AHDB HORTICULTURE

Grower Summary

PE 028

Tuta absoluta: Investigating resistance to key insecticides and seeking alternative IPM compatible products

Final 2015

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The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.

Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

Further information

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Project title:	*Tuta absoluta*: Investigating resistance to key insecticides and seeking alternative IPM compatible products
Project number:	PE 028
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Report:	Final report, December 2015
Previous report:	Not applicable
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Location of project:	Rothamsted Research, Harpenden, Hertfordshire RJC Ltd, Bramham, West Yorks Libraries at Fera and Lancaster, Leeds and York Universities
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Date project commenced:	1 July 2015
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GROWER SUMMARY

Headlines

- Significant resistance to spinosad has been confirmed in *Tuta absoluta* populations at two UK nurseries and the existing IPM programme must be modified accordingly.
- Potentially useful additional products are identified for each stage of the IPM programme.

Background

Tuta absoluta arrived in the UK in 2009 and rapidly became the most important pest of home-grown tomatoes. By 2013, HDC projects PC 302 and PE 020, and associated studies, had developed a completely new IPM strategy for use against the pest and this was detailed in HDC Factsheet 02/14. The programme was based on the predator, *Macrolophus pygmaeus*, integrated with the chemical insecticides, spinosad (Conserve), chlorantraniliprole (Coragen) and indoxacarb (Steward). *Macrolophus pygmaeus* was released at the start of the growing season so that it would start to provide some control of the pest by late spring or early summer. When the pest arrived, it was allowed to colonise the crop but population growth was slowed by applying spinosad through the irrigation system before the first generation of caterpillars completed their development. If necessary, a high volume spray of chlorantraniliprole was applied as a second line of defence during the summer to keep the pest and predator populations in balance. If crop monitoring indicated that a clean-up spray was required at the end of the season, then the third insecticide, indoxacarb, was used to reduce the number of *T. absoluta* surviving in the glasshouse to infest the next crop. The IPM programme was very successful and British tomato growers admit that they became complacent about the pest.

The three insecticides used in the IPM programme were from different Insecticide Resistance Action Committee (IRAC) Mode of Action Classification Groups and, together with the biological control agent, should have formed a robust resistance management strategy. Nonetheless, a strict warning about maintaining an effective insecticide resistance management strategy was incorporated in HDC Factsheet 02/14.

In February 2015, a leading British tomato grower reported concern over recent poor results with spinosad against *T. absoluta* on his nursery. There soon followed similar reports from three other British tomato growers in other parts of the country. At about the same time, a Scandinavian grower reported poor results with spinosad in a *T. absoluta* population recently inherited from a Spanish supplier. There were no such difficulties reported with chlorantraniliprole in the UK but 100 fold resistance to this chemical had been confirmed in a

T. absoluta population in Italy. Indoxacarb has rarely been used against *T. absoluta* in the UK because the pest population has usually been reduced to an acceptable level by *M. pygmaeus* before the end of the growing season. However, one British grower did experience treatment failures with this product in 2011. An on-site investigation confirmed that the sprays were prepared and applied correctly yet mortality six days post-treatment was only 11-19% for medium-sized larvae and 23-41% for small larvae. This *T. absoluta* population had only recently become established on that nursery and was believed to have arrived on imported produce from Italy. These control failures made it clear that the British tomato industry must take measures to remain one step ahead of this potentially devastating pest. The British Tomato Growers' Association Technical Committee requested the following actions which became the focus of this project:

1. Spinosad and chlorantraniliprole resistance tests be undertaken by the Insecticide Resistance Team at Rothamsted Research (IRT RR) to establish the current status of populations of *T. absoluta* in the UK.
2. A desk study to search for all products used to control *T. absoluta* and other leaf mining caterpillars in the Americas, Africa, southern Europe, Middle East and Far East, and then to categorise them according their potential value within the UK tomato IPM programme.

Summary

Part one: The original objective was to test the sensitivity of four UK strains of *T. absoluta* to spinosad and chlorantraniliprole. However, one of the growers who had reported poor results with spinosad in the early part of 2015 stopped producing tomatoes and no insects were available from that site. That population was replaced with one from Denmark that was associated with spinosad treatment failure in 2015. The Danish population provided added value as one resistance test had already been completed on that strain and it was therefore possible to investigate whether 'tolerance' declined when spinosad selection pressure was removed for 7-8 months. Two IRT RR 'susceptible' laboratory strains were also incorporated in the study to provide a base line. Full-dose response bioassays were performed using the standard leaf-dip bioassay procedure outlined in the IRAC Susceptibility Test Method 22. The LD50s (*i.e.* the amount of insecticide required to kill 50% of the population) were determined for each population and resistance ratios calculated by dividing the LD50 of the test population by the LD50 of the most susceptible laboratory strain.

In summary, the bioassays confirmed that *T. absoluta* populations at two locations in the UK exhibited high levels of resistance to spinosad. The levels of resistance were high enough to seriously compromise control as both strains would show very significant survivorship at the field rate commonly used for spinosad (87-100 mg L^{-1}). No spinosad resistance was detected in the third UK population and other possible causes of treatment failure are being investigated at that site. The original Danish strain showed some tolerance to spinosad but only 8-fold greater than the most susceptible laboratory strain. This had declined to approximately twice that of the most susceptible laboratory strain at the second test. The interim period of 29 weeks equates to 8-9 generations of *T. absoluta* at the usual temperatures in a commercial tomato crop. It would therefore appear that in the absence of spinosad selection pressure the more susceptible individuals in a population have some developmental advantage and gradually become more dominant. This is good news for growers as it indicates that spinosad should still have some value within the IPM programme if treatments are restricted to no more than one application per growing season.

None of the tested populations showed significant levels of resistance to chlorantraniliprole. However, published information from Italy and Greece has confirmed that resistance to this chemical is present within southern Europe. The fact that there is currently unrestricted importation of tomatoes infested with *T. absoluta* from Italy suggests that British growers could inherit this problem at any time.

Part two: The overall aim of this part of the project was to source and collate information on insecticidal control options for *T. absoluta* and other leaf mining Lepidoptera from around the world. A review of the scientific and horticultural literature was carried out and information was acquired from the IRAC worldwide network of technical specialists. Unpublished information was sourced using the authors' international network of collaborators in both academia and industry. Finally, efficacious products were categorised according to their IRAC resistance group, IPM compatibility and physical properties.

The search identified over 40 chemical insecticides that had been used against leaf mining caterpillars around the world as well as several biopesticides, botanical extracts, entomopathogenic nematodes and macro-biocontrols. The main issue with the chemical compounds was that many were already compromised by direct resistance or they were subject to cross resistance arising from another insecticide within the same IRAC Mode of Action Classification Group. There seemed little to be gained in the long term by pursuing a candidate insecticide if resistance to it or a related compound had already been recorded in another country. As a consequence, the initial screen based on the biochemical mode of action and the likelihood of resistance, selected just seven potentially useful compounds (*i.e.* abamectin, azadirachtin, *Bacillus thuringiensis* (Bt), clorfenapyr, emamectin benzoate, metaflumizone, methoxyfenozide) in addition to the three already used within the UK tomato IPM programme (spinosad, chlorantraniliprole and indoxacarb).

The next step in the screening sequence was to consider compatibility with the biological control agents used by UK tomato growers. It is important to stress that this screen had to include the full range of biocontrols used in the whole tomato IPM programme and not just those used against *T. absoluta*. Without this diligence, the project may have resolved the main issue but created other pest control failures. This stage reduced the number of potentially useful additional compounds for use during the UK tomato growing season to three candidates (Bt, azadirachtin, methoxyfenozide) and one additional compound for use as an end of season clean-up treatment (abamectin). This list could be increased to five potentially useful compounds if we included emamectin benzoate, although important questions remain to be answered about the suitability of that compound.

The final step in the selection procedure considered the physical properties of the remaining compounds with emphasis on their ability to penetrate leaves and / or have systemic activity that would allow application via the irrigation system. It is important to understand that young *T. absoluta* caterpillars usually feed on the surface for less than 90 minutes after hatching before they start to burrow into the plant tissue. This results in a very narrow window of opportunity for surface acting insecticides. There may be other opportunities if the caterpillars move to other parts of the plant during their development but such migrations are unpredictable and of very short duration. Repeated applications of surface acting insecticides are required to protect new growth post-application because this is where *T. absoluta* most commonly lay their eggs.

Bt and methoxyfenozide have no translaminar or systemic activity. Despite this, a niche has already been found for Bt within the tomato IPM programme. Under certain exceptional circumstances, which are not yet fully understood, young caterpillars migrate to the tops of the plants where they ‘graze’ more openly in and around the growing points. Bt sprayed repeatedly at 7-10 day intervals has prevented loss of growing points. However, this technique requires a good understanding of the pest’s activity patterns as well as a significant labour input. The moult accelerating compound, methoxyfenozide, could fulfil a similar role within the IPM programme.

It has proved difficult to source irrefutable evidence of translaminar and / or systemic activity of azadirachtin in tomato pants due to the many different extracts and formulations that have been prepared and used in trials. Nonetheless, several papers indicate that the insecticide could have potential as a direct replacement for spinosad in the UK tomato IPM programme. One researcher stated that systemic treatments of azadirachtin-based products were most effective on young tomato plants, which is consistent with current use of spinosad in the UK.

The translaminar activity of both abamectin and emamectin benzoate is well documented. Emamectin benzoate has short persistence on the leaf surface but is rapidly absorbed into plant tissue. It is therefore ideally suited for high volume spray application against *T. absoluta*. It is not thought to be truly systemic but this should be further investigated.

Financial Benefits

Tuta absoluta is currently the most important pest of tomato crops in the UK. For example, at one nursery in 2012, 30% of fruit were damaged by the pest and graded out during June and July causing losses of approximately £50k per hectare to that grower for that period alone. The existing *Macrolophus*-based IPM programme has prevented such damage but the predator must be supported by other control measures. In particular, the loss of spinosad and / or chlorantraniprole through resistance would take the industry back to the 2012 situation. It is vitally important that additional insecticidal products are added to the armoury.

Action Points

The following modifications to the existing IPM programme are suggested:

- *Macrolophus pygmaeus* remains the biological ‘backbone’ to the IPM programme and should continue to be released, with supplementary food, at the start of the crop.
- Spinosad applied via the irrigation should remain the preferred treatment to slow down *T. absoluta* population growth while the *M. pygmaeus* population is becoming established in the crop. To avoid resistance, spinosad should not be used more than once in a six month period. Where resistance has already been confirmed, the product should not be reused unless resistance tests show that the population has reverted to susceptible status. Thereafter, such populations should only be treated with spinosad at intervals greater than 12 months.
- Alternatives to spinosad should be developed as quickly as possible. The most promising candidate is currently azadirachtin. However, further research is required to determine its efficacy via the irrigation system and compatibility with the biological control agents used

in the UK tomato IPM programme. The authors' understand that approval is already being sought to use a product containing azadirachtin in UK tomato crops.

- As yet, there is no known resistance to chlorantraniliprole in the UK although it has been confirmed in southern Europe. This should remain the first choice of second line of defence treatment to keep the pest and predator populations in balance during the summer. However, it must not be used twice in succession unless there is an interval of at least six months.
- The entomopathogenic nematodes, *Steinernema feltiae*, provide a useful second line of defence option for growers of organic crops who are not allowed to use synthetic insecticides. However, at least three applications at 7-10 day intervals are probably required to give acceptable levels of control.
- It will be important to further investigate the potential of emamectin benzoate to provide an alternative to chlorantraniliprole. This will require research to determine its compatibility with the biological control agents currently used in UK tomato crops and its systemic activity. Approval will be required for use in UK tomato crops.
- *Bacillus thuringiensis* can provide useful control of *T. absoluta* larvae when the pests are 'grazing' for prolonged periods in the heads of the plants. However, at least three applications at 7-10 day intervals are required to give acceptable levels of control.
- The moult accelerating compound, methoxyfenozide, could provide an alternative to Bt when *T. absoluta* larvae are 'grazing' in the heads of the plants. An EAMU is already being sought for use of this product in UK tomato crops.
- Indoxacarb remains the first choice as an end of season 'clean-up' treatment. Where there have been difficulties obtaining control of *T. absoluta* with this insecticide, then abamectin should provide an acceptable alternative. Neither product should be used during the main growing season when bumblebees and biological control agents are still active in the crop.