SCEPTREPLUS

Final Trial Report

Trial code:	SP 22
Title:	**Bean Seed Fly (*Delia platura*): A review of control and management techniques in vegetable crops, including legumes with a focus on insecticides and bio-insecticides.**
Crop	Vegetable crops including Legumes
Target	Bean Seed Fly (*Delia platura*)
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Organisation(s):	Warwick Crop Centre PGRO
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ORETO Number: (certificate should be attached)	N/A

I the undersigned, hereby declare that the work was performed according to the procedures herein described and that this report is an accurate and faithful record of the results obtained

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Date Authors signature

Review Summary

Introduction

Bean seed fly can be a pest of a wide range of crops, but is particularly damaging currently to legumes and alliums. Management of bean seed fly has always been challenging. In recent years the most effective insecticide treatments have been seed treatments. These have relied on a limited number of active ingredients and generally one active ingredient has been available for each crop. If these treatments are lost, for whatever reason, it leaves growers in a very vulnerable position. This has occurred recently in terms of the chlorpyrifos seed treatment on *Phaseolus* beans and thiamethoxam seed treatment on pea; for both crops treated seed was imported to the UK. This document reviews studies on insecticidal control and also considers other potential management/control techniques for bean seed fly to identify further options that might be investigated within the SCEPTREplus project or in other ways.

Summary

This document contains a review of control and management techniques for bean seed fly (*Delia platura*) in vegetable crops, including legumes. It focuses particularly on control with insecticides and bio-insecticides, to inform the design of any efficacy trials to be undertaken in the SCEPTREplus project. It is not a comprehensive review but uses key papers to highlight possible approaches. The main conclusions are:

- There have been few recent studies on control of bean seed fly.
- Bean seed fly is a 'problem' on a range of crops in various parts of the world.
- Cultural control methods have been evaluated on a number of crops (Table 1.1) and this is certainly an approach worth exploring in more detail for specific UK crops as part of an integrated control strategy.
- Information on the timing of peak periods of fly activity may also be useful to growers.
- Of approaches to control bean seed fly with insecticides, seed treatments are undoubtedly the most effective way of reducing bean seed fly damage (depending on active ingredient). However, several studies suggest that in-furrow treatments of appropriate insecticides may provide a useful level of control.
- Much of the research on insecticides has used active ingredients that would not be approved for this use in the UK. Two insecticides that are approved on other crops in the UK (chlorantraniliprole and cyantraniliprole) have shown potential, but their use for bean seed fly control would depend on a new method of application (either as an in-furrow treatment or a seed treatment). It is also possible that other insecticides, not tested previously against bean seed fly, may be identified for inclusion in SCEPTREplus trials.
- Control with garlic formulations and nematodes has been investigated. The garlic formulations proved ineffective. It may be worth investigating the application of entomopathogenic nematode products available in the UK.

Table 1.1 Some key points about cultural control methods identified in the publications reviewed. Some of these approaches may require further exploration before they are recommended.

1	Growers should ensure that weed or cover crop growth has died back before cultivation and seedbed preparation, and that there is little to no green organic material in soils.
2	A period of 2 to 3 weeks in advance of planting is sufficient to allow decomposition of residues.
3	When preparing soil for planting beans, some advisors recommend leaving about an inch of dry, well cultivated soil on the surface as it may be unattractive to the egg-laying flies.
4	Sowing seeds into warm, dry soils promotes rapid emergence and shortens the time that seeds are exposed to attack by bean seed fly
5	The use of reduced cultivations and stale seedbeds may aid management of bean seed fly. However, there is also a suggestion from colleagues in other parts of northern Europe that increasing problems with bean seed fly might be related to use of non-inversion and minimal tillage approaches, which is in contrast to some of the studies identified in the review.
6	Bean seed fly is more of a problem when susceptible crops are planted in succession and it is therefore advisable not to plant successive susceptible crop species.

Next Steps

The review has identified three approaches that could be pursued:

1. Exploration and evaluation of cultural control methods for specific crops grown in the UK. The best way to begin this is probably to hold a workshop to involve interested parties.
2. Evaluation of the value of monitoring/forecasting information – what might be feasible and how useful would it be to growers?
3. Trials to evaluate ‘new’ insecticide/bio-insecticide treatments (including nematodes) with a view to evaluating different methods of application e.g. in-furrow treatments with appropriate products. With agrochemical/biopesticide companies we need to identify products that might be used as seed treatments or in-furrow treatments.

Take home message

It seems very likely that future management of bean seed fly on susceptible crops will need to rely on an integrated approach which uses cultural control methods, information on bean seed fly activity and methods of insecticidal or biological control. There will be an opportunity this winter for growers and advisors to take part in a workshop about bean seed fly control.

Review

Introduction

Delia platura (bean seed fly) affects more than 40 species of plants and is an important pest of peas, maize and beans. Host plants include *Phaseolus* beans, peas, cucumber, melon, onion, pepper, potato and maize (alfalfa, cotton, strawberry and tobacco are secondary hosts) (University of Florida http://entnemdept.ufl.edu/creatures/FIELD/CORN/seedcorn_maggot.htm). The bean seed fly larva is a common pest found in most temperate countries, and more widely (CABI data sheet - https://www.cabi.org/isc/datasheet/28168), affecting a wide range of large-seeded plant hosts. In severe infestations plant loss at seedling stage may be high, often resulting in re-drilling and subsequent loss of production of high value vegetable crops at an early growth stage. Finch (1989) reported that in some crops in the UK, plant loss could be up to 60% in untreated vegetable crops, although plant loss was more likely to occur at a level of approximately 25%. Bean seed fly has been identified as a high priority for UK vining peas, picking peas and *Phaseolus* beans (green and runner beans), as well as in alliums, asparagus and leafy salads, due to increasing incidents of damage, the loss of key active insecticidal substances and the increased use of cover crops in rotations.

Description and Life-cycle

Adults are brownish-grey flies with three stripes on their back and are about half the size of a house fly, around 0.5cm long. The eggs are white, elongated, 0.16cm long and deposited in loose groups among plant debris and around the plant stems near the soil surface (Gill *et al.,* 2013). Each adult female lays an average of 270 eggs. Larvae are legless and white to yellowish in colour. They are about 0.5 cm long with a pointed head and two black mouth hooks.

Adult flies are attracted to freshly disturbed soil containing debris from previous crops, high levels of organic matter such as farmyard manure, or weed debris, and are scavengers of decaying organic matter in soils (Gratwick, 1992). In contrast to initial concerns, the adoption of conservation tillage does not seem to increase bean seed fly damage as there is minimal disturbance to soil (Hammond, 1997). There is evidence that the damage potential is reduced in no-tillage systems and germinating seeds alone are not sufficient to attract large populations of flies, although Gouinguene and Stadler (2006) reported the importance of the olfactory cues from germinating seeds that are used by *D. platura* to locate oviposition sites. The combination of recently cultivated soil, high levels of partially decayed organic material and germinating seeds is reported to attract large numbers of bean seed fly adults (Schmidt *et al.,* 2017).

Live, green organic matter or animal manure incorporated into soils in the spring attracts egg-laying flies. Eggs are laid on the soil surface and larvae hatch after a few days and feed on newly planted seeds or plant and crop debris. After 10-14 days, larvae pupate and emerge as a second generation of flies. There may be several overlapping generations per year in peas and *Phaseolus* beans, occurring from late spring until early autumn (Biddle and Cattlin, 2007). Generation time (adult to adult) is estimated at approximately 500-580 day-degrees (Funderburk et al.,

1984) or 376 day-degrees for egg-adult (Sanborn et al., 1982), all above a threshold of 3.9°C.

Symptoms and Identification

The seed of late planted peas or beans is attacked during germination. Eggs are laid on freshly disturbed soil by adults attracted to decaying vegetable and plant material. Larvae feed on newly planted seeds and seedlings, tunnelling into freshly imbibed seeds and the stems of small seedlings. Damage to the seed causes damage to the plumule and root and often to the growing point of the plant, resulting in a 'baldhead' symptom in *Phaseolus* beans, where the stem elongates but no terminal leaves are present (Biddle and Cattlin, 2007). In peas and *Vicia faba,* secondary shoots may be formed to compensate for the damage to the growing point, but in *Phaseolus* beans this is not the case, and the plants may die at early emergence. Damage arrests growth and may encourage the development of secondary diseases or subsequent attack by other invertebrates, also resulting in the death of plants (Gratwick, 1992). Damage often occurs in patches as bean seed flies aggregate before egg-laying, and late-cultivated fields containing high levels of green material, either weed or crop debris, are more prone to infestation. Cover crops may also increase the risk of bean seed fly attack in some instances but more information is required.

Cultural Control and Management

Late spring and early summer sowings of peas and *Phaseolus* beans are most at risk from attack in the UK. The flies lay most of their eggs in soil that contains large quantities of decaying plant matter or farmyard manure. Growers should ensure that weed or cover crop growth has died back before cultivation and seedbed preparation, and that there is little to no green organic material in soils. A period of 2.5 to 3 weeks following incorporation of green material has been found to be sufficient to reduce injury to soya bean crops in Ohio, and this was related to accumulated thermal units (Hammond and Cooper, 1993). Schmidt *et al.* (2017) also reported a requirement of 2 to 3 weeks in advance of planting to allow decomposition of residues.

The flies lay eggs in moist soil. When preparing soil for planting beans, some advisors recommend leaving about an inch of dry, well cultivated soil on the surface. This may be unattractive to the egg-laying flies. Quick germination in warmer conditions lessens the likelihood of injury from bean seed fly larvae because it shortens the period during which the seeds and young plants are most susceptible to injury (Elmore, 1962; Schmidt *et al.,* 2017). Therefore, planting into warm, dry soils promotes rapid emergence and shortens the time that seeds are exposed to attack by bean seed fly (Holm and Cullen, 2012).

Increased tillage is associated with increased numbers of bean seed fly larvae, and minimum tillage may help to manage the pest (Hammond, 1997). Hammond (1997) described the results of a long-term experiment to determine the impact of no-tillage systems on the abundance of the pest *D. platura* in soya-maize cropping systems. In 9 out of 12 years of the study, the lowest level of *D. platura* adults was recorded in the no-till plots. The highest numbers of adults were collected in the areas where the soil was more disturbed by cultivations. Experiments used 2 replications per treatment using different sites as the replications. Schmidt *et al.* (2017) also cited conservation tillage to reduce attack by bean seed fly, due to the generally higher levels of natural enemies recorded in no-till systems, and the fact that residual plant material is not incorporated into soils, bean seed flies being more attracted to incorporated, decomposing material. The use of reduced cultivations and stale seedbeds may therefore aid management of bean seed fly.

There are varying opinions about the effectiveness of crop rotation to reduce pest attacks by bean seed fly, as the insects can fly long distances (Finch, 1989). Bean seed fly is more of a problem when susceptible crops are planted in succession and it is therefore advisable not to plant successive susceptible crop species. Bean seed fly populations following the incorporation of live green pea haulm, or grass cover crops, are reported to be higher than when other crop residues are incorporated (Holm and Cullen, 2012).

Natural Predators

Approximately 30% of bean seed fly eggs may be predated by ground beetles (Finch, 1989) and there is some parasitism by Staphylinid beetles such as *Aleochara* spp. (Jonasson *et al.,* 1995). The predator/pupal parasitoid *Aleochara bilineata* (Gyllenhal) (Coleoptera: Staphylinidae) (Broach *et al.,* 2006) is present in the UK (NBN Gateway: https://species.nbnatlas.org/species/NHMSYS0001716666#overview).

Populations of natural predators should be encouraged. The development of semi-natural habitats such as field margins, hedgerows and copses may help to increase numbers of natural predators (Woodcock *et al.,* 2005).

Monitoring and Insect Development Models

Attractant traps are available for use to monitor bean seed fly activity and these include yellow sticky cards and yellow water traps (Ellis and Scatcherd, 2007). Ishikawa and Matsumoto (1984), in a Japanese study, analysed chemical constituents of decomposing onion pulp, and identified 2-phenylethanol plus n-valeric acid as a strong combined attractant for bean seed fly and onion maggot fly. Further study in the US in 2005 (Kuhar *et al*., 2006) found that yellow sticky traps baited with the attractant described by Ishikawa and Matsumoto (1984) were more effective in attracting both male and female bean seed flies than yellow sticky traps alone. This could be investigated in the UK as a potential option for monitoring or management by mass capture (unlikely to be effective with a generalist species with a wide range of hosts such as bean seed fly).

The use of models to predict periods when fly emergence and egg-laying activity is at its lowest may help to plan sowing dates to avoid attack from bean seed fly. However, altering the sowing timing of peas or *Phaseolus* beans to a ‘fly-free’ period when the insect is in its non-feeding pupal stage, may present challenges, as *Phaseolus* beans are not suitable for earlier sowing, and vining peas are grown in strict sowing schedules from March onwards to allow consistent throughput of peas at UK factories, harvested between the end of June and the end of August. However, the use of prediction models should be further explored, as should the development of commercial trapping systems.

Accumulated thermal units of 200-234 day-degrees are reported to be the requirement for development of eggs to pupae, when larval feeding ends (Hammond and Cooper, 1993; Holm and Cullen, 2012) and between 200 and 255 day-degrees for *D. platura* in onions, with 3.9°C as the developmental threshold (Wilson *et al.,* 2015). Larval feeding starts very soon after oviposition. Peak spring emergence of the overwintered generation occurs at 200 day-degrees from 1 January (3.9°C base temperature) (Holm and Cullen, 2012). The simplest formula for calculating insect day-degrees is: Day-degrees = (maximum temperature + minimum temperature/2) – base temperature. Each day's degree day calculation is added to the previous sum for a cumulative total. If the average daily temperature for a given day is less than the base temperature, then zero insect day-degrees are accumulated for that day. Approximately 250 to 270 Celsius day-degrees after peak adult emergence (470 day-degrees from 1 January), developing bean seed fly larvae will have reached the pupal stage, at which time the risk of damage to seed and seedlings is lower (Holm and Cullen, 2012).

Insecticides

There are no insecticidal seed treatments approved to control bean seed fly larvae on legumes in the UK and insecticide spray applications are of limited value to control the pest.

For some years imported pea seed was treated with the systemic neonicotinoid seed treatment thiamethoxam (TMX) (Cruiser) – the use of this active substance was restricted/ banned for use in Europe in 2013 for some outdoor crops and banned for all outdoor use in April 2018 (European Commission, 2018).

For some years *Phaseolus* bean seed was imported treated with chlorpyrifos seed treatment. Due to changes in UK regulation and the risk of produce exceeding maximum residue levels, use of imported seed treated with chlorpyrifos may not be advisable.

Tefluthrin seed treatment is approved in other outdoor crops (not legumes) in the UK, both as a straight active substance and in a mixture with fludioxonil (Austral Plus) (Fera Science Ltd., 2018). An approach was made to the manufacturer, but on-label approval for Force ST may not be appropriate for legumes.

In a recent study anthranilic diamide insecticides, chlorantraniliprole and cyantraniliprole, delivered as seed and as in-furrow treatments reduced *D. platura* damage to the same level as a standard neonicotinoid seed treatment (thiamethoxam) in snap beans (Schmidt-Jeffris and Nault, 2016). In a trial in 2009, of the untreated control plants, 55% were damaged by *D. platura* whereas 12% were damaged after seed treatment with thiamethoxam and 9-16% were damaged following seed treatment with different rates of diamides and 13-18% following in-furrow treatment with diamides. In 2010, the control treatments at 2 locations suffered 33 and 29% damage respectively. Damage after seed treatment with thiamethoxam was 9-10%, damage with diamide seed treatment was 6-25% and 9-26% respectively, depending on the rate applied, and crops treated with in-furrow treatments of chlorantraniliprole suffered damage of 14-26% and 12-14% respectively, again depending on the rate applied. Chlorantraniliprole and cyantraniliprole appear to be equally effective (Schmidt-Jeffris and Nault, 2016). Previous work by Palumbo (2011) showed that both active ingredients applied in-furrow reduced damage by *D. platura* to the same level as thiamethoxam (70% seedling emergence at 22 days after planting). These insecticides are not currently approved in peas or beans, and there are no seed treatment formulations of chlorantraniliprole or cyantraniliprole currently approved in any crops in the UK (Fera Science Ltd., 2018). Chlorantraniliprole is approved for use in fruit, tomatoes and root crops in the UK. Cyantraniliprole is approved for use in brassica and strawberry in the UK. Anthranilic diamides belong to IRAC Group 28 and are ryanodine receptor modulators. These insecticides are systemic and have long-lasting residues (Schmidt-Jeffris and Nault, 2016). They are recorded as having low toxicity to many beneficial organisms.

Another recent study was on control of onion fly and bean seed fly in onion in California (Wilson et al., 2015). They assessed yield and crop damage due to both species and so it is not possible to identify particular effects on bean seed fly. The treatments assessed are summarised in Table 1. Overall, seed treatments with spinosad or clothianidin + imidacloprid were the most consistently effective treatments. Of the in-furrow treatments, chlorpyrifos was the most effective, although not consistently so.

Table 1. Insecticide treatments evaluated for control of onion fly and bean seed fly on onion in California (Wilson et al., 2015).

Active ingredient	Application method	Comments
Chlorpyrifos	In furrow liquid	Effective in 1 of 3 years
Chlorpyrifos	In furrow granule	Not as good as liquid
Clothianidin & Imidacloprid	Seed treatment	Most consistently effective
Imidacloprid	In furrow	Ineffective
Spinosad	In furrow & Rototill – broadcast and incorporated before planting	Ineffective
Spinosad	Seed treatment	Most consistently effective
Thiamethoxam	Seed treatment	Not as good as other seed treatments
Thiamethoxam & spinosad	Seed treatment	No better than spinosad seed treatment

Spinosad as a seed treatment has been shown to give good control of *D. platura* in onions (Wilson *et al.,* 2015; Table 1), reducing feeding and increasing yield. Clothianidin + imidacloprid seed treatment also gave good control but this is unlikely to be permitted for use in the UK. Chlorpyrifos liquid in furrow gave good control on some occasions but is unlikely to be permitted in the UK. Recent restrictions on the use of neonicotinoid active substances mean that thiamethoxam will not be approved in the UK. Spinosad is not currently available as a seed treatment in the UK.

As opportunities for seed treatment may be limited it is worth considering the potential of in-furrow applications. A field trial with beans (*Phaseolus vulgaris* L.) was performed in Chile, to evaluate the insecticidal effect of aldrin, carbofuran, chlorpyrifos, diazinon and lindane, applied to the seed or the seed furrow, against *D. platura* (Montecinos et al., 1986). Plant emergence was reduced with carbofuran and diazinon as a seed treatment, and chlorpyrifos in the furrow, in relation to the control. All insecticidal treatments reduced damage to the plants. Of the control plants, 37% were damaged 30 days after sowing. The percentage of plants damaged when the seed was treated ranged from 4-13% depending on the active ingredient, whereas the percentage of plants damaged following in-furrow treatments was 4-12% - so effectively within the same range. Effects on the numbers of *D. platura* pupae at intervals after sowing were also assessed and most treatments had approximately halved the numbers of pupae in the soil 10 days after sowing.

Of the insecticides described above, most are active ingredients that would not be approved for this use in the UK. Two insecticides that are approved on other crops in the UK (chlorantraniliprole and cyantraniliprole) have shown potential, but their use for bean seed fly control would depend on a new method of application (either as an in-furrow treatment or a seed treatment). It is also possible that other insecticides, not tested previously against bean seed fly, may be identified for inclusion in SCEPTREplus trials. What this review has shown is that seed treatment is likely to be the most effective method of application but that in-furrow treatments are also worth investigation.

Bio-insecticides

There has been little uptake of non-insecticidal control agents in peas and *Phaseolus* beans due to the availability of seed treatments on imported seed for some years, and the availability of chlorpyrifos as a ground spray in the past (although this was somewhat less effective than seed treatments).

There are several garlic formulations approved in the UK in edible and non-edible crops. Ellis and Scatcherd (2007) found that garlic liquid and granules did not reduce the numbers of larvae and pupae in pot tests (natural oviposition) compared with the untreated control. The most effective treatments were conventional insecticides (chlorpyrifos and diflubenzuron drenches) and CERIO 14 and there was also a 50% reduction in numbers compared with the untreated control following application of *S. feltiae*, as mentioned below. Some of the ‘other treatments’ had more larvae and pupae per pot than the untreated control. This was perhaps the result of ‘patchy’ oviposition or of flies making ‘choices’.

Jaramillo *et al.* (2013) evaluated the susceptibility of bean seed fly to seven species of entomopathogenic nematodes from Colombia. They achieved up to 75-88% mortality with one species and showed that this species could reproduce in bean seed fly larvae, indicating the potential for control.

There are a number of nematode products available that might be evaluated and are approved for use in edible and non-edible crops. These are based on: *Steinernema carpocapsae, Steinernema feltiae* or *Steinernema kraussei*. Ellis and Scatcherd (2007) found that *S. feltiae* reduced larval and pupal numbers in pot trials by 50% and allowed ~94% onion plant survival, compared with tefluthrin seed treatment, used as a standard, where plant survival was 100% (tefluthrin seed treatment did not reduce the numbers of larvae and pupae). The untreated control had 94.5% survival of seedlings. One or more appropriate nematode products should certainly be tested in the field.

Current Research Overseas

Emails from colleagues working in other countries in northern Europe indicated that bean seed fly is of increasing concern, partially because of limited methods of insecticidal control. There is also a suggestion that increasing problems with bean seed fly might be related to use of non-inversion and minimal tillage approaches, which is in contrast to some of the studies described above. It appears that some insecticide trials focusing on bean seed fly have been undertaken in continental Europe in 2018 but their findings are likely to be confidential.

Integrated Control

The review has identified a number of components of a possible integrated control strategy including cultural control and use of information about the timing of egg-laying to time sowing or to target control methods using insecticides or bioinsecticides (if available). Possible other solutions may include: intercropping/ sterile male insect release (Finch, 1989). Finch (1989) also discussed the interaction of crop protection products with biological controls and beneficial organisms, including detrimental effects that may lead to reductions in parasitism and predation. He emphasised the importance of careful integration of methods, to avoid compromising cultural and biological controls where they were used.

Conclusions

The main conclusions are:

- There have been few recent studies on control of bean seed fly.
- Bean seed fly is a ‘problem’ on a range of crops in various parts of the world.
- Cultural control methods have been evaluated on a number of crops and this is certainly an approach worth exploring in more detail for specific UK crops as part of an integrated control strategy.
- Information on the timing of peak periods of fly activity may also be useful to growers.
- Of approaches to control bean seed fly with insecticides, seed treatments are undoubtedly the most effective way of reducing bean seed fly damage (depending on active ingredient). However, several studies suggest that in-furrow treatments of appropriate insecticides may provide a useful level of control.
- Much of the research on insecticides has used active ingredients that would not be approved for this use in the UK. Two insecticides that are approved on other crops in the UK (chlorantraniliprole and cyantraniliprole) have shown potential, but their use for bean seed fly control would depend on a new method of application (either as an in-furrow treatment or a seed treatment). It is also possible that other insecticides, not tested previously against bean seed fly, may be identified for inclusion in SCEPTREplus trials.

- Control with garlic formulations and nematodes has been investigated. The garlic formulations proved ineffective. It may be worth investigating the application of entomopathogenic nematode products available in the UK.

Overall, future management of bean seed fly on susceptible crops will need to rely on an integrated approach which uses cultural control methods, information on bean seed fly activity and methods of insecticidal or biological control. Further work needs to be undertaken on all of these aspects before robust strategies appropriate to particular crops can be recommended.

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