Grower Summary

PC 295a

Sweet pepper: Further development of IPM solutions for aphid infestations

Final Report 2010

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Headline

- An IPM programme based on the systematic release of parasitoids and the application of 'soft' soap treatments through a modified vertical spray boom configuration controlled aphids in wide bed organic pepper crops.

- A precise method of applying pymetrozine through irrigation also controlled local infestations of aphids within conventional pepper crops.

Background and expected deliverables

The preceding HDC Project (PC 295) devised a new IPM compatible strategy for aphid control in organic pepper crops. This consisted of primary biological control measures supported by fatty acids (Savona) or natural pyrethrins (Pyrethrum 5EC) as a second line of defence (SLoD). A 'proof of concept' trial was very successful. However, some difficulties were encountered when implemented on a larger scale:

- Spray coverage of the SLoD products was inadequate in wide-bed organic crops.
- The performance of the parasitoids was impaired by hyperparasitism (*i.e.* naturally occurring parasitoids which attack the parasitoids being used as biological control agents).
- There appeared to be a negative interaction between some biological control agents utilised in the IPM programme.

The current work built on the findings of the first study by addressing the difficulties and introducing some additional options for aphid control.

Conventional growers have access to more effective SLoD products. One such product, pymetrozine (Chess WG), had recently received a Specific Off Label Approval (SOLA - Number 2024/2009) for application through the irrigation system. This project sought a means of using the irrigation system for localised rather than entire crop treatments.

The project also investigated the possibility of using open rearing units (ORUs) in pepper crops, with particular emphasis on their use as a breeding base for alternative parasitoids (*e.g. Aphelinus* spp.) and novel biological control agents (*e.g.* syrphids).

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Summary of the project and main conclusions

Modification of vertical boom sprayer for wide bed organic crops

Some organic pepper crops are grown in double rows to facilitate incorporation of compost into the soil beds. This creates a wide canopy which is difficult to penetrate with sprays. Furthermore, many of the leaves on pepper plants hang at an angle of approximately 30° off vertical creating a virtual outer wall of foliage.

A critical assessment of the performance of the current robotic spray equipment was initially done. This was followed by the design and fabrication of a replacement unit. The important criterion was that the nozzles drove a spray underneath the near-vertical leaves, then lifted those leaves up momentarily to permit finer spray to penetrate and cover the lower leaf surfaces inside the canopy. Two types of nozzle were employed which were called 'lifters' and 'fillers' according to their purpose

A pair of replacement booms were built as a retro-fit to the robotic sprayers. The configuration incorporated ten lifters and ten fillers in separate rows on each boom. Each lifter was orientated upwards at 60° from the horizontal and fired into the spray cone of the filler nozzle on the tier above, close to the point where the spray met the outermost leaves of the crop. This had the effect of lifting the outer leaves and letting in the fine spray from the fillers. It also created maximum turbulence in a twisting motion so that no leaf stayed in one position for any length of time.

A pictorial illustration of the modified vertical boom sprayer as well as its image are given below (Figure i):

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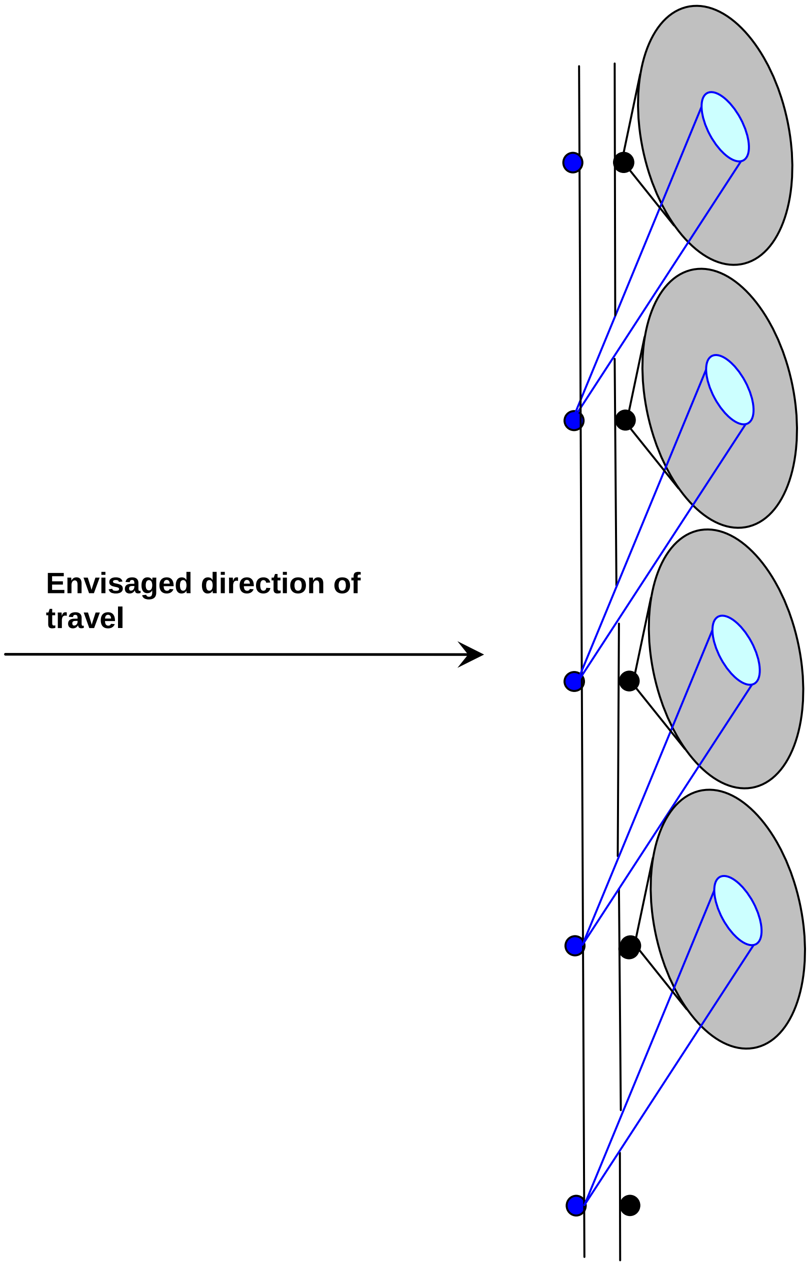
Figure i. Side of boom viewed from crop



(Note: Spray from the narrow-angle “lifter” nozzles is shown in blue, while spray from the finer “filler” nozzles is shown in grey.)

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Figure ii. New booms fitted to the robotic sprayer**:**

(Note: At this stage the fans are still fitted to the base of the unit)

Biological evaluation of new spray booms

This part of the project served to evaluate the efficacy of the new spray booms and the efficacy of the SLoD strategy against a *Myzus persicae* (peach potato aphid) population. The parasitoids, *Aphidius ervi* and *A. colemani*, had been released systematically since the start of the season and, in addition, a natural population of *Praon* spp. had become established. Overall, approximately 8% of the aphid population was mummified by these parasitoids at the start of the trial.

Aphid numbers increased rapidly toward the end of May 2010 and some plants were starting to become sticky. This was the agreed signal to apply the SLoD treatment (1.5% Savona). The effect was compared to untreated controls. There were a total of 50 sample stations within clearly defined plots. Assessments were done immediately before the spray was applied and 1, 6 and 42 days post-treatment. On each occasion and at each sample station,

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numbers of aphids and mummified aphids were recorded on one leaf in four positions within the crop canopy; *i.e.* upper inner, upper outer, lower inner and lower outer. In addition, intact aphid mummies were collected 1 and 42 days post-treatment and incubated in ventilated Petri-dishes to measure the proportion of parasitoids that successfully emerged from treated mummies. This provided a measure of the impact of the SLoD on the parasitoid population and a measure of the proportion of mummies that contained hyperparasites.

Following the application of Savona, there was an immediate reduction in aphid numbers and this was similar in all positions showing that the spray had successfully penetrated the whole canopy. Overall, the aphid numbers were reduced by approximately 90% at day 1 and by 97% at day 6. The aphid population recovered between day 6 and day 42 but numbers were still only one third of the pre-treatment count. No further spray interventions were required against aphids in that area. In contrast, in the untreated control, numbers of aphids increased nearly three fold during the first six days post-treatment leading to unacceptable quantities of sticky fruit and additional control measures were required.

Six days after application of the Savona treatment, mummies represented 66% and 11% of the remaining aphid population in the Savona and untreated plots respectively. Once again, there were no differences between sample points within the plant canopy. These results clearly illustrate how the SLoD treatment shifted the balance of the insect populations to the advantage of the parasitoids and thus helped to prevent any further fruit contamination. Hyper-parasitism by *Dendrocerus* increased from 5% to 15% during the trial but did not prevent season-long control of aphids in this case.

Pymetrozine applied via the irrigation system

The irrigation system can provide a useful vehicle for cost-effective application of systemic pesticides. When the product is applied at the central mixing point it is usually necessary to treat the whole area served by the system. However, aphid populations build up unevenly and SLoD treatments are only usually required in localised areas of crops. A more precise method of application was developed. This was based on a water powered Dosatron D20s applicator that accessed the system via individual irrigation manifolds thereby allowing the separate treatment of smaller areas served by each valve.

There was some debate over the interpretation of the information provided in the SOLA. The maximum individual dose for sweet pepper is 15 g product / per 1000 plants via the drip

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irrigation. The ‘advisory information’ suggests using this rate against whiteflies but a lower rate of 10 g product / per 1000 plants against aphids. The SOLA does not distinguish between ‘plants’ and ‘heads’, nor between young and mature plants, yet the quantity of foliage varies hugely at the extremes. All leaves are usually left on a pepper crop until the end of the season but, in this case, the lower leaves had been removed and it wasn’t clear whether this would affect the uptake of the chemical or its distribution within the plant. In this first trial of the delivery system, the SOLA was interpreted literally in terms of ‘plants’ but the maximum individual dose rate was used due to the maturity of the plants.

There were two distinct phases to the study. In the first phase, a method of calibrating the equipment to determine the time required to take up and distribute the stock solution throughout the trial area was developed. The method is described in detail in the full report. Growers are advised to fully understand their own irrigation system before applying products through drippers.

In the second phase of the work, the efficacy of the technique against *Myzus persicae* on 1644m^2 of mature pepper crop was evaluated. There were approximately 4,000 plants which required 60g Chess WG applied from a 15 litre stock solution. The irrigation was turned off mid-afternoon to allow the plants to partially dry out the rockwool growing medium. The treatment was applied during cloudy conditions in the late afternoon. There were no further irrigation runs that day and drainage was reduced the following day to maximise the uptake and minimise flushing of the product through the growing medium.

Sample points to measure the size of the aphid population were established throughout the crop prior to treatment. Pymetrozine is known to have a slow effect and so the second assessment was delayed until 13 days post-treatment. On both occasions, the numbers of live and mummified aphids were recorded at every sample position. In addition, at the post-treatment assessment, mummified aphids were collected from the sample points and confined in dishes to determine whether parasitoids successfully emerged, thus indicating whether the treatment had been harmful to the immature wasps. This also provided a measure of hyperparasitism.

Chess WG was totally effective against *M. persicae* when applied by this technique. However, it may be necessary to repeat the trial in different situations; the most demanding being a fully mature crop with a full leaf canopy using the lower ‘advisory’ rate of 10g product per 1,000 plants. The impact of the treatment on parasitic wasps was unclear because the

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results were complicated by the presence of hyperparasites and this may require further investigation.

Hyperparasitism

Hyperparasitoids are secondary insect parasitoids that develop at the expense of biological control agents and thereby threaten the success of IPM programmes. Prior to this season, we had very little information about levels of hyperparasitism in aphid populations in commercial pepper crops. We knew that they were present because we had seen typical emergence holes in mummified aphids. However, we had no information about the extent of the problem or the species that were involved.

Large samples of mummified aphids were collected from commercial pepper crops and incubated at room temperature. The emerging wasps were sorted into genera and examples were identified by a specialist insect taxonomist. Five species of hyperparasites of the genera *Dendrocerus*, *Asaphes* and *Pachyneuron* were found associated with *Myzus persicae* / *Aphidius* mummies between June and September. Levels of hyperparasitism ranged from 8% to 63%; in some cases the population increased as the summer progressed but in others it decreased. The majority of *Aphidius* adults emerged within seven days of collection while hyperparasitoids typically emerged much later. Samples were also collected from ORUs based on barley plants infested with the cereal aphid, *Sitobion avenae*, and the primary parasitoid, *Aphelinus abdominalis*. 72% were found to be hyperparasitised, including three species from the genera *Dendrocerus* and *Alloxysta*. The timing of emergence of the various hyperparasitoids suggested that they may be attacking each other.

In addition to the practical surveys, a desk study sought to gain more background knowledge about hyperparasitism. Although information of direct relevance to protected peppers was sparse, general information about the biology and behavior of hyperparasites in other situations was compiled.

Dendrocerus, *Asaphes* and *Pachyneuron* are known as ectophagus hyperparasites. The female deposits her egg on the surface of the primary parasitic larva after the aphid is killed and mummified. The hyperparasitic larva then feeds externally on the primary host while both are still inside the mummy. We have detailed life-table data for *Dendrocerus carpenteri* on *Aphidius smithi* which may provide an approximate guide to the insect's development in UK pepper crops. Adult *D. carpenteri* emerge from the mummy approximately 16 days after

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oviposition. In the case of *Asaphes californicus*, the development from egg to adult takes about 21 days. Other species of the *Asaphes* genera are known to attack other hyperparasites.

Alloxysta are known as endophagus hyperparasites. The female deposits her egg inside the primary parasitoid larva while it is still developing inside the live aphid but before the aphid is mummified. The egg does not hatch until after the mummy is formed and then the hyperparasitic larva feeds on the primary larval host. In the case of *Alloxystra victrix*, the adult emerges 19 days after the original oviposition.

All the ectophagus species that we have identified in our crops are non-specific feeders; *i.e.* they attack a wide range of primary parasites irrespective of the aphid. Although the endophagus hyperparasitoids are usually host specific, at least one member of the *Alloxystra* genus is an exception to this rule.

A thorough understanding of hyperparasitoid foraging behaviour could enable us to interrupt the process and thereby reduce the commercial impact of hyperparasitism. Unfortunately, little information is available about the factors involved in host location. Generally, aphid honeydew provides information about the presence of aphids as the first step in locating the primary parasitoids and, thereafter, the female may be influenced by volatile chemicals released by the primary parasitoid.

Interactions between biocontrol agents

Conflicts between natural enemies are known as 'intraguild predation' (IGP). A few reviews have focused on IGP among the natural enemies associated with aphids. It is commonly believed that this constitutes one of the main forces influencing the dynamics of aphid feeding natural enemy populations and should be taken into account in all research studies. It is also widely acknowledged that the direct and indirect implications of IGP are complex and extremely difficult to study in the field.

Orius are generalist predators and are reported in the scientific literature to feed upon many beneficial species, including *Aphidoletes* eggs and larvae. This supports our more practical observations that they predate upon *Aphidoletes* larvae in pepper crops. Various species of *Orius* form a very important component of the overall IPM programme; for example their role in suppressing western flower thrips populations and transmission of tomato spotted wilt

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virus is indisputable. The available evidence strongly suggests that *Orius* should be retained in the pepper IPM programme in preference to *Aphidoletes*.

Researchers have investigated IGP between *Aphidoletes* and *Aphidius colemani*. They found that *Aphidoletes* larvae readily killed parasitised but not yet mummified *Aphis gossypii*. In practice, we have frequently seen *Aphidoletes* larvae feeding on *M. persicae* / *Aphidius* mummies. There are also records of predatory bugs feeding on mummified aphids; for example *Anthocoris nemorum* preyed readily on immature *A. colemani* contained within *M. persicae* mummies. Our own observations in pepper crops show that *Orius* larvae feed on *M. persicae* / *Aphidius* mummies but it is very difficult to determine the overall impact of this on the parasitoid population.

Open rearing units

Open rearing units (ORUs) or banker plants have been used to boost numbers of natural enemies in protected cultivation for over 30 years. The objective is to sustain a reproducing population of the natural enemies which provides season-long suppression of the pest species. Typical ORUs have been based on wheat, barley or maize infested with *Rhopalosiphum padi* (bird cherry aphid) or *Sitobion avenae* (cereal aphid). These species of aphids are a common host for parasitoids, such as *A. colemani*, *A. matricarae* or *A. ervi*, without being a direct threat to the crop.

A grower and a biological control specialist tested ORUs in commercial pepper crops during 2010. Eight ORUs per hectare were placed in the crops per week for three weeks in February. Each unit comprised a hanging basket of wheat plants, infested with *Sitobion avenae,* positioned above the crop and irrigated / fed by the irrigation system. The aphid populations were colonised with *Aphelinus abdominalis*, which was believed to be less susceptible to hyperparasitism than *Aphidius*. The units were refreshed periodically by adding presoaked wheat seed. The nursery's routine pest monitoring procedures detected fewer colonies of aphids in glasshouses protected with ORUs than in glasshouses where the parasitoids had only been released systematically. Both the grower and the biocontrol specialist believed that the strategy had been successful up to week 20.

The units were examined in early July when many *Orius* and *Aphidoletes* were seen among the wheat plants. Although there was 93% adult wasp emergence from samples of intact mummified aphids, 72% were hyperparasitoids (*Dendrocerus* spp. and *Alloxysta* spp.). It was

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not clear when hyperparasites started to colonise the ORUs but it was clear that their value had become compromised by mid-summer.

Studies in Spanish pepper crops suggest that it may be possible to switch from ORUs based on parasitoids in the early season to ORUs based on syrphid flies in the summer. The aphid cultures in the ORUs provided an interim food source for larvae of released *Episyrphus balteatus* as well as increasing the ingress of other naturally occurring syrphid species. It has been shown that the presence of flowering plants (*eg* coriander or sweet alyssum) can enhance establishment of syrphids. However, analysis of the gut content of those predators has indicated that sweet pepper alone provides a suitable and adequate pollen source.

Financial Benefits

The cost of routine control measures applied against aphids in conventional pepper crops is about £5.8K per hactare per season. Where difficulties occur with the control of aphids, the overall cost of additional biocontrols, sprays, labour to wash fruit and loss of marketable yield may exceed £100K per hectare per season. It is estimated that successful control measures developed by this project could ultimately save growers between £0.8K and £95K per hectare per season depending on the severity of the existing problems. In addition, the work paves the way for further studies aimed at providing more sustainable biologically-based solutions. This in turn will help pepper growers to satisfy the standards sought by major food retailers and thus improve competitiveness of the UK industry.

Action Points for Growers

- Growers of wide bed organic crops should adopt the spray boom configuration developed in this project because it has been shown to greatly improve spray penetration and leaf coverage throughout the spray canopy.
- An IPM strategy based on *Aphidius colemani* and *Aphidius ervi* released systematically from planting and supported by a SLoD treatment of 1.5% Savona at first sight of sticky leaves / fruit provided effective aphid control except where the performance of the parasitoids was compromised by hyperparasites and / or intraguild predation.

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- Growers of conventional pepper crops should consider using a SLoD treatment based on pymetrozine (Chess WG) applied via the irrigation system using a water powered Dosatron D20s applicator accessing the system via individual irrigation manifolds.

- The SOLA for Chess WG via the irrigation system requires clarification to take into account the difference between plants and heads, as well as the difference in the quantity of foliage on young and mature plants / heads. (*HDC note - It has been confirmed that the application rate for control of aphid is 10 g per 1000 plants (irrespective of head number or plant size*)

- Further information is required about hyperparasitism of primary parasitic wasps with the aim of reducing the impact of this phenomenon on biological control of aphid pests in general.

- Growers should reconsider the use *Orius* and *Aphidoletes* within the same IPM programme due to intraguild predation. For sweet pepper crops, *Orius* should be retained in preference to *Aphidoletes*.

- Growers should consider boosting the numbers of biological control agents within their pepper crops by using parasitoid ORUs during the early season and syrphid ORUs during the summer. However, these techniques will require further refinement during the coming season.

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