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Project leader:	Dr G M McPherson
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Date project commenced:	01 August 2012
Date project completed (or expected completion date):	30 November 2015

DISCLAIMER

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

- Some merit was found in reducing application rates of active ingredients when applied as various tank mixes, allowing broader disease control with a lower risk of pesticide residues at harvest and minimizing the risk of resistance developing in pathogen populations.
- Using products containing mandipropamid (e.g. Revus) provide an opportunity to control the races of *Bremia lactucae* that are resistant to metalaxyl-M, but broad spectrum programmes are needed to provide effective control of a range of potential pathogens in lettuce.
- Products effective against *Sclerotinia sclerotiorum* are also effective against *S. minor*.

Background

Downy mildew (caused by the pathogen *Bremia lactucae)* is responsible for most losses in both outdoor and protected lettuce. Soil-borne diseases, such as *Sclerotinia* and *Rhizoctonia* are also important and contribute to significant losses in some field and glasshouse crops, though interestingly the latter pathogen only appears to be problematic under protection. *Sclerotinia* causes severe head decay, especially near maturity whilst bottom rot (caused by *Rhizoctonia solani*) tends to affect the lower leaves in the crop that, when severe, can render affected plants unmarketable. Grey mould (caused by the pathogen *Botrytis cinerea*) is very often present on the oldest leaves and is usually removed during the normal harvest trimming, but in wet seasons heavy infections can reduce head weight as more leaves need to be removed.

The primary purpose of the project is to identify a range of novel fungicides and bio-control products with activity against the primary pathogens mentioned above but also taking due regard of any ‘incidental’ control of more minor sporadic pathogens including with the current approved products. The main aim is to evaluate a series of spray programmes which provide broad activity against key pathogens on the crop but which also provide a reduced risk of residues at harvest and which ensure minimal risk of resistance development, in the pathogen population.

Summary

The outdoor (ADAS) and protected (STC) trials were completed in autumn 2012, spring and autumn 2013 and spring 2014.

In the autumn 2012 outdoor lettuce trial there were 16 treatment programmes at four application timings and downy mildew was the prevalent disease with *Botrytis* affecting plants secondarily. Other pathogens, where present, were at low to trace levels only. As this trial site was on a commercial farm it was not realistic to artificially introduce the pathogens so we were reliant on natural infection occurring via soil or airborne inoculum. There were significant differences between treatments for the control of downy mildew. Four of the treatment programmes looked particularly promising. Encouragingly, the most effective programmes for downy mildew control were based on products already approved for use on lettuce and included Fubol Gold (mancozeb + metalaxyl M), Revus (mandipropamid), Previcur Energy (fosetyl-aluminium + propamocarb hydrochloride) and Paraat (dimethomorph). There were no significant differences between treatment programmes for control of *Botrytis* or in terms of marketable yield. All pesticide residues remained below the limit of detection.

The autumn 2012 protected trial was done in a glasshouse at STC which had been used previously for lettuce disease trials and it was known to have moderate to high levels of fungal pathogens, especially *Sclerotinia* and *Rhizoctonia,* already present in the soil. In this trial there were 12 treatment programmes at four application timings. The treatments included an untreated, an industry standard, four commercial programmes, four experimental programmes, a straight conventional experimental (coded) active and a straight biological experimental (coded) product.

Downy mildew and *Botrytis* infected the crop early and *Sclerotinia* developed at moderate to severe levels, therefore no artificial inoculation, was required as expected. However, somewhat surprisingly, the levels of *Rhizoctonia* recorded during the cropping period were low, given the previous cropping, known problems with *Rhizoctonia* bottom rot and absence of soil sterilisation. Evidently, either the infection conditions for this prevalent pathogen were significantly below optimum or perhaps some antagonist had knocked the *Rhizoctonia* population down.

There were significant differences between treatments when assessed for downy mildew, *Sclerotinia* and the number of dead plants at each assessment date. There were no significant differences between treatments when assessed for *Botrytis* or *Rhizoctonia*. *Sclerotinia* was responsible for most of the plant deaths.

In terms of developing effective fungicide programmes to control such a broad range of target pathogens this trial has again amply demonstrated the challenges faced by growers. For example, the treatments that performed best for control of downy mildew did not perform well against *Sclerotinia* or *Botrytis*. The treatments that performed best for control of *Sclerotinia* were relatively poor for downy mildew or *Botrytis* control and the treatments that were most effective against *Botrytis* were less effective against downy mildew or *Sclerotinia*. Therefore, in order to deliver a broad and effective treatment programme, it is appropriate to develop either tank mixes with different active ingredients (included at reduced rates to keep overall costs and residue levels down) to maintain broad spectrum protection throughout or to tailor the fungicide programme based on prevailing climatic factors and relative to disease risk at specific times of year.

In this protected lettuce study, the standard commercial programme (Amistar/Fubol Gold/Teldor/Revus) provided the best control of downy mildew, but it performed poorly against *Botrytis* and below average against *Sclerotinia*. One of the commercial programmes (Fubol Gold/Signum/Switch/Serenade) provided the best overall control of the three pathogens present in this study, and three of the experimental programmes performed reasonably well against all target diseases also. As disease levels, predominantly *Sclerotinia*, in the glasshouse were so high by the end of the trial most of the plants in each plot had died or were severely diseased, so there were insufficient heads for samples to be taken for residue analyses.

Lab-based screening tests with novel active ingredients, including new SDHI's, for activity against oomycetes such as downy mildew, *Botrytis*, *Rhizoctonia*, *Sclerotinia sclerotiorum* and *S. minor* identified a number of active ingredients capable of inhibiting pathogen growth. Many of the SDHIs provided good to excellent inhibition of *Rhizoctonia* and *Sclerotinia*, but perhaps surprisingly, were less effective against *Botrytis* in this lab based study. Some products inhibited *Botrytis* growth as well as *Rhizoctonia* (iprodione e.g. Rovral) (Figure 1 (a) & (b)), and *Sclerotinia* (prochloraz e.g. Octave) (Figure 1 (c) & (d)). HDC F158 inhibited all three pathogens, but was most effective against *S. minor*. Fungicides containing metalaxyl and dimethomorph provided good inhibition of *Phytophthora*, an oomycete organism used to represent *Bremia* which cannot be cultured *in* *vitro*. Infinito (fluopicolide + propamocarb hydrochloride) also inhibited oomycete growth well. Alternatives to metalaxyl are needed as resistance to this active in downy mildews is well documented.

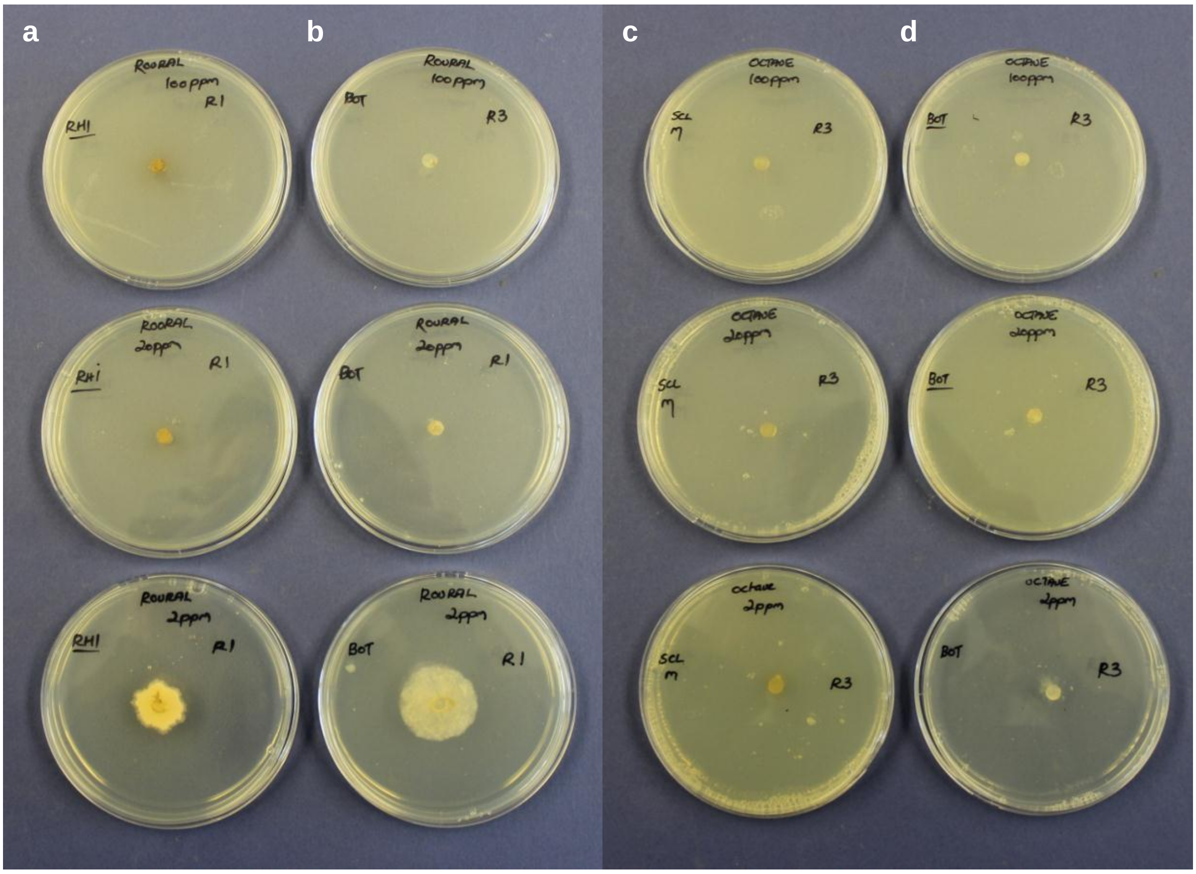

Figure 1. (a) Inhibition of growth of *Rhizoctonia* mycelium on agar plates by iprodione (e.g. Rovral). (b) Inhibition of growth of *Botrytis* mycelium on agar plates by iprodione (e.g. Rovral). (c) Inhibition of growth of *Sclerotinia* mycelium on agar plates by prochloraz (e.g. Octave). (d) Inhibition of growth of *Botrytis* mycelium on agar plates by prochloraz (e.g. Octave). The highest concentration of product (100ppm) is at the top of the photograph, followed by 20ppm in the centre and the lowest concentration (2ppm) is at the bottom.

A commercial crop of iceberg lettuce cv. Robinson was used for the spring 2013 outdoor trial. Pathogen infection was by natural occurrence, and the likelihood of infection was increased by using a field with a history of *Sclerotinia* and crop covers during the early part of the season because of the cold spring. There were 16 treatments combining tank mixes and single product applications. Four post-planting treatment applications were made. There was a high incidence, and moderate severity of *Botrytis* in the trial, and low levels of *Sclerotinia*. No downy mildew or ringspot were recorded in this trial. There was significantly more *Botrytis* in treatments that received Signum at the first application. Whilst the exact reason for this is unclear, it may relate to a slight phytotoxic response thus predisposing the treated plants to colonisation by this opportunist pathogen. *Sclerotinia* disease levels were low and no treatment differences were significant. Treatment 10, which contained products for downy mildew control at each application and HDC F151 in a tank mix at the second application, had a significantly lower incidence of *Botrytis* and a lower *Botrytis* severity than all the other treatments. No pesticide residues were detected in any of the samples and all remained below the limit of detection.

In the spring 2013 protected lettuce trial there were 12 treatment programmes including an untreated control (Figure 2). Four post-planting application timings were planned, but only three could be made as the crop matured quickly. The treatments included an untreated, an industry standard, two commercial programmes, four experimental commercial programmes and four experimental (non-commercial) programmes. Many of the programmes included Amistar early in the programme, primarily to control *Rhizoctonia* so that they could be compared to the use of Basilex pre-planting used as an industry standard treatment. The programmes in this trial were designed to see how late fungicide applications could be made before harvest without incurring residue exceedances. Currently the majority of the fungicide applications are made in the first three to four weeks after planting, potentially exposing the crop to pathogen risk later which could make heads unmarketable. Growers are cautious of applying fungicides close to harvest because they do not wish to exceed maximum residue limits (MRLs). These programmes were designed to space out the number of applications to give better control of fungal pathogens from planting to harvest and, by using half rates and tank mixes thus trying to minimise residues at harvest. Unfortunately, due to a spell of hot weather, the crop matured faster than expected and the final treatment applications could not be applied. The crop had to be harvested before the minimum recommended harvest intervals had been reached for many of the products. This enabled data to be gathered on whether reducing application rates also reduced residues at harvest.

The variety used was a butterhead lettuce of cultivar Tahamata (Rijk Zwaan). To increase the chances of infection by the target pathogens, the trial was done in a glasshouse which had been used in the past for lettuce disease trials and it was known to have high levels of fungal pathogens, especially *Rhizoctonia* and *Sclerotinia*, already present in the soil. In view of the unexpected low incidence of *Rhizoctonia* in the previous trial, *Rhizoctonia* was artificially introduced by inoculating the soil pre-planting. *Bremia lactucae* was artificially inoculated by applying a spore suspension to six plants per plot on two occasions during the trial. However, neither inoculation with *Bremia lactucae* established in the crop. *Botrytis cinerea* occurred naturally, without artificial infection.

Some treatment programmes included pre-planting applications 24 days prior to planting. The first foliar applications were carried out 2-3 days post-planting, with other applications made at 14 day intervals.

Figure 2. Spring 2013 protected trial at STC showing plots in the foreground that suffered from severe *Sclerotinia* and *Rhizoctonia* infections.

No *Bremia lactucae* was observed in the trial. There were high levels of *Botrytis* and moderate levels of *Rhizoctonia* and *Sclerotinia*. The presence of *Botrytis* was not consistent from one assessment to the next, and although there were significant differences between treatments in the first and last assessments, these differences were not repeated in both assessments and we suspect this might relate to the difficulty in differentiating between damage caused by the various pathogens on the same plant. Botrytis incidence in the untreated control was low, but may have been masked by the high levels of *Rhizoctonia* and *Sclerotinia* present. There were significant differences between the levels of *Rhizoctonia* and *Sclerotinia* at all assessments and these differences remained fairly consistent from one assessment to the next. There were low levels of bacterial rot to the lower leaves recorded at harvest.

Some low levels of pesticide residues were recorded at the end of the trial, but these were below the MRLs with the exception of HDC F152, which has an MRL in lettuce of 0.01

mg/kg anyway (the lowest limit of detection). Considering the crop was cut before the minimum harvest interval, the policy of using half rates in tank mixes has meant that products could potentially provide an alternative approach to maintaining disease control without necessarily increasing the risk of unacceptable residues at harvest. Naturally it would be necessary to have further discussion with CRD in this regard to ensure any applications made are within the legal framework. If not it may be possible to change this with appropriate data.

Treatment 3 (Commercial) – (Contans / Amistar / Fubol Gold / Paraat), treatment 6 (experimental commercial tank mixes) - (Amistar + Fubol Gold/ Signum + Switch/ Paraat + Rovral), and treatment 7 (experimental commercial tank mixes) - (Amistar + Fubol Gold/ Signum + Paraat) resulted in significantly fewer dead plants at the end of the trial than the industry standard. There were differences in the disease severity between these treatments and the standard, but these were not significant. The mean head weight for these treatments was slightly below that recorded for the standard programme, but not significantly so. The number of marketable heads was significantly greater in these treatments than in the standard (Figure 3). All three programmes had three products in common: Amistar, Fubol Gold and Paraat. Interestingly in agar plate tests azoxystrobin, the active ingredient of Amistar, did not provide good inhibition of *Rhizoctonia* and *Sclerotinia*, but it is known that some products provide additional activity *in vivo* e.g. the 'turning on' of host defence systems or leaf greening and these effects are not measurable during *in vitro* studies. Contans, which provided good inhibition of *Sclerotinia* in *in vitro* tests, may have helped control *Sclerotinia* in Treatment 3 and Signum, which provided good inhibition of *Rhizoctonia* and *Sclerotinia* in *in vitro* tests, may have helped to control these diseases in treatments 6 and 7, but it was not applied until later in the treatment programmes, as was Rovral in treatment 6, which does not explain why very low levels of these pathogens were recorded in earlier assessments. Treatment 7 only received two treatment applications in total, and yet was one of the best performing treatments. It seems possible that there may be an interaction between Amistar and Fubol Gold, when made as an early application, which is controlling these pathogens more effectively. These results suggest that by using these products in the effective tank mixes at the correct timings, it may not be necessary to use Basilex as a pre-planting treatment. As no *Bremia* infected the trial it is not possible to evaluate the performance of Fubol Gold, although in the field trial it performed well at controlling the pathogen in treatment programmes that also included Amistar. Such mixtures or alternating programmes will continue to be important to reduce the risk of resistance in the *Bremia* population. Paraat was also used in the field trial programmes and provided quite good control of *Bremia*, although not as good as Fubol Gold.

Figure 3. Spring 2013 protected trial: standard treatment (left) compared to treatment 7 (right). Photos taken at harvest and heads turned over to show condition of lower leaves.

None of the experimental programmes evaluated performed as well as the standard or any of the commercial programmes. Whilst this is disappointing, it does suggest that it may be possible to control these important pathogens using existing approved products available to growers without the necessarily waiting for new products to be registered and approved.

The autumn 2013 outdoor lettuce trial was a stern test of fungicide efficacy on downy mildew with over 70% leaf area affected by the disease in the untreated control at the harvest assessment. This trial included 16 treatment programmes applied at four application timings and downy mildew was the prevalent disease with *Botrytis* affecting plants secondarily. The most effective programme overall was Revus applied at all four application timings in combination with HDC F145 (22.5% leaf area affected), however this would not be possible to complete in commercial situations as Revus is only approved for 3 applications. Amistar + Karamate / Previcur Energy / Infinito / Revus in a programme were nearly as effective (22.8% leaf area affected) and represent a wider range of actives which is beneficial for resistance management and also contain broad spectrum products (Amistar + Karamate) to help control Botrytis and soft rots which are high risk after transplanting.

There were no significant differences between treatment programmes for control of *Botrytis*. However there was a trend for Switch, Karamate and Amistar at the T1 and T2 timings to improve control. Significant differences between some treatment programmes for marketable trimmed head weight and average weight per head were recorded after harvest. All test pesticide residues remained below the limit of detection.

The protected trial, carried out in spring 2014, focused on *Sclerotinia minor* and included several straight fungicide treatments, both approved and experimental, as well as programmes based on approved products and experimental products. Contans was applied as a pre-planting treatment on its own and also before all of the treatment programmes. Four post-planting treatment applications were made for each of the straight product applications, but the number of post planting applications varied for the programmes.

In the first assessment, after two treatment applications, there were no visual signs of *S. minor*, although there were some heads affected by virus symptoms, the predominant one being Lettuce Big Vein Disease. Both viruses associated with this disease (*Mirafiori lettuce big-vein virus* or MiLBVV and *Lettuce big-vein associated virus* or LBVaV) are transmitted by the fungus-like organism *Olpidium brassicae*, so incidence of big vein symptoms was recorded in the first and final assessments. However, there were no significant differences between treatments for incidence of this disease.

Amistar and Signum provided best control of *S. minor* (Figure 4). Further work would still be required on how to incorporate these into an effective programme as the programme containing these two products controlled *S. minor* significantly better than the untreated, but not as well as Amistar or Signum alone.

One pre-planting application of Contans reduced the incidence of the disease, but this was not significantly different from the untreated. The experimental products controlled *S. minor* well, better than the programmes, but not as well as Amistar or Signum.

As the majority of the treatments in this trial were repeat applications of the same product, to evaluate each product's individual efficacy, which is not standard practice, the MRLs would have been exceeded, so no residue data were recorded.

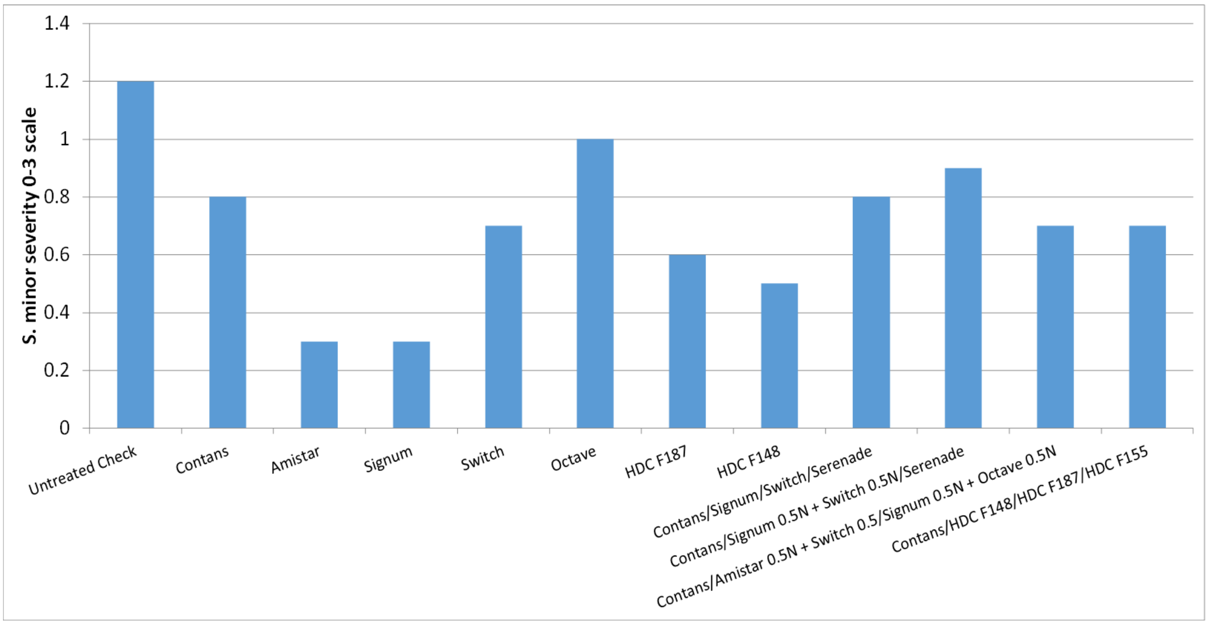

Figure 4. Severity of *Sclerotinia minor* at harvest in a trial in a commercial lettuce crop on grower holdings

Financial Benefits

Some useful initial benefits of the project work are the indication that a reduced number of treatment applications could be made per crop by improving timings of application. The use of effective tank mixes of products at reduced rates means that disease control can be maintained and products could potentially be applied closer to harvest. This could result in cost reductions for products and application time and a concomitant reduced risk of resistance development. As fungicides could also be applied closer to harvest, crop losses could also be reduced therefore increasing the economic yield. Further work would be required to ensure such uses stay within the regulatory framework.

Action Points

- Use specifically designed spray programmes, using already approved products, taking into account:
  - the likely risk of specific pathogens at the time of year
  - the type/cultivar of lettuce grown and the particular resistance/susceptibility rating
  - the cropping history of the site
- There is potential to use reduced application rates of products either in tank mixes or as alternating spray programmes to target two or more pathogens simultaneously. Prior to doing this it will be important to check the regulatory situation especially in

relation to applications closer to harvest as several products have specific restrictions relating to latest time of application.

- There are good products available for the control of downy mildew in outdoor lettuce and products containing mandipropamid (e.g. Revus) could be effective against strains resistant to Metalaxyl-M.
- For those growers with *Sclerotinia minor* problems, products effective against *S. sclerotiorum* can be used to control the organism without resorting to soil sterilization measures.

SCIENCE SECTION

Introduction

Lettuce (*Lactuca sativa* L.) is the most widely grown outdoor salad crop in the UK with a production area of over 5,000 ha. In 2010, 157,700 tonnes of lettuce were produced at an estimated value of £84.7 million (Defra Horticultural Statistics, 2013). There are five main types of lettuce; crisphead (mostly iceberg), romaine (cos), butterhead (round), leaf and babyleaf. Leafy types take many forms (oak leaf, lollo rosso etc) and include both green and red colours. Crisphead lettuce forms the major type of lettuce grown in the UK, of which iceberg is the most widely grown type (Figure 5).

Figure 5. Commercial Iceberg lettuce crop with downy mildew symptoms on outer leaves.

Downy mildew (*Bremia lactucae)* is a major and potentially devastating disease in protected and outdoor lettuce, including in iceberg varieties, especially when favourable wet, cool, humid conditions prevail. If not prevented or controlled from spreading whole crops can become unmarketable if the disease reaches the head of the lettuce. Where whole fields are lost or ploughed in due to severe outbreaks of the disease losses can reach into hundreds of thousands of pounds. A hectare of lettuce can be worth £67,000 (Defra Horticultural Statistics 2010).

Other diseases are also important and contribute to significant losses in some crops. Grey mould (*Botrytis cinerea*) is very often present on the oldest leaves and is usually removed during the normal harvest trimming. Occasionally it causes plant losses in young plants through severe basal rots when there are problems during plant establishment. *Sclerotinia sclerotiorum* and *S. minor* cause severe head rots near maturity. Even low levels of disease can reduce yield as infected leaves will require extra trimming, so reducing head weight and marketability. A small blemish on the head can still result in rejection or reduce its value, as the product is marketed in its fresh state and retailer protocols have stringent quality regulations to be met.

Bottom rot caused by *Rhizoctonia solani* is more prevalent on protected crops than in field lettuce. Ringspot (*Microdochium panattonianum*) is easily overlooked, though can seriously affect patches in field and protected crops given prolonged wet conditions. In glasshouse crops it is occasionally found in wetter parts of the crop e.g. under leaky gutters. The 2013 autumn outdoor trial was designed to target downy mildew, so products with known oomycete activity were selected at the later application timings.

This study aims to evaluate the activity of new disease control programmes involving fungicides and biological control agents for control of the broad spectrum of pathogens that occur in lettuce crops. The best combinations of treatments for control of the various pathogens were investigated, whilst diversifying programmes to reduce the risks of both unacceptable residues at harvest and to minimise the risk from fungicide resistant strains.

Project aim(s)

To carry out an evaluation of the broader efficacy of various approved and novel fungicides and bio-pesticides on both protected and outdoor lettuce in order to formulate a series of disease control programmes and strategies for the control of the most important pathogens of lettuce e.g. *Bremia lactucae, Botrytis cinerea, Rhizoctonia solani* and *Sclerotinia sclerotiorum* and any other incidental pathogens that happened to occur in the trial sites.

Project objective(s):

1. To conduct *in vitro* & *in vivo* (*in planta*) studies to screen new experimental products for the control of *Sclerotinia*, *Botrytis, Rhizoctonia & Bremia.* Select those most effective for *in vivo* screening in replicated field & glasshouse trials.
2. To carry out replicated trials in both field and glasshouse lettuce to a) evaluate the activity of the short-listed novel products against the primary pathogen targets and b) to compare a range of integrated fungicide/bio-control programmes designed to investigate and optimise their broader efficacy and crop safety.
3. To validate the integrated programmes not only in terms of efficacy and crop safety but also with respect to residue levels through a series of multi-residue analyses at harvest to ensure retailer and consumer acceptance of the optimised programmes.
4. Prepare Annual & Final Reports, including HDC articles and an updated Factsheet to effectively communicate new knowledge to the industry

A number of experiments on field (ADAS) and glasshouse lettuce (STC) were completed in 2012 and 2013 (Table 1). Four experiments were reported in detail in the Year 1 report. This, Year 2, report details a field crop planted in August 2013 and a glasshouse crop planted in March 2014.

Table 1. Sites and crop growing seasons carried out in this project

Type of experiment	Site	Crop period	Crop year	Partner	Report date
Field	East Coast Growers, Martham, Norfolk	August - October	2012	ADAS	July 2013
Glasshouse	STC, Yorkshire	October - December	2012	STC	July 2013
Field	PDM Produce (UK) Ltd, Great Chatwell, Staffordshire	April - June	2013	ADAS	July 2013
Glasshouse	STC, Yorkshire	May - June	2013	STC	July 2013
Field	J.E. Piccaver, Gedney Drive End, Lincolnshire	August - October	2013	ADAS	July 2014
Glasshouse	S&M Brankley, Goole, East Yorkshire	March - May	2014	STC	July 2014

The Annual report in 2013 has already covered *in vitro* screening and 2012-2013 outdoor and protected trials. This report covers the outdoor trial carried out in Lincolnshire from August to October 2013 and protected trials conducted in spring 2014. Each section of the report has been written according to the project objectives and includes, in order: autumn 2013 Field Trial, spring 2014 Protected Trial specifically on *Sclerotinia minor*. The 2014 spring protected trial was designed specifically to test the activity of a range of fungicides and programmes against *S. minor*.

Materials and methods

Autumn 2013 Field Trial

August to October 2013

Programme design

Programmes were designed taking into account requirements for the number of permitted applications, harvest intervals, diversification of different active ingredients and the spectrum of diseases expected. Typically fungicides are applied every 7–10 days commercially to maintain protection against downy mildew. All the fungicides used are protectants but some have known problems with pesticide residues in produce if applied too late in the programme, e.g. dithiocarbamates. Although these are very effective as protectant, and as multisite inhibitors useful as part of an anti-resistant strategy, they often have long harvest intervals to minimise the residue risk, and therefore they are best used early in the programme to give good early protection with low risk. Subsequent further applications can then be made using different actives with action against downy mildew to maintain protection. It is important to vary the chemical groups used within the programme to guard against fungicide resistance, and where single actives are used that have a high resistance risk; they are best used in combination as an authorised tank mix. When tank mixes are used it is important to check that the conditions on each product label can be met when both products are mixed e.g. that rates, harvest intervals and conditions of application can be complied with.

In field crops it is also advisable to apply a fungicide with activity against *Botrytis cinerea* and *Sclerotinia* early in the treatment programme. This is because the highest risk of infection from these pathogens is from damage at planting as *Botrytis* is an opportunist secondary pathogen which will quickly colonise any damaged or wilting tissues. *Sclerotinia* is soil-borne and young leaves need to be protected against apothecial infection before the lettuce produces its head. As the lettuce matures it becomes more difficult to effectively target the older leaves which can act as a senescing substrate for germinating ascospores released from apothecia.

The programmes designed using the principles described above are shown in Table 2.

Table 2. Fungicide programmes in Autumn Field Trial, Lincolnshire 2013.

	Fungicide treatments and rates			
Trt	**T1 2-4 days post transplant**	**T2 7-10 days after T1**	**T3 7-10 days after T2**	**T4 7-10 days after T3**
1	Untreated	Untreated	Untreated	Untreated
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha
6	Revus 0.6 l/ha + HDC F147 0.028 kg/ha	Revus 0.6 l/ha + HDC F147 0.028 kg/ha	Revus 0.6 l/ha + HDC F147 0.028 kg/ha	Revus 0.6 l/ha
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F146 2.5 l/ha	Revus 0.6 l/ha
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha

Trial design

The 15 treatment programmes (Table 2) plus a double untreated control were set out in a randomised block design replicated four times to give a total of 68 plots. Each plot consisted of a 5m length of bed to give at least 60 lettuces per plot, and a bed was 1.8 metres wide with four rows of lettuces. The trial was carried out using a commercial lettuce crop with a variety susceptible to downy mildew. Pathogen infection was by natural occurrence.

Treatment applications

Treatments at all timings were applied with an Oxford precision knapsack sprayer with a 2m boom using a fine – medium spray at 2.4 bar pressure.

Assessments

The plots were assessed at each spray timing and at harvest for incidence (percentage of plants affected) and severity (percentage leaf area of plants affected) of any of the target pathogens under investigation and crop safety. Downy mildew was observed during the trial after the T3 application, with significant results recorded. At harvest *Botrytis* was also assessed. A measure of yield was taken at harvest from the weight of 10 trimmed heads of lettuce. The trimmed heads were also graded according to marketability. Typical symptoms of downy mildew in the experiment are shown in Figure 6. For residue analysis, samples were taken from treatments 1 (untreated), 2 (Amistar + Karamate, Signum, Fubol Gold, Revus), 4 (HDC F150 + Revus at all four spray timings) and 6 (Revus + HDC F147, Revus + HDC F147, Revus + HDC F147, Revus). All treatments were put through LC and GC analysis, with treatments 1 and 2 also having dithiocarbamate analysis. Plots were sampled so that 3 untrimmed heads were taken from each treatment replicate from the previously mentioned treatment programmes. Samples were then bulked together so that treatments from replicates 1 and 2 were tested together, and samples from replicates 3 and 4 were tested together.

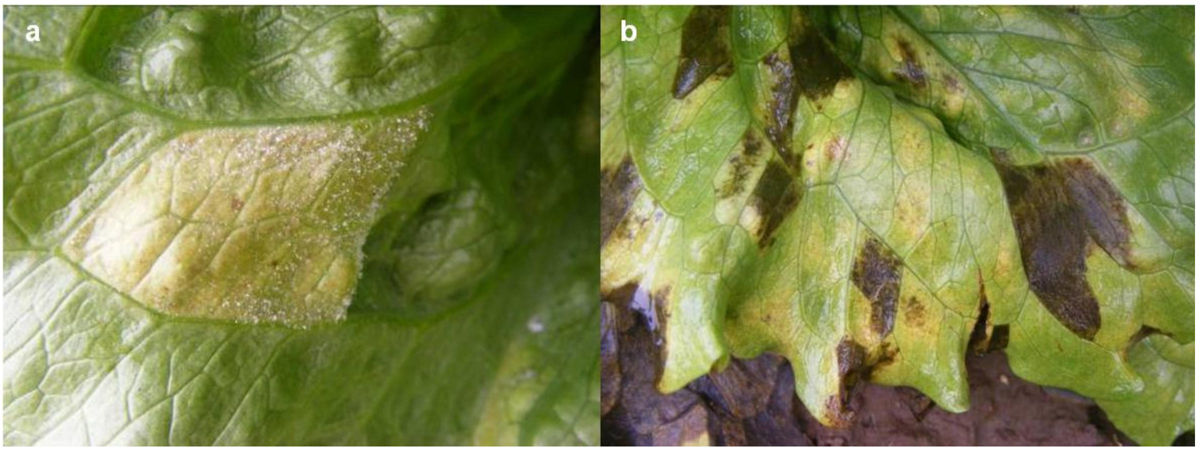

Figure 6. (a) Early downy mildew lesion with sporulation on underside of leaf and typical chlorotic angular lesion. (b) Severe mildew infection with angular chlorotic and necrotic patches on lower leaf.

Spring 2014 Protected Trial: *Sclerotinia minor*

March to May 2014

Background

Sclerotinia minor is less common in lettuce than *Sclerotinia sclerotiorum*, but poses slightly different control challenges. Both species produce a dense, white cottony mat of mycelia on the surface of the host and on adjacent soil surfaces. Within the mycelial mat, dense white areas of mycelium form which become hard and turn black as they mature. These are called sclerotia. These are resting structures which allow the fungus to survive for years in the soil. *S. sclerotiorum* sclerotia are between 2 and 10 mm in diameter and resemble mouse droppings, whilst *S. minor* sclerotia are much smaller and are between 0.5 and 2 mm in diameter.

S. sclerotiorum sclerotia produce apothecia (inverted mushroom-like fruiting bodies) which release ascospores into the air. These ascospores initially require dead plant material as a substrate to penetrate into before mycelium invades healthy plant tissue. In lettuce the lower senescing leaves are usually the part of the plant where infections start. The infection spreads to younger leaves and then to the heart causing collapse of the plant.

S. minor sclerotia rarely produce apothecia and instead mycelium grows directly out of the sclerotia and into the soil. The mode of infection is via penetration of the root or stem at or near the soil line. Lesions develop unnoticed on the stem, and the pathogen destroys the vascular tissue of the crown, then causing rapid wilting and subsequent collapse of the plant (Figure 7).

As *S. minor* is spread by tiny sclerotia and microscopic mycelial strands in the soil, it can be transported in minute amounts of soil on footwear and machinery. It cannot be easily removed from the soil without rigorous disinfection and since Methyl Bromide was withdrawn inoculum levels have increased at some sites, especially those where they don't have access to steam boilers for cost effective steam sterilisation.

Results from *in vitro* tests done in the previous year of the project showed that active ingredients with activity against *S. sclerotiorum* also had activity against *S. minor*.

Figure 7. (a) Wilting caused by *Sclerotinia minor* infection. (b) Plant collapse caused by *S. minor* infection. (c) Small black sclerotia of *S. minor* under lower leaves of plant. These remain in the soil and produce mycelium that infects the following crop. (d) *Sclerotinia sclerotiorum* stem base infection which has caused the plant to collapse. Large black sclerotia have been produced on the stem base. They remain in the soil and produce apothecia (inset, not to scale) which release spores that infect the following crop.

Programme design

In this trial there were 12 treatment programmes including an untreated control replicated four times. One pre- and four post- planting applications were included as described in Three disease assessments were made and as the incidence of *Lettuce Big Vein Disease* was moderate to high this was also recorded to see if any of the treatments were effective against the root colonising organism, *Olpidium brassicae*, which transmits the viruses, *Mirafiori lettuce big-vein virus* (MiLBVV) and *Lettuce big-vein associated virus* (LBVaV), associated with this disease.

Table 3. The treatments included an untreated, five straight commercial products, two straight experimental products, a commercial programme, three experimental commercial programmes using tank mixes and one experimental programme.

The trial was done on a commercial nursery which has a recurrent problem with *Sclerotinia minor*. The trial was arranged in a randomised complete block design over the area of the glasshouse which was prone to *S. minor* outbreaks (Figure 8).

Three disease assessments were made and as the incidence of *Lettuce Big Vein Disease* was moderate to high this was also recorded to see if any of the treatments were effective against the root colonising organism, *Olpidium brassicae*, which transmits the viruses, *Mirafiori lettuce big-vein virus* (MiLBVV) and *Lettuce big-vein associated virus* (LBVaV), associated with this disease.

Table 3. Fungicide programmes in *Sclerotinia minor* spring protected trial, Yorkshire 2014

			Application Timing			
Treatment		**T1**	**T2**	**T3**	**T4**
Type	**Pre-planting**	**2-3 days post-planting**	**10-14 Days after T1**	**10-14 Days after T2**	**10-14 Days after T3**
Date	**18/03/2014**	**27/03/2014**	**07/04/2014**	**17/04/2014**	**28/04/2014**
1	No application	Untreated	Untreated	Untreated	Untreated
Commercial products					
2	Contans	-	-	-	-
3	No application	Amistar	Amistar	Amistar	Amistar
4	No application	Signum	Signum	Signum	Signum
5	No application	Switch	Switch	Switch	Switch
6	No application	Scotts Octave	Scotts Octave	Scotts Octave	Scotts Octave
Experimental products					
7	No application	HDC F187	HDC F187	HDC F187	HDC F187
8	No application	HDC F148	HDC F148	HDC F148	HDC F148
Commercial programme					

9	Contans	Signum	Switch	Serenade	Serenade
Experimental commercial programme					
10	Contans	Signum 0.5N + Switch 0.5N	-	Serenade	Serenade
11	Contans	Amistar 0.5N + Switch 0.5N	Signum 0.5N + Octave 0.5N	-	-
Experimental programme					
12	Contans	HDC F148	HDC F187	HDC F155	-

Trial design

The 12 treatment programmes above were set out in a complete randomised block design replicated four times to give a total of 48 plots. Each plot was 1.6 metres wide and 2 metres long and was planted with 60 lettuces, of which 24 were assessed. The variety used was a butterhead lettuce of cultivar Thalita. To increase the chances of infection by the target pathogens, the trial was done in a commercial glasshouse which had a history of *Sclerotinia minor* already present in the soil.

Figure 8. Spring 2014 *Sclerotinia minor* trial on grower holdings.

Treatment applications

Treatments at all timings were applied with an Oxford precision knapsack sprayer with a 2m boom using a fine–medium spray at 2 bar pressure. All applications were applied at a water rate of 200 l/ha with 01F110 flat fan nozzles.

Assessments

The plots were assessed three times for *Sclerotinia minor* incidence and crop safety. Severity of *Sclerotinia minor* at harvest was scored per plant on a 0-3 scale where:

0 = no disease

1 = low disease (early infection)

2 = moderate disease (plant wilting)

3 = high disease (plant collapsing)

At harvest the untrimmed weight per head, trimmed weight per head and number of marketable heads/plot were recorded based on 24 plants per plot.

Crop Diary

Date	Action
18/03/14	Pre-planting Contans treatments applied
25/03/14	Crop planted
27/03/14	First treatment applications applied
07/04/14	Second treatment applications applied
17/04/14	First disease assessment
17/04/14	Third treatment applications applied
28/04/14	Fourth treatment applications applied
07/05/14	Second disease assessment
13/05/14	Third disease assessment
13/05/14	Harvest assessment

Statistical Analyses

The data for the outdoor trials were analysed using Genstat statistical software package and the data for the indoor trials were analysed using ARM statistical software package.

Results and Discussion

Autumn 2013 Field Trial

Downy mildew was the main disease observed in the trial. Little disease was observed at the T2 (23 August 2013) and T3 (3 September 2013) with no significant treatment differences identified. However disease progress increase rapidly from the 12 September assessment until harvest (4 October) (Figure 9) with highly significant differences between treatments (P<0.001) evident (Table 4). There was a rapid increase in downy mildew severity between the assessment made after the third treatment application and the one made at harvest (Figure 10). *Botrytis* was also assessed at harvest.

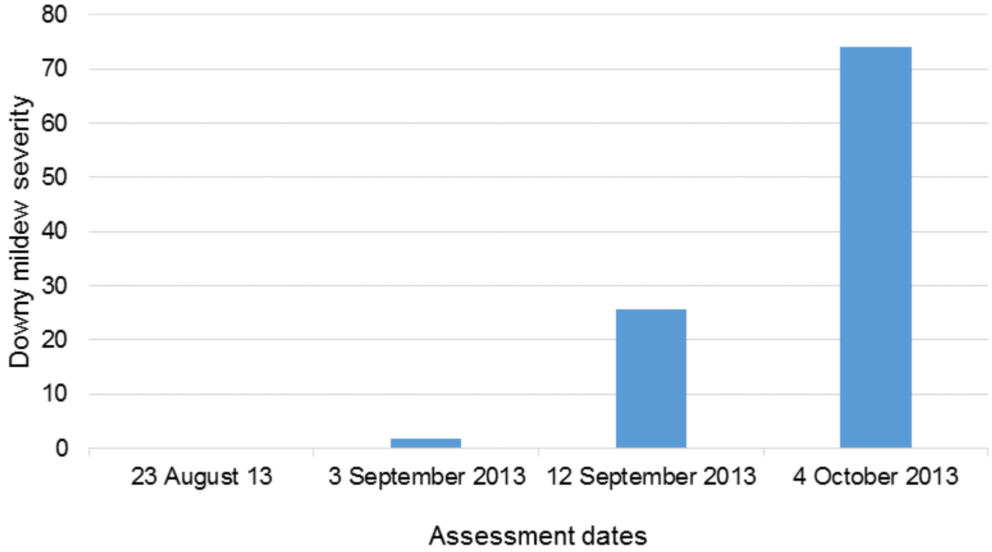

Figure 9. Untreated disease progress - autumn 2013 outdoor trial.

Table 4. Downy mildew severity in autumn 2013 outdoor trial.

Treatment	Assessment after 3rd application		Harvest assessment	
1	25.68	b	74.1	d
2	22.82	b	33.9	ab
3	21.08	b	43.0	abc
4	9.19	a	22.5	a
5	21.67	b	33.8	ab
6	9.41	a	31.1	ab
7	17.26	ab	30.9	ab
8	20.74	b	28.3	ab
9	15.40	ab	22.8	a
10	18.46	ab	29.0	ab
11	22.68	b	53.4	c
12	21.32	b	53.9	c
13	21.37	b	26.9	ab
14	21.66	b	33.0	ab
15	22.05	b	42.4	abc
16	25.90	b	42.2	abc

Means followed by the same letter do not differ significantly

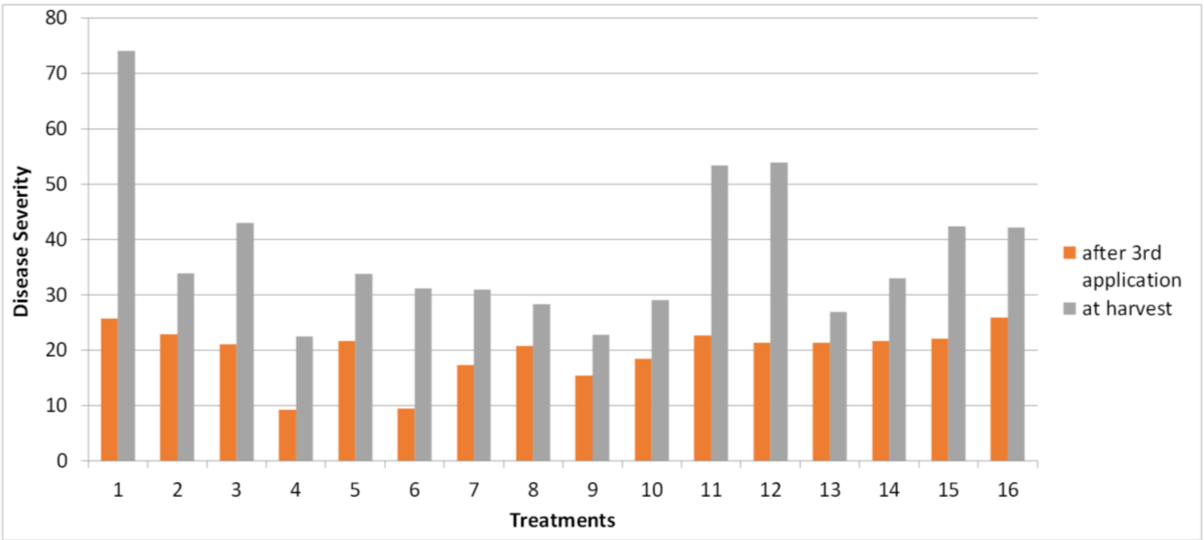

Figure 10. Downy mildew disease severity following the third treatment application and at harvest.

The best control of downy mildew was provided by treatments 4 and 6 at the third disease assessment just before the final fungicide applications (9 days after the third fungicide applications). Treatment 4 contained Revus (mandipropamid), an oomycete fungicide, and an experimental product (HDC F145) at each spray timing, so it was not surprising this programme was the most effective considering the active ingredients. Treatment 6 also contained Revus at each spray timing, except in this treatment Revus was mixed with another experimental product with a different mode of action. Although good levels of control were observed until the fourth application, at the harvest disease assessment the levels of downy mildew had increased in treatment 6, but were still significantly lower than the untreated. Unfortunately these two treatments also did not control *Botrytis* well, resulting in low marketable head weights at harvest due to bottom rot. This may be because as there were no broad spectrum sprays applied at the beginning of these programmes to protect against soft rots.

The second lowest levels of downy mildew at harvest were recorded in treatment 9 which was an alternating programme of products which predominantly had activity against downy mildew (Amistar + Karamate, Previcur Energy, Infinito, Revus). The use of broad spectrum products Amistar and Katamate 2-3 days post-planting may have controlled *Botrytis* better, reducing the need for removal of rotten lower leaves at harvest. As a range of actives were used in this programme, it was also beneficial from a disease resistance management perspective.

Treatment 7 (Amistar + Karamate, Previcur Energy, Infinito, HDC F145 + Revus) returned similar results to treatment 9 and this was to be expected as the only difference between the treatments was the addition of the plant extract, HDC F145, at the final application.

Treatments 3 (Switch + Karamate, Amistar, Fubol Gold, Revus) and 5 (HDC F145 + Amistar, Signum, Fubol Gold, Revus) provided good control of *Botrytis* (Figure 11), but did not perform as well at controlling downy mildew. Treatment 3 also had poor head weights at harvest.

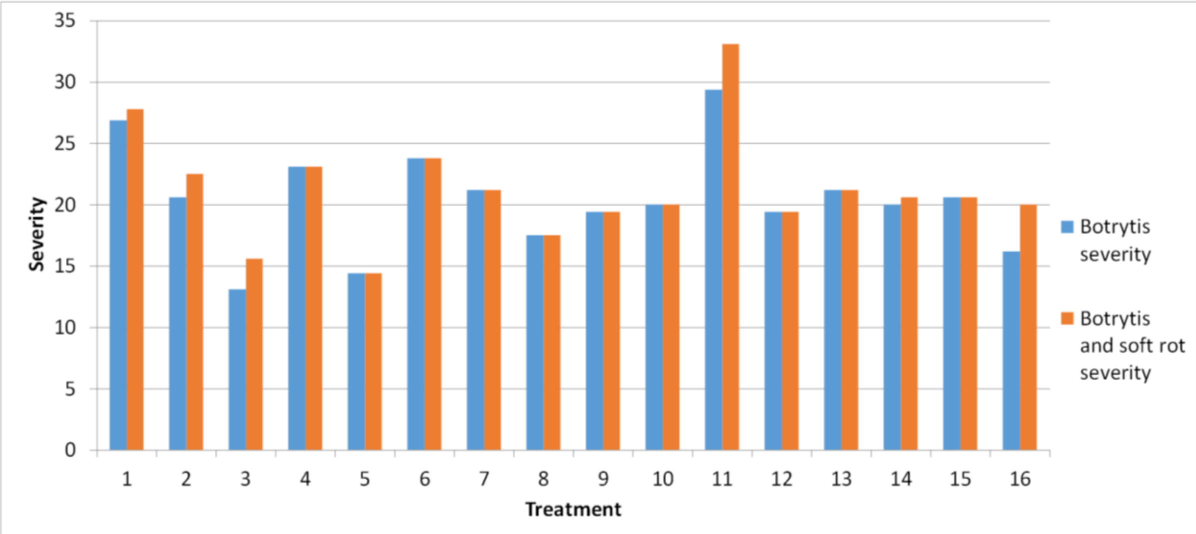

Figure 11. Botrytis severity and soft rot severity at harvest

The effects of tank mixing conventional products with HDC F145 can be evaluated by comparing a number of the treatments. Treatments 4 has HDC F145 mixed with Revus at the first application and treatment 5 has HDC F145 mixed with Amistar at the first application. However, there were no significant differences between the two treatments at the first assessment. Treatments 7 and 9 had identical products applied at the first three applications. At the final application, treatment 7 mixed HDC F145 with Revus, but treatment 9 was Revus alone. However, there were no significant differences between the two treatments at the final assessment. Treatments 13 and 15 had identical products applied at the first three applications. At the final application, Revus was applied alone in treatment 13 and HDC F145 was applied alone in treatment 15. Treatment 15, which had Revus applied, was found to have lower levels of downy mildew than treatment 15, which had HDC F145 applied, although differences between treatments were not significantly different.

Similarly, tank mixing Switch with Infinito in treatment 2 at the third application timing can be compared to applying Fubol Gold alone in treatment 13. Tank mixing Switch and Infinito reduced disease severity at harvest by 9% compared to applying Fubol Gold alone. Again differences, however, were not significantly different.

Average head weight was significantly different between treatments before trimming, with the untreated control and treatment 3 (Switch + Karamate, Amistar, Fubol Gold, Revus) having head weights significant lower than nine of the other treatment programmes.
The untrimmed head weight at harvest did not reflect the trimmed head weight due to the amount of diseased leaves that had to be removed. Only minimal trimming was required for treatment 8 (HDC F150, Previcur Energy, Fubol Gold, Revus) to make the heads marketable (Figure 12). This treatment also provided reasonable control of downy mildew and *Botrytis*.

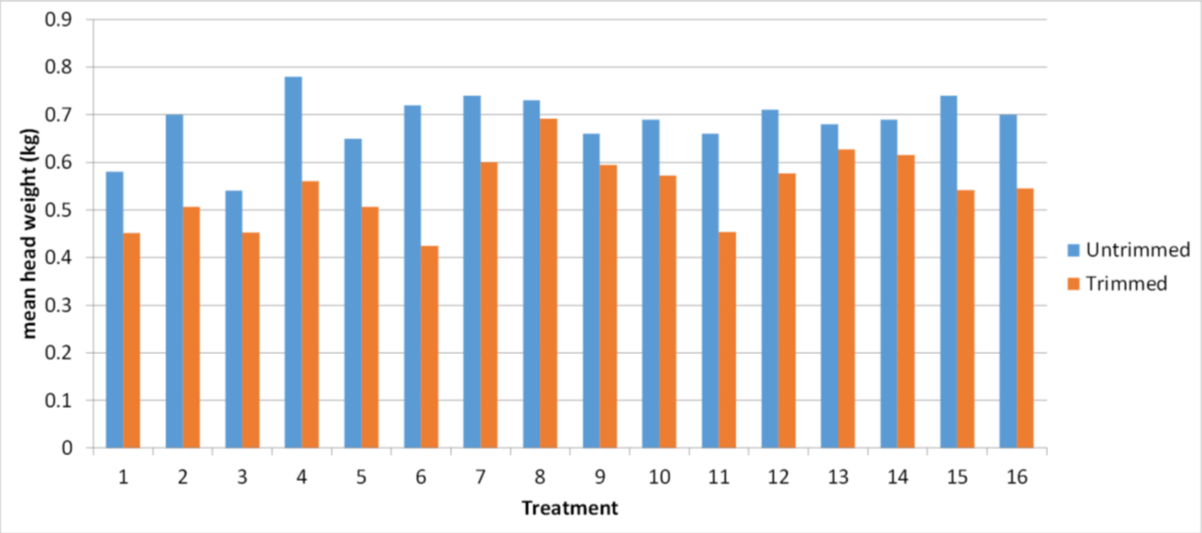

Figure 12. Mean untrimmed and trimmed head weights.

Residue analysis

No residues were found above the limit of detection for any of the following treatments: 1 (untreated); 2 (Amistar + Karamate, Signum, Fubol Gold, Revus); 4 (HDC F150 + Revus at all four spray timings) and 6 (Revus + HDC F147, Revus + HDC F147, Revus + HDC F147, Revus). The only residue recorded in the other treatments was from the maintenance application of the insecticide imidacloprid (0.01 mg/kg).

Spring 2014 Protected Trial: *Sclerotinia minor*

Incidence of *S. minor* was recorded at three assessments, but only severity was recorded at harvest as the pathogen was slow to develop in this particular crop and this was thought to be due to the prevailing weather conditions that were not particularly conducive to infection unfortunately. There were significant treatment differences (P = 0.02) in this assessment (Table 5 & Figure 13).

Table 5. Severity (0-3 scale) of *Sclerotinia minor* at harvest in the spring protected trial.

No.	Treatment	Severity of *S. minor* at harvest	
1	Untreated Check	1.2	a
2	Contans	0.8	a-d
3	Amistar	0.3	d
4	Signum	0.3	d
5	Switch	0.7	bcd
6	Octave	1.0	ab
7	HDC F187	0.6	bcd
8	HDC F148	0.5	cd
9	Contans/Signum/Switch/Serenade	0.8	abc
10	Contans/Signum 0.5N + Switch 0.5N/Serenade	0.9	abc
11	Contans/Amistar 0.5N + Switch 0.5/Signum 0.5N + Octave 0.5N	0.7	bcd
12	Contans/HDC F148/HDC F187/HDC F155	0.7	bcd

Means followed by the same letter do not differ significantly

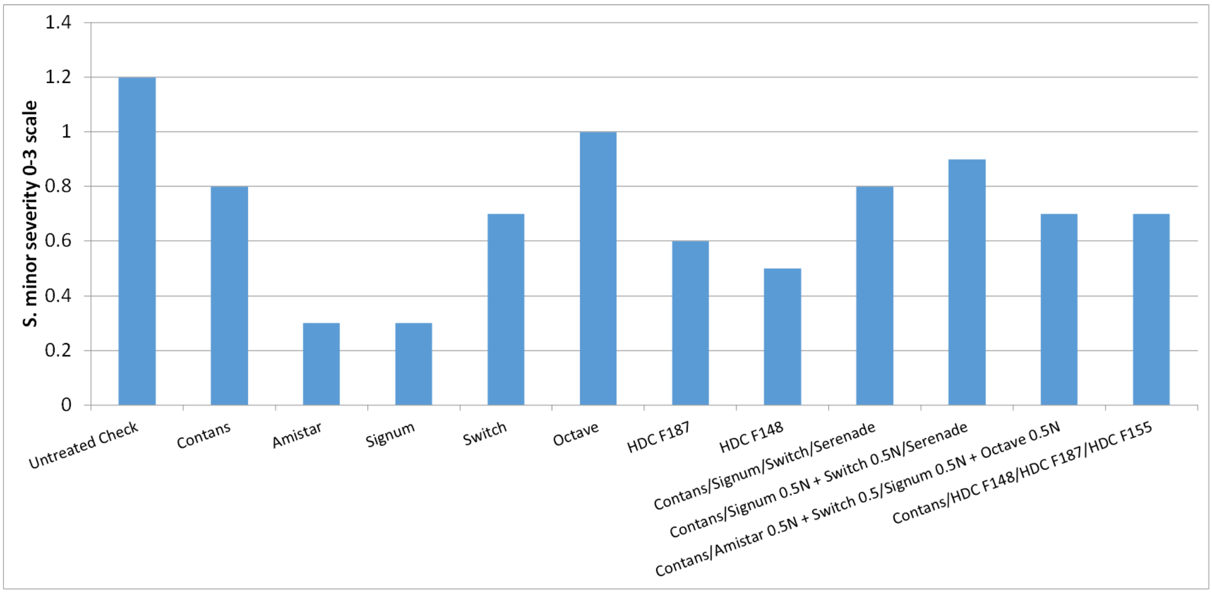

Figure 13. Severity (0-3 scale) of *Sclerotinia minor* at harvest in the spring protected trial.

Incidence of *Lettuce Big Vein Disease* was also recorded, but there were no correlations between assessments, indicating that the treatments applied were unlikely to have had any effect on this organism.

No other diseases were observed in the trial.

Amistar and Signum both provided very good control of *S. minor*, followed by HDC F148 and then HDC F187. Switch, Contans and Octave provided poorer control. , In comparison to the best straight treatments, poorer control was provided by the treatment programmes in this study.

There were no significant differences between trimmed or untrimmed head weights at harvest.

A full set of treatment data and analyses for this trial is provided in Appendix II.

Conclusions

Field Trials

Downy mildew is a major disease that affects UK lettuce crops and can be potentially devastating where epidemics occur. The disease is most likely to occur when conditions are cool (10 – 15 °C), humidity is high and when there is prolonged leaf wetness. Cultural controls such as choosing less susceptible or resistant cultivars with appropriate downy mildew gene combinations, plant spacing, row orientation, irrigation timing and weed control can all assist in reducing disease risk. In spring and autumn it is difficult at certain times to avoid these conditions and here a robust fungicide programme is needed to complement and maintain varietal resistance and other disease control strategies. The project tested some experimental programmes including several products that may be approved in the near future. Three programmes tested stood out, these were:

1. Treatment 9 (Amistar + Karamate, Previcur energy, Infinito, Revus)
2. Treatment 4 (Revus + HDC F145 (x 4))
3. Treatment 6 (Revus + HDC F147 (x 4))

The availability of Revus provides an opportunity to control the races of *Bremia lactucae* that are resistant to metalaxyl-M as was seen in HDC FV 357. However, relying on Revus mixed only with either HDC F145 or HDC F147 did not control *Botrytis* and therefore resulted in fewer marketable heads and lower head weights at harvest. This emphasises the need to identify broad spectrum programmes to provide effective control of a range of potential pathogens in lettuce.

The treatment programmes that provided good control of downy mildew, medium control of Botrytis and had good, marketable heads of good weights were as follows:

1. Treatment 8 (HDC F150, Previcur energy, Fubol Gold, Revus)
2. Treatment 9 (Amistar + Karamate, Previcur energy, Infinito, Revus)
3. Treatment 7 (Amistar + Karamate, Previcur energy, Infinito, HDC F145 + Revus)
4. Treatment 10 (Previcur energy, Previcur energy + HDC F151, Infinito, Revus)

Therefore, there are promising options for the future as long as the residue tests can be satisfied. *Botrytis* control is still a challenge as it often occurs secondarily. Some programmes worked well against this pathogen, but at the expense of downy mildew control.

Protected *Sclerotinia minor* Trial

The spring trial demonstrated that approved products are available to control the pathogen, but further work is needed to pinpoint timings in order to produce an effective programme that will control other key diseases as well. In general it would appear that those products with good activity against *S. sclerotiorum* are also effective against *S.minor* and that is useful information for those growers struggling with *S. minor* control.

For both outdoor and protected crops, tank mixtures and/or programmes of products will need to be adjusted according to the disease control spectrum required. Therefore, in order to deliver a broad and effective control programme, the approach of using reduced rate tank mixes using a range of different mode of action products, including biological products, has some merit both from an efficacy standpoint, but also from a residue and anti-resistance perspective.

There is, to date, little evidence from the trials to suggest that the biological products provided effective disease control in lettuce, especially where used alone. However, further exploration is still required to evaluate their use in integrated programmes to help reduce residue risk close to harvest and also reduce reliance on conventional fungicides thus further minimising the risk of resistance development whilst maintaining the health of the crop.

Acknowledgements

We would like to thank J.E. Piccaver, Gedney Drive End, Lincolnshire for their cooperation allowing us to use their holdings for the outdoor trial site and S&M Brankley, Goole, East Yorkshire for their cooperation allowing us to use their holdings for the protected trial site.

Knowledge and Technology Transfer

RDPE meeting at Gee's – 12 December 2013

February 2014 project review meeting

Project reviews at BLSA meetings (protected and outdoor)

References

Laemmlen, F. (2001). Sclerotinia diseases. Publication 8042. University of California Agriculture and Natural Resoures.

Gladders, P., Green, K., Huckle, A. and Kirkpatrick, L. (2010). Outdoor lettuce: evaluation of novel fungicides for downy mildew control. Horticultural Development Company Final report for project FV 357.

Horticultural Statistics (2013). Published by the Department for Environment, Food and Rural Affairs.

Appendices

Appendix I Assessment data for autumn 2013 outdoor trial.

Downy mildew severity after 3rd treatment application

	T1 **2-4 days post transplant**	**T2** **7-10 days after T1**	**T3** **-7-10 days after T2**	**Downy mildew severity**
1	Untreated	Untreated	Untreated	25.68
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	22.82
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	21.08
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	9.19
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	21.67
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	9.41
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	17.26
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	20.74
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	15.4
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	18.46
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F146 2.5 l/ha	22.68
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	21.32
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	21.37
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	21.66
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	22.05
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	25.9
		Fpr		<.001
			min.rep	6.63
			max-min	5.74
		SED	max.rep	4.69X
			min.rep	13.32
			max-min	11.53
		LSD	max.rep	9.42X

Harvest assessments

	T1 2-4 days post transplant	T2 7-10 days after T1	T3 -7-10 days after T2	T4 -7-10 days after T3	Downy mildew severity
1	Untreated	Untreated	Untreated	Untreated	74.1
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	33.9
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	43
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	22.5
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	33.8
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha	31.1
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	30.9
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha	28.3
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	22.8
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	29
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F1462.5 l/ha	Revus 0.6 l/ha	53.4
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	53.9
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha	26.9
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	33
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha	42.4
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha	42.2
		Fpr			<0.001
			min.rep		10.08
			max-min		8.73
		SED	max.rep		7.13X
			min.rep		20.26
			max-min		17.54
		LSD	max.rep		14.33X

	T1 2-4 days post transplant	T2 7-10 days after T1	T3 -7-10 days after T2	T4 -7-10 days after T3	Botrytis severity
1	Untreated	Untreated	Untreated	Untreated	26.9
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	20.6
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	13.1
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	23.1
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	14.4
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha	23.8
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	21.2
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha	17.5
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	19.4
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	20
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F1462.5 l/ha	Revus 0.6 l/ha	29.4
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	19.4
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha	21.2
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	20
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha	20.6
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha	16.2
		Fpr			0.451
			min.rep		6.25
			max-min		5.41
		SED	max.rep		4.42X
			min.rep		12.56
			max-min		10.88
		LSD	max.rep		8.88X

	T1 2-4 days post transplant	T2 7-10 days after T1	T3 -7-10 days after T2	T4 -7-10 days after T3	Average weight per head (Kg)
1	Untreated	Untreated	Untreated	Untreated	0.58
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	0.70
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	0.54
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	0.78
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	0.65
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha	0.72
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	0.74
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha	0.73
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	0.66
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	0.69
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F1462.5 l/ha	Revus 0.6 l/ha	0.66
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	0.71
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha	0.68
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	0.69
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha	0.74
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha	0.70
		Fpr			<.001
			min.rep		0.05
			max-min		0.04
		SED	max.rep		0.036X
			min.rep		0.10
			max-min		0.09
		LSD	max.rep		0.073X

	T1 2-4 days post transplant	T2 7-10 days after T1	T3 -7-10 days after T2	T4 -7-10 days after T3	Marketable Trimmed weight (out of 10 plants per plot) (kg)
1	Untreated	Untreated	Untreated	Untreated	4.51
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	5.07
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	4.52
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	5.61
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	5.06
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha	4.25
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	6
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha	6.92
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	5.94
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	5.72
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F1462.5 l/ha	Revus 0.6 l/ha	4.54
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	5.77
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha	6.27
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	6.16
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha	5.42
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha	5.45
		Fpr			0.043
			min.rep		0.8
			max-min		0.693
		SED	max.rep		0.565X
			min.rep		1.607
			max-min		1.392
		LSD	max.rep		1.136X

	T1 2-4 days post transplant	T2 7-10 days after T1	T3 -7-10 days after T2	T4 -7-10 days after T3	% marketable heads (cat 3+4 scores removed)
1	Untreated	Untreated	Untreated	Untreated	78.8
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	80
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	90
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	87.5
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	97.5
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha	90
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	90
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha	92.5
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	90
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	90
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F1462.5 l/ha	Revus 0.6 l/ha	75
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	87.5
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha	97.5
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	92.5
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha	87.5
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha	85
		Fpr			0.294
			min.rep		8.47
			max-min		7.33
		SED	max.rep		5.99X
			min.rep		17.01
			max-min		14.73
		LSD	max.rep		12.03X

	T1 2-4 days post transplant	T2 7-10 days after T1	T3 -7-10 days after T2	T4 -7-10 days after T3	% marketable heads (graded at weighing)
1	Untreated	Untreated	Untreated	Untreated	78.8
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	72.5
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	82.5
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	72.5
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	80
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha	60
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	82.5
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha	95
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	90
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	82.5
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F1462.5 l/ha	Revus 0.6 l/ha	67.5
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	82.5
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha	92.5
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	90
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha	75
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha	77.5
		Fpr			0.221
			min.rep		11.45
			max-min		9.92
		SED	max.rep		8.10X
			min.rep		23.02
			max-min		19.93
		LSD	max.rep		16.28X

	T1 2-4 days post transplant	T2 7-10 days after T1	T3 -7-10 days after T2	T4 -7-10 days after T3	Botrytis and soft rot incidence
1	Untreated	Untreated	Untreated	Untreated	51.2
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	37.5
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	30
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	52.5
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	35
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha	55
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	50
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha	45
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	45
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	42.5
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F1462.5 l/ha	Revus 0.6 l/ha	62.5
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	40
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha	52.5
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	42.5
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha	40
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha	40
		Fpr			0.575
			min.rep		12.73
			max-min		11.03
		SED	max.rep		9.00X
			min.rep		25.59
			max-min		22.16
		LSD	max.rep		18.09X

	T1 2-4 days post transplant	T2 7-10 days after T1	T3 -7-10 days after T2	T4 -7-10 days after T3	Botrytis and soft rot severity
1	Untreated	Untreated	Untreated	Untreated	27.8
2	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	22.5
3	Switch 0.8 kg/ha + Karamate 2.0 kg/ha	Amistar 1.0 l/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	15.6
4	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	HDC F145 1.25 l/ha+ Revus 0.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	23.1
5	HDC F145 1.5 l/ha + Amistar 1.0 l/ha	Signum 1.5 kg/ha	Fubol Gold 1.9 kg/ha	Revus 0.6 l/ha	14.4
6	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha + HDC F147 0.028kg/ha	Revus 0.6 l/ha	23.8
7	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	HDC F145 1.25 l/ha + Revus 0.6 l/ha	21.2
8	HDC F150 2.5 kg/ha	Previcur Energy 2.5 l/ha	Fubol Gold 1.9 l/ha	Revus 0.6 l/ha	17.5
9	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Previcur Energy 2.5 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	19.4
10	Previcur Energy 2.5 l/ha	Previcur Energy 2.5 l/ha + HDC F151 0.8 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	20
11	HDC F146 2.5 l/ha	Invader 2.0 l/ha	HDC F1462.5 l/ha	Revus 0.6 l/ha	33.1
12	Signum1.5 kg/ha	Invader 2.0 l/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	19.4
13	Amistar 1.0 l/ha + Karamate 2.0 kg/ha	Signum 1.5 kg/ha	Switch 0.8 kg/ha + Infinito 1.6 l/ha	Revus 0.6 l/ha	21.2
14	HDC F150 2.5 kg/ha	Signum1.5 kg/ha	Infinito 1.6 l/ha	Revus 0.6 l/ha	20.6
15	Amistar 1.0 l/ha +Karamate 2.0 kg/ha	Signum1.5 kg/ha	Switch 0.8 kg/ha + Infinito	HDC F145 2.5 l/ha	20.6
16	Signum1.5 kg/ha	Signum 1.5 kg/ha +Serenade 8.0 l/ha	Amistar 1.0 l/ha	Revus 0.6 l/ha	20
		Fpr			0.395
			min.rep		6.46
			max-min		5.6
		SED	max.rep		4.57X
			min.rep		12.99
			max-min		11.25
		LSD	max.rep		9.18X

Appendix II

Assessment data for spring 2014 protected trial on *Sclerotinia minor*.

Pest Type	D Disease	D Disease	D Disease	D Disease	D Disease				
Pest Code	SCLEMI	MILBVV	SCLEMI	SCLEMI	MILBVV				
Pest Scientific Name	Sclerotinia mi>	Mirafiori lett>	Sclerotinia mi>	Sclerotinia mi>	Mirafiori lett>				
Pest Name	Sclerotinia di>	Mirafiori lett>	Sclerotinia di>	Sclerotinia di>	Mirafiori lett>				
Crop Code	LACSA	LACSA	LACSA	LACSA	LACSA	LACSA	LACSA	LACSA	LACSA
BBCH Scale	BVNH	BVNH	BVNH	BVNH	BVNH	BVNH	BVNH	BVNH	BVNH
Crop Scientific Name	Lactuca sativa	Lactuca sativa	Lactuca sativa	Lactuca sativa	Lactuca sativa	Lactuca sativa	Lactuca sativa	Lactuca sativa	Lactuca sativa
Crop Name	Lettuce	Lettuce	Lettuce	Lettuce	Lettuce	Lettuce	Lettuce	Lettuce	Lettuce
Part Assessed	- P	- P	- P	- P	- P	HEAHAR C	HEAHAR C	HEAMAR C	HEAMAR C
Assessment Date	17/04/2014	17/04/2014	07/05/2014	13/05/2014	13/05/2014	13/05/2014	13/05/2014	13/05/2014	13/05/2014
Assessment Type	PESINC	PESINC	PESINC	PESSEV	PESINC		WEIGHT		WEIGHT
Assessment Unit	NUMBER	NUMBER	NUMBER	0-3	NUMBER	NUMBER	kg	NUMBER	kg
Sample Size, Unit	24 PLANT	24 PLANT	24 PLANT		24 PLANT	24 PLANT	1 PLANT	24 PLANT	1 PLANT
Number of Subsamples	1	1	1	24	1	1	1	1	1
Assessed By	JAT, AO	JAT, AO	GMM	JAT	JAT				
Trt Treatment									
No. Name	1	2	3	4	5	6	7	8	9
1 Untreated Check	0 a	0.1 b	1.1 a	1.2 a	5.7 a	22 a	0.2838 a	22 a	0.2413 a
2 Contans	0 a	0 b	0.4 a	0.8 a-d	5.1 a	23.3 a	0.2788 a	22.5 a	0.244 a
3 Amistar	0 a	0 b	0.1 a	0.3 d	6.4 a	24 a	0.2595 a	24 a	0.2318 a
4 Signum	0 a	0 b	0.1 a	0.3 d	2.7 a	24 a	0.2898 a	24 a	0.2608 a
5 Switch	0 a	0 b	0 a	0.7 bcd	5.3 a	24 a	0.2688 a	23.8 a	0.2353 a
6 Octave	0 a	3.5 a	0.3 a	1 ab	5.5 a	22 a	0.257 a	22 a	0.221 a
7 HDC F187	0 a	0.1 b	0 a	0.6 bcd	4.3 a	23.8 a	0.2735 a	23.8 a	0.2475 a
8 HDC F148	0 a	0 b	0.3 a	0.5 cd	6 a	24 a	0.2848 a	24 a	0.25 a
9 Contans/Signum/Switch/Serenade	0 a	0 b	0 a	0.8 abc	3.6 a	22.5 a	0.2663 a	22.3 a	0.233 a
10 Contans/Signum 0.5N + Switch 0.5N/Serenade	0 a	0.1 b	0 a	0.9 abc	5.2 a	23.8 a	0.2825 a	23.8 a	0.2408 a
11 Contans/Amistar 0.5N + Switch 0.5/Signum 0.5N + Octave 0.5N	0 a	0 b	0.1 a	0.7 bcd	5.3 a	24 a	0.2713 a	23.5 a	0.239 a
12 Contans/HDC F148/HDC F187/HDC F155	0 a	0.1 b	0.1 a	0.7 bcd	5.2 a	23.8 a	0.2778 a	23.8 a	0.2435 a
LSD (P=.05)	0	2.74t	3.97t	0.45	0.32t	1.77	0.03538	2.11	0.03408
Standard Deviation	0	1.90t	2.75t	0.31	0.22t	1.22	0.0245	1.46	0.0236
CV	0	137.85	156.62	44.45	28.43	5.22	8.93	6.29	9.81
Grand Mean	0	1.38t	1.75t	0.71	0.77t	23.42	0.27	23.27	0.24
Replicate F	0	1.419	0.719	0.289	0.588	0.149	1.67	0.165	3.407
Replicate Prob(F)	1	0.2547	0.5476	0.833	0.6273	0.9298	0.1923	0.919	0.0288
Treatment F	0	10.273	1.784	2.555	0.582	1.682	0.702	1.262	0.727
Treatment Prob(F)	1	0.0001	0.0978	0.0184	0.8295	0.1215	0.7271	0.2886	0.705

Means followed by same letter do not significantly differ (P=.05, LSD)

t=Mean descriptions are reported in transformed data units, and are not de-transformed.

Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Key:

Pest Type

D, Disease, G-BYRD7, G-DisStg = Disease, such as a fungus, bacteria, or virus

Pest Code

SCLEMI, Sclerotinia minor, = US

MILBVV, Mirafiori lettuce big vein virus, = US

Crop Code

LACSA, BVNH, Lactuca sativa, = US

Part Assessed

HEAHAR = head - harvestable

HEAMAR = head - marketable

P = Pest is Part Rated

C = Crop is Part Rated

Assessment Type

PESINC = pest incidence

PESSEV = pest severity

WEIGHT = weight

Assessment Unit

NUMBER = number

0-3 = 0-3 index/scale

kg = kilogram

PLANT = plant/plant biomass/shrub