crop groups with maggot pests, not just onion. However, the ambitious proposal lacked sound efficacy data to back it up. A national efficacy program, coordinated by IR-4, was set up in 2007 and 2008 to address this deficiency as well as collect additional confirmatory data for onion maggot, the original and still main target pest.

Efficacy data were generated during 2007 on the following crops: onion, green onion, cabbage, kale, corn, peas, beans, carrot and melon. In general, spinosad was confirmed to be an effective seed treatment against onion maggot and also seedcorn maggot (*Delia platura*). Commercial levels of control were not seen for cabbage maggot (*Delia radicum*) or carrot rust fly (*Psila rosae*). We were surprised to see some early control of onion-infesting thrips with the spinosad seed treatment, but the level of control was not considered commercially significant and it was not observed in all trials.

The data collected in 2008 focused on refining seed treatment rates and finalising the pest control spectrum. Trials were established for cabbage, turnip, parsnip, onion, bunching onion, shallots, dry beans, snap beans, field corn, sweet corn, cucumber, peas and pumpkin. These trials once again demonstrated commercial control of seedcorn maggot and onion maggot. Carrot rust fly and cabbage maggot were eliminated as targets, essentially confirming the 2007 results. Cabbage maggot was not controlled even at rates 7.5× higher than rates effective for onion maggot and seedcorn maggot control.

During the summer of 2008, IR-4 requested the US Environmental Protection Agency (EPA) to outline the process for seed treatment registration on the target crops (eventually narrowed down to carrot, bulb vegetables, cucurbit vegetables, legume vegetables, sweet corn and field corn). Much to our surprise and consternation, EPA was concerned about the potential for violative spinosad residues in the crops at harvest.

Not to be thwarted at this point, IR-4 coordinated with the researchers to provide crop samples from their 2008 efficacy plots for spinosad residue analysis. Crop samples of cucumber, onion, sweet corn, field corn, carrot (tops and roots), dry bean and snap bean were collected at commercial maturity and shipped frozen to Dow AgroSciences for spinosad analysis.

Currently the analysis is not complete; however, preliminary numbers appear to be encouraging. Most crops are free of spinosad residues, and in the cases where residues were detected, they were very low, even so low as to be unquantifiable. Once the analysis is completed and a report written, IR-4 will present the data to EPA for their consideration. It is hoped that some uses may be approved in time for the 2009 use season. All target crops should be registered in time for 2010 planting.

This is a fine example of how researchers can identify innovative control solutions for growers and then stay involved in the process until the technology is made commercially available. Great research can only have an impact when it is put into practice.

# Neonicotinoid seed treatments for early-season management of cucumber beetles in cucurbits

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## Introduction

In North America, the striped cucumber beetle, *Acalymma vittatum* (Fabr.), and the spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber, are serious pests of cucurbit crops, especially cucumbers, muskmelons and squash. Adult beetles emerge in the spring and aggregate on cucurbit plants. Female beetles oviposit in the soil at the base of plants where larvae subsequently feed on roots, occasionally reducing plant vigour and yield. However, it is the adults that cause the most severe damage by feeding on foliage and by transmitting the bacterial wilt pathogen, *Erwinia tracheiphila*, which they harbour within their bodies. Young plants are most susceptible to beetle feeding injury and bacterial transmission. Most plant mortality occurs at the cotyledon and first true leaf stage. Cucurbit plants typically can overcome the feeding injury inflicted by cucumber beetles past the second and third true leaf stage.

For decades, growers have used foliar applications of insecticides (often pyrethroids) to control cucumber beetles. Multiple sprays were often needed to achieve effective control. Since the late 1990s, the systemic neonicotinoid insecticides, imidacloprid and thiamethoxam, have provided growers with an alternative to foliar insecticide sprays. Transplant drenches, at-planting soil drenches, and drip irrigation injections of imidacloprid or thiamethoxam have been quite efficacious against cucumber beetles, offering plant protection for up to 56 days after planting (McLeod, 2006). A recently considered alternative to using soil-applied neonicotinoids on cucurbit crops has been to treat the seeds directly, an approach that has achieved much success in other crops such as corn and beans. The purpose of this study was to examine the efficacy of neonicotinoid seed treatments for the control of cucumber beetles in cucumber (*Cucumis sativus*) and pumpkin (*Cucurbita maxima*).

## Materials and methods

Field experiments were conducted in summer 2008 at six locations in the eastern United States (Table 1). Seeds of 'Vlaspik' cucumber and 'Gladiator' pumpkin were treated in the laboratory of Alan Taylor (Cornell University NYSAES, Geneva, NY*)*. A film coating method was used with Disco A and water (1:1) binder. All treatments including the control received the fungicide Thiram Technical grade (98.5% tetramethylthiuram disulfide) at 2.57 g a.i./kg.

**Table 1** Locations and planting information where cucurbit seed treatment experiments were conducted in 2008

| Location | Crop | Plot size and no. of reps | PD |
|---|---|---|---|
| Freemont, Ohio | Cucumber | 1 row × 7.6 m, 4 reps | 6 Jun |
| Columbus, Ohio | Cucumber | 4 rows × 6.1 m, 4 reps | 24 Jun |
| Painter, Virginia | Cucumber | 2 rows × 6.1 m, 6 reps | 27 May |
| Georgetown, Delaware | Cucumber | 4 rows × 6.1 m, 4 reps | 9 Jun |
| Geneva, New York | Pumpkin | 2 rows × 6.1 m, 6 reps | 28 May |
| Upper Marlboro, Maryland | Pumpkin | 5 rows × 15.2 m, 5 reps | 5 Jun |

All experiments included the insecticide seed treatments: thiamethoxam (Cruiser™, Syngenta Crop Protection, Inc., Greensboro, NC) at 0.75 mg a.i./seed, and chlothianidin + imidacloprid (Sepresto™, Bayer CropScience LP, Research Triangle Park, NC) at 1 mg a.i./seed. At most locations, soil insecticide treatments were also applied for comparison and included: thiamethoxam (Platinum™ 2FS, Syngenta Crop Protection) at 584.36 ml of product/ha, and imidacloprid (Admire Pro™ 4.6F, Bayer CropScience LP) at 511.3 ml of product/ha. Soil insecticides were applied at-planting in-furrow with a backpack sprayer that delivered 400 to 500 l/ha.

Potential phytotoxicity of the seed treatments was evaluated by assessing seed germination or cotyledon emergence in the field. Seed germination was evaluated in the laboratory by wrapping at least 10 seeds per treatment in a moistened paper towel. All field experiments were arranged in a randomised complete block design. Plot sizes and number of replications varied by location (Table 1). At various plant growth stages from cotyledon to 4-leaf stage, attempts were made at least weekly to count numbers of live and dead cucumber beetles or other insect pests per 10 plants per plot and evaluate beetle feeding injury (defoliation and percentage of killed seedlings) in the field. Cucumber beetle feeding injury was rated on a 0–3 scale (see Table 3 footnote). In addition, cucumber beetle toxicity assays using excised leaves

**Table 2** Results of pumpkin neonicotinoid seed treatment field efficacy trial, Upper Marlboro, Maryland, 2008

| | Mean no. live beetles/plant | | | % dead plants |
|---|---|---|---|---|
| **Treatment** | **13 Jun (7 DAP)** | **18 Jun (12 DAP)** | **23 Jun (17 DAP)** | **27 Jun (24 DAP)** |
| Control | 10.7 a | 12.3 a | 2.2 a | 15.2 a |
| Thiamethoxam | 1.5 b | 0.5 b | 0.2 a | 1.3 b |
| Imidacloprid + clothianidin | 2.1 b | 0.8 b | 0.2 a | 0.0 b |

Means in a column followed by the same letter are not significantly different ($P \leq 0.05$, orthogonal contrasts).

from the field plots were conducted at two to four different plant growth stages depending on location. Assays consisted of field-collected cotyledons or leaves placed on moistened floral foam along with five to 10 cucumber beetles (striped or spotted) per container. Beetles were field-collected from untreated cucurbits spatially separated from the experimental plots. Leaf bioassays were replicated at least four times per treatment. Beetle mortality was recorded at 72, 96 or 120 h. All data were analysed using analysis of variance procedures. Mean separation tests included Fisher's protected LSD, Tukey's HSD, or orthogonal contrasts depending on location (each cooperator analysed his/her own data).

## Results

### *Seed germination and stands*

Germination tests at two of the locations revealed >98% germination of all treatments. Stand counts were highly variable across locations, and generally did not reveal differences from the insecticide seed treatments except at the Delaware location, where the imidacloprid + clothianidin seed treatment and the thiamethoxam in-furrow spray treatment had a significantly reduced stand in comparison with the control plots or other treatments. Also, at the Maryland location, the thiamethoxam seed treatment had a significantly reduced stand (40%) compared with the other treatments. However, replanted seeds of this treatment had nearly perfect emergence.

### *Cucumber beetle control in the field*

Natural cucumber beetle densities were low across the region in 2008, and at only one of the six locations (Upper Marlboro, Maryland) were beetle counts sufficiently high to obtain useful data. At this location, striped cucumber beetles started to feed at the cotyledon to 1-leaf stage about 8 days after planting. All treatments were effective in killing beetles and reducing

**Table 3** Results of cucumber neonicotinoid seed treatment field efficacy trial, Freemont, Ohio, 2008

| | **4-leaf stage (25 DAP)** | |
|---|---|---|
| **Treatment[1]** | **Mean no. live beetles/plant** | **Leaf feeding injury (0–3 rating scale[2])** |
| Control | 0.2 | 0.6 ab |
| Imidacloprid (IF) | 0.2 | 0.4 bc |
| Thiamethoxam (IF) | 0.3 | 0.7 a |
| Imidacloprid + clothianidin (ST) | 0.4 | 0.5 abc |
| Thiamethoxam (ST) | 0.2 | 0.3 c |

[1] ST, seed treatment; IF, in-furrow application at planting.

[2] Cucumber beetle leaf feeding injury scale: 0 = no injury; 1 = <10% of leaf injured; 2 = 10–50% of leaf injured; 3 = >50% of leaf injured.

Means within a column followed by the same letter are not significantly different ($P \leq 0.05$; Fisher's LSD).

**Table 4** Mean percentage mortality of striped cucumber beetle after 120 h placed on excised cucumber leaves during the cotyledon, 1-leaf and 2-leaf stages from a field experiment in Columbus, Ohio, 2008

| **Treatment**[1] | **Cotyledon** | **1-leaf stage** | **2-leaf stage** |
|---|---|---|---|
| Control | 25 | 10 | 10 |
| Imidacloprid (IF) | 75 | 25 | 15 |
| Thiamethoxam (IF) | 80 | 30 | 30 |
| Imidacloprid + clothianidin (ST) | 75 | 40 | 25 |
| Thiamethoxam (ST) | 65 | 10 | 20 |

[1] ST, seed treatment; IF, in-furrow application at planting.

damage (Table 2). At the 4–5-leaf stage (24 DAP) the untreated control had approximately 15% of the plants killed by beetle feeding, while the seed treatments had few to no plants killed. In addition, at the Freemont, Ohio location there was a significant difference in beetle feeding injury on leaves despite a relatively low beetle population (Table 3). By the 4-leaf stage, the thiamethoxam seed treatment had significantly less beetle feeding injury than the control.

### *Residual toxicity of leaves against cucumber beetle*

Excised leaf bioassays showed toxicity of the seed treatments against cucumber beetles at all locations. At the Columbus, Ohio location, all treatments had a higher percentage mortality of beetles compared with the untreated check at the cotyledon stage (Table 4), but by the 1-leaf stage (16 DAP) none of the treatments were effectively killing beetles.

In excised leaf bioassays conducted 20 days after planting at the Virginia location, both seed treatments provided significant beetle mortality, whereas the in-furrow applications did not (Table 5). In addition, the thiamethoxam seed treatment appeared to be more toxic than the imidacloprid + clothianidin seed treatment at 20 DAP, although not statistically significant.

**Table 5** Mean percentage mortality (after 96 h) of striped cucumber beetles placed on excised cucumber leaves 20 days after planting at Painter, Virginia, 2008

| **Treatment**[1] | **16 Jun (20 DAP)** |
|---|---|
| Control | 5.0 b |
| Imidacloprid (IF) | 10.0 b |
| Thiamethoxam (IF) | 15.0 b |
| Imidacloprid + clothianidin (ST) | 65.0 a |
| Thiamethoxam (ST) | 95.0 a |

[1] ST, seed treatment; IF, in-furrow application at planting.
Means within a column followed by the same letter are not significantly different ($P \leq 0.05$; Fisher's LSD).

**Table 6** Mean percentage mortality (after 96 or 72 h) of striped cucumber beetles placed on excised cucumber leaves collected at the cotyledon and 4-leaf stages at Georgetown, Delaware, 2008

| **Treatment**[1] | **Cotyledon stage 19 Jun (10 DAP)** | **4-leaf stage 30 Jun (21 DAP)** |
|---|---|---|
| Control | 0.0 b | 0.0 b |
| Imidacloprid (IF) | n/a | 62.5 a |
| Thiamethoxam (IF) | n/a | 75.0 a |
| Imidacloprid + clothianidin (ST) | 80.0 a | 68.8 a |
| Thiamethoxam (ST) | 85.0 a | 81.3 a |

[1] ST, seed treatment; IF, in-furrow application at planting.

Means within a column followed by the same letter are not significantly different ($P \leq 0.05$; Tukey's mean separation test).

In excised leaf bioassays conducted at the Delaware location, both seed treatments provided significant beetle mortality at the cotyledon stage and at the 4-leaf stage 21 DAP (Table 6). The two in-furrow insecticide applications were also efficacious at 21 DAP.

In pumpkin excised leaf bioassays conducted at the New York location, both seed treatments provided significant beetle mortality at the 2-leaf stage and at the 4-leaf stage 26 DAP (Table 7). By the 7-leaf stage (33 DAP), none of the treatments effectively killed beetles. The thiamethoxam seed treatment was significantly more toxic than the imidacloprid + clothianidin seed treatment at 19, 26 and 33 DAP. These results were consistent with numerical differences noted with cucumber seed treatments at 20 and 21 DAP at the Virginia and Delaware locations, respectively.

**Table 7** Mean percentage mortality of striped cucumber beetle after 72 h placed on excised pumpkin leaves during the 2-leaf, 4-leaf and 7-leaf stages from a field experiment in Geneva, New York, 2008

| **Treatment**[1] | **2-leaf stage 16 Jun (19 DAP)** | **4-leaf stage 23 Jun (26 DAP)** | **7-leaf stage 30 Jun (33 DAP)** |
|---|---|---|---|
| Control | 1.7 c | 0.0 c | 3.3 bc |
| Imidacloprid (IF) | 24.6 bc | 11.4 c | 1.7 c |
| Thiamethoxam (IF) | 41.1 b | 67.4 a | 8.1 bc |
| Imidacloprid + clothianidin (ST) | 44.1 b | 11.7 c | 1.7 c |
| Thiamethoxam (ST) | 68.0 a | 47.4 b | 11.5 ab |

[1] ST, seed treatment; IF, in-furrow application at planting.

**Table 8** Results of cucumber neonicotinoid seed treatment and in-furrow application efficacy trial, Painter, Virginia, 2008

| **Treatment**[1] | **Mean no. tobacco thrips/10 plants (16 DAP)** |
|---|---|
| Control | 36.5 a |
| Thiamethoxam (IF) | 13.5 b |
| Imidacloprid (IF) | 10.3 b |
| Imidacloprid + clothianidin (ST) | 1.8 b |
| Thiamethoxam (ST) | 0.5 b |

[1] ST, seed treatment; IF, in-furrow application at planting.
Means followed by the same letter are not significantly different ($P \leq 0.05$; LSD).

### *Thrips control in the field*

Seed treatments may also provide control of other insect pests in addition to beetles. At the Virginia location, tobacco thrips, *Frankliniella fusca*, were present on leaves with an average of 37 thrips per 10 plants in the control plots at the second true leaf stage (16 DAP). Although this insect may not be considered a serious pest of cucurbits, it should be noted that all treatments significantly controlled tobacco thrips compared with the untreated control, with the highest efficacy obtained from the seed treatments (Table 8).

## Discussion

In summary, the results of our experiments conducted on cucumbers and pumpkins demonstrated that the neonicotinoid seed treatments thiamethoxam at 0.75 mg a.i./seed and the combination of imidacloprid + clothianidin at 1.0 mg a.i./seed were consistently efficacious against cucumber beetles. Control extended up to the 4-leaf stage or about 20–26 days after planting. Thiamethoxam seed treatment appears to have a longer active residual than imidacloprid + clothianidin. Neonicotinoid seed treatments offer growers an effective new method of combating cucumber beetles and other insect pests that may attack plants early in their development. Seed treatments have the added benefits of less insecticide input in the environment and limited insecticide exposure for the applicator as compared with in-furrow or foliar applications.

## References

McLeod P (2006) Use of neonicotinoid insecticides to manage cucumber beetles on seedling zucchini. *Plant Health Progress* 10. doi:10.1094/PHP-2006-1020-01-RS

# A new treatment for spinach seed with efficacy against seed- and soil-borne fungal pathogens, in particular *Verticillium dahliae*

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## Summary

A commercial development programme has been conducted to generate a new treatment for spinach seed. The focus has been to address the occurrence of *Verticillium dahliae* on spinach seed as well as other seed-borne fungal pathogens. The treatment, GoSeed™, is suitable for organic use (USA-approved). Diagnostic test data are presented for a range of seedlots. The data show that levels of fungal infection differ widely between seedlots, and that several pathogens may be present on individual seeds. The efficacy of a new treatment is evaluated in terms of reduction of on-seed *V. dahliae*. The new process has been designed to be effective against even the highest levels of *V. dahliae* infection. Excellent efficacy against other pathogens such as *Cladosporium variabile* and *Fusarium oxysporum* is also demonstrated. The treatment is also effective against soil-borne pathogens such as *Pythium ultimum* as well as pathogens that are both seed and soil-borne, such as *F. oxysporum*. Seed safety has been a primary consideration. Data are presented showing that treated seed retains germination and, moreover, shows an enhanced speed of emergence.

## Introduction

A programme to generate a commercial spinach seed treatment has been conducted. In order to develop the new treatment, the following aims were established:

- effective treatment of seed-borne *Verticillium dahliae*
- no adverse effect on germination
- acceptability to the organic industry (initially USA)
- efficacy against other seed-borne fungal pathogens
- protection against soil-borne pathogens; seed-borne pathogens are often soil-borne too.

## Methods

Twenty-five different spinach seedlots, mostly different varieties, were solicited under confidentiality from seed producers around the world for testing purposes.

In order to ascertain seed safety, germination testing was conducted according to ISTA methods: 100 seeds per pleat, three replicate pleats, each imbibed with de-ionised water and incubated at 20°C for 14 days. Observations of normal and abnormal emergence were recorded at 42 h and after 14 days. The 42-h count provided an indication of speed of emergence.

To determine on-seed efficacy of the treatment, diagnostics were conducted following the modified freeze-blotter method of du Toit *et al.* (2005). Seeds were imbibed in the dark for

24 h on 10 × 10 cm blotters, 20 seeds per blotter, in sealed square petri dishes, 400 seeds per test. After imbibition, seeds were frozen for 24 h (dark), following which the seeds were incubated at 20°C under a light bank (12/12 h with UV) for up to 14 days. Seeds were examined microscopically for appearance of fungi.

Additionally, pot tests were conducted to challenge seed growth by using artificially inoculated growing media. Planting medium (John Innes seed formulation) was used. *Pythium ultimum* (a causal agent of damping-off) was grown for 7 days on corn meal agar in 9-cm petri dishes and cut into ≈5-mm cubes. Three seeds were sown into each 5-cm pot and a layer of agar cubes with *P. ultimum* was added with the seed prior to covering over with planting medium.

## Results and discussion

A candidate treatment was identified, and treated seed was subjected to germination and diagnostic testing as well as to pot tests. The three samples shown in Figure 1 show little change in the proportion of normal germination as a consequence of the treatment. Similarly, there was little change in the proportion of abnormal germination. However, early emergence

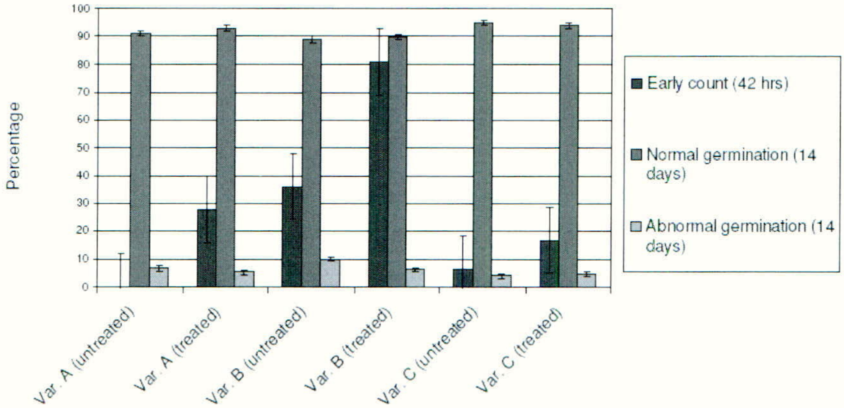

**Figure 1** Germination of three varieties before and after treatment (±SE)

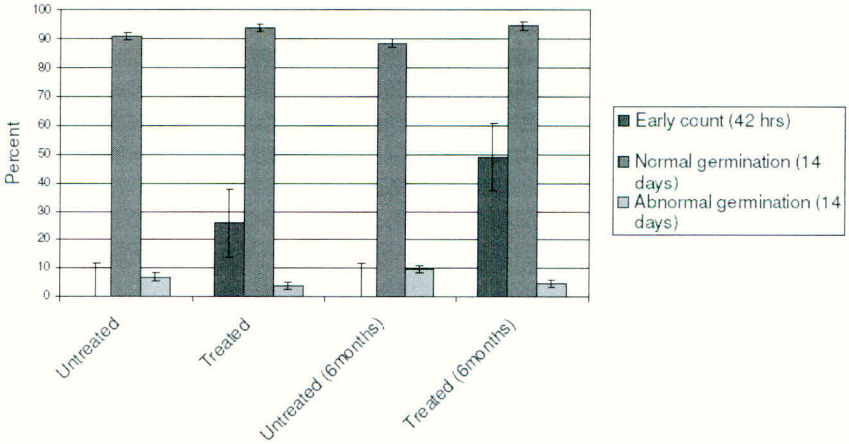

**Figure 2** Variety A: 6-month storage of treated and untreated seed (±SE)

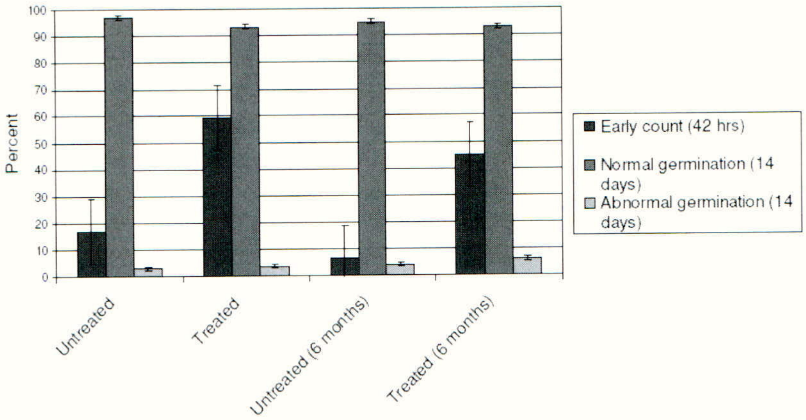

**Figure 3** Variety B: 6-month storage – treated *vs* untreated (±SE)

was improved in all varieties, significantly so for two of the three varieties shown. Variety A, as an example of real-time storage for 6 months at 15°C (Figure 2), shows that for treated seeds there was a slight increase in the proportion of normally germinating seed. There was a slight reduction in abnormally germinating seed. The improvement in early emergence seen in treated seed was retained even after 6 months' storage, and actually showed an increase to result in a proportion approaching 50%. Variety B, as a second example of real-time storage, again for 6 months at 15°C (Figure 3), showed little change in the proportion of normally germinating seeds after 6 months. There was a slight reduction in the proportion of abnormally germinating seed. Early emergence had increased after 6 months' storage to give a figure of just over 45%. The two examples show a good indication that the treated seed has stored well for 6 months.

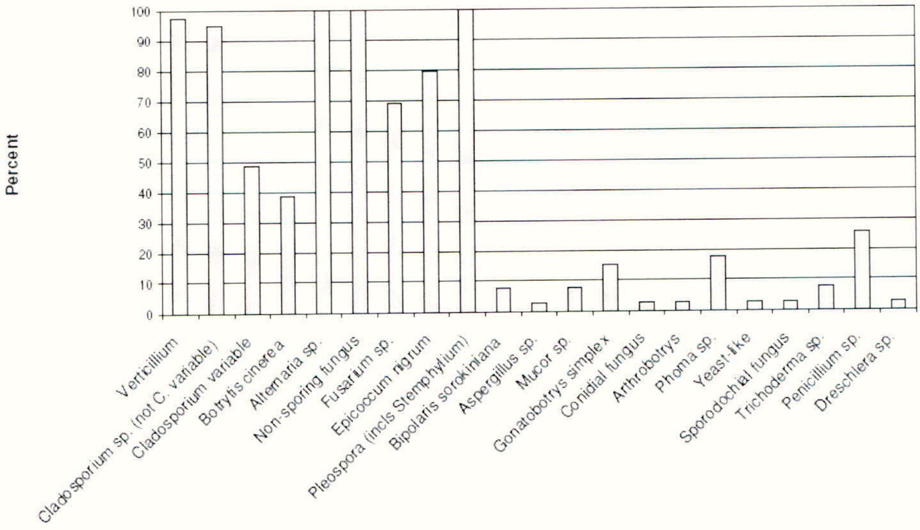

**Figure 4** Frequency of fungi across all untreated seedlots

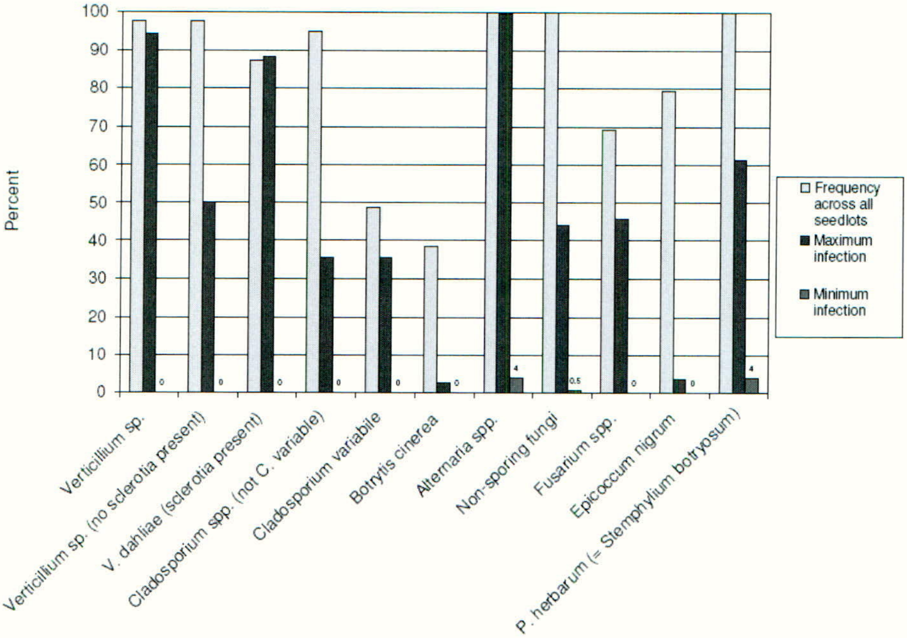

**Figure 5** Fungi on untreated seed: maximum and minimum levels of infection within seedlots

In order to determine the efficacy of the treatment, diagnostics were conducted on all samples. In total over 60,000 seeds were examined, for which data on all fungi observed were individually scored.

Figure 4 shows the frequency of fungi across the 25 untreated seedlots. The fungi on the left are those that were most frequent among the seedlots; the right-hand side shows those of lesser frequencies. The listing is not exhaustive, but serves to illustrate that untreated seed is populated by a wide range of fungi, with a wide range of ecological roles ranging from pathogens to beneficials.

When considering the maxima and minima, on any given seedlot, of the fungi most frequently present across all seedlots (Figure 5), it can be seen that the ranges varied considerably. For example, on some seedlots *Verticillium* was present at levels approaching 100% of seed infected, but in other seedlots was completely absent. The only taxa present on all seedlots were *Alternaria* spp. and *Pleospora herbarum*.

As an example of the treatment efficacy, variety A (Figure 6A) showed initially low levels of most fungi, with the exception of *Alternaria* spp. and *Stemphylium botryosum*. After treatment, levels of all fungi were reduced. *Verticillium dahliae*, the main target, was present only at about 15% initially, but this was reduced to 2.5% post-treatment. *Stemphylium botryosum*, a secondary target for the treatment, was reduced by 58% to about 18%. A second example, variety B (Figure 6B), showed that most of the fungi present initially were at comparatively low levels, with the notable exception of a very high level for *V. dahliae*. After treatment, most fungi were reduced to zero, including *V. dahliae*. A third example, variety C (Figure 6C) initially had high levels of *Alternaria*, *Stemphylium* and *Fusarium* spp. *Verticillium dahliae* was also present, but at a lower level than in variety B. After treatment, *Alternaria* spp. and *S. botryosum* were reduced to very low levels, whilst *V. dahliae* was reduced to zero.

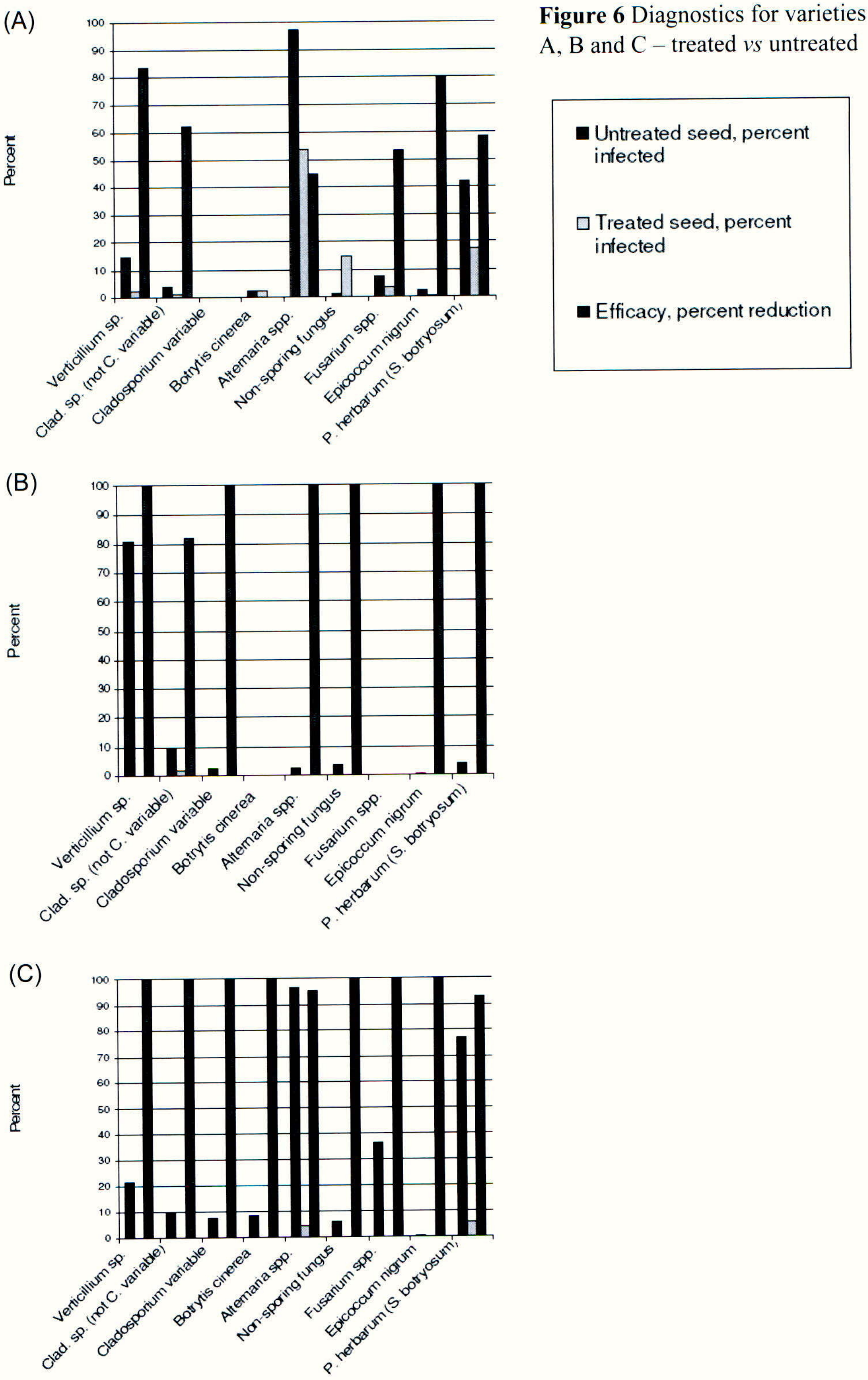

**Figure 6** Diagnostics for varieties A, B and C – treated *vs* untreated

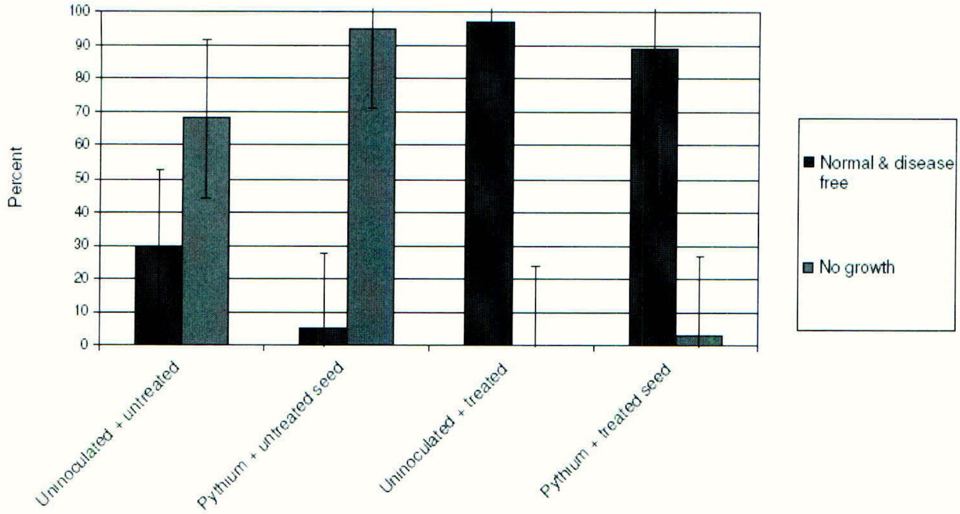

**Figure 7** Pot experiment – inoculated with *Pythium ultimum*, seedlings at 14 days

The diagnostic tests have shown that the species present on untreated seed can vary, and the levels of infection of those particular fungi can also vary. Nonetheless, our treatment has been very effective against the main target, *V. dahliae*, as well as *Cladosporium variabile* and *Fusarium* spp., and it has also shown good efficacy against *S. botryosum*.

Figure 7 summarises data from one of the pot tests. For the uninoculated pots, 30% of untreated seed showed normal emergence after 14 days, whereas ≈97% of the treated seed showed normal emergence in uninoculated pots. With *P. ultimum* present, only 5% of the untreated seed showed normal emergence, whilst treated seed showed ≈89% normal emergence.

## References

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# Pest and virus control in winter oilseed rape in northern Europe using a clothianidin-based seed treatment

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## Summary

To meet the challenges of more severe and diverse pest pressures in establishing oilseed rape crops, a new clothianidin + beta-cyfluthrin seed treatment, applied at 5g + 1g a.i. per kg seed, has been developed for use in northern Europe. Results demonstrate that the clothianidin-based treatment gives enhanced crop establishment and leaf protection against damage caused by adult cabbage stem flea beetle. In addition, the seed treatment gives useful reduction in damage caused by the larvae of turnip sawfly and cabbage root fly. Very good control of peach potato aphid is achieved, resulting in substantial reductions in the levels of turnip yellows virus in crops that were not subsequently re-infected by early spring aphid migrations.

## Introduction

Oilseed rape is a major arable crop in northern Europe. Its importance is not just as a cash crop, the value of which has increased significantly over the past few years along with other commodity prices, but also as the principal break crop in what would otherwise be cereal monocultures. This demand has been driven by an increase in the consumption of rapeseed oil as a source of biodiesel in the EU and the rest of the developed world. The yields of oilseed rape crops, however, have hardly increased at all during the past 20 years, despite genetic advances, and the causes of the suppression of yield potential have been attributed to fungal diseases (Booth, 2008) and viral diseases (Stevens *et al.*, 2008).

It has long been recognised that adult cabbage stem flea beetle (*Psylliodes chrysocephala*) could, under certain circumstances, be a major pest of emerging and establishing winter oilseed rape crops. Following the banning of gamma HCH, the first neonicotinoid-based seed treatment, Chinook® (imidacloprid + beta-cyfluthrin) was introduced in Europe in the early 2000s. This treatment gave effective short-term protection against adult cabbage stem flea beetle damage, and remains widely used. However, the increasing frequency of long, dry and relatively mild autumns in northern Europe has resulted in increased economic damage being caused by a more diverse range of hitherto 'minor' pests. A new seed treatment suitable for these more challenging conditions has been developed, based on the neonicotinoid insecticide clothianidin and the pyrethroid beta-cyfluthrin, and this was recently registered in the UK and other EU countries under the trade name Modesto®. This paper summaries some of the more than 100 field trials conducted in Europe in the development of this seed treatment from 2003 up until the current season.

## Materials and methods

The clothianidin and beta-cyfluthrin seed treatment (CTD&CYB), applied at a rate of 5 g+1 g a.i. per kg seed was tested in comparison with untreated seed and seed treated with imidacloprid with beta-cyfluthrin (IMD&CYB), applied at the commercial rate of 2 g+2 g a.i. per kg seed. Small-scale applications were applied using laboratory-scale spinning disc batch applicators such as the 'Mini-Rotostat' or 'Norogard'. Commercial batch applicators were used for the larger field trials. Immediately after the introduction of the liquid seed treatment, talcum powder or a similar material was applied to dry and separate the treated seed, and to allow it to flow freely through applicators and seed drills.

### *Efficacy and crop safety trials*

Over 100 trials were carried out throughout northern Europe (UK, France, Germany, Sweden and Poland) between 2003 and 2009, targeting a range of pests and conditions. Trial plots were drilled using Hege- or Wintersteiger-type plot drills, with plot sizes ranging from 10 to 40 $m^2$ and normally incorporating four replicates per treatment (range three to six replicates). Where pests were active, the efficacy of the treatments was determined by assessing one or more of: the plant stand; the numbers of larvae or adult individuals per species present; the percentage leaf area or numbers of leaves or roots damaged. Root damage was also assessed for incidence and severity using a 0–5 score where 0 = 0%; 1 = 1–10%; 2 = 11–30%; 3 = 31–50%; 4 = 51–75%; 5 = >75%. The presence of *Turnip yellows virus* (TuYV), formerly known as *Beet western yellows virus* (BWYV), was determined by assessing 20 leaves per plot using ELISA tests carried out at IACR Brooms Barn in Suffolk, UK. Trials were harvested using standard plot combines and grain moisture corrected to 89% DM.

## Results

Crop safety results are covered by Adam & Hopkinson (2008). Crop establishment counts from trials where insect pest damage was observed are given in Table 1. Reductions in crop stand were attributed to damage caused by adult cabbage stem flea beetle in the majority of trials. At two sites the causal pest was the larva of turnip sawfly (*Athalia rosea*).

Direct observations of damage caused by cabbage stem flea beetle (from UK, France, Germany and Sweden) are given in Table 2, and by turnip sawfly (from UK, France and Germany) in Table 3.

**Table 1** Mean number of established oilseed plants in insect-infested crops treated with insecticide seed treatments compared with untreated control (25 results)

| | Plants/m row (assessed at 1–3 true leaf stage) | | |
|---|---|---|---|
| **Treatment a.i./kg** | **Mean** | **Range** | **Relative** |
| Untreated | 9.3 | 3.3–25.9 | 100.0 |
| IMD&CYB 2 g+2 g | 10.2 | 3.7–25.1 | 109.7 |
| CTD&CYB 5 g+1 g | 10.6 | 3.1–24.3 | 114.0 |