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Authentication

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

Signature .....

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PRACTICAL SECTION FOR GROWERS

Commercial benefits of the project

The project has:

- Identified that the addition of sugars can improve the efficacy of certain pesticides and help to reduce current dependence on limited availability of active ingredients for thrips control.
- Determined and illustrated the possible phytotoxic effects resulting from the use of inappropriate sugar mixtures, high sugar concentrations or from frequent applications.
- Determined that the addition of sugar with pesticides is permissible under current legislation as advised by the PSD (see attached memo).

Background and objectives

Western Flower Thrips (WFT), *Frankliniella occidentalis*, remains the most economically damaging pest of protected flower crops such as chrysanthemums. In crops where biological control programmes are not yet effective, control has relied on two organophosphate (OP) insecticides, malathion and dichlorvos, one of which (dichlorvos) has been recently withdrawn from use. A novel active ingredient, spinosad (as Conserve), has recently become available for thrips control on ornamentals in the UK. Other chemicals such as abamectin and deltamethrin can be used but they tend to be less effective. There is some evidence that the addition of sugars improves the efficacy of certain insecticides but there are no clear guidelines for growers. Therefore there is a need to produce recommendations on the use of 'sugar' products to improve the control of WFT on flower crops and reduce the reliance on individual products.

Objective
The overall commercial objective of this project was to determine the efficacy of sugar products in combination with pesticides in controlling WFT and to provide growers with recommendations on the use of sugar products to improve the control of WFT on flower crops.

Summary of results and conclusions

1. Evaluation of the effect of sugar mixtures on plant quality

The effect on plant quality arising from spray applications of sugar mixtures was determined in a glasshouse trial in August 2000 under high light conditions using pot chrysanthemum cv. 'Crystal Time'. The occurrence of spotting, stickiness and the development of sooty moulds were examined for different sugar treatments. The incidence of these three quality-affecting criteria were assessed for applications of three sugar products (brown sugar, white sugar and Eradicoat) at four concentrations (0·5, 1, 2 & 4%, wt/vol). Six repeated sprays of each concentration were applied at three-day intervals and compared to control sprays using only water. The results are summarised as follows:

- ***Flower spotting*** - Spotting of the flowers is potentially the most important detrimental effect on plant quality (Figure 1). More spotting occurred on treated flowers than on the water sprayed controls but no differences were observed between the sugar products. Flower damage increased with both sugar concentration (above 1%) and repeated sprays. Petal spotting showed earliest with brown sugar, which occurred after the fourth spray was done. Both white sugar and Eradicoat showed an increase in spotting after six sprays.
- ***Leaf spotting*** – Sprays with sugar products resulted in some spotting of the leaves, irrespective of the type of sugar used, the concentration applied or the number of sprays done in up to six applications.
- ***Leaf stickiness*** –Sticky residues resulting from sprays of sugar products were evident on the leaves of treated plants (Figure 2) but they occurred infrequently. Although stickiness was recorded in 58% of the samples only 1 in 6 had more than 10% of the leaves affected. No differences were observed between the different sugar products or between sprays of different sugar concentrations.
- ***Sooty mould*** – Development of sooty moulds on the leaves was observed infrequently with any of the treatments. There were no differences between the products but increasing sugar concentration above 1% resulted in increased incidence of sooty mould.
- ***Saprophytic fungi after 16 days incubation*** - Following sprays with 1% sugar solutions there were differences between all the treatments in the number of colonies of sooty mould that developed on leaves after they were incubated for 16 days. The highest numbers of colonies were found with Eradicoat, followed by white and brown sugar respectively. A similar pattern was observed for the amount of leaf area covered by sooty mould.

Figure 1. Flower spotting after spraying with brown sugar (1% wt/vol), detail of flower from chrysanthemum cv.'Chisel' (a) and detail of ray floret from cv. 'Surf' (b).

(a) **(b)**

Figure 2. Residue 24 h after spraying with 1% white sugar on leaf (a) and bract (b) of chrysanthemum cv. Swingtime.

(a) **(b)**

2. Laboratory evaluation of best sugar-pesticide combination for glasshouse trial

The number of thrips killed by Decis and Dynamec, used either alone or in combination with sugars (white sugar or Eradicoat), added at a range of concentrations (0·5%, 1% & 2%, wt/vol), was compared with full control (sugars only) treatments. Twenty one different treatments were compared (using 2,100 thrips larvae) to select the most promising sugar-pesticide combination for evaluation in a glasshouse trial. The results are summarised as follows:

- More thrips were killed with Dynamec than with Decis.
- No significant kill of thrips was obtained with either sugar product or with Decis when used alone.
- A similar pattern of increased kill of thrips was shown when both Eradicoat or white sugar were combined with pesticides.
- Increasing the concentration of either white sugar or Eradicoat increased the number of thrips killed by both Decis and Dynamec.
- A combination of 1% white sugar (wt/vol) and Dynamec was selected for evaluation in a glasshouse trial (2% sugar affected plant quality and white sugar is a more easily available product).

3. Laboratory evaluation of combining sugars with the fungal pathogen *Beauveria bassiana*.

A bioassay was done to investigate the effects of combining white sugar (1% wt/vol) with two proprietary products (Naturalis-L and BotaniGard-WP) that contain spores of the fungal pathogen *Beauveria bassiana*. The results are summarised as follows:

- No differences in the kill or infection of thrips were observed by adding sugars to Naturalis and BotaniGard but low levels of infection were obtained overall.
- An electron microscope study revealed that the low infection rate might be due to problems with the adhesion of fungal spores to thrips but more work is needed on this topic.

4. Glasshouse efficacy trial with Dynamec and sugar.

The most promising pesticide-sugar combination identified in the laboratory screening was Dynamec + 1% white sugar. Sprays of this combination were compared with three control treatments (Dynamec alone, 1% white sugar and a water spray) against western flower thrips on pot grown chrysanthemum (cv 'Swingtime'). To evaluate the consistency of the results, each treatment was repeated six times in two glasshouse trials during the summer 2001. The numbers of thrips (alive and dead) were recorded three days after the sprays were applied.

The results are summarised as follows:

- Treatment effects were consistent across all six replicates in the two trials.
- The number of dead thrips revealed a highly statistically significant difference, with twice as many thrips found dead with Dynamec+sugar (1% wt/vol) than with Dynamec alone.

Action points for growers

- Adding sugar or Eradicoat should increase the efficacy of certain pesticides in controlling western flower thrips (WFT). In these trials, the addition of 1% (w/v) white sugar to abamectin (as Dynamec) doubled the kill of WFT.
- Use of sugar concentrations of 1% (wt/vol) should not cause phytotoxic damage if used prior to flower opening, by which time it is essential to have achieved adequate control of WFT in order to avoid damage to the flowers. It is recommended that white sugar be used in preference to brown sugar as it is less likely to cause quality problems.
- Exercise caution and test for adverse effects on plant quality prior to using sugar additives with any pesticide and reduce the sugar concentration, if necessary.

Practical and financial benefits from the study

The immediate benefits of the project will be:

- To offer the potential of improving the control of thrips using existing pesticides without the need for additional registration.
- Description of possible phytotoxic effects arising from adding sugar to spray treatments.

Other benefits will be:

- Increased reliability in the control of WFT in protected ornamental crops and consequent improvement in the competitiveness of UK industry.
- Broaden the current reliance on just two products, the OP malathion and the novel active ingredient spinosad, for the control of WFT.
- Reduction in the use of broad spectrum pesticides, which will permit greater use of effective biological control agents in the control of thrips and other pests, such as aphids and leafminer.

Copy of statement from PSD concerning the use of sugars with pesticides:

From: Inform (PSD) (Information Section)
[information@psd.defra.gsi.gov.uk]
Sent: 08 April 2002 15:05
To: 'Michael.DeCourcyWilliams@hri.ac.uk'
Subject: using sugar with pesticides

Dear Michael,

Thank you for your e-mail sent to PSD on 3 April 2002, requesting information on whether the use of sugar with a pesticide would be classed as an adjuvant.

My colleague in the Pesticides Registration and Enforcement Policy Branch has provided the following response to your enquiry. In schedule 3, 5 (5) of the Control of Pesticide Regulations (as amended) 1986, there is a paragraph relating to adjuvants, which is relevant to this enquiry. In this paragraph 'adjuvant' means a substance other than water, without significant pesticidal properties, which enhances or is intended to enhance the effectiveness of a pesticide when it is added to that pesticide.

Schedule 3 is available on the PSD website at the following link,
http://www.pesticides.gov.uk/applicant/registration_guides/applicant_handbook/section-a/a3_app_2_consents%20copr.pdf

From the information that you have given us it would appear that the sugar is acting in the following ways. The sugar on the plant either encourages the thrips to make contact with the pesticide or the thrips eat the sugar and they take in more insecticide. Neither of these uses are enhancing the pesticide, they are attracting the target species. The sugar itself does not have any pesticidal claims, and therefore is not acting as an adjuvant or as a pesticide.

I hope that this information is useful. Please contact me again if you have any further questions.

Regards,

Rosemary Mitchell.

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SCIENCE SECTION

INTRODUCTION

Background

Western Flower Thrips (WFT) remains the most economically damaging pest of protected flower crops such as chrysanthemums. Control has relied mainly on the OP insecticides, dichlorvos (e.g. Luxan Dichlorvos 600) and malathion (Malathion 60). However, from April 2002 the sale of products containing dichlorvos have been suspended following the advice of the Advisory Committee on Pesticides (ACP). The safe storage and use of aerosol, most slow release controllable and non-controllable products can continue until approval is revoked on 15 April 2005. A novel active ingredient derived from soil bacteria has been commercialised as spinosad (Conserve) (Bylemans & Schoonejans, 2000) for use against thrips and is available in the UK for use on ornamentals from April 2002. Other chemicals are available to growers, but these provide relatively poor control, partially because of resistance and partially because WFT hide inside flowers and growing points, which makes them difficult to control with contact insecticides. If growers could improve the efficacy of products such as Decis (deltamethrin) and Dynamec (abamectin), they could be used in rotation with more effective chemicals in order to reduce the reliance on key insecticides and thereby manage resistance. Improved efficacy will be essential for WFT control until some of the newer, more effective, insecticides are registered or other biocontrol measures are perfected.

Since the 1980s, a number of workers have demonstrated improved chemical control of WFT by combining chemicals with sugar (Robb *et al,*1988; Heungens, 1990; Heungens & Butaye, 1996; Parrella, 1996; Kahn & Morse, 1997). It is not known whether these work by attracting WFT out of flowers onto leaf surfaces, by sticking the insecticide onto the pests or by increasing the uptake through feeding. Growers have tried different sugar products with varying results but do not have clear guidelines for use, cost-benefit analyses or knowledge of potential problems. Specific problems might include increased disease incidence, stickiness, phytotoxicity or the attraction of ants. ‘Sugar’ products may also increase the reproduction rate of WFT, and possibly counter-act the benefits of improved control (Sabelis & van Rijn 1997). In the longer term, growers are looking for an integrated pest management approach to WFT control. It is possible that the use of ‘sugar’ products will improve the efficacy of biological control agents by attracting WFT onto leaf surfaces making them more vulnerable to predator attack or by providing a food source for the natural enemies. The Pesticides Safety Directorate (PSD) policy branch has stated that the mixing of sugars with insecticides is not illegal because sugars are not classed as adjuvants, in this use.

Commercial objective

The commercial objective of this project was to determine the efficacy of sugar products in combination with pesticides in controlling WFT and to provide growers with recommendations on the use of sugar products to improve the control of WFT on flower crops.

The specific objectives of the project were to:

1. Evaluate the ease of use and effect on plant quality of spray mixes using standard label recommended rates of Decis (deltamethrin) and Dynamec (abamectin) with:
   - White sugar
   - Brown sugar
   - Eradicoat (glucose polymer / starch – supplied by BCP Ltd.).

2. Determine the efficacy of the best sugar product and concentration when combined with Decis and with Dynamec in a laboratory bioassay.

3. Evaluate the potential of combining sugar products with the entomopathogenic fungus *Beauveria bassiana,* using the products Naturalis and BotaniGard.

4. Evaluate the efficacy of the best sugar – pesticide combination in a glasshouse trial during the summer.

5. Produce a grower fact sheet.

PART 1. THE EASE OF USE AND EFFECT ON PLANT QUALITY OF SUGAR AND ERADICOAT MIXTURES

Introduction

Since the 1980s, when it was demonstrated that improved chemical control of WFT might be achieved by combining chemicals with sugar, growers have not had clear guidelines for the use of sugars or knowledge of potential problems that may arise. Specific problems might include increased disease incidence, stickiness, phytotoxicity or the attraction of ants. An initial priority of this project was to determine the possible effects on plant quality of sugar type, sugar concentration and frequency of application.

Objective

To determine the effects on plant quality arising from residues (spotting & stickiness) and the development sooty mould when sugar and Eradicoat (glucose polymer) are applied at different concentrations and frequencies.

Materials and methods

Treatments: 78 treatments including: three sugar products, four concentrations (% wt/vol) and water treated controls by six applications.

Products:

Brown sugar (0·5%)	White sugar (0·5%)	Eradicoat (0·5%)
Brown sugar (1%)	White sugar (1%)	Eradicoat (1%)
Brown sugar (2%)	White sugar (2%)	Eradicoat (2%)
Brown sugar (4%)	White sugar (4%)	Eradicoat (4%)
Water treated control		

Application: Each product concentration was applied on six different occasions with each application separated by an interval of three days.

Experimental design:

Pot chrysanthemums (cv 'Crystal Time') were used as test plants. Batches of six plants for each product concentration were arranged in a randomised split plot design. Two plants (one from each plot) were sampled for every product/concentration combination at each of the six applications. The experiment was done in mid-August during high light levels.

Assessments:

1. Five leaves from each plant were selected at random and were assessed for:
    - 1.1 Number of brown spots.
    - 1.2 Presence or absence of shininess or stickiness (expressed as a proportion of total leaf sample).

1.3 Presence or absence of sooty mould (expressed as a percent of total leaf sample).

2. Five flowers (the oldest in an inflorescence) from each plant were selected at random and were assessed for the percent of petals with brown spotting.

3. On day 16, two leaves from each plant in the 1% concentration category were removed and placed on damp filter paper in a Petri dish. After seven days the number of saprophytic fungal colonies were counted and the percent leaf area colonised by fungi were estimated.

Statistical analysis:

An analysis of variance was done to test for significant differences between treatments. Prior to analysis the data were subjected to the following transformations: square root transformation for the count data, a logit transformation for the proportional data and an angular transformation for the percent data. Least significant differences (LSD) quoted are for the 95% probability level.

Results and discussion

1.1 Brown spots on leaves

Significantly ($P < 0{\cdot}05$) more brown spots were observed on the leaves of plants treated with sugar based products compared to the water treated control (Table 1). However, no significant differences were found between the sugar and Eradicoat treatments (Table 1). No significant differences in the number of brown spots were detected for the applications of different product concentrations (Table 2) or number of applications, up to six consecutive sprays at three-day intervals (Table 3).

Table 1. The mean (square root transformed) number of brown spots observed on leaves (n = 240) with applications of different sugar products.

	Treatment product			
	Control	**Brown sugar**	**White sugar**	**Eradicoat**
Number of spots (square root)	2·5	3·4	3·8	3·4

LSD = 0·99, 14 df to compare control with treatments and
0·88, 14 df to compare between treatments.

Table 2. The mean (square root transformed) number of brown spots observed on leaves (n = 60) for different product concentrations (% wt/vol).

Sugar product	Treatment concentration			
	0·5%	**1%**	**2%**	**4%**
Brown sugar	3·4	4·0	3·4	2·9
White sugar	2·9	3·7	3·7	4·8
Eradicoat	3·4	3·5	3·8	2·9
mean	3·2	3·7	3·6	3·5

LSD = 1·63, 14 df.

Table 3. The mean (square root transformed) number of brown spots observed on leaves (n = 40) with increasing number of spray applications.

Spray	Number of sprays					
	1	**2**	**3**	**4**	**5**	**6**
Control	2·4	2·2	2·9	2·6	2·4	2·5
Brown sugar	3·2	4·1	3·2	3·2	3·7	3·1
White sugar	3·5	4·6	3·7	4·0	3·2	3·6
Eradicoat	3·2	3·1	3·6	3·3	3·8	3·6

LSD = 0·57, 75 df.

1.2 Stickiness of leaves

Residues from applications of sugar products were evident on the leaves of treated plants (Figure 1). Accumulations of these sugar deposits lead initially to leaf stickiness and subsequently to the development of sooty moulds, following repeated applications over time (see section 1.3, below). The data from the repeated applications were combined prior to ANOVA in order to avoid means of zero because the incidence of leaf stickiness was low. No significant differences were observed in the proportion of leaves showing stickiness between the different sugar product treatments (Table 4) or between the different concentrations applied for each sugar product (Table 5).

Table 4. The mean (logit transformed) proportion of leaves (n = 240) showing stickiness with applications of different sugar products.

	Treatment product			
	Control	**Brown sugar**	**White sugar**	**Eradicoat**
Stickiness (logit)	-5·71	-4·71	-4·04	-3·54

LSD = 2.052, 14 df to compare control with treatments and
1.657, 14 df to compare between treatments

Table 5. The mean (logit transformed) proportion of leaves (n = 240) showing stickiness for applications of different sugar product concentrations (% wt/vol).

	Treatment concentration				
	0	**0·5%**	**1%**	**2%**	**4%**
Stickiness (logit)	-5·71	-4·90	-3·58	-4·08	-3·84

LSD = 2.163, 14 df to compare control with treatments and
1.934, 14 df to compare between treatments

1.3 Sooty mould on leaves

Development of sooty moulds on the leaves was scored infrequently across all the treatments. Therefore, to avoid means of zero, the data were totalled over all the consecutive spray applications prior to ANOVA. No significant differences in the proportion of leaves showing the development of sooty moulds were detected between the treatment products (Table 6). However, significantly ($P < 0{\cdot}05$) more sooty mould was observed with applications of the higher concentrations (Table 7). A regression analysis showed that there was a dose relationship where both the linear and quadratic terms were significant (Figure 3).

Table 6. The mean (logit transformed) proportion of leaves (n = 240) with sooty mould for applications of different sugar products.

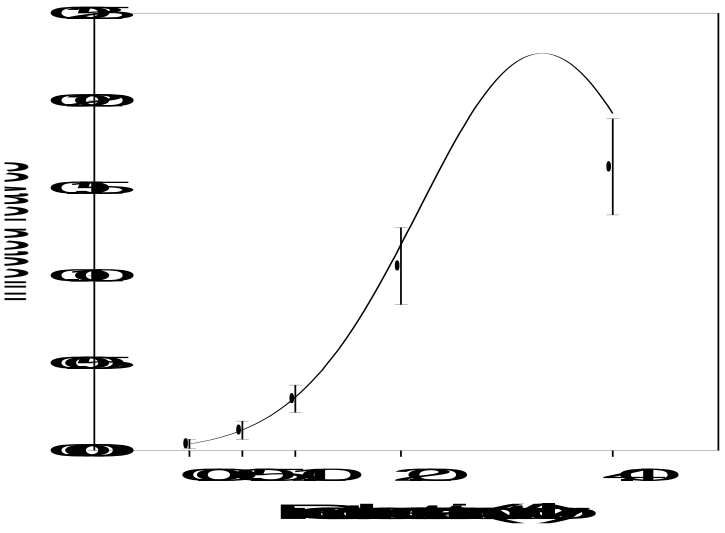
	Treatment product			
	Control	**Brown sugar**	**White sugar**	**Eradicoat**
Sooty mould (logit)	-5·10	-3·75	-3·43	-3·26
d.f.	4	8	8	8

LSD = 1.951, 14 df to compare control with treatments and
1.593, 14 df to compare between treatments

Table 7. The mean (logit transformed) proportion of leaves (n = 240) with sooty mould for applications of different sugar product concentrations. (% wt/vol).

	Treatment concentration				
	0	**0·5%**	**1%**	**2%**	**4%**
Sooty mould (logit)	-5·58	-4·45	-3·49	-2·14	-1·64
Standard error	0.732	0.458	0.275	0.234	0.202

Figure 3. The mean proportion of leaves with sooty mould from applications of different sugar product concentrations with fitted regression ($y = 5.583 + 2.46\ x - 0.369\ x^2$). Error bars are standard errors.



2. Brown spots on flowers

Spotting of the flowers is potentially the most important detrimental affect on plant quality (Figure 2). Significantly ($P < 0{\cdot}001$) more spotting on the petals was observed for the flowers treated with sugar products than for the water treated controls (Table 8). There was no significant difference between the product treatments (Table 8). However, there was a significant ($P < 0{\cdot}01$) effect of increasing sugar concentration on the percent of flowers showing damage (Table 9). For each product there was a significant ($P < 0{\cdot}001$) increase in the percent of flowers showing spotting with increasing spray applications (Table 10) and some significant ($P < 0{\cdot}01$) differences between the sugar treated and the water treated control at the different concentrations. Brown sugar was the first to show an increase in petal spotting (Figure 2) and this

occurred after the fourth spray was done. Both white sugar and Eradicoat showed a significant increase in spotting after six spray applications.

Table 8. The mean (angular transformed) percent of flowers (n = 240) with brown spots for applications of different sugar products.

	Treatment product			
	Control	**Brown sugar**	**White sugar**	**Eradicoat**
Percent with spots	3·9	9·2	8·7	7·9

LSD = 1·66, 14 df to compare control with treatments and
1·36, 14 df to compare between treatments.

Table 9. The mean (angular transformed) percent of flowers (n = 240) with brown spots for applications of different sugar product concentrations.

	Treatment concentration				
	0	**0·5%**	**1%**	**2%**	**4%**
Percent with spots	3·9	7·4	7·5	9·8	9·8

LSD = 1·75, 14 df to compare control with treatments and
1·57, 14 df to compare between treatments

Table 10. The mean (angular transformed) percent of flowers (n = 40) with brown spots with increasing number of spray applications.

Sugar product	Number of sprays					
	1	**2**	**3**	**4**	**5**	**6**
Control	3·0	4·8	4·2	3·6	4·2	3·7
Brown sugar	6·7	7·6	7·5	10·2	12·5	11·0
White sugar	6·7	7·1	7·8	8·7	9·5	12·6
Eradicoat	6·6	5·5	7·1	8·3	9·2	11·0
Mean	5·8	6 ·3	6·7	7·7	8·9	9·6

LSD = 1·16, 75 df to compare between the mean number of sprays,
2·86, 78 df to compare control with treatments and
2·34, 78 df to compare between treatments.

3. Saprophytic fungi after 16 days

As reported in section 1.3 above, the numbers of colonies of sooty mould were rare so the data from repeated applications were combined prior to ANOVA of both the number of colonies and percent of leaf area covered. No differences were observed in the number of sooty mould colonies found on the incubated leaves with different number of spray applications. However, there were significant ($P < 0{\cdot}001$) differences in the number of colonies of sooty mould observed between the all the treatments (Table 11). The largest number of colonies was observed with the Eradicoat treatment followed, in decreasing order, by white and brown sugar (Table 11).

No differences were observed in the leaf area covered by sooty mould on the incubated leaves with different number of spray applications. As before, there were significant ($P < 0{\cdot}05$) differences between treatments (Table 12). Eradicoat showed the highest proportion of the leaf area covered by sooty mould but here there was no significant difference between the white and brown sugar treatments.

The overall incidence of sooty mould was low and it was concluded that if both white sugar and Eradicoat showed equal efficacy white sugar would be preferred because of the lower incidence of sooty mould with this product.

Table 11. The mean (square root transformed) number of colonies of sooty mould on leaves (n = 12) treated with different sugar products.

	Treatment product			
	Control	**Brown sugar**	**White sugar**	**Eradicoat**
Number of colonies (square root)	0·08	0·34	0·64	1·33

LSD = 0·492, 23 df.

Table 12. The mean (angular transformed) percent of leaf area covered by sooty mould with different sugar products (n = 12 leaves).

	Treatment product			
	Control	**Brown sugar**	**White sugar**	**Eradicoat**
Percent of leaf covered (angular)	0·3	2·2	1·8	3·6

LSD = 2.29, 23 df.

Conclusions

- Sugar solutions can cause browning, sooty mould and stickiness (see Figures 1 & 2).
- Flowers are more susceptible to damage than leaves.
- Problems increase with:
    - Sugar concentration
    - Number of treatments.

There were small differences between treatments:

- Brown sugar caused more spotting on the petals than did the other two treatments.
- More sooty mould occurred on the leaves with the Eradicoat treatment than with the other two treatments.
- Applications of 2% and 4% sugar solutions resulted in more sooty mould on leaves than with the use lower sugar concentrations. Sugar solutions of 2% and 4% are not recommended for use.
- White sugar and Eradicoat are recommended for testing in the laboratory assessment using concentrations of 0·5%, 1% and 2%. The 2% concentration is included for a comparison of efficacy but should not be recommended to growers because of the increased problems with sooty mould and overall quality.
- Growers should not use sugars repeatedly, as phytotoxicity problems will increase.

PART 2. THE EFFICACY OF SUGAR AND ERADICOAT AT DIFFERENT CONCENTRATIONS IN A LABORATORY BIOASSAY

Introduction

Two sugar products, white sugar and Eradicoat (a glucose polymer) were identified from section one for testing simultaneously under identical conditions in a replicated bioassay. The result of the bioassay would be used to determine which product and sugar combination would be carried forward for further evaluation in a subsequent glasshouse trial.

Objective

To determine the efficacy of different concentrations of white sugar and Eradicoat in combination with standard rates of Decis (deltamethrin) and Dynamec (abamectin) for the control of thrips prior to a glasshouse evaluation.

Materials and methods

Treatments: Twenty one treatments, including two pesticides, two sugar products, three sugar concentrations, and full controls including water treated control:

Dynamec + white sugar (0·5%)	Dynamec + Eradicoat (0·5%)
Dynamec + white sugar (1%)	Dynamec + Eradicoat (1%)
Dynamec + white sugar (2%)	Dynamec + Eradicoat (2%)
Decis + white sugar (0·5%)	Decis + Eradicoat (0·5%)
Decis + white sugar (1%)	Decis + Eradicoat (1%)
Decis + white sugar (2%)	Decis + Eradicoat (2%)
White sugar (0·5%) control	Eradicoat (0·5%) control
White sugar (1%) control	Eradicoat (1%) control
White sugar (2%) control	Eradicoat (2%) control
Decis control	Dynamec control
Water treated control	

(percent = wt/vol)

Standard rates: Dynamec (abamectin, 18 g/l active ingredient): 0.5mls/litre
Decis (deltamethrin, 25 g/l active ingredient): 0.7mls/litre

Application: A Potter tower was used to apply 2 ml of each treatment solution to the target arena, comprising a 9 cm Petri dish. The spray pressure was 34·5 kPa and provided a mean volume of 0.00271 ml/cm^2 to the target to ensure complete coverage of the leaf with droplets.

Experimental design:
One full replicate was done every time an assay was run, until ten replicates of each treatment were completed.

Procedure: An excised chrysanthemum (*Dendranthema* cv. 'Swingtime') leaf was cut to provide a flat surface area of approximately 6 cm^2. The leaf was placed on cotton wool dampened with water in a 9 cm Petri dish. A fine dusting of pollen (castor oil plant, *Ricinus communis* L.) was added to the centre of the leaf as additional food to ensure that the thrips larvae remained in place. Ten early second instar thrips larvae were placed onto the centre of the leaf with a fine paintbrush and the leaf was then sprayed. Following treatment application in the Potter tower, the leaf was immediately removed from the cotton wool and anchored on the surface of a water filled, 9 cm Petri dish. The water provided a barrier to retain the thrips on the treated leaf surface. The Petri dish was covered with a ventilated lid and incubated at 20°C and 16L:8D photoperiod for 24 hours. Following incubation, the leaf was examined under a dissecting microscope and the numbers of living and dead thrips on the leaf were recorded.

Statistical analysis:

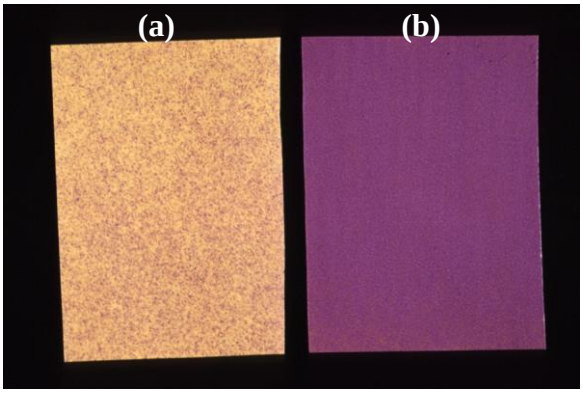
An analysis of variance was done to test for significant differences between treatments. The data analysed were angular transformations of the percent dead thrips recorded per treatment replicate.

Results and Discussion

Spray coverage

The use of water sensitive paper confirmed that complete coverage of the target leaf containing the thrips larvae was obtained when 2 ml of solution were applied through the Potter tower (Figure 4).

Figure 4 Water sensitive paper showing coverage of target area with 1ml (a) and 2ml (b) of solution applied through a Potter tower at 5lb/$inch^{-2}$.



Thrips mortality

The number of thrips killed and the number surviving all the individual treatments across the ten replicates are given in Table 13. Escapes of individual thrips during the transfer of sprayed leaves often resulted in fewer than 10 individuals per replicate. The mean percent of thrips killed from the ANOVA are shown in Figure 5. Almost no kill of thrips was obtained with either sugar product or with Decis when these were applied alone. There was a highly significant ($P < 0{\cdot}001$) effect of treatment over the water treated control and the percent kill of thrips was significantly ($P < 0{\cdot}001$) greater for Dynamec than for Decis (Figure 5). The higher activity of Dynamec over Decis was true irrespective of sugar additive.

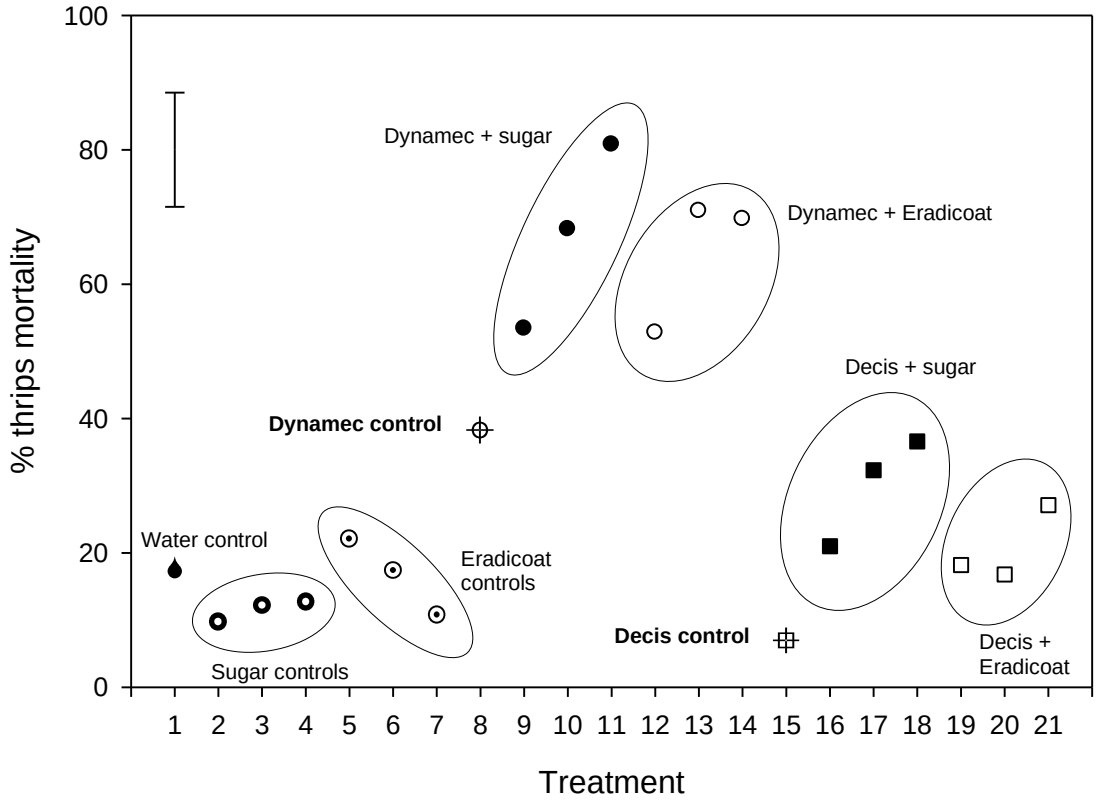
A similar pattern of increased kill of thrips was shown when either sugar was combined with both pesticide products. No significant difference in effect was observed between sugar and Eradicoat at any of the concentration levels. However, increasing concentration of both white sugar and Eradicoat significantly ($P < 0{\cdot}05$) increased the percent kill of thrips for both Dynamec and Decis (Figure 5). This effect was significantly greater ($P < 0{\cdot}05$) with Dynamec than with Decis (Figure 5).

The Dynamec + sugar 1% (wt/vol) combination was prioritised for further evaluation in the glasshouse trial. A higher sugar concentration lead to an increased risk of detrimental effects on plant quality (Part 1) and white sugar is more easily available than Eradicoat.

Table 13 Numbers of alive (A) and dead (D) thrips recovered 24 h after being sprayed with different treatments.

Treatment	Rep 1		Rep 2		Rep 3		Rep 4		Rep 5		Rep 6		Rep 7		Rep 8		Rep 9		Rep 10		Total	
	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
Water	9	1	7	1	7	0	8	0	10	0	5	1	9	0	9	0	6	1	9	0	**79**	**4**
Decis	4	0	5	4	7	0	6	0	8	2	10	0	7	0	10	0	10	0	10	0	**77**	**6**
Dynamec	7	3	6	2	5	5	9	1	8	1	2	4	2	2	7	3	3	7	5	5	**54**	**33**
0·5% sugar	1	1	9	1	4	0	7	3	7	0	7	0	3	0	10	0	8	0	9	0	**65**	**5**
1% sugar	5	1	8	0	7	0	9	0	5	3	10	0	7	3	10	0	9	0	8	2	**78**	**9**
2% sugar	6	4	2	0	9	1	9	0	8	0	7	1	10	0	9	0	10	0	4	5	**74**	**11**
0·5% Eradicote	3	1	7	2	2	2	7	1	10	0	8	1	6	2	10	0	8	1	7	2	**68**	**12**
1% Eradicote	7	0	3	2	6	1	4	2	9	1	10	0	7	1	10	0	10	0	5	3	**71**	**10**
2% Eradicote	3	1	9	0	6	0	8	0	7	1	10	0	2	5	10	0	6	0	8	0	**69**	**7**
Decis+0·5% sugar	3	4	5	1	6	1	6	0	6	2	9	0	8	1	8	1	8	2	8	1	**67**	**13**
Decis+1% sugar	3	2	4	3	3	5	5	3	5	3	7	1	6	2	10	0	6	1	5	4	**54**	**24**
Decis+2% sugar	2	3	8	0	6	2	9	0	2	6	4	3	0	4	7	1	2	4	9	1	**49**	**24**
Decis+0·5% Eradicote	10	0	3	3	6	1	10	0	5	2	9	1	5	5	10	0	10	0	8	1	**76**	**13**
Decis+1% Eradicote	9	0	5	3	7	1	6	0	5	4	10	0	10	0	4	3	9	0	8	2	**73**	**13**
Decis+2% Eradicote	6	0	6	2	9	1	8	0	9	1	8	1	1	8	4	1	7	3	2	4	**60**	**21**
Dynamec+0·5% sugar	7	1	0	8	1	6	5	5	8	2	2	8	2	6	10	0	1	8	0	10	**36**	**54**
Dynamec+1% sugar	7	1	0	6	0	10	3	7	1	8	2	8	0	10	6	4	1	9	0	10	**20**	**73**
Dynamec+2% sugar	1	8	0	10	0	10	2	8	1	8	0	10	0	10	2	8	0	10	0	9	**6**	**91**
Dynamec+0·5%Eradicote	2	6	2	1	0	9	6	2	1	8	3	7	1	7	6	1	3	4	5	5	**29**	**50**
Dynamec+1% Eradicote	0	10	1	7	1	7	5	3	4	6	0	9	2	7	2	6	0	7	0	10	**15**	**72**
Dynamec+2% Eradicote	0	10	0	8	6	4	2	8	0	10	1	9	0	10	1	9	8	1	1	9	**19**	**78**

Figure 5 Graph showing the mean percent of thrips killed for each treatment from the laboratory bioassay (error bar shows 95% confidence = 16.7, 189 df). (Water control ; Decis control ; Dynamec control ; sugar controls ; Eradicoat controls ; Decis + sugar ; Decis + Eradicoat ; Dynamec + sugar & Dynamec + Eradicoat)



Treatment list		
1. Water	8. Dynamec (abamectin)	15. Decis (deltamethrin)
2. 0·5% sugar	9. Dynamec + 0·5% sugar	16. Decis + 0·5% sugar
3. 1% sugar	10. Dynamec + 1% sugar	17. Decis + 1% sugar
4. 2% sugar	11. Dynamec + 2% sugar	18. Decis + 2% sugar
5. 0·5% Eradicoat	12. Dynamec + 0·5% Eradicoat	19. Decis + 0·5% Eradicoat
6. 1% Eradicoat	13. Dynamec + 1% Eradicoat	20. Decis + 1% Eradicoat
7. 2% Eradicoat	14. Dynamec + 2% Eradicoat	21. Decis + 2% Eradicoat

Conclusions

- Dynamec gave a better control of thrips than Decis (Figure 5).
- Increasing the concentration of either white sugar or Eradicoat improved this effect (Figure 5).
- Incidence of sooty mould was higher with Eradicoat than with white sugar. Plant quality was adversely affected by using 2% of either sugar or Eradicoat (Part 1)
- Dynamec combined with 1% white sugar should be evaluated further in a glasshouse trial.

PART 3. LABORATORY ASSAY TO DETERMINE THE POTENTIAL OF COMBINING SUGAR WITH THE ENTOMOPATHOGENIC FUNGUS *BEAUVERIA BASSIANA*

Introduction

Proprietary *B. bassiana* based mycopesticides have been proposed as a second line of defense to support preventative thrips management using biological control with the predatory mite *Amblyseius cucumeris* on cucmber (Jacobson *et al.*, 2001). With care, especially to ensure that adequate crop cover is obtained from spray applications, effective control of thrips can be achieved with *B. bassiana* based mycopesticides. There are currently no registered *B. bassiana* products available in the UK but if this approach were effective on a range of crops, including ornamentals, it would represent a realistic alternative to chemical based control programmes for WFT. The efficacy of two *B. bassiana* based mycopesticides (BotaniGard WP and Naturalis-L) against WFT were compared when they were prepared in the normal way and when prepared using a 1% (wt/vol) white sugar solution.

Objective

To determine the potential of adding sugar to increase the efficacy of two proprietary *B. bassiana* mycoinsecticide products, Naturalis and BotaniGard.

Materials and methods

Treatments: Six treatments, including primary treatment and controls:

1. BotaniGard
2. Naturalis
3. BotaniGard + white sugar (1%)
4. Naturalis + white sugar (1%)
5. White sugar (1%) treated control
6. Water treated control

(percent = wt/vol)

Experimental design:

An even aged cohort of second instar thrips larvae were used in all experiments and the number varied between occasions depending on availability from the cultures. For every run of an experiment the number of thrips available was divided between treatments to ensure that each treatment was included at every occasion.

Procedure: Three methods were assessed for the fungal bioassay:

1. **Direct spray:** The same procedure used for the pesticide applications (Part 2) but incubated for five days to allow the fungus to kill any infected thrips (leaf bioassay).

2. **Wet transfer:** The same procedure used for the direct spray assay except that the thrips were removed after 24 hours and transferred into vials for five days to allow the fungus to kill any infected thrips. The plastic vial (a cylinder 22 mm intenal diameter, 18 mm tall) was ventilated through two holes (6 mm diameter) covered with fine (60µ) mesh. A plastic cap fitted perfectly into one end and the other end was sealed with two layers of stretched parafilm, between which was a thin layer (1-2 drops from a pipette) of 10% sucrose solution. The sucrose solution along with a fine dusting of pollen provided food for the thrips. To maintain high humidity (≥ 95% rh) the vials were placed on a grid to suspend them above water in a ventilated plastic container.

3. **Dipping:** A modification of the microimmersion bioassay method of Dennehy *et al*. 1993 was used. This involved using a fine paintbrush to submerge thrips larvae for 30 seconds in a single drop of the prepared fungal solutions. The thrips larvae were dried on a small piece of filter paper and transferred into the vial described previously and left for six days.

Two fungal products, Naturalis-L (Troy Biosciences Inc., USA) and BotaniGard-WP (Emerald BioAg., USA), both containing spores of *Beauveria bassiana*, were used for the bioassays. A solution containing 1ml of product to 250mls of water was made up. Treatments containing sugar were made up with a 1% (wt/vol) white sugar solution.

Spore viability: Solutions of both products (Naturalis & BotniGard) were made up to give aqueous suspensions of 10^{-3} spores/ml. Sample volumes of 100µl, 50µl and 20µl were spread evenly onto nutrient agar in 90 cm Petri dishes and incubated at 23°C for 5 days. Counts of the number of individual colonies were made to assess spore viability.

Assessments: For all methods the thrips were kept in an incubator at 23°C and relative humidity ≥ 95 %. The fungus takes at least three days to kill infected hosts so any dead thrips were removed from the vials four days after treatment (earlier examination of the vials facilitated escape of live thrips). The number of thrips alive and dead was recorded. Any dead thrips were incubated on damp filter paper in an unventilated Petri dish sealed with Parafilm and stored at 23°C. The Petri dishes were examined over the next seven days for the appearance of sporulating *B. bassiana* on the thrips cadavers.

Statistical analysis:

An analysis of variance was done to test for significant differences between treatments. The data used were the numbers of dead and infected thrips and both an angular transformation of the percent counts and a logit transformation of the direct counts were applied.

Results and discussion

A low mortality (10-15%) and high loss (33-68%) of thrips was obtained with the leaf bioassays, either using the direct spray or wet transfer methods (Table 15). The high losses resulted from many of the sprayed thrips attempting to escape the leaf arena and drowning in the water barrier, which was intended to confine them on the leaves. Lower losses were obtained with the modified microimmersion method (Dennehy *et al.* 1993), which was therefore used subsequently to compare both products with and without sugar. Three experiments, using between 29-119 thrips per replicate, were done to compare the six treatments (Table 16).

In the tests of spore viability using serial dilutions the number of colonies counted was high for both Naturalis (92% of expected) and BotaniGard (excess of expected) and the mean (± standard deviation) germination was 98.6% ± 0.5%.

Although humidity was high (≥ 95% rh) the level of infection recorded was low; almost no infection was obtained with Naturalis and only between 5-13% was obtained with BotaniGard (Table 16). Fungal induced mortality can arise without the production of sporulating bodies, which was the critera used here to confirm infection. However, an analysis of the number of dead thrips (Table 16) revealed no significant differences between any of the treatments. The high level of variability in the data evident in Table 16 probably masked any effects of the pathogen products, which have been used successfully against WFT in a glasshouse trial (Jacobson *et al* 2001.).

Table 15 Comparison of the number of thrips recorded using different methods of product application.

Product	Application	n	Alive		Dead		Loss	
			n	%	n	%	n	%
BotaniGard	Spray	40	13	32.5	0	-	27	67.5
	Transfer	40	20	50.0	6	15.0	14	35.0
	Dip	20	10	50.0	10	50.0	0	-
Naturalis	Spray	40	17	42.5	4	10.0	19	47.5
	Transfer	40	22	55.0	5	12.5	13	32.5
	Dip	20	13	65.0	4	20.0	3	15.0

A scanning electron microscope study was done in an attempt to investigate the cause of the low level of fungal infection. Ten early second instar thrips larvae were treated with BotaniGard using the microimmersion technique and kept for 24h in a vial, as described before, to allow for adhesion of the fungal spores. After 24h the thrips were cryofixed in Argon, sputter coated in gold and examined in an electron

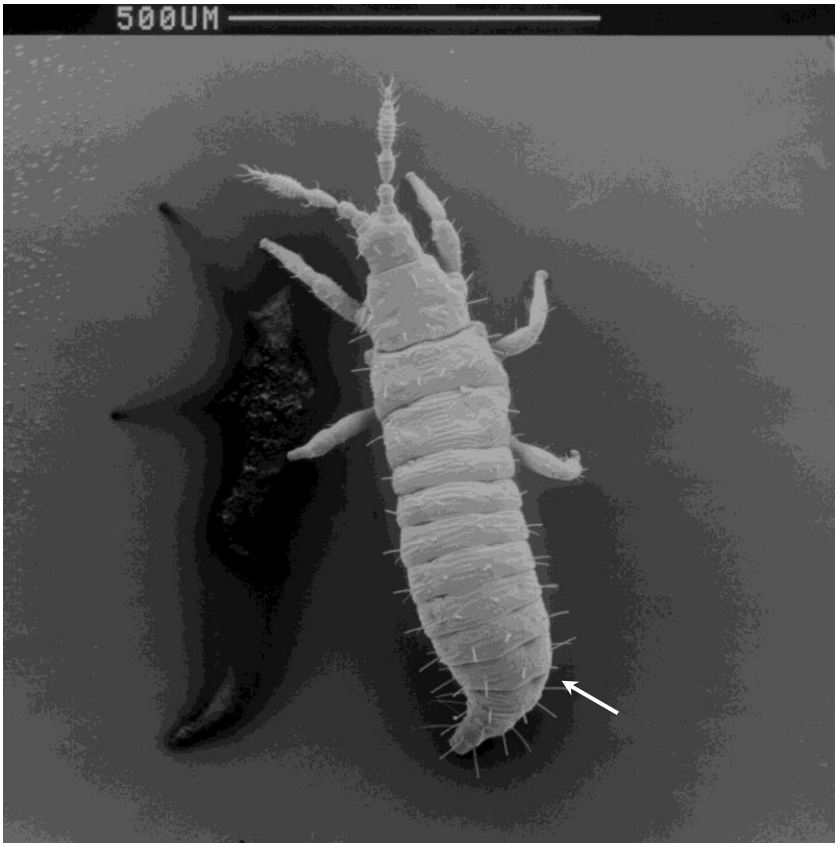
microscope to detect for adhesion of fungal spores on the body surface of the thrips. Most of the thrips examined were found to be free of spores and only one individual had a spore mass attached to the intersegmental membrane (Figure 9). Although not conclusive, this indicates that the low level of infection obtained might result from poor adhesion of fungal spores. Similar experiments using *B. bassiana* with spider mites (*Tetranychus urticae*) in HDC project PC 163 have shown that a 40% infection from direct sprays was increased to 100% infection arising from secondary pick up of fungal spores from the sprayed surface. A clearer understanding of the role of secondary pick up of spores and the ability of spores to adhere to thrips larvae is central to the future development and use of mycoinsecticides in thrips control.

Table 16 The number of dead and infected thrips obtained from the six treatments using a microimmersion bioassay.

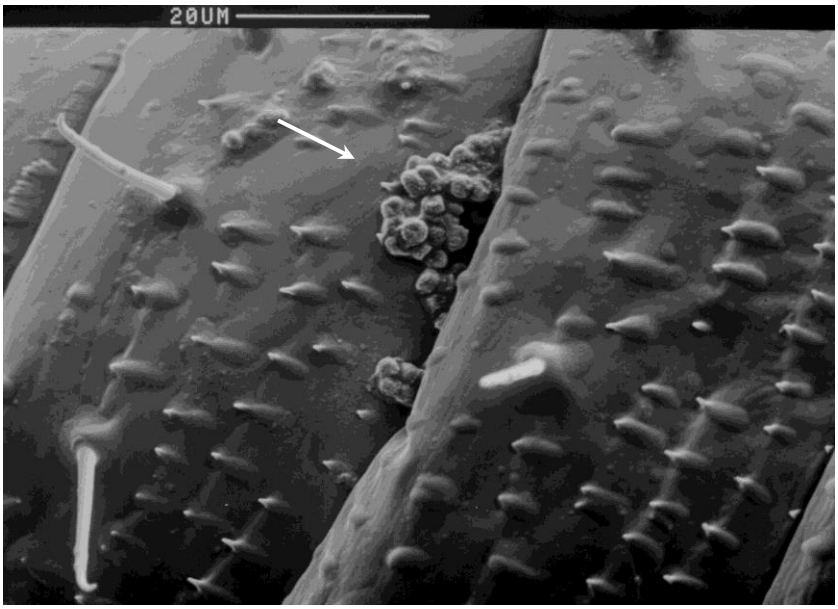
Product	**n**	**Dead**		**Infected**	
		n	%	n	%
1. BotaniGard	119	63	52.9	11	9.2
	55	39	70.9	3	5.5
	59	7	11.9	3	5.1
Total	233	109	46.8	17	7.3
2. BotaniGard + sugar	31	11	35.5	4	12.9
	63	26	41.3	6	9.5
	79	24	30.4	9	11.4
Total	173	61	35.3	19	11.0
3. Naturalis	103	47	45.6	3	2.9
	56	15	26.8	0	-
	65	3	4.6	0	-
Total	224	65	29.0	3	1.3
4. Naturalis + sugar	32	10	31.3	0	-
	51	22	43.1	0	-
	29	3	10.3	0	-
Total	112	35	31.3	0	-
5. Sugar	40	7	17.5	0	-
	35	4	11.4	0	-
Total	75	11	14.7		-
				0	
6. Water	34	8	23.5	0	-
	22	3	13.6	0	-
Total	56	11	19.6	0	-

Figure 9 Scanning electron micrographs of second instar western flower thrips larvae treated with BotaniGard showing entire insect (a) and detail of spores of *Beauveria bassiana* attached to the intersegmental membrane (b). The white arrow indicates the area with spores.

(a)



(b)



Conclusions

- No difference in the kill or infection of thrips larvae were observed by adding sugar to the proprietary products Naturalis and BotaniGard but low levels of infection were obtained overall.
- An electron microscope study revealed that the low infection rate might be due to poor adhesion of fungal spores to thrips.
- More work is needed to understand the role of secondary pick up and ability of spores to adhere to thrips larvae for the future development of mycopesticides in thrips control.

PART 4. GLASSHOUSE TRIAL OF THE BEST SUGAR/PRODUCT MIXTURE

Introduction

The laboratory bioassay done in Part 2 compared the efficacy of two pesticides, Decis (deltamethrin) and Dynamec (abamectin), when combined with white sugar and Eradicoat at three concentrations. The best sugar – pesticide combination out of the 21 treatments compared in the bioassay was taken forward into a glasshouse trial to test the efficacy on a crop scale. Increased efficacy was obtained by combining sugars with either pesticide. However, Dynamec was chosen because it provided the better control of thrips. Both Eradicoat and white sugar worked equally well but white sugar was selected because it resulted in less sooty mould (Part 1.3 above) and was less expensive. In order to make a complete evaluation of the best sugar – pesticide combination this treatment was compared with full controls comprising sprays of Dynamec alone, white sugar alone and a water-treated control. An experimental design was used to maximise the replication of treatments to address the variability often associated with glasshouse trials. This could be achieved by confining the glasshouse trial to a comparison of the efficacy of the treatments against thrips larvae. Adult thrips could move from one plot to another in the glasshouse leading to cross contamination of treatments. This was avoided by using thrips larvae and preventing the development of adults in the glasshouse by early removal of the plants for sampling. The consequence of this approach was to shorten the duration of the glasshouse trial and therefore two trials, each with three treatment replicates, could be completed in the time available.

Objective

To determine, in a crop scale experiment, the efficacy against WFT larvae of the best sugar – pesticide mixture, identified from the laboratory bioassay.

Materials and methods

Treatments: Four treatments, including primary treatment and controls:

1. Dynamec (abamectin at 0·5ml/litre) + white sugar (0·5% wt/vol)
2. Dynamec (abamectin at 0·5ml/litre) control
3. White sugar (0·5% wt/vol) control
4. Water treated control

Application: Each treatment was applied as a foliar spray to just before run off.

Experimental design:

Pot chrysanthemums (*Dendranthema* cv Swingtime) were used as test plants and grown to normal grower practice. Each pot contained five plants and 16 pots were arranged into a single plot of $1m^{-2}$. There were four plots per bench and three benches in the greenhouse compartment allowed for three full replicates of each treatment (Figure 6). The glasshouse trial was repeated to give six replicates

of each treatment over time. Treatments were randomised across the benches of the compartment and across the two trials. The replication could only be achieved by restricting the glasshouse trial to the larval stages as adult thrips could disperse and cross contaminate adjacent plots.

Procedure: Each plot was infested with 100 thrips (late first to early second instar stage) by placing 25 thrips on each of the central four pots. Thrips larvae were used to prevent cross contamination of the plots by flying adult thrips. Larval thrips of known age were produced by allowing adult female thrips to oviposit into bean pods for 24 hours and subsequently collecting hatched larvae. Thrips larvae were counted into gelatine capsules at five thrips per capsule to minimise cannibalism. The thrips were allowed to disperse naturally and settle by opening and placing the capsules on the plants. Two days after the thrips were released the sprays were made and the samples were collected three days after the plants were sprayed.

Assessments:

1. All five plants from each of the four central pots were sampled destructively into alcohol and the thrips were extracted and counted.
2. A single plant from each of the outer 12 pots was sampled destructively and the thrips were extracted and counted using a turpentine extraction method (de Courcy Williams 2001).

Figure 6 Glasshouse layout showing the four treatment plots per bench (a) and detail of a single plot (b).

(a)

(b)

Statistical analysis:

The data comprised counts of the number of thrips recovered and these were square root transformed prior to using an analysis of variance to test for significant differences between treatments.

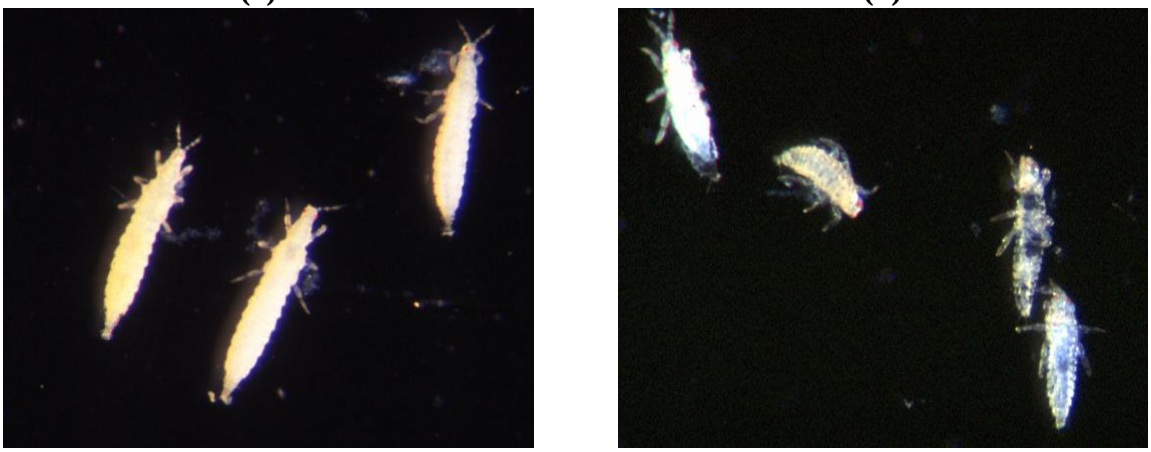
Results and discussion

Thrips counts

Thrips numbers from both the assessment procedures were combined to give a total count from each plot. The sampling method allowed thrips to be categorised as either alive or dead at the time of sample (Figure 7) and both counts were analysed separately. The treatment effects were found to be consistent across all replicates and no significant differences were found between the same treatments from either of the two glasshouse trials or between benches within the glasshouse. Therefore the data were analysed as six full replicates of each treatment.

Figure 7 Second instar thrips larvae recovered from the glasshouse trial showing individuals alive (a) and dead (b) at the time the samples were taken.

(a) **(b)**



No differences were observed between the sugar and water treated controls, either in the number of thrips alive or in the number of dead thrips recovered from the two trials (Table 13 & Figure 8).

There were significantly ($P < 0{\cdot}05$) fewer thrips alive in both of the Dynamec treatments than in the sugar or water control treatments (Table 13 & Figure 8). However, no difference was evident in the number of thrips alive between the Dynamec and Dynamec + sugar treatments (Table 13 & Figure 8).

The difference in the pesticide treatments was more pronounced when the number of dead thrips was compared between treatments. There was a highly significant ($P < 0{\cdot}001$) difference between the Dynamec and the sugar or water control treatments and significantly ($P < 0{\cdot}05$) more dead thrips were found in the Dynamec + sugar treatment than with Dynamec alone (Table 13 & Figure 8). Almost twice as many thrips were killed when sugar (1 % wt/vol) was added to Dynamec than with Dynamec alone (Figure 18b).

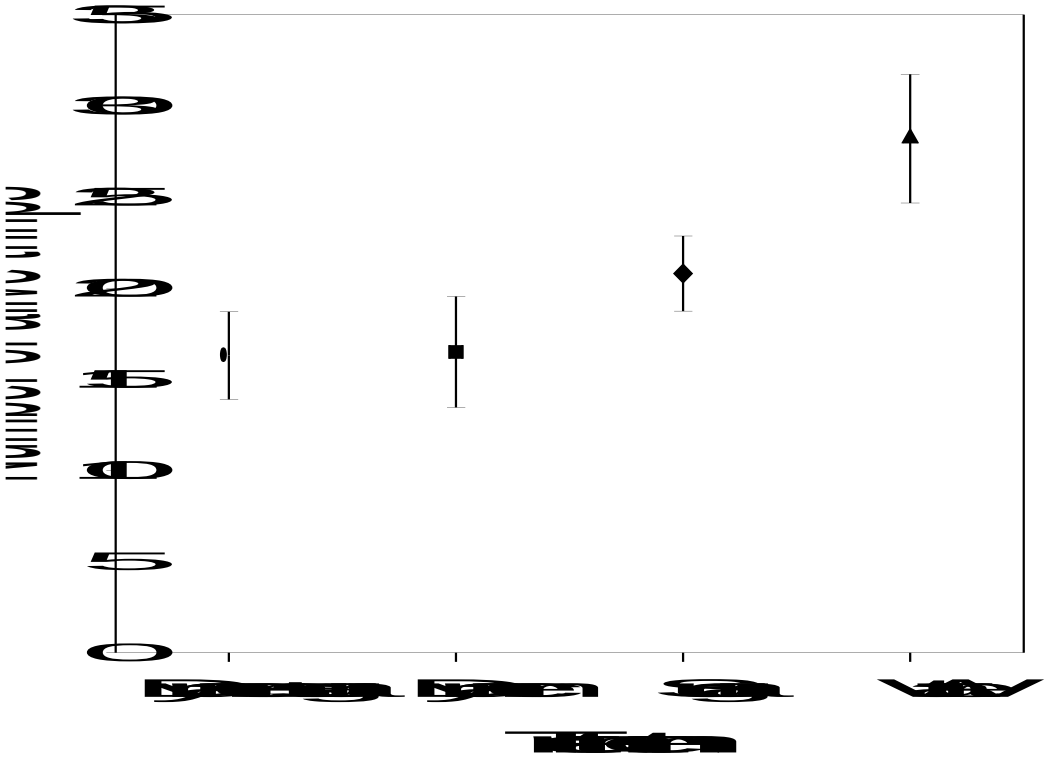
The increased mortality of thrips obtained with the addition of sugar to Dynamec, which was observed in the laboratory bioassay (Part 2), was confirmed in the glasshouse trial when the numbers of dead thrips were compared between treatments.

Table 13. The mean (square root transformed) number of thrips recovered from two glasshouse trials with different spray treatments.

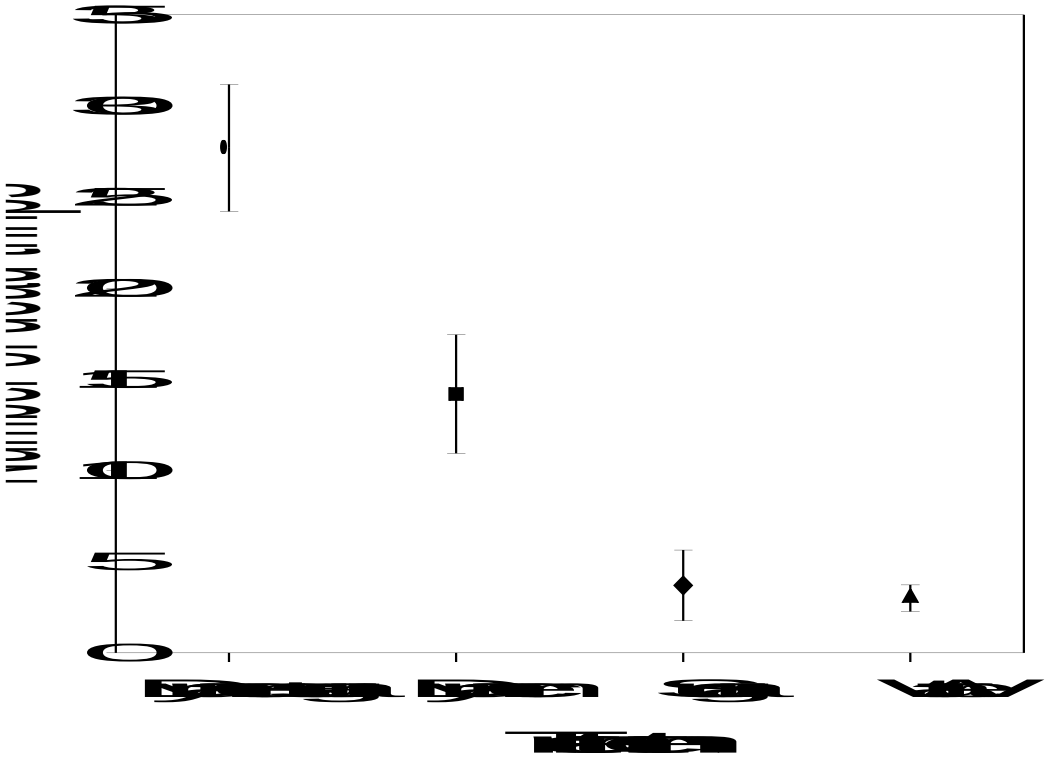
	Treatment				**LSD, 15 df ($P < 0.05$)**
	Dynamec + sugar	**Dynamec**	**Sugar**	**Water**	
Alive thrips	1.90	1.84	2.22	2.50	0.539
Dead thrips	2.54	1.72	0.59	0.64	0.592

Figure 8 Graph showing the mean number of thrips alive (a) and dead (b) recovered from each treatment in two glasshouse trials (error bars show se).

(a)



(b)



Conclusions

- The treatment effects were consistent across all six replicates.
- There were fewer thrips left alive after sprays of Dynamec (with or without sugar) than after either the sugar or water sprays. However, no difference was evident between sprays of Dynamec alone or Dynamec + sugar.
- The number of dead thrips revealed a highly statistically significant difference, with twice as many thrips found dead with Dynamec + sugar than with Dynamec alone.

CONCLUSIONS

The addition of sugar to pesticides can lead to a significant increase in the kill of thrips and both white sugar and Eradicoat showed the same effect. Although increasing the sugar concentration increases the kill of thrips, care should be taken to prevent likely detrimental effects on plant quality, particularly when flowers are present or high sugar concentrations are used. A strong effect was found in this study with the addition of 1% sugar but mixed results have been reported with 0·1% sugar (Parrella, 1996), 0·2% sugar (Heungens & Butaye, 1990) and 0·5% sugar (Kahn & Morse, 1997). No direct mortality was seen when sugars were used on their own but Eradicoat, which is a glucose polymer or starch, has been used successfully in IPM (Anon, 2001). The advantage of combining sugars with pesticides is to help reduce current reliance on a few active ingredients, particularly OPs for thrips control. In addition, the use of pesticides with short persistence, such as Dynamec or in the future, the newer neonicotinoids, would facilitate the integration of chemical and biological control options.

The main findings of the glasshouse assessment of effects on plant quality are summarised as follows:

- Sugar solutions can cause browning, sooty mould and stickiness (see Figures 1 & 2).
- Flowers are more susceptible to damage than leaves.
- Problems increase with:
    - Sugar concentration
    - Number of treatments.

There were small differences between treatments:

- Brown sugar caused more spotting on the petals than did the other two treatments.
- More sooty mould occurred on the leaves with the Eradicoat treatment than with the other two treatments.
- Applications of 2% and 4% sugar solutions resulted in more sooty mould on leaves than with the use lower sugar concentrations. Sugar solutions of 2% and 4% are not recommended for use.
- Growers should not use sugars repeatedly, as phytotoxicity problems will increase.

The main findings of the Laboratory bioassay are summarised as follows:

- Dynamec gave a better control of thrips than Decis (see Figure 5).
- Increasing the concentration of either white sugar or Eradicoat improved this effect (see Figure 5).

The main findings of the Glasshouse trial are summarised as follows:

- A highly statistically significant difference was found in the number of dead thrips observed in a glasshouse trial on chrysanthemum when sugar was added to Dynamec. Twice as many thrips were found dead with sprays of Dynamec + sugar (1% wt/vol) than with sprays Dynamec alone.
- The results of the treatment effects were consistent across all six replicates in two glasshouse experiments.

The main finding of the evaluation of fungal pathogens are summarised as follows:

- No difference in the kill or infection of thrips larvae were observed by adding sugar to the proprietary products Naturalis and BotaniGard but low levels of infection were obtained overall.
- An electron microscope study revealed that the low infection rate might be due to poor adhesion of fungal spores to thrips.
- More work is needed to understand the role of secondary pick up and ability of spores to adhere to thrips larvae for the future development of mycopesticides in thrips control.

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