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Ecological approaches to the control of pollen beetles in oilseed rape

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At a time of increasing demand for rapeseed oil for biofuel and food use and as increasing areas are grown, the risk of pollen beetle resistance to pyrethroids presents a significant threat to the sustainability of the oilseed rape crop and to farm incomes. Measures are urgently required to reduce the use of insecticides against pollen beetles, to preserve activity of the limited armoury of insecticides and minimise environmental pollution. In this paper, the status of pollen beetle resistance to pyrethroid insecticides and current control methods are presented from a UK perspective. Three ecological approaches to the control of pollen beetles that are based on research into their behaviour and ecology and that of their natural enemies are highlighted: use of monitoring, trap cropping and conservation biological control. These approaches have the potential to significantly reduce insecticide use against pollen beetles by helping to identify when spray thresholds have been breached, reducing pest incidence in the crop and increasing populations of natural enemies, respectively.

The problem

The pollen beetle (*Meligethes aeneus*) is the most numerous of a suite of pests that attack oilseed rape (Alford *et al*., 2003). In the UK, it is economically the most important spring pest of oilseed rape and is the major target of spring-applied insecticides (Defra & SEERAD, 2006). Adults emerge from over-wintering sites in early spring and migrate to winter oilseed rape crops where they mate and lay eggs in the flower buds. Oviposition and feeding damage by adults and first instar larvae within the bud results in bud abscission and loss of yield. Second instar larvae feed on pollen from open flowers and do not cause significant damage (Williams & Free, 1978). Only plants at the green–yellow bud growth stages are susceptible to yield-limiting damage (Tatchell, 1983; Axelsen & Nielsen, 1990). Backward winter- and spring oilseed rape crops are most at risk, as the damage-susceptible growth stage occurs after pollen beetles have emerged from over-wintering and are actively seeking feeding and oviposition sites. Current spray thresholds reflect this, and in the UK it is recommended that action should be taken when over 15 beetles/plant are found at green–yellow bud for a normal winter crop, over 5/plant for backward crops and over 3/plant for spring oilseed rape crops (Oakley, 2003).

For the past decade, control of the pollen beetle in the UK has relied exclusively on the pyrethroid class of insecticides. Insecticide sprays were applied to 85% of crops in 2006, 13% receiving four or more sprays and > 99% of applications were pyrethroids (Defra & SEERAD, 2006). Half of sprays were applied in spring and pollen beetles are often exposed to at least two treatments: once at green–yellow bud stage (pollen beetles the direct target) and again, when the larvae are active, during flowering (targeted at seed weevils, *Ceutorhynchus assimilis*).

Pyrethroids are well documented as being vulnerable to the development of resistance by pest species, and sole reliance on this chemical class has recently selected for strong and widespread resistance in some Northern European countries (see accompanying papers in this volume). In the UK, monitoring work in 2006 and 2007 has shown resistance to remain rare, and localised mostly in coastal districts in the south and east of the country (unpublished data). This geographical pattern is consistent with immigration of resistant beetles from mainland Europe rather than resistance genes appearing *de novo* in the UK. However, sustained reliance on and use of pyrethroids seems bound to cause the problem to intensify and spread, resulting eventually in control failures and, if unchecked, a need to switch wholly to more costly alternatives such as neonicotinoids.

Foremost, among a suite of tactics for combating resistance, is the need to minimise insecticide exposure through measures aimed at reducing pest incidence and exploiting non-chemical control agents to the greatest extent possible (Roush, 1989; Denholm & Rowland, 1992). Such measures benefit from a sound knowledge of the ecology and behaviour of pests, and how these interact with crop phenology and agronomy. These aspects of pollen beetle biology and control are the subject of several recent or ongoing projects funded by national agencies or the European Union (e.g. the MASTER project, Williams, 2006). Ecological approaches to control of pollen beetles emerging from such research include development of monitoring traps (so that growers can more easily and accurately identify when spray thresholds have been breached), trap cropping tactics, and practices that promote conservation biocontrol. Each approach can help to reduce the number of insecticide applications and the area sprayed, and would be particularly effective if adopted as part of an integrated pest management strategy.

Monitoring traps

As pyrethroids are inexpensive, spraying for pollen beetles often occurs prophylactically or at population levels far below the established thresholds. Growers and advisors therefore probably lack confidence in the current thresholds, but easier methods to implement the thresholds are critical to reduce the number of unnecessary sprays. Current advice on methods for crop monitoring is to walk a transect into the field and along the way dislodge the beetles from selected plants into a tray or the hand and calculate the mean number of beetles per plant across the transect. However, where crop monitoring is used for risk assessment, it is likely that the pest population is overestimated because in reality, most plants are usually selected from the crop edge where the population is often higher than further towards the crop centre (Free & Williams, 1979; Cook *et al*., 2004). Moreover, mapping studies have shown beetle distributions in fields to be patchy; so even the recommended transect samples may be inaccurate (Ferguson *et al*., 2003). Monitoring traps could help to define more accurately when spray thresholds have been breached and be easier to use.

It is known that pollen beetles locate their host plants using a combination of visual and olfactory cues (Blight & Smart, 1999; Jönsson *et al*., 2007). This host-location behaviour is exploited in the design of monitoring traps. In studies during the 1990s to develop a monitoring trap for oilseed rape pests, volatile extracts from flowering shoots and leaves of oilseed rape were collected (Blight, 1990) and 25 compounds which stimulated the antennae of pollen beetles were located (Blight *et al*., 1995). Slow release dispensers were developed to test the responses of oilseed rape pests to oilseed rape volatiles in field trapping trials (Smart *et al.,* 1997). Trials were conducted to determine the best trap design, assess the effects of trap colour and to identify an attractive volatile bait for pollen beetles (Blight & Smart, 1999; Smart & Blight, 2000). Beetles were most attracted to a yellow sticky card trap angled at 45° to the vertical and baited with a slow release dispenser of 2-phenylethyl isothiocyanate. However, trap catch of non-targets was high and the traps were not calibrated. Recent developments in the visual ecology of insects using electroretinogram (ERG) techniques mean that it is now possible to optimise trap colour for pests and minimise catch of non-target species (Döring & Chittka, 2007; Döring & Kirchner, 2007). New mixed modelling techniques (Welham *et al*., 2004) have the potential to help in calibration and to determine the optimal positioning of traps based on spatial relationships. Developments in decision support systems can now provide more detailed advice about when to focus monitoring effort and this can be tailored to local conditions and distributed interactively over the web (Newe *et al*., 2003; Johnen *et al*., 2006).

Trap cropping tactics

Trap crops are plant stands that are designed to attract, intercept and retain insects, thereby reducing pest density and damage to the main crop (Cook *et al*., 2007a). Knowledge of host plant location, acceptance and preferences of pests as well as their natural enemies is exploited in this tactic. Several studies in the 1990s indicated that turnip rape (*Brassica rapa*) was a preferred host plant of pollen beetles and that it had potential as a trap crop for oilseed rape crops (Hokkanen *et al*., 1986; Buechi, 1989, 1990; Hokkanen, 1991). Recent research developments have now led to a greater understanding of how the strategy works and will enable the development of robust and effective commercial-scale trap cropping tactics for both winter and spring oilseed rape production.

Field studies using a spring oilseed rape model indicated that turnip rape (*Brassica rapa*) shows good potential as a trap crop for pollen beetles as turnip rape plots were more heavily infested (Cook *et al*., 2006). Laboratory and semi-field studies revealed that the preference of oilseed rape pests for turnip rape over oilseed rape is at least partially due to the early flowering nature of turnip rape, and its more attractive volatile profile (Cook *et al*., 2007b). An individual-based model developed at Rothamsted predicted that a border trap crop would be the most efficient arrangement of the trap crop, particularly since the pest infests the crop from the edges (Potting *et al*., 2002, 2005). A replicated field study showed that oilseed rape plots bordered with a turnip rape trap crop were less infested by pollen beetles and suffered less damage than plots without a turnip rape trap crop on which action thresholds were breached (Cook *et al*., 2004). There was evidence that pollen beetle parasitoids were attracted earlier to plots with trap crops than to control plots (Cook *et al*., unpublished data).

Current studies aim to develop a trap cropping tactic for pests of winter cropping systems (e.g. Barari *et al*., 2005; Carcamo *et al*., 2007). Studies in 2006 identified an early-flowering winter turnip rape and this was tested in field experiments in 2007 with some promising results (Cook *et al*., unpublished data). Future studies will test the trap cropping tactic on a whole field scale in commercial systems and examine the effect of field size on the success of the method.

Conservation biocontrol

Understanding the ecology and behaviour of parasitoids and other natural enemies of pollen beetles could help to improve natural pest control in oilseed rape crops. Parasitoids can act as very efficient biocontrol agents of pollen beetles, with parasitism rates often exceeding 50% in untreated fields (Nilsson, 2003). The three key parasitoids of pollen beetles are *Phradis interstitialis*, *Phradis morionellus* and *Tersilochus heterocerus*. They migrate to the oilseed rape crop during flowering and parasitize the larvae in the buds and flowers. The parasitoids develop to adulthood in the hosts' pupal cocoon in the soil. They over-winter as adults in the cocoon and emerge in spring in the following crop (usually wheat).

Fewer than 2% of parasitized hosts give rise to adult parasitoids the following spring under conventional agronomy. If parasitism rates of 25–50% can be achieved when mortality between generations is 98%, any measures which improve their survival by even a small proportion are likely to have a significant impact in reducing the need for chemical control of pollen beetles.

Minimising tillage would help to conserve parasitoids. As they over-winter in the top few centimetres of the soil, they are subject to tillage for establishment of the crop that follows. Emergence of parasitoids following minimum tillage (non-inversion) was around double that emerging from conventionally ploughed and cultivated plots (Ferguson *et al*., 2007). Furthermore, the percent increase in abundance of these parasitoids in plots with non-inversion tillage or no tillage significantly exceeded the increased abundance of their hosts in the same plots (Ferguson *et al*., 2007).

Avoiding unnecessary sprays would also help to conserve parasitoids. Phenological studies show that the earliest species of pollen beetle parasitoid arrives on the crop two weeks later than its host and few are present in the crop before flowering (Ferguson *et al*., 2003). The parasitoids would be conserved by adherence to current UK recommendations that insecticide sprays for pollen beetles are unnecessary once the crop is in flower. Pollen beetle parasitoids are also vulnerable to insecticides applied for control of seed weevils. This could again be minimised by the proper use of risk assessment and decision support systems.

Conclusions

In many respects, problems being encountered currently with pollen beetles epitomise the risks inherent in control strategies that rely almost exclusively on the cheapest and simplest option available. Moves are underway in many countries to combat resistance through rotation of pyrethroid and non-pyrethroid insecticides. However, the latter remain in short supply, and alternatives to pyrethroids such as neonicotinoids are themselves proving prone to resistance development (Nauen & Denholm, 2005). Unlike insecticide applications, none of the measures described above are likely to prove 'silver bullets' in their own right, but integrated into strategies that take account of realistic damage thresholds and threats posed by the pest complex as a whole, they offer a far greater prospect of achieving long-term sustainability of oilseed rape production.

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Approches écologique pour lutter comme les méligèthes du colza

Dans une période d'augmentation de la demande pour l'huile de colza comme biocarburant et pour l'alimentation et alors que les zones cultivées se développent, le risque de résistance des méligèthes aux pyréthrinoïdes présente une menace importante pour la durabilité de la culture du colza et les revenus des agriculteurs. Des mesures sont nécessaires d'urgence pour réduire l'utilisation des insecticides contre les méligèthes, pour préserver l'activité de la panoplie limitée des insecticides et minimiser la pollution du milieu naturel. Dans cet article, la situation de la résistance des méligèthes aux insecticides pyréthrinoïdes et les méthodes de lutte actuelles sont présentées, du point de vue du Royaume-Uni. Trois approches écologiques pour lutter contre les méligèthes et qui sont basées sur la recherche sur leur comportement et leur écologie et celle de leurs ennemis naturels sont mises en valeur: suivi, cultures pièges et lutte biologique par conservation. Ces approches pourraient de diminuer de façon importante l'utilisation d'insecticides contre les méligèthes en aidant à identifier le moment où les seuils d'application ont été atteints, en réduisant l'incidence du ravageur dans la culture et en augmentant les populations d'ennemis naturels, respectivement.

Экологические подходы к борьбе с цветоедами на масличном рапсе

В период увеличения спроса на рапсовое масло в качестве биотоплива и для пищевого использования и расширения площадей выращивания рапса опасность появления резистентности рапсового цветоеда к пиретроидам представляет собой существенную угрозу поддержанию этой масличной культуры и стабильности доходов производителя. Поэтому необходимо срочно принять меры, позволяющие уменьшать использование инсектицидов против рапсового цветоеда, с тем чтобы сохранять действенность ограниченного арсенала препаратов и свести к минимуму экологическое загрязнение. В статье рассматривается статус резистентности рапсового цветоеда к пиретроидным инсектицидам, а также имеющиеся в настоящее время способы борьбы с ним в Великобритании. Рассматриваются три экологических подхода к борьбе с рапсовым цветоедом, основанные на исследовании его поведения и экологии, также поведения и экологии его природных врагов: применение мониторинга, отлов в ловушки и консервационная биологическая борьба. У всех этих подходов есть возможность значительного уменьшения использования инсектицидов в борьбе с рапсовым цветоедом путем выявления сроков достижения пороговых значений для опрыскиваний, уменьшения уровня численности вредителя на сельскохозяйственной культуре или увеличения численности популяций их естественных врагов, соответственно.

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