some years in other crops.

Aren't flowering margins hard to establish and manage?
Given optimal weather conditions and a properly prepared site (see our section on establishment guidelines), flowering margins should establish well. Choosing a mix tailored for your site should increase establishment likelihood, though as noted in response to the previous question establishment can never be 100% guaranteed. Management will almost certainly be required to restrict grass growth (see our section on management). The degree of management needed will depend on factors such as site conditions, weather and land-preparation pre-sowing, though typically involves relatively straight-forward techniques such as mowing or gramicide application.

Where can I buy seed?
Stockbridge Technology Centre have been approved to supply seed to those wanting to purchase any of the HortLINK mixes. For those wanting to source non-HortLINK mixes, we recommend contacting a UK supplier.

Do I need to use only native or locally-produced seed?
There is some evidence to suggest that using seed of local provenance will help to maximize margin establishment (as this seed should be better suited to local conditions). However, it will not always be possible to source local seed and whilst there may be advantages to doing so, we do not consider it essential to ensure good margin establishment (especially as soil types can differ over small spatial scales and climate can differ on a single site from one year to the next). There are similar advantages to including only native flowers in seed mixes, where personal preference may also determine a 'native-only' option be selected. In order to provide us with the broadest possible range of beneficial flower species to choose from, we also include naturalized flower species and a selection of common introduced species when generating our suggested margin mixes. These have all been shown to perform well in the UK and are already present in our towns and countryside, some even being grown commercially as crops.

What if I can't source seed from all the species listed in my recommended mix?
Although all of the flower seed we recommend can be readily obtained from one or more of the suppliers in our links section, supply can vary according to demand and annual 'crop' yields for any given species. In cases where seed of a particular species is not available we recommend contacting your seed supplier. He/she should be able to advise on a suitable alternative species with similar characteristics (e.g. flowering period, flower type, establishment likelihood).

EcoSTAC