Project Title	Management and biology of flea beetle species and other key pests of leafy Brassica crops
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The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

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.

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Headline

Mesh covers, a coded product, bifenthrin and deltamethrin all reduced flea beetle damage significantly, although to different degrees. The coded product was particularly interesting, because it was effective at reducing damage caused by weevils, which the other spray and seed treatments were unable to prevent.

Background and expected deliverables

In a previous research strategy, growers identified the Brassica flea beetle complex as a research priority (HDC research strategy & Pesticide Gap Analysis, 2005), because adult flea beetle feeding causes 'shot-holes' in the leaves of the crop. This significantly reduces quality and thus marketability of Brassicas grown for salads. In addition to flea beetles, speciality salad and leafy vegetables are also attacked by a range of other insect pests such as diamondback moth caterpillars and weevils.

Brassica flea beetle control is a challenge, partly because some insecticides that were used in the past have been withdrawn and are no longer available to growers. The situation is made worse by the increase in rape acreage (source of immigrant pests) and because of reduced use of insecticide on rape. Several potentially useful insecticides such as spinosad (registered for Brassicas since the start of the project) and neonicotinoids, which could offer growers some additional choices to manage flea beetles are being evaluated within this project. It is also planned to assess the potential of some new experimental products, because there is a risk that the flea beetles will develop insecticide resistance, if growers are forced to rely only on a small number of active substances.

In addition to the use of insecticidal sprays, there are some other potentially useful pest management technologies. One possibility is the use of seed coated with a film of pesticide. Such seed treatments are already available for several fodder Brassica crops. Previous research on cabbage and cauliflower has shown that flea beetle damage could be reduced with imidacloprid. However imidacloprid was ineffective at controlling cabbage root fly and caterpillars. Previous research on spinosad was inconclusive and so additional work carried out on this project was required to clarify the situation.

Another potential non-chemical control tactic is the use of trap crops. This was investigated recently in the UK, but few practical recommendations of use to growers came out of this research (Parker et al., 2002). The main problem with using trap crops is that high-value leafy Brassicas are extremely attractive in their own right to Brassica-feeding flea beetles and so differences in attractiveness are probably minimal.

One well proven control technique is use of physical barriers, particularly meshes such as Wondermesh and Enviromesh, although some growers use fleece, plastic sheets or glass to protect this category of high value crops. Meshes protect crops against many insect pests, but are expensive and labour intensive to use. They are considered cost-effective, however, in situations where even low numbers of insects can quickly destroy the quality and value of the crop. Although highly effective, meshes alone may not be sufficient to completely prevent insect damage. Some pests can either feed through the mesh, their larvae may be small enough to pass through the mesh or enter the crop underneath the mesh at the edges. Additional insecticidal sprays are the normal practice to reduce this problem.

The project has several main lines of research. One aim is to investigate the potential for reducing reliance on mesh barriers, using them more cost-effectively, or using mesh impregnated with insecticide. The work carried out this year was aimed mainly at exploring whether or not seed treatments can play a useful role in the spectrum of control technologies. This management technique was considered to have potential, because it delivers the insecticide directly to the plant and should protect it during early growth when insect feeding can cause the greatest damage. The trial also assessed the efficacy of a new coded product as another important project aim is to identify additional insecticides that could potentially be useful in the future.

Summary of the project and main conclusions

The trials were carried out on a farm near Deal in Kent during June/July 2008. Nine treatments involving various combinations of seed treatments, meshes and/or sprayed insecticides and an untreated control were tested to assess ways to improve flea beetle protection on leafy Brassica crops. The main conclusions that can be drawn from the data collected this year are that:

- Flea beetle populations were atypically low and much of the damage was attributed to other pests including weevils.
- Meshes again proved highly effective at preventing damage from a range of pests.
- The new coded product, applied twice (eight days between treatments) was effective against the insect pest complex and weevils in particular.
- Seed treatments gave disappointing results, possibly because the rate of product applied was restricted to comply with the maximum area rate determined by PSD. Because the Tatsoi crop uses a very high seed rate, each seed received a relatively low level of treatment, possibly too low to exert the required systemic insecticidal effect.

Financial benefits

A cost-benefit analysis of the different treatments has not been carried out, but some are clearly highly effective at protecting the crop. One of the aims of the project is to try to identify control technologies that could dispense with the use of the mesh covers that the growers currently use to protect their crops. The coded product is of particular interest in this respect, because it appears to be highly effective against a wide range of insect pests and is able to prevent them causing damage.

Action points for growers

- As was the case in 2007, bifenthrin was effective at reducing damage by flea beetles and remains a possibility for registration for use on leafy Brassicas.
- The coded product showed considerable promise, as it reduced damage by a range of insect pests and weevils in particular. This is particularly important, because the other sprays and seed treatments had no apparent effect on damage caused by this pest. As flea beetle pressure was relatively low during the trial period this year, we suggest that further work next year on this product is merited, in order to give it a more rigorous test.

Science Section

Introduction

The Brassica flea beetle complex was identified as a priority researchable topic (HDC research strategy & Pesticide Gap Analysis, 2005). The increasing importance of these pests on Brassicas and, in particular speciality salad and leafy vegetables, may be related to reduced insecticide use on oil seed rape crops, which allows high populations to build up and subsequently emigrate from them. P*hyllotreta undulate*, *P. atra* and *P. diademata* are the main species in the flea beetle pest complex. Adult feeding causes 'shot holes' in the crop which significantly reduce quality and thus marketability. In addition to flea beetles, speciality salad and leafy vegetables are also attacked by a range of other insect pests including caterpillars such as the Diamondback moth (DBM), the cabbage stem weevil, *Ceutorhynchus pallidactylus*, Brassica weevil, *Ceutorhynchus assimilis* and the cabbage stem flea beetle, *Psylliodes chrysocephala*, which has become the most important establishment pest in autumn grown crops in the UK (Winfield, 1992; Walters *et al*., 2001). Control of these pests, particularly flea beetles, is an increasing challenge because some insecticides that were used in the past are no longer available to growers. However, several potentially useful insecticides such as alternative pyrethroids and neonicotinoids could offer growers some additional choices to manage these highly damaging pests. It is planned to assess the potential of some new unregistered products also, because there is risk of resistance developing if growers are forced to rely on the existing small number of active substances.

Some previous work with insecticides such as spinosad (recently registered for leafy Brassicas) and imidacloprid had given equivocal results. A report on field experiments with cabbage and cauliflower crops indicated that flea beetle damage could be reduced with imidacloprid, but that it was ineffective at controlling cabbage root fly and caterpillars. Use of seed treatments, commonly used for forage Brassicas was an interesting research line to clarify the potential usefulness of treated seeds for crops destined for consumption by people.

Another potential non-chemical control tactic was the use of trap crops, and this was recently investigated in the UK. Unfortunately, few practical recommendations came out of this research (Parker *et al*., 2002). One serious problem with using trap crops would be that high-value leafy Brassicas are extremely attractive in their own right to Brassica-feeding flea beetles and it is unlikely that there are plant species that are more attractive than the crops themselves. Research on Chinese cabbage as a trap crop grown in white cabbage showed no difference in the numbers of flea beetle adults or in the damage when the crop was grown either in monoculture or as a mixed crop (Trdan *et al*., 2005). Trap crops have several other drawbacks in that they utilise space and resources, may sometimes draw more pests into the area, and trap crops do not generally address the problems caused by other 'generalist' pests that attack the crop.

One widely used control technique with proven success is use of physical barriers that prevent the pest from having access to the crop. Growers use various types of barriers such as fleece, plastic sheets, glass or meshes. Of these, Wondermesh and Enviromesh are the most commonly ones deployed to protect high value crops. For the leafy vegetable (salad) crops, meshes protect against several insect pests and despite their significant capital cost (*c*. £400 for a 13 m width x 50 m length) and the high labour requirement to manipulate them during the season, they are currently considered necessary and cost-effective. The key reason for this is that they efficiently exclude a big percentage of potential pests and in these high value crops even a very low numbers of insects can destroy the quality of the crop.

Physical barriers alone are not always enough to protect from insect damage because some pests can get under the barrier, so additional sprays of insecticide may be needed. Insects get in at the edges of the mesh sheets or lay eggs on the mesh and the tiny newly hatched first instar larvae crawl through the mesh on to the crop, where they cause damage. Holes in the mesh caused by handling damage also allow pests to get underneath the mesh. When this happens the meshes prevent the departure of any pests that manage to reach the crop, so one can envisage that in some circumstances meshes could be counter productive unless combined with pesticides.

There is little published data available on flea beetles in the United Kingdom so information describing their patterns of emergence, movement and behaviour is sparse. Flea beetle pressure is not constant throughout the season and unpublished trap data for 2004 and 2005, provided by Intercrop Ltd, showed that there are two peak periods of adult flea beetle immigration into the crops in late May to early June, and August to September.

Research into odour-baited flea beetle traps has been carried out in Hungary and traps are commercially available. An improved population monitoring method for flea beetles would be of benefit to growers and so a number of the Hungarian flea beetle traps were purchased and their efficacy with the field trial flea beetle populations was assessed.

A prolonged wet period with consistently heavy rain occurred in May – early June and so the beginning of the trial was delayed until the 17th June 2008, when the crop was sown. It was therefore not possible to target the period in late May for the trial, when the first of the two peaks in flea beetle populations normally occurs.

Summary of the work and conclusions of 2007

The work in 2007 demonstrated that flea beetles were not emerging within the crop beds, but were immigrating into crops from nearby areas, many of which contained crops of oilseed rape. The flea beetle life cycles took six to eight weeks in the NRI insectary, with the majority of this time being spent as root feeding larvae in the soil. This is longer than the period over which most leafy Brassica crops are in the ground and because the ground is tilled between crops, carry over of pests from one crop to the next on the farm is highly improbable. The problem faced by leafy-Brassica growers, therefore, is clearly one that is generated by an immigrant flea beetle population.

The year 1 trial proved that meshes protect the crops from most damage caused by insect pests to a highly significant extent and also increased crop growth – beds protected by insecticide-impregnated and normal mesh both produced higher yields, independent of pest damage. Minor insect damage did occur under meshes, either because early instar DBM larvae migrated through the mesh or because of immigration underneath the edges. Meshes also protected crops from damage caused by birds and small mammals to such an extent that in year 2, it was decided that the whole trial should be covered in a coarse hail and pigeon-proof netting from the first day.

An encouraging finding was that several insecticides provided significant protection even when the crop was not covered by mesh. The two most promising were bifenthrin and spinosad and the latter has since been registered for use on these crops.

Materials and Methods

The activities carried out this year included, (i) prioritisation of experimental treatments in consultation with HDC and industry stakeholders, (ii) obtaining product samples from manufacturers for application in sprays and seed treatments, (iii) liaising with a specialist company to have batches of seeds treated with three different systemic insecticides, (iv) obtaining experimental approval and a licence from the PSD for the 2008 products, (v) conducting a field trial with nine different treatments including insecticidal seed treatments, spray-applied insecticides and meshes (with and without additional spray treatments), (vi) identification of the causes of other damage types in the crop, (vii) assessing the efficacy of the Hungarian flea beetle traps and (viii) visits to other leafy-salad producers.

Experimental field trial

Choice of experimental treatments and obtaining samples from manufacturers

In consultation with HDC personnel and the Intercrop farm staff, several insecticides that were considered to be potentially useful against flea beetles were obtained from agrochemical companies. One was a coded development product that has not yet been registered in the United Kingdom. Others were products registered for use in other crops (not including leafy salads) or for other uses (i.e., seed treatment). All fulfilled the criteria of being active against Coleopteran species and/or flea beetles specifically. For the field trial in this second year, the registered products Tracer (spinosad), Talstar (bifenthrin) and the current standard Decis Protech (deltamethrin) were applied as sprays, as was the coded product (designated NRI1 in the report). In addition to the spray-based treatments, three seed treatments were prepared, which were Thiamethoxam (from Syngenta), imidacloprid (from Bayer) and acetamaprid (from Certis). Each treatment and the control plots were replicated three times.

Compliance with statutory regulations

In order to carry out field trial in the United Kingdom, it is necessary to comply with criteria laid down by the Pesticides Safety Directorate. An Administrative Experimental Approval for Research and Development Work was obtained for the products used in 2008. The personnel that carried out the trial had obtained certification (PA1 and PA6) in application of pesticides in accordance with the regulations on use of experimental pesticides.

Experimental crop and timing

Tatsoi, variety ‘Tozer’, was used as the trial crop, because it is highly attractive to flea beetles and they can cause damage that reduces the value significantly, even at low levels of infestation. Historical data, confirmed by our experience in 2007, showed that flea beetle pressure is not constant throughout the season and that there are two peak periods of the adult flea beetle populations that occur in late May to early June and in August-September. It was therefore planned to start the field trial using a crop sown at the beginning of June to target the first attack peak. However May and early June were atypically wet so sowing had to be delayed and the trial crop was sown on 17th June in 2008.

Field trial treatments

The nine treatments of the field trial are described below and the product details and rates applied are summarised in Table 1 and described below.

1. Untreated control plots (control type 1 - no insecticides were applied or meshes used to cover plots, apart from the bird-proof netting).
2. Wondermesh on it own (control type 2 - the plots were covered with Wondermesh immediately after sowing. The edges of the mesh in this treatment were buried under soil at the ends and pinned along the inter-bed furrows to prevent insect movement into or out from underneath the mesh. No insecticides were used on this treatment).
3. Deltamethrin on its own (control type 3 - Bayer Decis Protech. Plots were sprayed using the same timing and product [deltamethrin] as that used by the farm agronomist for the rest of the crop. The rate and dates when crop was sprayed appear in Tables 1 and 2).
4. Spinosad (Dow Tracer 480 SC) & Wondermesh. The plots were covered with Wondermesh immediately after sowing. The edges of the mesh in this treatment were buried under soil at the ends and pinned along the inter-bed furrows to prevent insect movement into or out from underneath the mesh. Insecticide sprays were applied at the same timing as the standard treatment (3).
5. Bifenthrin on its own (Belchim Talstar Flo 80). The plots were sprayed with bifenthrin using the same timing as the standard treatment.
6. Coded product on its own (NRI 1). The plots were sprayed with NRI1 after 4 days then a second spray was applied after 12 days.
7. Seed treatment Thiamethoxam (Syngenta). No sprays or mesh apart from the bird-proof netting.

8. Seed treatment Imidacloprid (Bayer). No sprays or mesh apart from the bird-proof netting.
9. Seed treatment Acetamaprid (Certis). No sprays or mesh apart from the bird-proof netting.

Table 1 The experimental insecticide rates for trial plots in 2008 season.

Product and recommended dose rate	**Quantity (units) per plot**	**Quantity (units) for three plots**	**Quantity allowing for dead spray in tank**
Volume of spray	***400 (ml)***	***1200 (ml)***	***1600 (ml)***
Spinosad **Tracer** 480 g/l Use at 250 ml/ha	0.25 (ml)	0.75 (ml)	1.0 (ml)
Bifenthrin **Talstar** 80g/l use at 90 ml/ha	0.09 (ml)	0.27 (ml)	0.36 (ml)
Deltamethrin **Decis** Protech 1.5% Farm rate is 420ml/ha	0.42 (ml)	1.26 (ml)	1.68 (ml)
Coded product (1000ml/ha)	1.00 (ml)	3.00 (ml)	4.00 (ml)
Thiamethoxam 100g/ha	(3.8g on 700g of seed)		
Imidacloprid 125g/ha	(4.7g on 700g of seed)		
Acetamaprid 100g/ha	(3.8g on 700g of seed)		

Notes: The rate of product or active ingredient in column 1 was that recommended by the manufacturing company. For all sprays the volume rate was 400 litres per hectare, as used on the farm. The total spray liquid (right column) allows for the approximately 400 ml of liquid that remains in the sprayer when it has finished spraying. The last three rows are seed treatments specially applied before drilling by Elsom Seeds Ltd at a rate based on the area seeding rate (9m/ha) and the upper permitted area dose rate.

Table 2. The timing of the trial and spray activities during the 2008 season.

Date	Assessment of crop for damage and pest presence	Spay treatments applied
Day 1 (17th June 2008) Crop sown (17th June) Tatsoi Meshes applied Plots irrigated Propachlor herbicide applied to all plots	No	No
Day 2 bird netting applied)	No	No
Day 8 (24th June 2008)	Yes (observational)	Yes
Day 11 (27th June 2008)	Yes	Yes
Day 15 (1st July 2008)	No	Yes
Day 19 (5th July 2008)	Yes	Yes
Day 24 (10th July 2008)	Yes	No

Simulation of the current farm spray regime

Sprayers used on farm are fitted with flat Lurmark Drift-beta nozzles in front of flat fan nozzles. Both apply spray simultaneously at a total rate of 400 litres per Ha. For the experimental spray treatments, compression sprayers (Hozelock 5 litre Killaspray) were used to apply the sprays including the spray treatment that simulated the standard farm practice for the application of deltamethrin (treatment 3). The volume for experimental spray plots required to mimic the farm application rate was calculated as: 400 * 10/10000 litres = 0.4 litres per plot. Prior to treatments, 1600 ml of spray liquid had been put in the sprayer, each of which had been set to give a flow rate of 400 ml per minute. This was achieved by pumping around 50 times (the number required was written on the sprayer – there was slight variation between sprayers). Although only 1200 ml (400 ml x 3) was needed for the trial, dead volume in the sprayer (spray liquid remaining after the spray became intermittent) meant that an additional 400 ml was required in the container (making a total of 1600 ml of spray liquid for each treatment).

Spray protocol to ensure a precise insecticide dose

Compression sprayers are pumped up before use. In this case, around 50 compressions (pumped 50 times) gave the desired flow rate for treating a plot. Each sprayer varied slightly so the number of compressions was marked on individual sprayers to achieve the exact output. When liquid is emptied from the reservoir during spraying, the pressure falls and the flow rate is reduced. Laboratory tests prior to the fieldwork had showed that this would have reduced the dose applied to the second plot. To compensate for the fall in pressure after one minute of spraying (spraying a single plot), the sprayer needed to have 7 additional pumps before the next minute of spraying (one plot) to reinstate the original pressure. After the second plot had been sprayed another 7 pumps were needed. In this way the same flow rate of 400 ml per minute and spray quality was retained for all three replicates.

The trial land

The trial was carried out on the Intercrop farm in fields at Bramble Hill (Grid ref. from GPS: N 51o 14’ 21.8’’ E 001o 18’ 47.1’’) on land kindly provided by Intercrop (Figures 3 and 4). Three separate beds (experimental blocks) each contained all nine treatments. The experimental area also included an untreated guard strip at each end of the layout. An un-sprayed area of crop separated the plots along each row.

Figure 3. Layout of the trial with growing crop. Photo taken on 11th July.

Figure 4. Layout of trial plots. The trial was surrounded by an unsprayed row of guard crop to provide a buffer between it and the surrounding commercial crops, which were sprayed regularly with insecticide. ST denotes seed treatment. Other products applied as spray.

Applying the spray

When treating the plots, the operator sprayed from the side of the plot to avoid walking on the bed. The spraying operation was rehearsed several times with water to practice achieving an even coverage at the required volume rate. The compression sprayers (one for each chemical) had been set to give 400ml/min flow rate before the trial, so each plot had to be sprayed for 60 seconds. To help pace the operator, ten second intervals were called out by a colleague.

The plots required small quantities of the three supplied pesticide formulations so these quantities of formulated product (Table 1) were measured by weight on a four figure balance. All samples were pre-prepared and held in sealed, labelled glass bottles before use.

Mesh-based treatments

The farm's standard treatment involves mesh placed over the beds with weighted bags used to hold down the edges and the ends. The hole size of this mesh is approximately 0.6 mm. Farm mesh is used in 13 m x 50m strips. The 13 m width can cover five beds.

To simulate this practice, the mesh used in the experimental plots was pinned down with tent pegs along the sides of the bed and covered with soil at the ends of the plots. The ends were covered with soil, because it was considered that there would be much more opportunity for insect entry at these points and, if left open, the plots would underestimate the efficacy of the standard farm practice.

Assessment of crop damage and observations of insects

The crop in individual plots was inspected and assessed quantitatively for presence of insects and for damage to the leaves. Twenty plants in each plot were selected randomly for assessment. To select individual plants for assessment a die was thrown while looking away from the plot, i.e. 'blind' into the plot and the nearest plant to the die was assessed. If two or more plants appeared to be equidistant from the die, the plant which faced either the facet with two spots or one spot was assessed. The number of points of damage were counted and recorded. Care was taken to avoid confusing marks caused by soil splash with damage caused by flea beetles or other pests. Holes per plant were counted and recorded after examining every leaf of the selected plant. In the final assessment an attempt was made to separate flea beetle damage from the tiny perforations caused by a pest whose identity was at that time unknown, and the counts for the different types of damage were kept separate.

Flea beetle population monitoring

Insect pests are commonly captured on a glue-covered surfaces referred to as a sticky traps to monitor abundance. There are other mechanisms to trap them for monitoring numbers, including water traps in which a little surfactant is added, and odour-baited traps (figures 5, 6 and 7). Yellow is known to be attractive to a wide range of insects, but some species are attracted more strongly to blue. Both these colours of water trap were tried. Observations were made on the numbers and species of trapped insect.

Figs 5 and 6 The yellow and blue water traps

Figure 7. The Hungarian odour-baited trap for flea beetle species.

Results and Discussion

Cause of damage in 2008

In the early period of the trial, very few flea beetles were observed and the population was noticeably lower than in 2007. Indeed, during observations a week after sowing and ten days after sowing, no flea beetles were seen on the plots. Some pollen beetles were noted, many Diptera (fly) species and various hymenoptera (bees and wasps), bumble bees and predatory beetles. Later, by around day 14, flea beetles were seen, but not in the high numbers observed during 2007. From this time onwards in the trial, diamond back moths and weevils were also seen on the crop, together with significant numbers of predatory species including ladybird larvae and hoverfly adults.

In terms of leaf damage, three distinct types were observed:

1. the typical holing resulting from flea beetle bites;
2. windowing, i.e., a single epidermis removed by early instar diamond back moth larvae that makes the leaf translucent - followed later by holes in the leaf;
3. clusters of very small leaf holes, scrapes and indentations, which we later established were caused by weevils (figure 8 - 10 below).

Figure 8 Clusters of weevil feeding damage on Tatsoi leaves from the field trial.

Figure 9. Similar feeding damage caused by weevils maintained on tatsoi plants in the insectary at NRI.

Figure 10. Weevil adult maintained on tatsoi plants in the NRI insectary.

Two types of disease damage were observed in the plots. The first and most obvious was a mosaic virus, which affected about 1% of plants, causing yellowing and mottling of leaves. The second, possibly blight, caused a watery effect (figure 11 below) between leaf veins and was more easily seen on the lower surface.

Figure 11. The watery patches observed on some leaves.

Field trial results

Early damage assessment on 05/07/08

Towards the end of the trial, an initial assessment of damage was carried out, which combined the various damage types. As in the previous year's work, the Wondermesh covered treatments suffered the lowest amount of damage. Bifenthrin and the coded product were able to reduce damage substantially, but deltamethrin and the three seed treatments all had damage levels equivalent to the unprotected control plots (Figure 12).

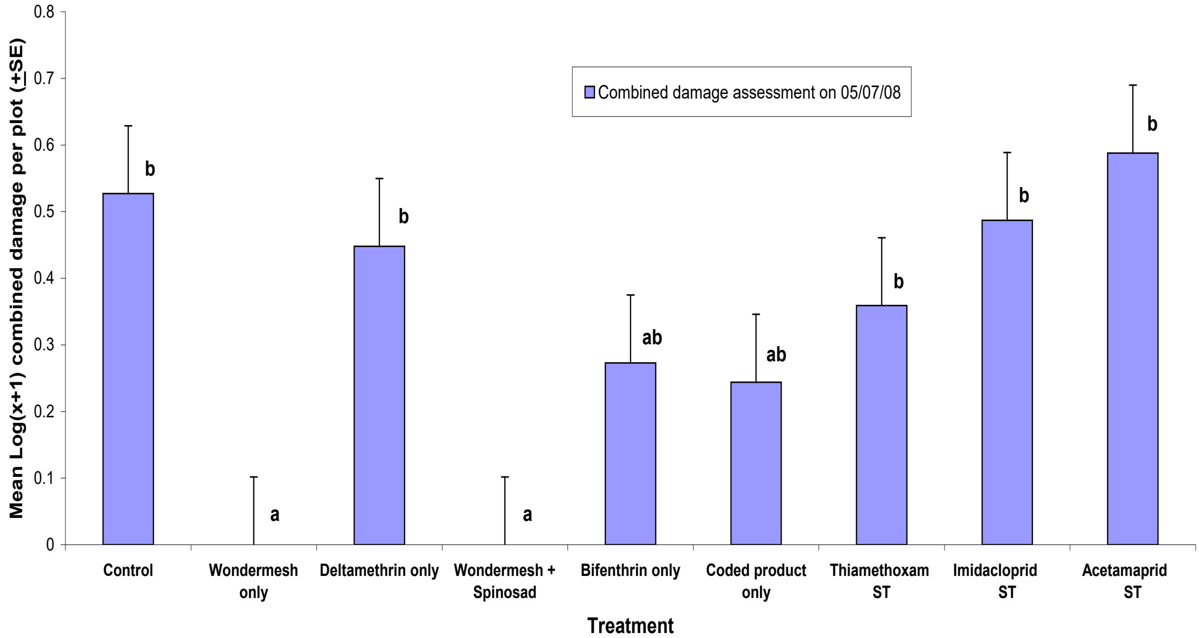

Figure 12. The combined damage assessment carried out towards the end of the crop on 05/07/08. Damage data were collected by counting the number of holes of all types in 20 randomly selected plants per plot, which were then $Log_{10}(x+1)$ transformed and a mean calculated per plot. ANOVA was carried out on plot means followed by Tukey's pairwise comparisons at the $P < 0.05$ significance level. Means with the same adjacent letters are not significantly different. Error bars are standard errors of differences of means.

Final damage assessment on 10/07/08

Damage assessments were also carried out on the crop immediately prior to harvest. On this occasion, the data for the damage attributable to the different insect pests was collected separately. The results showed that the plots covered by Wondermesh experienced the least weevil damage. The coded product provided the best control of weevils, whereas the sprayed insecticide or seed treatments experienced similar damage levels to the unprotected control plots (Figure 13).

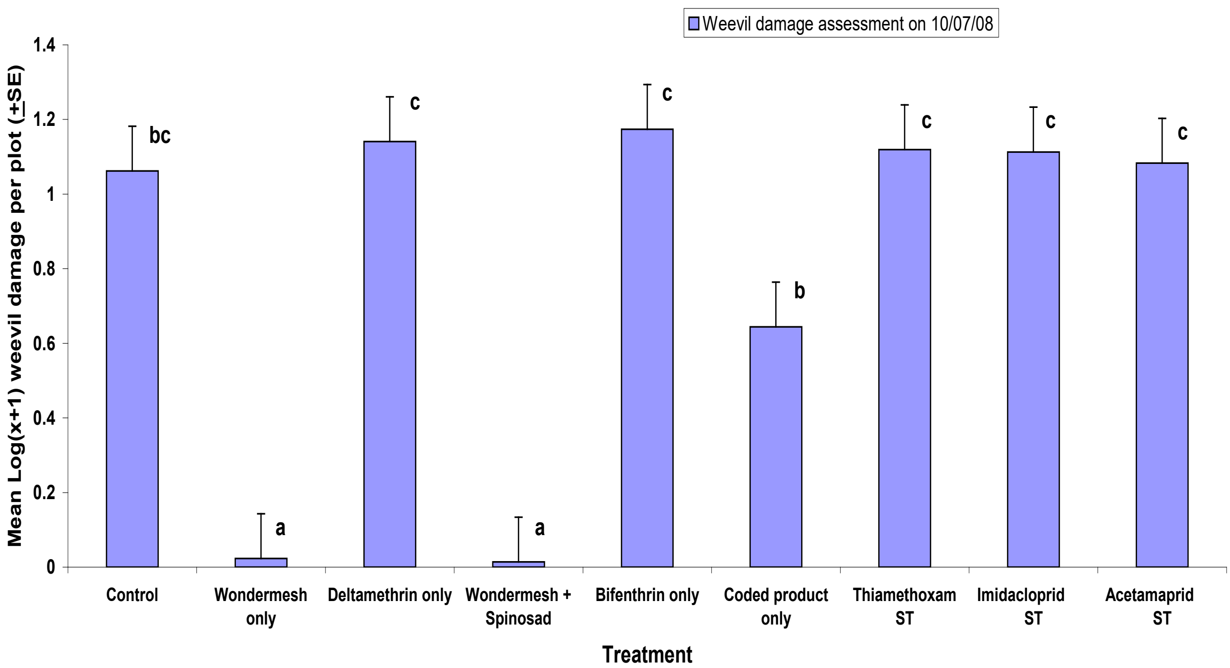

Figure 13. The damage caused by weevils as measured on 10th July, 24 days after sowing. The scores were the number of the small, clustered indentations/holes, mainly in the lower surface of the leaves present on 20 randomly selected plants per plot. Data were $Log_{10}(x+1)$ transformed and a mean calculated per plot. ANOVA was carried out on plot means followed by Tukey's pairwise comparisons at the $P < 0.05$ significance level. Means with the same adjacent letters are not significantly different. Error bars are standard errors of differences of means.

The Wondermesh treatments also provided the best control against DBM larvae and although the difference was not significant, the additional application of spinosad reduced damage still further. The sprayed products and the seed treatments reduced DBM damage considerably in comparison to the control plots (Figure 14).

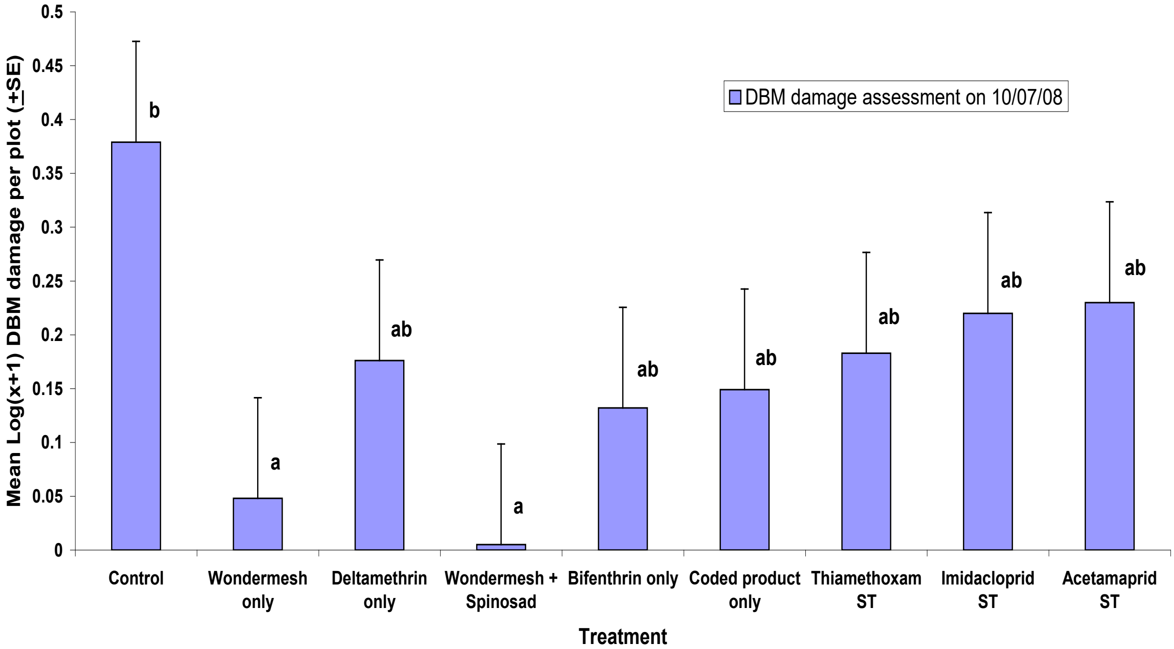

Figure 14. Damage caused by diamond back moth, measured on 10th July. The scores are the number of windowed areas or irregular holes in 20 randomly selected plants per plot. Data were were $Log_{10}(x+1)$ transformed and a mean calculated per plot. ANOVA was carried out on plot means followed by Tukey's pairwise comparisons at the $P < 0.05$ significance level. Means with the same adjacent letters are not significantly different. Error bars are standard errors of differences of means.

Although the flea beetle population was low at the beginning of the trial, in comparison to 2007, significant differences were still apparent between treatments. As with the other types of pest damage, the mesh covered treatments provided the best protection. Deltamethrin, bifenthrin and the coded product provided significant levels of control. Of the three seed treatments, Thiamethoxam provided the best protection against flea beetles (Figure 15).

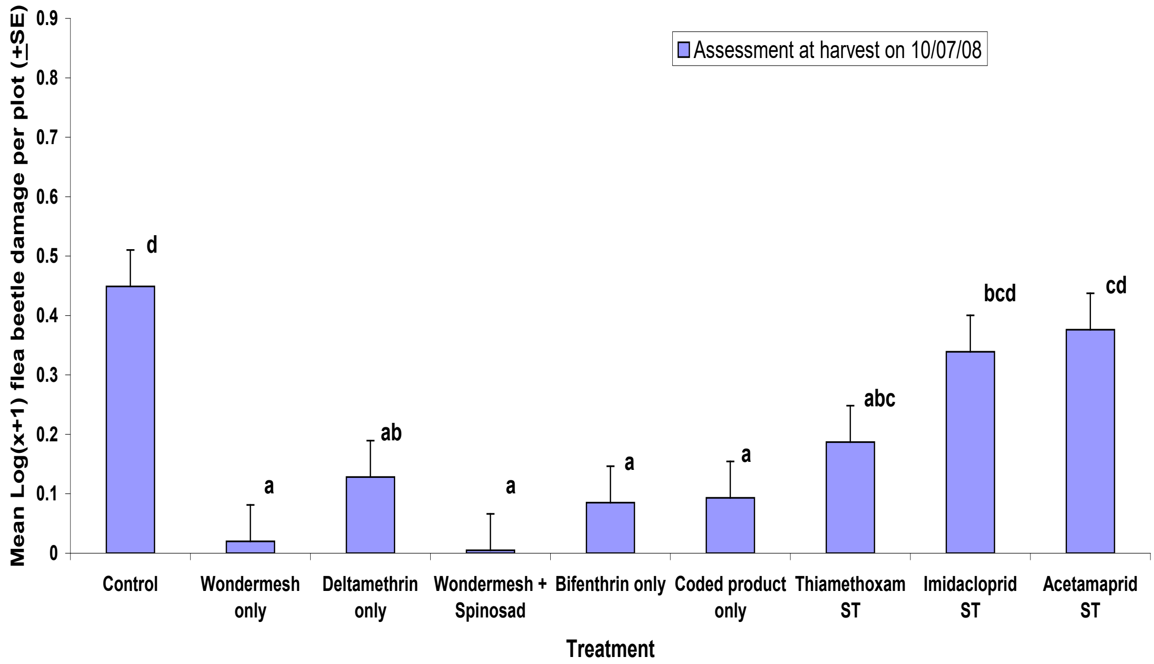

Figure 15. Damage caused by flea beetles as measured on 10th July. Damage data were collected by counting the number of 'shot' holes in 20 randomly selected plants per plot, which were $Log_{10}(x+1)$ transformed and a mean calculated per plot. ANOVA was carried out on plot means followed by Tukey's pairwise comparisons at the $P < 0.05$ significance level. Means with the same adjacent letters are not significantly different. Error bars are standard errors of differences of means.

The data from the second damage assessment were then pooled to gain an indication of the overall efficacy of the different treatments. The mesh-covered treatments provided the best control and the addition of spinosad as a spray reduced damage further. Of the spray treatments, the coded product preformed the best and this was due to its activity against weevils as well as the other pests (see figure 16). The damage levels suffered by the deltamethrin, bifenthrin and the three seed treatments were all similar to the unprotected plots.

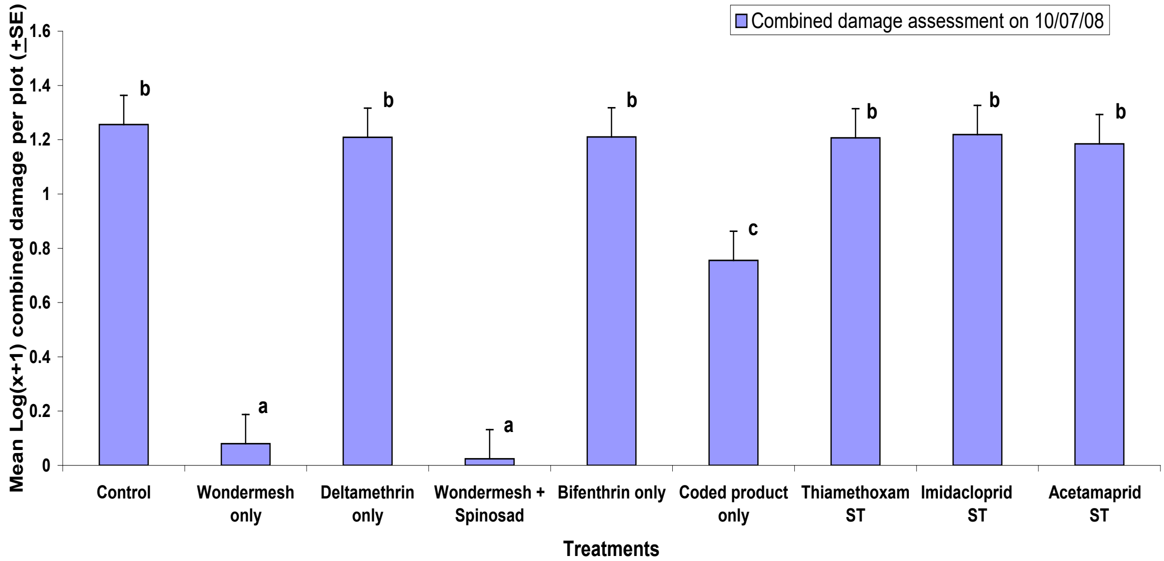

Figure 16. Total damage caused by flea beetles, diamond back moth and weevils. Damage data were the sum of the three damage types on 20 randomly selected plants per plot. Data were $Log_{10}(x+1)$ transformed and a mean calculated per plot. ANOVA was carried out on plot means followed by Tukey's pairwise comparisons at the $P < 0.05$ significance level. Means with the same adjacent letters are not significantly different. Error bars are standard errors of differences of means.

As was the case for 2007, the mesh-covered treatments provided the best control. Spinosad sprays increased the degree of control to some extent by reducing damage cause by DBM larvae. While the quality of the harvested crop was better when sprayed with spinosad, the difference my not be great enough to warrant the cost.

Of the spray treatments, the coded product performed the best and this was due to its activity against weevils as well as the other pests. The weevils appeared in particularly high numbers towards the end of the trial and so the coded product was presumably still have been active during this period. Bifenthrin generally performed better than deltamethrin, although higher number of replicates in the trial would be necessary to ensure that this is a real effect. The performance of bifenthrin this year, however, is consistent with last year's data confirms the potential usefulness of this product for leafy Brassica insect-pest control.

It has been suggested that relatively low flea beetle populations during 2008 season were related to the preponderance of wheat in fields surrounding the trial site, whereas in more typical years a much greater proportion of these fields would contain crops that are good flea beetle hosts, such as oilseed rape. If a relationship between nearby crops and flea beetle abundance could be established it may be possible to reduce control operations aimed at flea beetles when non-host crops predominate in the region on and around the farm. An efficient population monitoring tool would therefore be desirable, but the Hungarian odour-baited trap unfortunately proved ineffective at sampling the flea beetle population (see below).

Yield assessment

As was the case for the 2007 yield data, the mesh covered treatments gave the best yields. In the previous year, the maximum yield obtained was approximately 135 g per sample. The maximum yields this year, however, were several-fold higher and were approximately 455 g per sample. It is probable that this can be attributed to the much higher rainfall and wetter ground conditions experienced this year. The lowest yield was obtained from the imidacloprid seed treatment and it is possible that the treatment my have reduced plant growth or seed survival (figure 17).

Samples from each of the treatments are being maintained in a -80°C freezer for residue analysis, if required.

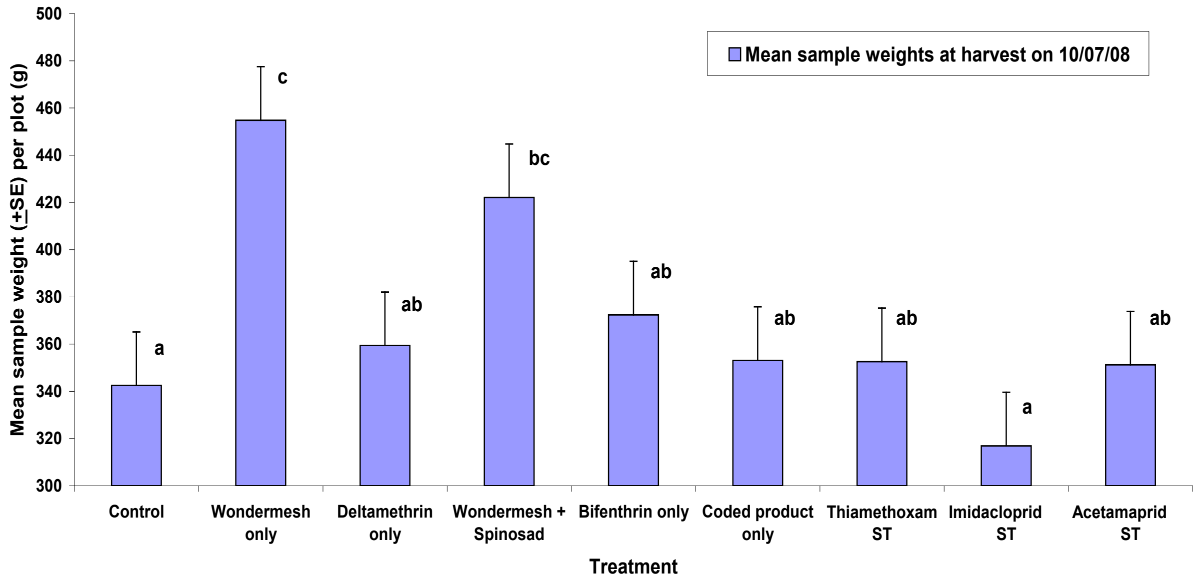

Figure 17 The scores are the weight of three samples harvested from each of the three plots per treatment. Quadrats of 0.1 m^2, made from wire were thrown on to the plot and all material down to soil level within the quadrat was harvested. ANOVA was carried out on plot means followed by Tukey's pairwise comparisons at the $P < 0.05$ significance level. Means with the same adjacent letters are not significantly different. Error bars are standard errors of differences of means.

Sampling results

The population of flea beetles was low throughout the trial period and this may have been due to several factors. The most important were probably the crop switch to cereals that was evident in the surrounding farms combined with high rainfall. Fields that had produced rape in 2007 were sown with wheat and barley in the current year. The higher rainfall may have increased mortality in the flea beetle population.

Water traps

Due to the low numbers of flea beetles, accurate data were not collected from the water traps. The yellow coloured traps, however, caught more flea beetles than the blue traps. The blue traps were much more effective at catching Diptera.

Hungarian odour-baited traps

This trap type was not effective at catching the flea beetle species present on Intercrop farm this year. Even at the end of the trial, when flea beetle numbers were highest, the traps only caught a very few flea beetles. It is not known why the traps were so ineffective and this could be the subject of further research.

Conclusions

The conclusions from the second year of work are:

1. Flea beetle damage was atypically low. The crop switch that occurred this year resulting in the absence of nearby oilseed rape crops probably accounts for this.

2. For a second year, meshes protected the crops from most damage caused by insect pests to a highly significant extent.

3. A significant proportion of the damage observed on the crop this year was caused by weevils and diamondback moth, against which the coded product was highly effective.

Technology transfer

The performance of the meshes was impressive and no other treatment, so far, has proved as effective against the pest complex.

Seed treatments gave disappointing results, possibly because the rate of product applied was restricted because PDS imposes a ceiling area rate. The tatsoi crop uses a very high seed rate and so each seed received a relatively low level of treatment, possibly too low to exert the required systemic insecticidal effect.

Although not immediately ready for transfer, the coded product appears to offer promise as a control agent for several pests, including flea beetle and weevils. It is intended to follow up this up with further work on this product in the 2009 field season.

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