Final Report

Effectiveness of mineral & vegetable oils in minimising the spread of non-persistent viruses in potato seed crops in GB

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1. SUMMARY

1.1. Aim

The aim of the project was to investigate the potential for mineral oils to be used as a control method for potyviruses (non-persistent viruses) in seed crops subject to the GB Certification system of growing crop inspection and control programmes for persistent viruses (Potato Leaf Roll Virus, PLRV) and potato late blight (*Phytophthora infestans*).

1.2. Methodology

1.2.1. Determine the effectiveness of treatment programmes in minimising potyvirus spread.

Four field virus transmission trials were established in each of the three years of the project. These were located in Fife, Edinburgh, Yorkshire and Cambridge. All trials were planted as randomised complete block designs. Each trial, with the exception of the Yorkshire site, had infector rows placed in equal proximity to the plots. There were different treatments at the four locations. The core treatments evaluated in Cambridge, Yorkshire and Fife were:

- Untreated
- Fortune (vegetable oil; @ 0.5% total spray volume)
- Olie-H (mineral oil; @ 3.1% total spray volume)
- Hallmark Zeon (75ml/ha)
- Hallmark/Fortune (Hallmark Zeon 75ml/ha + Fortune 0.5%)
- Hallmark/Olie-H (Hallmark Zeon 75ml/ha + Olie-H 3.1%)
- Hallmark/Biscaya/SumiAlpha/Tepekki
- Olie-H 3.1%/ Hallmark/Biscaya/SumiAlpha/Tepekki

The integrated programmes with sequences including more than one product were devised to evaluate the integration of potyvirus control with measures targeting colonising aphids and persistent virus transmission (PLRV).

At the Edinburgh site, the aim was to investigate the effect on virus transmission and acquisition of applying Fortune and Olie-H to four varieties susceptible to the most prevalent potyviruses (PVY^N and PVA). Virus transmission was assessed by post-harvest virus testing of progeny tubers. This involved growing on the harvested tubers and measuring virus levels in the resulting leaves by ELISA.

1.2.2. Determine the effect of tank mixes of mineral oils and common blight sprays

Two field trials were established in Ayrshire in each of the three years to compare the blight control achieved by commonly used blight control products with and without the addition of Olie-H 3.1% of the spray volume (6.25 l/ha in a tank mix in 200 litres of water per hectare). The first trial was to examine the effects at the rapid canopy expansion phase from rosette stage to full crop canopy. The second was targeted at canopy stable when full crop canopy had been achieved.

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1.2.3. The effect of mineral oils on crop inspection

Observation plots were established to evaluate the impact of oil treatments on the visual inspection of seed crops. The plots were located at SASA, Edinburgh and NIAB, Cambridge. At each location variety / virus combinations were chosen to determine the effect of oil application on the visual assessment of the growing crop for seed certification. At each site the plots were viewed by inspectors from the Certifying authority to establish the acceptability of the treatments under their standard visual inspection protocols.

1.3. Key findings

1.3.1. Determine the effectiveness of treatment programmes in minimising potyvirus spread.

Evidence for oil-based treatments performing significantly better than the control (ie untreated plots) was observed in specific sites and seasons for PVA and PVY^N.

It is acknowledged that differences in transmission rate associated with vector activity, inherent variations in virus titre in infected plants and variation in virus incidence between different trials make it challenging to directly compare results across sites and seasons. At the Fife, Edinburgh and Cambridge sites, the majority of the transmission pressure occurred in different 7 day periods in the different locations. Therefore, the products applied during these periods were placed under the greatest pressure. The results for the entire programme at different locations may hinge on the performance of a single application at a critical time.

Fife:
For most viruses at the Fife site in 2011, only low numbers of infected bulks were found therefore, the only results that are presented are those from PVA and the combined total of all viruses. In these cases, differences between treatments were not evident. In 2012, PVA and PVY^N was found in the test material. Again, statistical differences between treatments were not evident. In 2013, the proportion of infected bulks was higher and significant differences between treatments were evident. Plots treated with Olie H at 6.2% had a lower rate of infection than the control overall (%) as did this treatment for PVY^N and PVA compared to their control.

Cambridge:
At the Cambridge site in 2011, differences between treatments were evident for PVA and PLRV. For PVA, there was evidence that all treatments apart from “Hallmark/Biscaya/Sumi Alpha/Plenum” had lower proportions of infected tubers than the control. For PLRV, the treatments “Hallmark Fortune”, “Hallmark Olie H” and “Hallmark/Biscaya/Sumi Alpha/Plenum” were found to be more effective than the control. In 2012, differences between treatments were evident only for PVY^N. The treatments “Olie-H” and “Hallmark Olie-H” were found to be more effective than the control. In 2013, because of high rates of infection seen for PVY^N and $PVY^{o/c,}$ 30 tubers from 30 plants from each plot were tested individually. For PVY^N, strong evidence was found for differences between the treatments. In particular, the “Hallmark Olie H”; and “Crop Spray 11E” treatments clearly performed better than the control, though, even with these, the proportion of infected plants was still high.

No consistent effects were noted on tuber yield or number at the Fife, Yorkshire or Cambridge sites.

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Three years of trials at Edinburgh compared varieties that were either left untreated or treated with Olie H 3.1% (Headland Fortune 0.5% was also studied in 2013). The overall analysis for the entire three years suggests that mineral oil (Olie H) treatment reduced potyvirus transmission however, this was not seen consistently in each year for all varieties tested.

A previously published review of the use of mineral oils (Al-Mrabeh *et al* 2010) provided evidence for a reduction in potyvirus spread in the range of 30 – 60% when oil based treatments were compared to untreated control. Within the data sets generated at the Cambridge, Edinburgh and Fife sites, reductions in this range have been observed for treatment means for PVA and PVY^N. These results encourage the continued investigation of integrated programmes where oils are used to replace or supplement pyrethroids in conjunction with insecticides with alternative modes of action such as Biscaya and Tepekki.

1.3.2. Determine the effect of tank mixes of mineral oils and common blight sprays

Olie H (and Newman Cropspray 11E and Headland Fortune when tested in one trial in 2013) consistently improved foliar blight control for the three fungicides Percos, Revus and Invader. In 12 out of the 15 comparisons involving these fungicides, the improvement in foliar blight control was statistically significant. However, the impact of oil added to fungicide on leaf blight was greatly influenced by the fungicide product used in the tank mix. In 2011 Olie-H had deleterious effects when tank mixed with Shirlan or Ranman TP. The formulation of Ranman TP was changed to Ranman Top by the manufacturer during the period of study. Foliar blight control with Olie H added to the mix was not detrimental for the replacement Top formulation. Seasonal variability in foliar blight control with added Olie H was evident in the results for Valbon + ZinZan, Ranman Top and to a lesser extent Infinito.

For 22 out of the 27 paired comparisons, adding oil to the blight fungicide did not significantly affect blight-free yield. For three comparisons the oil plus fungicide had significantly higher blight-free yields. For two comparisons yield was significantly reduced in the oil tank mix compared with the straight fungicide. Four out of these five tank mixes with a significant yield response to added oil had an associated statistically significant difference in foliar blight. The exception was the reduction in blight-free yield with the Valbon + ZinZan and Olie H mix.

Tuber blight incidences in the six trials ranged from very low to low and therefore prevented any conclusion regarding the impact of oil plus fungicide tank mixes on tuber blight control. However, there was no evidence that adding oil to blight fungicides had a substantial detrimental effect on control of this aspect of the disease.

Symptoms of phytotoxicity associated with oil use were only observed with one treatment, i.e. Shirlan + Olie H. A much more frequent and widespread effect was the beading of water droplets on the surface of leaflets treated with oil, resulting in delayed drying of leaf surfaces. Greater leaf blight severity due to this delayed drying is a possibility but this could not be specifically tested in the field trials. The predominantly positive response to added oil suggests that any such enhancement of leaf infection, if it occurred, was relatively small.

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1.3.3. The effect of mineral oils on crop inspections

The concern within the industry that the use of mineral oils would be detrimental to statutory growing crop inspections for Certification has not been borne out by the trials carried out to date. Inspectors from both SGRPID and PHSI concluded that the ability to identify both varieties and virus symptoms were not diminished by treatment with Olie-H or Fortune (not tank mixed with other products). These conclusions were drawn in the presence of low levels of phytotoxic reactions at the Edinburgh and Cambridge inspection plots.

SASA inspectorate staff at Edinburgh concluded on the two occasions where necrosis was observed that "despite phytotoxic symptoms being observed with the application of oils, the severity of the symptoms observed were not at a level that would impact on the visual inspection of a commercial seed crop for purity and freedom from disease." The number of occasions where phytotoxic symptoms were observed were in the minority and may have related to limitations of the methods of application.

PHSI officials from FERA visiting the virus demonstration plots at Cambridge concluded that the markings observed, on the material available, would not compromise either variety identification or virus recognition during crop inspection.

1.4. Practical Outcomes

- **The trials results do not represent a recommendation to growers. Always read and follow the product label.**
- The data presented was generated using sites with virus infection pressure far higher than would be anticipated for certified seed crops but was necessary to generate treatment differences.
- Aphid vector species and number were variable between sites and seasons but also over the course of a season at a single site. The insecticide resistance status of the aphids present relative to the product applied at a specific point in time could dictate the outcome of a control programme for the whole season.
- Reductions in non-persistent virus transmission were recorded with the use of pyrethroid insecticides despite the shift in sensitivity shown by a proportion of the Grain aphid (*Sitobion avenae*) population.
- Mineral oil sprays applied from 50 – 75% emergence, or programmes with oil sprays included as part of the sequence can provide significant reduction of potyvirus transmission but under high infectivity pressure (vector and virus source) may not always provide the necessary levels of prevention of virus infection for certified seed crops. The highest concentration tested provided the greatest reduction (although the highest concentration was not included in all trials in all years).
- The findings of this work are consistent with the information provided in the Potato Council review (Al-Mrabeh *et al* 2010) on the use of mineral oils. The literature cited in the review indicated a reduction in potyvirus spread in the range of 30 – 60% when oil based treatments were compared to untreated control.
- Application timing and dose rate will be restricted by the label requirements of the product selected. On most, but not all, current labels the latest timing of application for mineral oils is at tuber initiation; this could be as soon as 14-21 days after emergence.
- While yield may occasionally be reduced by oil sprays, this could be managed by delaying desiccation by a few days to achieve the desired tuber size range.

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- Avoiding oil spray applications before periods of sunny weather may help to minimise the appearance of any phytotoxic effects. Application method and water volume may also be a contributory factor.
- The symptoms did not compromise crop inspection for certification and neither masked nor mimicked virus symptoms when viewed by officials and crop inspectors in either England or Scotland.
- Tank mixes were only tested for a limited number of blight products in this project. The mineral oils consistently improved foliar blight control for the three fungicides Percos, Revus and Invader. In 12 out of the 15 comparisons including these fungicides the improvement was statistically significant. However, the impact of oil added to fungicide on leaf blight was greatly influenced by the fungicide product used in the tank mix. In 2011, Olie-H had deleterious effects when tank mixed with Shirlan or Ranman TP.
- Further tank mixing evaluations will be required by manufacturers to generate commercial recommendations. These should include 3 way mixes of blight fungicide, insecticide and mineral oil. Wider experience has highlighted phytotoxic effects from tank mixes of Biscaya (oil dispersible formulation) and mineral oil.

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2. INTRODUCTION

Potato viruses and their vectors

In the past decade, non-persistent viruses (potyviruses) have increased in frequency to become the main virus problem for seed potato growers. Potyviruses most commonly affecting the potato crop in the UK include PVA, PVY^{N}, $PVY^{O/C}$, PVY^{NTN} and PVV. Further information about the viruses and their aphid vectors are provided in the final report for the project R428 Aphids & Virus Transmission in Seed Crops (2013).

The R428 report describes the methods that are used to help understand which aphids are important in spreading poytviruses. Relative Efficiency Factor (REF) values give an indication of the transmission efficiency of a particular aphid species in relation to that of the peach-potato aphid, *Myzus persicae*, which is considered to be the most efficient vector of PVY. A table of potyvirus vectors, with their current REF values, is provided below:

Species	Common name	PVY REF value
Myzus persicae	peach -potato aphid	1.00
Acyrthosiphon pisum	pea aphid	0.70
Cavariella aegopodii	carrot-willow aphid	0.50
Macrosiphum euphorbiae	potato aphid	0.20
Metopolophium dirhodum		0.30
Rhopalosiphum padi		0.40
Sitobion avenae	grain aphid	0.60

Insecticide resistance status of aphid vectors of potato viruses

Genetic characterisation of *M. persicae* in GB using microsatellite markers has identified a turnover of insecticide resistance mechanisms carried by different clones (Kasprowicz *et al* 2008; Fenton *et al* 2010). Each new immigrant has a more optimised phenotype, meaning it carries a selection of beneficial insecticide resistance mechanisms but it also has a capacity to survive in field conditions where it will be attacked by predators and subject to hostile climatic conditions. The culmination of this process has resulted in two clones denoted O and P (Fenton *et al* 2010), dominating in the UK and most probably all of northern Europe in areas of intensive agriculture (Fontaine *et al* 2011). These clones carry a potent pyrethroid resistance mutation in the super kdr region, M918L, which dramatically increases their resistance compared to the kdr L1014F (Fontaine *et al* 2011). They also carry resistance to dimethyl carbamates, through a modified acetylcholinesterase. Unlike the previous generations of resistant clones these have not turned over and since 2008 almost the entire population of *M. persicae* in the UK consists of clones O and P, now in approximately equal proportions (B. Fenton, unpublished observation).

The development of resistance to neonicotinoid insecticides in populations of *M. persicae* in southern Europe has been reported. This creates the potential for migration and the establishment of neonicotinoid resistance within the clonal GB population of this species. There is currently no evidence that these clones have arrived in GB, however, a co-ordinated management strategy employing control

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measures with different modes of action is a wise precaution to reduce the selection pressure.

In seed potato production the greatest threat of poytviruses, such as PVY, comes from within the crop. In earlier generations, residual volunteer tubers from previous crops are most likely to contribute (E. Anderson pers observation), but in later field generations this will come from low levels of infected tubers introduced within the seed. Sources within the crop can increase the risk of virus spread by up to 56%. Movement of potyviruses from sources outside the production field are going to be reduced by the rapid loss of transmissibility of potyviruses after vector feeding. This decreases after 30 minutes and has essentially gone after one hour (Gibson *et al* 1982; Kotzampigikis *et al* 2009).

In field conditions there is a complex of aphid species transmitting potyviruses in potato crops. Until recently *M. persicae* was the only one of the sixteen recognised virus vectors in UK to show resistance pyrethroids. In 2009, the grain aphid, *Sitobion avenae,* developed the L1014F mutation in one copy of its sodium channel gene (Foster *et al* 2014). Compared to the most sensitive clone of *S. avenae* resistance increased by a factor of 35 - 40. However, there was a range of measurements within sensitive clones and compared to the most tolerant, but still susceptible *S. avenae* clone (*kdr*-SS, 2011b), the most resistant clone (*kdr*-SR, 2011b) was only 10 fold more resistant (Foster *et al* 2014). In a range of samples, the equivalent L1014F mutation in the heterozygous form in *M. persicae* may boost resistance by up to six fold (Fuentes-Contreras *et al* 2013) which is in the same order. The L1014F mutation is in the kdr locus and not the super kdr locus where for example, *M. persicae* genotype O, carries one copy of the M918L mutation. A single copy of this mutation can boost pyrethroid resistance up to 256 fold (Kasprowicz *et al* 2008).

In the grain aphid, *S. avenae*, the effects of lambda-cyhalothrin applied at a rate of 7.5g active ingredient per hectare (a.i./ha) have been sufficient to control heterozygotes with the less potent L1014F mutation eight days after application (97% control in susceptible and 96% control in the L1014F (Dewar *et al* 2014)). While this was tested in a cereal crop and it is more than the recommended rate for this type of crop, it is the rate recommended for a potato crop. In the same series of experiments the control of resistant *S. avenae* for the other pyrethroids: cypermethrin (25g a.i./ha) and deltamethrin (7.5g a.i./ ha) was not as good in field conditions as lambda-cyhalothrin, although they still provided 70 – 83% control eight days after application (Dewar *et al,* 2014). The results in cereal crops suggest that pyrethroids are still going to affect *S. avenae* behaviour of both L1014F and non L1014F carrying clones and be of value in disrupting potyvirus transmission in seed potato crops.

The occurrence of *M. persicae* clones resistant to many common insecticides and the reduction in sensitivity of *S. avenae* to pyrethroid insecticides provides a strong impetus for the need to develop alternative control strategies. However, there may still be a benefit from the inclusion of pyrethroid based products within an integrated programme as there is a need to control a number of other aphid species. Unlike persistent viruses (e.g. Potato Leaf Roll Virus), the vectoring of potyviruses does not depend on a close association with particular species of potato colonising aphid such as the *M. persicae*. The potential contribution of other aphids such as Carrot-Willow aphid and cereal aphids in virus transmission is mentioned above. The transitory nature and feeding habits of these non-colonizing aphids creates a

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significant difficulty for methods of reducing virus transmission through controlling the feeding of aphids on crops using aphicide products. Systemic aphicides are contained within the leaf phloem tissue and are only acquired through deep stylet probing and may take several hours to be effective in halting feeding. Many aphids can acquire potyvirus within 30 seconds of probing of the surface of the epidermis (Bradley, 1959).

The potential for mineral oils to be used effectively for the reduction of potyvirus in seed crops was identified by the Potato Council funded review R428 (Al-Mrabeh et al 2010). This review evaluated published data and commercial practice outside of the UK. Despite the differences in experimental methodology oils were found to significantly contribute to the reduction of virus spread of between 30 and 60% relative to the untreated controls. A reduction in yield of between 5 and 10% was noted in some cases from their use.

Historically, the use of oils has been discounted in UK seed crops primarily because of a concern that their use would impair the ability to visually identify varieties and virus symptoms in the growing crop. This is currently the primary methodology to inspect and certify seed crops in the UK. There are also industry concerns relating to tank mixing oils with fungicides applied for blight control particularly crop safety and antagonism leading to impaired foliar blight control.

This project sought to investigate the use of oils to reduce the occurrence of potyvirus in progeny tubers and the potential barriers to integrating oils into the crop protection programs and certification practices applied to GB seed crops. The objectives of the project were to establish the following:

1. Determine the effectiveness of treatment programmes utilising mineral oils, vegetable oil and aphicide products in minimising the incidence of potyvirus in daughter tubers.
2. Determine the effect of tank mixes of oils and common blight sprays including the identification of any phytotoxic effects in addition to assessment of the effects on levels of foliar & tuber blight.
3. Quantify the impacts of the treatment programmes on crop yield.
4. Evaluate the impact of the treatments on crop inspection and certification, establishing the acceptability of oil treated crops for phenotype and visual recognition of mild mosaic symptoms.
5. Progress towards the development of a sustainable integrated programme for the reduction of potyvirus, as well as control of potato leafroll virus. This must be within the context of a tank mix with foliar blight control products.
6. Evaluate the virus incidence in progeny tubers of different cultivars with and without the use of oils.

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3. MATERIALS AND METHODS

3.1. Field trials evaluating virus transmission 2011-13

Four separate field trials were conducted in each season 2011-13 evaluating potyvirus transmission. These specifically assessed a range of integrated programmes for potyvirus and persistent virus control as well as the epidemiology of specific potyviruses with the application of mineral or vegetable oil products.

Varieties were selected based on an analysis conducted at SASA using data collected from the Scottish Seed Certification Scheme. This demonstrated that individual varieties differ in their propensity to exhibit virus symptoms (i.e. mild or severe mosaic (http://www.sasa.gov.uk/seed-ware-potatoes/virology/varietal-propensity-virus-infection). Varietal propensity is different to varietal susceptibility as it does not register latent symptomless infection. For example, a variety such as Estima is in practice as susceptible to PVY^N as Desiree where infection is measured by ELISA, but its propensity value to PVY^N is 6-fold less. In addition, Estima is 3 times more sensitive to PVA than Desiree, but their propensity values are 5.9 and 5.1, respectively (see Potato Council report R428: Aphids and virus transmission in seed crops). This explains in part the historic experience of rapid degeneration of Estima crops in the face of latent infection. Using this information the varieties Maris Piper, King Edward, Desiree and Estima were selected for the virus transmission trials.

Integration of Mineral or Vegetable Oils Compared with Conventional Virus Control Products

Field trials were conducted by Scottish Agronomy Ltd at Pittenweem, Fife and by NIAB at Headley Hall, Yorkshire and Cambridge to evaluate the effectiveness of mineral oils or vegetable oils compared to and in conjunction with conventional chemistry. The sites were planted using methods in accordance with standard farm practice for the areas. The plots to which the treatments were later applied were established using the variety Estima and were 3.6 m (4 rows) wide and 6m long.

At the Fife site, a PB (Pre-Basic) seed stock that had been tested post-harvest and found to be virus free was selected in each season. At the Yorkshire and Cambridge sites common SE2 Estima seed stocks were used. At the Fife site infector beds were planted between each replicate to introduce known virus infection on to the site. This included infection with PVA, PVY^N and PVV. At the Cambridge site the infector rows introduced a consistent inoculum of PVA, PVY^N . No PLRV or $PVY^{O/C}$ infectors were included in the infector rows of the Cambridge trial, however, infected plants were present in the same field providing a background source. The consistency of infection pressure across the replicated trial blocks could not be quantified when relying on point source inoculum. At Yorkshire no infector rows were included at the discretion of the trial site manager. A representation of the trial layouts adopted at Fife and Cambridge is given in figure 3.1.1.

The growing infector rows were tested for virus loading by leaf sampling from 100 sequential plants along the row per variety and testing using ELISA. The results are shown in table 3.1.1 expressed as virus incidence in the infector rows and the incidence across all plants on the site at planting including the uninfected test plots.

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Table 3.1.1: Virus loading in the infector rows and whole sites

	PVA	PVY^N	PVV	All Virus
2011 Fife				
Harmony Infector Rows	0	45.6%	0	-
Estima Infector Rows	17.5%	0	14%	-
Whole Site	-	-	-	*16.52%*
2011 Cambridge				
Estima Infector Rows	15%	15%	0	-
Whole Site	-	-	-	*3%*
2012 Fife				
Harmony Infector Rows	0	84%	0	-
Estima Infector Rows	29%	0	17%	-
Whole Site	-	-	-	*21%*
2012 Cambridge				
Estima Infector Rows	15%	15%	0	-
Whole Site	-	-	-	*3%*
2013 Fife				
Harmony Infector Rows	9%	88%	1%	-
Estima Infector Rows	48%	44%	23%	-
Whole Site	-	-	-	*29.8%*
2013 Cambridge				
Estima Infector Rows	15%	15%	0%	
Whole Site	-	-	-	3%

For comparison with the statutory levels in Certified seed, the potyvirus permitted at growing crop inspection within seed crops in Scotland is 0.05% for Super Elite. The transmission rate within the field and trials varies with infector pressure as well as total virus loading from the field and surrounding environmental sources. Previous literature reviews have indicated that reductions of potyvirus in the daughter tubers of between 30 – 60% have been observed where oils are used as a control strategy. High infectivity rates are therefore required in any attempt to produce treatment differences. Elevating the virus source on the Fife and Cambridge sites was intended to counteract potential seasonal effects reducing the vector numbers or limited environmental virus sources so that treatment effects would be expressed in a quantifiable manner.

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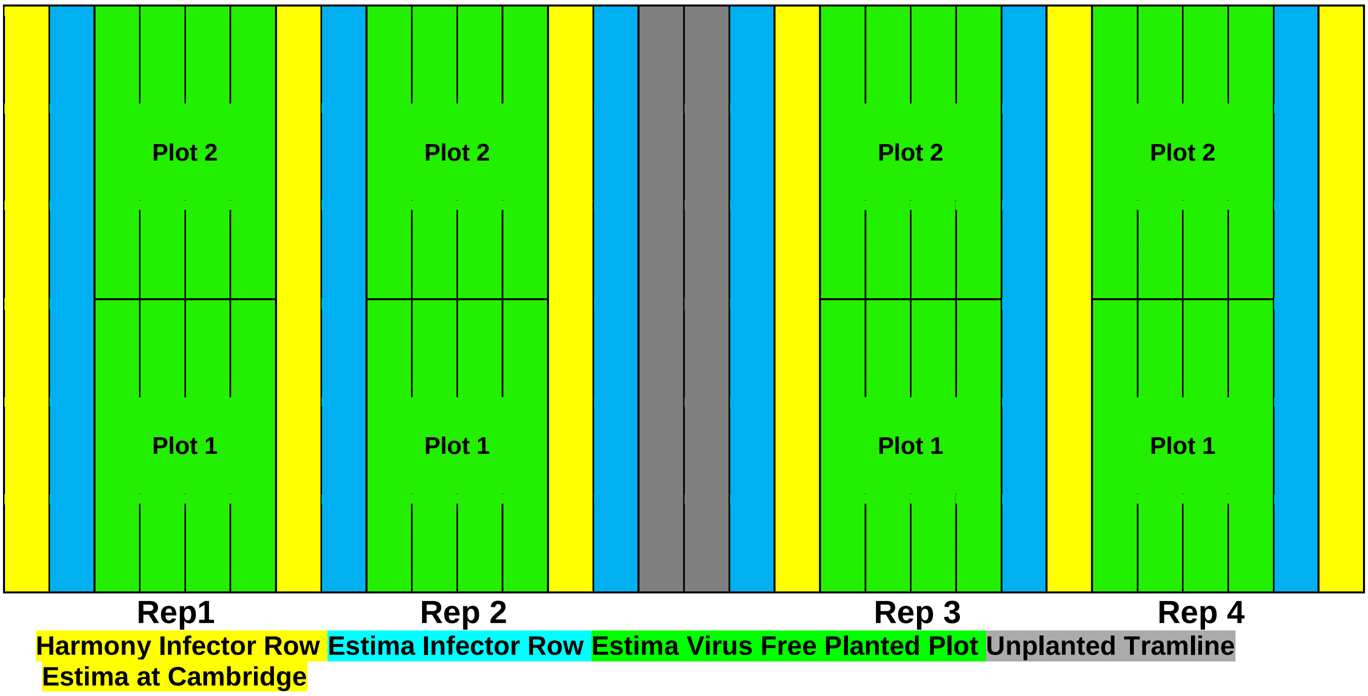

No infector rows were included on the Yorkshire site.

Figure 3.1.1. Representation of the trial layout of two plots by two replicates.

The trial layout was extended in the field to provide 8 or 10 plots by 4 replicates. Treatments were randomised to provide a complete block design.

Treatment lists are provided in tables 3.1.2 – 3.1.4 and include untreated controls, reference products as multiple applications of single products and integrated programmes with sequences including more than one product. The integrated programmes were devised to evaluate the integration of potyvirus control with measures targeting colonising aphids and persistent virus transmission (Potato Leaf Roll Virus). Information about adjuvants, including a database of adjuvants for use in the UK, is available at the Chemical Regulations Directorate website: http://www.pesticides.gov.uk/guidance/industries/pesticides/topics/pesticide-approvals/legislation/adjuvants-an-introduction

In each of the three years, treatments 1 to 8 were common to the Fife, Yorkshire and Cambridge sites. Treatments 1 - 6 were standard in all three years of testing. The programme approach was modified after 2012 to reflect best practice for the control of potato colonising aphids. The active ingredient in each of the test products is given in Table 3.1.5.

In 2011 (the first year of this project), the Fife site had two further treatments evaluating the adjuvant Newman Cropspray 11E (99% highly refined paraffinic oil). This was included as a bridging treatment to work previously conducted by Scottish Agronomy Ltd. Newman Cropspray 11E may be applied to potatoes as an adjuvant in conjunction with any approved pesticide (applied at up to the full approved rate) up to the tuber initiation growth stage. Headland Fortune (75.0 % w/w rapeseed fatty acid esters) may also be applied to potatoes as an adjuvant in conjunction with any approved pesticide (applied at up to the full approved rate) up to the tuber initiation growth stage. An exception to this growth stage restriction is if the approved pesticide is being applied to the crop at half or less than half of the approved pesticide rate stated on the label (or if the application is to a non-edible crop). The mineral oil product Olie-H is currently not approved in the UK but the manufacturer, Certis, is actively pursuing registration. In 2012-13, treatments 9 & 10 evaluating Olie-H at a

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higher rate of 6.2% of the spray volume compared to 3.1% were only included at the Fife site.

At the Fife site, all test applications were made using Pulvexper compressed CO_2 powered hydraulic nozzle sprayers applying 200 l/ha of solution using Teejet 110 degree 02 VP flat fan nozzles. The spray pressure was adjusted to provide an output of 0.48 l/min and a medium spray quality (BCPC classification). The nozzle height was set at 50cm above the crop canopy using the fixed mounting points on the sprayer. The plots were sprayed at 1m/s in the direction of the rows. At the Yorkshire and Cambridge site, AZO compressed air sprayers were used. The nozzles were 110 Flat Fan and the spray harness was adjusted for each operator to give a standard 40cm above the canopy. Sprays were applied in the direction of the rows at all of the sites. Each site received a comprehensive blight programme (grower's programme at Fife & Yorkshire) applied separately to the mineral oil treatment programmes. The use of Ranman Top was avoided within the blight programme at all sites as previous work conducted by Scottish Agronomy Ltd has indicated that virus transmission is reduced when this blight control product is used. Spray timings for each site are shown in Table 3.1.6.

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Table 3.1.2: Treatments and timing (T) 2011. Fife, Yorkshire and Cambridge. Dose Rates are given per hectare or as % of the total spray solution.

T	Tr 1 Control	Tr 2 Fortune	Tr 3 Olie-H 3.1%	Tr 4 Hallmark	Tr 5 Hallmark Fortune	Tr 6 Hallmark Olie-H	Tr 7 Programme 1	Tr 8 Programme 1 Olie-H 3.1%	Tr 9† Crop Spray 11E 2%	Tr 10† Hallmark Crop Spray 11E
0	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	UT	UT	Crop Spray 11E 2% (CS 11E)	CS 11E 2% Hallmark Zeon 75ml
1	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Olie-H 3.1%	Crop Spray 11E 2%	CS 11E 2% Hallmark Zeon 75ml
2	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Olie-H 3.1%	Crop Spray 11E 2%	CS 11E 2% Hallmark Zeon 75ml
3	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Olie-H 3.1%	Crop Spray 11E 2%	CS 11E 2% Hallmark Zeon 75ml
4	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml Biscaya 0.4	Hallmark Zeon 75ml Biscaya 0.4	Crop Spray 11E 2%	CS 11E 2% Hallmark Zeon 75ml
5	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2 l	Sumi Alpha 0.2 l	Crop Spray 11E 2%	CS 11E 2% Hallmark Zeon 75ml
6	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l Biscaya 0.4l	Sumi Alpha 0.2l Biscaya 0.4l	Crop Spray 11E 2%	CS 11E 2% Hallmark Zeon 75ml
7	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l	Sumi Alpha 0.2l	Crop Spray 11E 2%	CS 11E 2% Hallmark Zeon 75ml
8	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l Plenum 0.22kg	Sumi Alpha 0.2l Plenum 0.22kg	Crop Spray 11E 2%	CS 11E 2% Hallmark Zeon 75ml

†Fife Only

Table 3.1.3:Treatments and timing (T) 2012. Fife, Yorkshire and Cambridge. Dose Rates are given per hectare or as % of the total spray solution.

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T	Tr 1 Control	Tr 2 Fortune	Tr 3 Olie-H 3.1%	Tr 4 Hallmark	Tr 5 Hallmark Fortune	Tr 6 Hallmark Olie-H	Tr 7 Programme 2	Tr 8 Programme 2 Olie-H 3.1%	Tr 9† Programme 2 Olie-H 6.2%	Tr 10† Olie-H 6.2%
0	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	UT	Olie-H 3.1%	Olie-H 6.2%	Olie-H 6.2%
1	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l Biscaya 0.4l	Sumi Alpha 0.2l Biscaya 0.4l	Sumi Alpha 0.2l Biscaya 0.4l	Olie-H 6.2%
2	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l	Olie-H 3.1%	Olie-H 6.2%	Olie-H 6.2%
3	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l Biscaya 0.4l	Sumi Alpha 0.2l Biscaya 0.4l	Sumi Alpha 0.2l Biscaya 0.4l	Olie-H 6.2%
4	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l	Olie-H 3.1%	Olie-H 6.2%	Olie-H 6.2%
5	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml Tepekki 160g	Hallmark Zeon 75ml Tepekki 160g	Hallmark Zeon 75ml Tepekki 160g	Olie-H 6.2%
6	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml	Hallmark Zeon 75ml	Olie-H 6.2%
7	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml Tepekki 160g	Hallmark Zeon 75ml Tepekki 160g	Hallmark Zeon 75ml Tepekki 160g	Olie-H 6.2%
8	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml	Hallmark Zeon 75ml	Olie-H 6.2%

†Fife Only

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Table 3.1.4: Treatments and timing (T) 2013. Fife, Yorkshire and Cambridge. Dose Rates are given per hectare or as % of the total spray solution.

T	Tr 1 Control	Tr 2 Fortune	Tr 3 Olie-H 3.1%	Tr 4 Hallmark	Tr 5 Hallmark Fortune	Tr 6 Hallmark Olie-H	Tr 7 Programme 2	Tr 8 Programme 2 Olie-H 3.1%	Tr 9 Crop Spray 11E 2.5%	Tr 10[†] Programme 2 Olie-H 6.2%	Tr 11[†] Olie-H 6.2%
0	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	UT	Olie-H 3.1%	Crop Spray 11E 2.5%	Olie-H 6.2%	Olie-H 6.2%
1	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l Biscaya 0.4l	Sumi Alpha 0.2l Biscaya 0.4l	Crop Spray 11E 2.5%	Sumi Alpha 0.2l Biscaya 0.4l	Olie-H 6.2%
2	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l	Olie-H 3.1%	Crop Spray 11E 2.5%	Olie-H 6.2%	Olie-H 6.2%
3	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l Biscaya 0.4l	Sumi Alpha 0.2l Biscaya 0.4l	Crop Spray 11E 2.5%	Sumi Alpha 0.2l Biscaya 0.4l	Olie-H 6.2%
4	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Sumi Alpha 0.2l	Olie-H 3.1%	Crop Spray 11E 2.5%	Olie-H 6.2%	Olie-H 6.2%
5	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml Tepekki 160g	Hallmark Zeon 75ml Tepekki 160g	Crop Spray 11E 2.5%	Hallmark Zeon 75ml Tepekki 160g	Olie-H 6.2%
6	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml	Crop Spray 11E 2.5%	Hallmark Zeon 75ml	Olie-H 6.2%
7	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml Tepekki 160g	Hallmark Zeon 75ml Tepekki 160g	Crop Spray 11E 2.5%	Hallmark Zeon 75ml Tepekki 160g	Olie-H 6.2%
8	UT	Fortune 0.5%	Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml Fortune 0.5%	Hallmark Zeon 75ml Olie-H 3.1%	Hallmark Zeon 75ml	Hallmark Zeon 75ml	Crop Spray 11E 2.5%	Hallmark Zeon 75ml	Olie-H 6.2%

[†] **Fife Only**

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Table 3.1.5: Ingredients of Trade Names

Trade Name	Active Ingredient	Concentration
Biscaya	Thiacloprid	240 g/l
Crop Spray 11E	Refined Paraffinic Oil	99%
Fortune	Oilseed Derived Fatty Acid Esters + n-butyl	75%
Hallmark Zeon	Lambda-cyhalothrin	100 g/l
Olie-H	Mineral Oil (petroleum oil)	96%
Plenum	Pymetrozine	50% w/w
Tepekki	Flonicamid	50% w/w

Table 3.1.6: Field work schedule 2011-13

	Fife		Yorkshire		Cambridge	
Task	**Date**	**Interval (Days)**	**Date**	**Interval (Days)**	**Date**	**Interval (Days)**
Planting	02/05/11	-	23/04/11	-	18/04/11	-
T0 (75% emergence)	10/06/11	39	01/06/11	38	24/05/11	35
T1	17/06/11	7	07/06/11	6	01/06/11	8
T2	23/06/11	6	14/06/11	7	08/06/11	7
T3	30/06/11	7	21/06/11	7	15/06/11	7
T4	07/07/11	7	29/06/11	8	22/06/11	7
T5	14/07/11	7	06/07/11	7	29/06/11	7
T6	21/07/11	7	13/07/11	7	06/07/11	7
T7	27/07/11	6	21/07/11	8	14/07/11	8
T8	03/08/11	7	28/07/11	7	20/07/11	6
Initial Desiccation	03/08/11	0	03/08/11	5	28/07/11	8
Harvest	30/09/11	58	08/09/11	37	15/08/11	18
Planting	09/05/12	-	24/05/12	-	11/04/12	-
T0 (75% emergence)	20/06/12	42	03/07/12	40	24/05/12	43
T1	26/06/12	6	09/07/12	6	31/05/12	7
T2	03/07/12	7	18/07/12	9	06/06/12	6
T3	12/07/12	9	25/07/12	7	13/06/12	7
T4	19/07/12	7	31/07/12	6	20/06/12	7
T5	25/07/12	6	07/08/12	7	29/06/12	9
T6	31/07/12	6	15/08/12	8	05/07/12	6
T7	08/08/12	8	21/08/12	6	12/07/12	6
T8	16/08/12	8	28/08/12	7	19/07/12	7
Initial Desiccation	16/08/12	0	13/08/12	15	31/07/12	12
Harvest	08/10/12	53	16/10/12	64	23/08/12	23
Planting	31/05/13	-	05/05/13	-	17/04/13	-
T0 (75% emergence)	25/06/13	25	11/06/13	38	26/05/13	39
T1	03/07/13	8	19/06/13	8	31/05/13	6
T2	09/07/13	6	26/06/13	7	07/06/13	7
T3	16/07/13	7	03/07.13	7	17/06/13	10
T4	22/07/13	6	10/07/13	7	27/06/13	10
T5	30/07/13	8	17/07/13	7	05/07/13	8
T6	06/08/13	7	24/07/13	7	12/07/13	7
T7	13/08/13	7	31/07/13	7	18/07/13	6
T8	20/08/13	7	07/08/13	7	27/07/13	9
Initial Desiccation	20/08/13	0	16/08/13	9	07/08/13	11
Harvest	25/09/13	36	12/09/13	27	03/09/13	27

Four yellow water traps (YWT) were situated on each site. At Yorkshire and Cambridge, these were located at the corners of the trials. At the Fife site, the four traps were positioned in a square within the infector rows between replicates 1 & 2 and 3 & 4, 18m from either end of the trial. The weekly

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catches were sent to FERA, York for aphid species identification and numeration from 75% potato crop emergence until one week after haulm desiccation.

At the Fife site, measurements were made of canopy height at the canopy stable phase of growth. Any phytotoxicity observed was recorded at all three sites.

Desiccation was carried out using diquat (200g/l) applied at 1.5 l/ha followed by 2.5l/ha at 7 day intervals. The desiccant was applied using the same methodology as the insecticide treatments. At the Fife site, the first application of diquat for haulm destruction was applied on the same day as the final application of the aphicide treatment programmes. At the Yorkshire and Cambridge sites desiccation commenced after the final aphicide treatment. This would have resulted in a period of unprotected crop growth at the end of season on the Yorkshire and Cambridge sites. Commercial best practice on seed crops is to include an aphicide application with the first desiccant and as long as green material is present.

All three sites were harvested by hand digging a 3 m length of row from one of the middle two rows of each plot. At the Fife site, plant and stem counts were conducted along the 3m length of the yield dig. Potato tubers were graded into 5mm splits and all size categories were weighed and counted.

At each site a further 3m was harvested from the remaining middle row to give a minimum of 152 tubers for ELISA testing (in practice 200 tubers were harvested). In addition, a 30 tuber sample, one tuber from each of 30 plants per plot, was taken at Cambridge in 2013 and held in reserve pending statistical analysis of bulk sample results. This more detailed analysis provides greater resolution but was in excess of the available budget if applied to all sites.

The tubers from the Fife site were harvested by Scottish Agronomy Ltd and despatched to SASA, Edinburgh for virus testing as follows. Tubers were held in a cold store at *c.* 5°C prior to testing. Each individual tuber was eye-plugged, treated with gibberellic acid (0.01g/l for 10 minutes) and grown in an insect-free glasshouse (22°C-18°C day-night, 16h photoperiod) for a period of 4 weeks. One leaf from each of the 4 plantlets from each bulk were pooled and tested by DAS-ELISA for the following aphid transmitted viruses (PVY^N, $PVY^{O/C}$, PVA, PVV, PLRV) using monoclonal antibodies as previously described (Pickup *et al*, 2010).

Virus testing of the tubers from Yorkshire and Cambridge was conducted by NIAB using the following methodology. Eye cores were placed in a solution of giberellic acid (0.01g/l for 10 minutes) and then planted in compost trays in a glasshouse with mercury lighting and a comprehensive biological control regime to maintain an aphid free environment. Two leaves per plantlet were harvested after four weeks and bulked together for extraction in groups of four plantlets, i.e. representing 4 tubers. A standard DAS ELISA test was carried out using Neogen reagents for PVA and PVY^N. Additional ELISA tests were carried out for both viruses in tubers from the Cambridge and Yorkshire sites.

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Evaluation of the Effect of Oil Treatments on Virus Epidemiology

A trial was conducted at Gogarbank, Edinburgh by SASA to evaluate the epidemiology of PVY^N and PVA when four varieties susceptible to these viruses were treated with one of two different oil products. The trial consisted of a total of 48 individual plots of which 32 plots were treated either with Olie-H or Fortune and 16 control plots. The composition of the test products is given in Table 3.1.5. Two adjacent trials were planted with varieties susceptible to either PVY^N (Maris Piper and King Edward) or PVA (Estima and Desiree) and were used to assess virus transmission in untreated and treated (Olie-H, Fortune) crops. Each plot consisted of 4 x 6m long drills (24 plants) bordered on each side by infectors. There were 8 to 9 infectors per plot per row on each side of the plot, giving a uniform total virus inoculum pressure of 13% per trial. This was calculated by dividing the total numbers of infectors of a given virus by the total numbers of infectors and bait plants per trial (see Figure 3.1.2). Tubers from known PVY^N and PVA infected plants were used as a source of tuber-borne inoculum. The PVY^N and PVA trials were laid out as randomised complete block designs.

A summary of the timing of application of treatment applications and actions taken is presented in Table 3.1.7. Treatments for each of the three years were: (*i*) Fortune 0.5% (i.e. 1.0 litre of Fortune per ha in 200 litres water) and (*ii*) Olie-H at 3.1% (i.e. 6.25 l/ha in 200 l/ha of water). Applications were made using a plot sprayer fitted with Lurmark 80-03 flat fan nozzles providing medium spray quality at 2.5 bar pressure. The nozzles were mounted in a hand supported boom 45cm above the target and a forward speed of 0.83m/s was used. For each treatment, 8 applications were made starting one week after 75% emergence. For each of the PVY^N and PVA trials, weekly aphid catches were monitored using four aphid YWT.

Assessment of virus transmission was undertaken by post-harvest testing of tubers. Four tubers from each of the individual 40 plants per plot were harvested (Figure 3.1.3) and kept as individual bulks for each plant to determine the infection rate per plant for each treatment replicate, allowing a greater resolution of the virus infection levels between plots. The virus testing was conducted at SASA using the methodology described in 3.1.1.

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Table 3.1.7: Summary of treatments - SASA Mineral Oil and virus transmission trial 2012 (Milestone 30).

Task	**Date**	**Interval (Days)**
Planting	09.05.2012	-
75% emergence	06.06.2012	28
T1	14.06.2012	8
T2	19.06.2012	5
T3	26.06.2012	7
T4	03.07.2012	7
T5	10.07.2012	7
T6	17.07.2012	7
T7	23.07.2012	6
T8	30.07.2012	7
Initial Desiccation	16.08.2012	17
Harvest	28.08.2012	12
Planting	01.05.2013	-
75% emergence	04.06.2013	34
T1	11.06.2013	7
T2	18.06.2013	7
T3	25.06.2013	7
T4	01.07.2013	6
T5	09.07.2013	8
T6	16.07.2013	7
T7	23.07.2013	7
T8	30.07.2013	7
Initial Desiccation	13.08.2013	14
Harvest	09.09.2013	27

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Figure 3.1.2: Layout of SASA trial. Infectors row are highlighted in grey. Left panel: PVY^N trials on bait plants Maris Piper and King Edward. Right panel: PVA trial on bait plants Desiree and Estima. Aphids Yellow Water Traps are represented as yellow circles.

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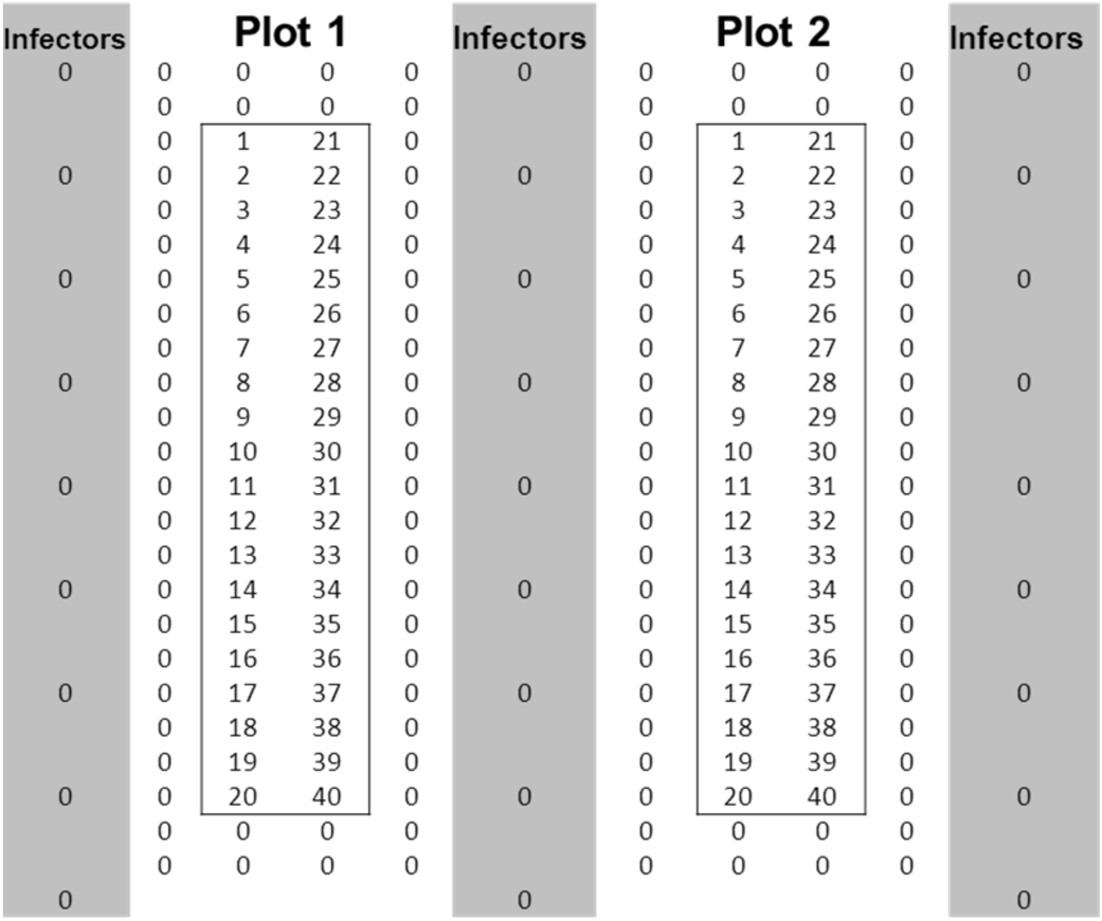

Figure 3.1.3: Details of experimental plots at Edinburgh site. Each plant is represented by the symbol “0”. The harvested tubers are from each individual plant (4 tubers per plant) numbered 1 to 40 within the two central rows.

3.2. Field Trials Evaluating Phytotoxicity and the Effects of Oil treatments on Visual Seed Crop Inspection

In 2011-13 field trials were established to evaluate the impact of oil treatments on the visual inspection of seed crops. These included visual assessments of virus disease symptoms and trueness-to-variety-type assessment as conducted during Certification inspections.

The trials were managed by SASA, Edinburgh and NIAB, Cambridge. SASA is the certifying authority for seed potatoes in Scotland and provides training to Scottish Government (SGRPID) inspectors. The trials were supervised by Maureen McCreath, Growing Crop Certification Manager. NIAB provides training to PHSI. At both sites the plots were available for field inspectors and PHSI officials to observe.

In year 1 of the project (2011), three variety / virus combination plots were established at Edinburgh. Plots of Estima infected with PVA, Maris Piper infected with PVY^N and Saturna infected with PVX were planted on 12th April 2011. Each plot comprised 4 drills, with each drill containing 18 healthy seed sized tubers and 2 virus infected seed sized tubers, randomly placed per

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drill. Half of each plot (2 drills) was sprayed with the mineral oil 6.25 l/ha Olie-H in 200 l/ha of water with the other half acting as an untreated control. Applications of Olie H were made on a weekly basis between 1st June and 20th July, giving eight applications in total. All plots received a standard blight and aphicide programme applied as a separate spray on a different day to the oil application.

The plots were assessed on at least a weekly basis to determine any effect of the mineral oil application on crop inspectability for virus symptoms and trueness-to-variety-type.

A PHSI inspector made observations on the trial designed to investigate virus transmission at Cambridge. The plots were inspected on 16/06/11. In addition Olie H was sprayed across PHSI inspectors training plots on five consecutive occasions; 22/06, 29/06, 06/07, 14/07, 20/07/11. Observations were made on these plots by NIAB staff during this period independently of the PHSI inspectors.

In 2012-13 at the Edinburgh site, ten variety / virus combinations were chosen and are shown in table 3.2.1. The varieties chosen for the trial are all popular varieties grown for seed, with seven of the varieties common to the inspection trial at Cambridge. The viruses chosen for the trial were based on varietal propensity to virus and to explore a range of different viruses.

Table 3.2.1: 2012-13 variety and virus combinations in demonstration plots, Edinburgh.

Variety	Viruses present
Cabaret	PVA
Desiree	PVA
Estima	PVA + PVV
Charlotte	PVY^N
Harmony	PVY^N
Maris Peer	PVY^N
Maris Piper	PVY^N
Saxon	PVY^o
Valor	PVY^o
Wilja	PVY^o

There were 30 trial plots, comprising 3 identical plots of each of the 10 variety / virus combinations, to enable assessment of 3 oil treatments.

Each plot comprised 4 drills, with each drill containing 18 healthy tubers and 2 virus infected tubers randomly placed per drill. Half of each plot (2 drills) received an oil treatment while the other half remained untreated (Figs. 3.2.1 & 3.2.2).

In 2012 applications of the different oil treatments were made between 12th June and 31st July; six applications in total. In 2013 they were made between 11th June and 30th July; eight applications in total. All plots received a standard blight and aphicide programme applied as a separate spray on a different day to the oil application.

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Figure 3.2.1. Edinburgh 2012. One replicate 4 drill plot in foreground.

Figure 3.2.2. Edinburgh 2012. One replicate plot of cv. Maris Peer (flowering). The other two replicate plots are to the left and right of this plot. The 2 drills on the left hand side of each plot were sprayed with oil.

At Cambridge a range of virus infected seed stocks from different varieties were selected from material submitted for commercial testing in 2012 & 2013 (Tables 3.2.2 & 3.2.3). Two rows each of 50 tubers were established for each seed stock by virus combination. Rows were marked into four 2.5m sections.

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One section was left untreated, while the other three were sprayed at weekly intervals from 75% crop emergence. Sprays were applied across the drills with an AZO compressed air sprayer on the same dates as the virus transmission plots. The blight control programme was applied separately, avoiding the use of Ranman Top. A short untreated length of drill was left in each of the sprayed bands to allow easy direct comparison of treated and untreated material. The level of virus infection in each combination was such that at least two infected plants might be expected to occur in each of the four marked sections.

Table 3.2.2: 2012 Variety and virus combinations in demonstration plots. Cambridge

Variety	Viruses present
M Piper	PVY^N
M Peer	PVY^N
Unknown	PVY^N
Marfona	PVY^N
M Piper	PVY^N
Saxon	PVY^N
Bambino	No virus
M Piper	PVY^N
Estima	PVA
Harmony	PVY^N
Charlotte	PVY^N
Unknown	PVY^N
M Peer	PVY^N
Sapphire	PVY^N
M Peer	PVY^N
Desiree	PVY^N and PVA

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Table 3.2.3: 2013 Variety and virus combinations in demonstration plots. Cambridge

Variety	Viruses present
Charlotte	PVY^N
Maris Peer	PVY^N
Maris Peer	PVY^N
Harmony	PVY^N
Charlotte	PVY^N
Cultra	PVY^N
Estima	PVA
Gasthorpe	PVY^N
Corolle	PVY^N
Unknown	PVA
Desiree	PVY^N
King Edward	PVY^N
Marfona	PVY^N

Table 3.2.4: Oil treatments applied to the crop inspection trials 2012-13 Edinburgh & Cambridge. All treatments were applied in 200 l/ha of water.

Tr No.	Product	Dose % of Spray Volume	Dose litres per ha
1	Untreated	-	-
2	Olie-H	3.1%	6.25
3	Olie-H	6.25%	12.5
4	Fortune	0.5%	1

The oil treatments and dose rates shown in Table 3.2.4 were selected to reflect those being evaluated in the virus control and epidemiology work. They are therefore in the range that crop inspectors are expected to encounter in commercial seed crops if the products under investigation are used.

3.3. Trials Investigating the Effect of Tank Mixing Oils with commonly used Fungicides for Foliar Blight Control

Field trials were established at SRUC, Auchincruive Estate, Ayr to compare the blight control achieved by commonly used blight control products with and without the addition of Olie H @ 6.25 l/ha in a tank mix in 200 litres of water per hectare. One trial was to examine the effects at the rapid canopy expansion phase and another was targeted at canopy stable. The distinction is necessary due to the differing nature of the target plant at these stages. Applications made at rapid canopy need to protect new leaf growth between subsequent applications. At stable canopy the fungicide product is required to protect existing leaf area. Also, applications of oil tank mixed with blight fungicides are generally only approved up to tuber initiation. A positive, neutral or undesirable effect on the foliar blight or tuber blight activity

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associated with the introduction of mineral oil to the tank mix could occur. Products that are commonly used during these phases of growth were included in the trial with and without the addition of Olie-H to the tank mix.

Efficacy of oil and fungicide tank mixes 2011

Both trials were planted with the cv. King Edward, chosen for its susceptibility to potato blight; foliar blight resistance rating 3 and tuber blight resistance rating 4. The rapid canopy trial was planted on the 6th of June and the canopy stable trial on the 27th of May 2011. The rapid canopy trial was inoculated with blight isolate 7654A, genotype 13_A2, on the 8th and 13th July. The canopy stable trial was inoculated with the same isolate and an additional 13_A2 isolate, 6082F, on the 8th of August. Small areas at both ends of all plots that were not treated with fungicide were inoculated to provide even disease pressure within each trial. Treatment details and application dates for the rapid canopy trial are given in Tables 3.3.1, 3.3.2 and 3.3.3. In this trial the test fungicides applied during rapid haulm growth were sandwiched between one blanket spray of Shirlan at the rosette stage of growth and further Shirlan applications during stable canopy. All test treatments were applied in 200 l/ha of water at 3.5 bar using Lurmark F03-110 nozzles to provides a Medium – Fine spray quality.

Table 3.3.1 Details of test products for rapid canopy development trial (2011)

Fungicide / adjuvant	**Active ingredient(s)**		**Rate (kg or L/ha)**	
	Common name	**composition**	**Active ingredient**	**Product**
Shirlan	fluazinam	500 g/L	0.15	0.3
Ranman TP	cyazofamid	400 g/L	0.08	0.2 + 0.15
Revus	mandipropamid	250 g/L	0.150	0.6
Resplend	ametoctradin + dimethomorph	300:225 g/L	0.240 + 0.180	0.8
Olie-H	Paraffinic mineral oil	96.0%	-	6.25

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Table 3.3.2 Treatment regimes – rapid canopy trial (2011). *Maintenance applications which were applied to all plots are shown in italics.*

Tr Number	Product	Dose Rate (kg or L/ha)	Planned Interval (Days)	Application Number
1	*Shirlan*	0.3	7	1
	Ranman TP	0.2 + 0.15	7	2,3,4,5
	Shirlan	0.3	7-10	6-9
2	*Shirlan*	0.3	7	1
	Ranman TP + Olie-H	0.2 + 0.15 + 6.25	7	2,3,4,5
	Shirlan	0.3	7-10	6-9
3	*Shirlan*	0.3	7	1
	Revus	0.6	7	2,3,4,5
	Shirlan	0.3	7-10	6-9
4	*Shirlan*	0.3	7	1
	Revus + Olie-H	0.6 + 6.25	7	2,3,4,5
	Shirlan	0.3	7-10	6-9
5	*Shirlan*	0.3	7	1
	Resplend	0.8	7	2,3,4,5
	Shirlan	0.3	7-10	6-9
6	*Shirlan*	0.3	7	1
	Resplend + Olie-H	0.8 + 6.25	7	2,3,4,5
	Shirlan	0.3	7-10	6-9

Table 3.3.3 Fungicide application dates and intervals – rapid canopy trial (2011)

Application Number	1	2	3	4	5	6	7	8	9
Date	11 Jul	19 Jul	27 Jul	4 Aug	13 Aug	22 Aug	1 Sep	14 Sep	22 Sep
Actual Interval (days)	-	8	8	8	9	9	10	13	8

Stable Canopy (2011)

In this trial the blanket fungicide programme used during rapid haulm growth was Shirlan x 1 then Consento x 3. There were six applications of the test fungicides, the first at the end of rapid haulm growth and the sixth close to desiccation of the trial. Details of the test products are given in Table 3.3.4. The programmes evaluated and the dates of application are given in Tables 3.3.5 & 3.3.6.

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Table 3.3.4 Composition of test fungicides for canopy stable trial (2011)

Fungicide / adjuvant	Active ingredient(s)		Rate	
	Common name	**composition**	**Active ingredient (g/ha)**	**Product (kg or L/ha)**
Shirlan	fluazinam	500 g/L	0.15	0.3
Consento	propamocarb-HCl + fenamidone	375 g/L + 75 g/L	750 + 150	2.0
Infinito	propamocarb-HCl+ fluopicolide	625 + 62.5 g/L	1000 + 100	1.6
Olie-H	paraffinic mineral oil	96.0%	-	6.25
Invader	mancozeb + dimethomorph	66.7% + 7.5%	1601 + 180	2.4
Valbon	benthiavalicarb-isopropyl + mancozeb	1.75 +70.0%	28 + 1120	1.6
Zin Zan	1,2 bis ethansulphonate	70.0%	-	0.15

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Table 3.3.5 Treatment summary – canopy stable (2011). *Maintenance applications which were applied to all plots are shown in italics.*

Tr	Product	Rate (kg or l /ha)	Target Interval	Application number
1	*Shirlan* *Consento* Untreated	0.3 2.0 -	7 7-10 -	1 2-4 -
2	*Shirlan* *Consento* Shirlan	0.3 2.0 0.4	7 7-10 7-10	1 2-4 5-10
3	*Shirlan* *Consento* Shirlan + Olie H	0.3 2.0 0.4 + 6.25	7 7-10 7-10	1 2-4 5-10
4	*Shirlan* *Consento* Infinito	0.3 2.0 1.6	7 7-10 7-10	1 2-4 5-10
5	*Shirlan* *Consento* Infinito + Olie H	0.3 2.0 1.6 + 6.25	7 7-10 7-10	1 2-4 5-10
6	*Shirlan* *Consento* Invader	0.3 2.0 2.4	7 7-10 7-10	1 2-4 5-10
7	*Shirlan* *Consento* Invader + Olie H	0.3 2.0 2.4 + 6.25	7 7-10 7-10	1 2-4 5-10
8	*Shirlan* *Consento* Valbon + ZinZan	0.3 2.0 1.6 + 0.15	7 7-10 7-10	1 2-4 5-10
9	*Shirlan* *Consento* Valbon + ZinZan + Olie H	0.3 2.0 1.6 + 0.15 + 6.25	7 7-10 7-10	1 2-4 5-10

Table 3.3.6 Fungicide application dates and intervals - canopy stable (2011)

Application Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Date	07-Jul	14-Jul	21-Jul	30-Jul	9 Aug	17 Aug	24 Aug	2 Sep	14 Sep	22 Sep
Actual Interval (days)		7	7	9	10	8	7	9	12	8

For both trials, weekly assessments of foliar blight were made to document disease progression over time. The severity (percentage of foliage destroyed by blight) was recorded using the key in Table 3.3.7. In addition visual observations were made on phytotoxicity symptoms and moisture retention within the canopy.

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Table 3.3.7 Potato foliage blight key

%	Description
0	Not seen in plots
0.1	1 or 2 lesions per plot
0.2	3 or 4 lesions per plot
0.3	5 to 8 lesions per plot
0.4	9 to 16 lesions per plot
0.5	17 to 31 lesions per plot
0.6	32 to 63 lesions per plot
0.7	1 or 2 lesions per plant
0.8	3 or 4 lesions per plant
0.9	5 to 9 lesions per plant
1.0	10 lesions per plant
5.0	50 lesions per plant
25	Nearly every leaflet with lesions, plants still retaining normal form; plot may smell of blight but looks green though every plant affected.
50	Every plant affected and about one half of leaf area destroyed by blight; plot looks green flecked with brown
75	About three-quarters of leaf area destroyed by blight; plot looks neither predominantly green or brown
95	Only a few leaves green, but stems green.
100	All leaves dead, stems dead or dying

Yield and tuber blight were recorded for the treatments. Tuber blight was assessed pre- and post-storage. Total yield of one centre row, i.e. 7.5 x 0.85 m, was recorded. Tuber blight was assessed by external inspection of two random samples of 50 tubers from each plot. The samples were taken at harvest and the assessment carried out several weeks later, after the tubers had been thoroughly washed. Blighted tubers were discarded and the healthy tubers stored for a post-storage assessment in March 2012.

Efficacy of oil and fungicide tank mixes 2012

Two field trials investigating the effect of adding Olie-H to blight control fungicides were conducted at SRUC, Auchincruive Estate, Ayr in 2012. The first trial examined applications made at the rapid canopy development and the second those made during the stable canopy phase. The trial was a randomised complete block with four replicates. The plot size was 3.4m (4 rows) wide by 7.5m long. The stable canopy trial was planted on the 26th of May. The rapid canopy trial was intentionally planted later, on the 11th of June. For the rapid canopy phase trial, gaps between the plots were inoculated with a known isolate of *Phytophthora infestans* in order to generate even disease pressure on the site. These 'infector gaps' were sprayed with a single application of isolate 7654A (13_A2) on 19 July 2012. The canopy stable phase trial which was initiated later in the season did not require inoculation. The 2012 season provided conditions extremely conducive to the development of potato blight. The occurrence of Smith Periods was monitored on the site during the trial period.

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All test applications were made using a tractor-mounted, modified AZO compressed air sprayer applying 200 l/ha with 03 110 flat fan nozzles of medium-fine spray quality (BCPC classification).

Rapid Canopy Phase Trial (2012)

The test treatments were applied at three 7-day intervals starting on the 20th of July. The first applications of test fungicides were applied 7 days after the initial maintenance blight fungicide application which was applied when the crop was at the rosette stage of growth. On completion of the rapid canopy expansion phase maintenance treatments of Quell Flo were applied to all plots. The rosette blanket spray and stable canopy blanket sprays were changed from the Shirlan used in the 2011 trials in order to avoid any possibility of selection for genotype 33_A2. In 2012 it was established that there was a wide range of sensitivity to Fluazinam within the general *Phytophthora* population. The 33_A2 group was found to be at the lower end of the spectrum. Details of the test products are given in Table 3.3.8. The treatment combinations and dates in are shown in Tables 3.3.9 & 3.3.10.

Table 3.3.8 Details of test products for rapid canopy development trial (2012)

Fungicide / adjuvant	Active ingredient(s)		Rate (kg or L/ha)	
	Common name	composition	Active ingredient	Product
Curzate M WG	cymoxanil + mancozeb	4.5%: 68%	0.090 + 1.360	2.0
Ranman Top	cyazofamid	160 g/L	0.080	0.5
Revus	mandipropamid	250 g/L	0.150	0.6
Percos	ametoctradin + dimethomorph	300:225 g/L	0.240 + 0.180	0.8
Olie-H	Paraffinic mineral oil	96.0%	-	6.25
Quell Flo	mancozeb	455 g/L	1275	2.8

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Table 3.3.9 Treatment regimes – rapid canopy trial (2012). *Maintenance applications which were applied to all plots are shown in italics.*

Tr Number	Product	Dose Rate (kg or L/ha)	Planned Interval (Days)	Application Number
1	*Curzate M* Untreated *Quell Flo*	2.0 - 2.0	7 - 7-10	1 2,3,4 5-9
2	*Curzate M* Ranman Top *Quell Flo*	2.0 0.5 2.0	7 7 7-10	1 2,3,4 5-9
3	*Curzate M* Ranman Top + Olie-H *Quell Flo*	2.0 0.5 + 6.25 2.0	7 7 7-10	1 2,3,4 5-9
4	*Curzate M* Revus *Quell Flo*	2.0 0.6 2.0	7 7 7-10	1 2,3,4 5-9
5	*Curzate M* Revus + Olie-H *Quell Flo*	2.0 0.6 + 6.25 2.0	7 7 7-10	1 2,3,4 5-9
6	*Curzate M* Percos *Quell Flo*	2.0 0.8 2.0	7 7 7-10	1 2,3,4 5-9
7	*Curzate M* Percos + Olie-H *Quell Flo*	2.0 0.8 + 6.25 2.0	7 7 7-10	1 2,3,4 5-9

Table 3.3.10 Fungicide application dates and intervals – rapid canopy trial (2012).

Application Number	1	2	3	4	5	6	7	8	9
Date	13 July	20 July	27 July	03 Aug	10 Aug	17 Aug	24 Aug	03 Sep	11 Sep
Actual Interval (days)	-	7	7	7	7	7	7	10	8

Canopy Stable Phase Trial (2012)

The blanket fungicide programme applied during rapid canopy was more robust than that originally planned due to the early and severe blight pressure in 2012. One application of Curzate M (2.0 kg/ha), three applications of Revus + C50 (0.6 l/ha + 0.24 kg/ha) and one application of Consento (2.0 l/ha) were applied to each treatment plot before the first application of test fungicides. This approach was reasonably successful and the average severity of foliar blight in plots on 8 August (first application of test fungicide) was limited to 1.5%.

Details of the test products are given in Table 3.3.11. The programmes evaluated and the dates of application are given in Tables 3.3.12 & 3.3.13.

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Table 3.3.11 Composition of test fungicides for canopy stable trial (2012).

Fungicide / adjuvant	Active ingredient(s)		Rate	
	Common name	**composition**	**Active ingredient (g/ha)**	**Product (kg or L/ha)**
Curzate M WG	cymoxanil + mancozeb	4.5 + 68%	90 + 1360	2.0
Revus	mandipropamid	250 g/L	150	0.6
C50	cymoxanil	50%	120	0.24
Consento	propamocarb-HCl + fenamidone	375 g/L + 75 g/L	750 + 150	2.0
Infinito	propamocarb-HCl+ fluopicolide	625 + 62.5 g/L	1000 + 100	1.6
Olie-H	paraffinic mineral oil	96.0%	-	6.25
Invader	mancozeb + dimethomorph	66.7% + 7.5%	1601 + 180	2.4
Valbon	benthiavalicarb-isopropyl + mancozeb	1.75 +70.0%	28 + 1120	1.6
Zin Zan	1,2 bis ethansulphonate	70.0%	-	0.15

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Table 3.3.12 Treatment summary – canopy stable (2012). *Maintenance applications which were applied to all plots are shown in italics.*

Tr Number	Product	Dose Rate (l or kg/ha)	Planned Interval (Days)	Application Number
1	*Curzate M* *Revus + C50* *Consento* Untreated	2.0 0.6 +0.24 2.0 -	7 7 7-10 -	1 2,3,4 5 6-12
2	*Curzate M* *Revus + C50* *Consento* Curzate M	2.0 0.6 +0.24 2.0 2.0	7 7 7-10 7-10	1 2,3,4 5 6-12
3	*Curzate M* *Revus + C50* *Consento* Curzate M + Olie-H	2.0 0.6 +0.24 2.0 2.0 + 6.25	7 7 7-10 7-10	1 2,3,4 5 6-12
4	*Curzate M* *Revus + C50* *Consento* Infinito	2.0 0.6 +0.24 2.0 1.6	7 7 7-10 7-10	1 2,3,4 5 6-12
5	*Curzate M* *Revus + C50* *Consento* Infinito + Olie-H	2.0 0.6 +0.24 2.0 1.6 + 6.25	7 7 7-10 7-10	1 2,3,4 5 6-12
6	*Curzate M* *Revus + C50* *Consento* Invader	2.0 0.6 +0.24 2.0 2.4	7 7 7-10 7-10	1 2,3,4 5 6-12
7	*Curzate M* *Revus + C50* *Consento* Invader + Olie-H	2.0 0.6 +0.24 2.0 2.4 + 6.25	7 7 7-10 7-10	1 2,3,4 5 6-12
8	*Curzate M* *Revus + C50* *Consento* Valbon + ZinZan	2.0 0.6 +0.24 2.0 1.6 + 0.15	7 7 7-10 7-10	1 2,3,4 5 6-12
9	*Curzate M* *Revus + C50* *Consento* Valbon + ZinZan + Olie-H	2.0 0.6 +0.24 2.0 1.6 + 0.15 + 6.25	7 7 7-10 7-10	1 2,3,4 5 6-12

Table 3.3.13 Fungicide application dates and intervals - canopy stable (2012)

Application Number	1	2	3	4	5	6	7	8	9	10	11	12
Date	11 July	17 July	24 July	31 July	04 Aug	08 Aug	15 Aug	22 Aug	29 Aug	06 Sep	18 Sep	26 Sep
Actual Interval (days)	-	6	7	7	4	4	7	7	7	8	12	8

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In addition to the foliar blight, assessments were also made on yield and tuber blight post storage for both trials. One of the middle two drills of each plot was harvested and the yield of all tubers recorded. Tuber blight was assessed by external inspection of two random samples of fifty tubers per plot (400 tubers per treatment). The tubers were thoroughly washed prior to assessment. The samples were taken at harvest but due to the knock-on effect of the late harvest the first assessment of the rapid canopy trial was not carried out until mid-January. At the first assessment blighted tubers were discarded and the healthy tubers stored at ambient temperature in a frost-free store for a post-storage assessment at the end of March 2013. The method of assessment was the same. For the canopy stable trial only one assessment of tuber blight was made because of the late harvest. The assessment was carried out in March 2013, after storage at ambient temperature in a frost-free store.

Efficacy of oil and fungicide tank mixes 2013

Two field trials investigating the effect of adding Olie H, Cropspray 11 E or Headland Fortune (Headland Diamond) to the efficacy of blight control fungicides were conducted at SRUC, Auchincruive Estate, Ayr in 2013. As in the two previous years the first trial examined applications made at rapid canopy development and the second those made during the stable canopy phase. Fungicide products that are commonly used during these phases of growth were included in the trials with and without the addition of Olie H, Cropspray 11 E or Fortune to the tank mix.

The trial area was planted with the variety King Edward. The stable canopy trial was planted on the 22nd of May. The rapid canopy trial was intentionally planted later on the 10th of June. Both trials were randomised complete block designs with four replicates. The plot size was 3.4m (4 rows) wide by 7.5m long. For both trials there were untreated potato plants between the plots in order to generate even disease pressure on the site. These ‘infector gaps’ in the rapid canopy trial were inoculated on 18th of July, 26th of July and 1st of August with the single *Phytophthora infestans* isolate 7654A (genotype 13_A2). The canopy stable phase trial, in which test fungicide application was initiated later in the season, did not require inoculation. Trials in the same field were inoculated on the 10th of July, 18th of July, 24th of July, 26th of July, 31st of July and 1st of August with the same isolate. The 2013 season provided conditions conducive to the development of foliar blight. The occurrence of Smith Periods was monitored on the site during the trial period. All test applications were made using a tractor-mounted, modified AZO compressed air sprayer applying 200 l/ha with 03 110 flat fan nozzles of medium-fine spray quality (BCPC classification).

Rapid Canopy Phase Trial 2013

The test treatments were applied at intervals of 9, 8, 8 and 9 days starting on the 22nd of July. The first applications of test fungicides were applied 7 days after the initial maintenance application which was applied when the crop was at the rosette stage of growth. Maintenance treatments of Quell Flo were applied to all plots on completion of the rapid canopy expansion phase. Details of the test products are given in Tables 3.3.14. The treatment combinations and dates in are shown in Tables 3.3.15 and 3.3.16.

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Table 3.3.14 Details of fungicides: rapid canopy (2013)

Fungicide / adjuvant	Active ingredient(s)		Rate (kg or L/ha)
	Common name	composition	Product
Curzate M	cymoxanil + mancozeb	4.5 + 68%	2.0
Quell Flo	mancozeb	455 g/L	2.8
Ranman Top	cyazofamid	160 g/L	0.5
Revus	mandipropamid	250 g/L	0.6
Percos	ametoctradin + dimethomorph	300 + 225 g/L	0.8
Invader	mancozeb + dimethomorph	66.7% + 7.5%	2.4
Valbon	benthiavalicarb-isopropyl + mancozeb	1.75 +70.0%	1.6
Zin Zan	1,2 bis ethansulphonate	70.0%	(0.075% v/v)
Olie H	paraffinic mineral oil	96.0%	6.25
CropSpray 11E	paraffinic mineral oil	> 90%	(2.5% v/v)
Fortune	mixed fatty acid esters	75% w/w	(0.5% v/v)
Axidor	propamocarb + cymoxanil	400 g/L + 50 g/L	2.0

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Table 3.3.15 Treatment regimes for the rapid canopy trial (2013). All treatments received Quell Flo 2.8 l/ha at 7 – 10 day intervals for application numbers 6-10.

Treatment	Product	Dose Rate (kg or L/ha)	Planned Interval (Days)	Application Number
1	*Curzate M* Untreated	2.0 -	7 -	1 2,3,4,5
2	*Curzate M* Ranman Top	2.0 0.5	7 7	1 2,3,4,5
3	*Curzate M* Ranman Top + Olie H	2.0 0.5 + 6.25	7 7	1 2,3,4,5
4	*Curzate M* Revus	2.0 0.6	7 7	1 2,3,4,5
5	*Curzate M* Revus + Olie H	2.0 0.6 + 6.25	7 7	1 2,3,4,5
6	*Curzate M* Revus + CropSpray 11E	2.0 0.6 + 2.5% v/v	7 7	1 2,3,4,5
7	*Curzate M* Revus + Fortune	2.0 0.6 + 0.5% v/v	7 7	1 2,3,4,5
8	*Curzate M* Revus + Axidor	2.0 0.6 + 2.0	7 7	1 2,3,4,5
9	*Curzate M* Revus + Axidor + Olie H	2.0 0.6 + 2.0 + 6.25	7 7	1 2,3,4,5
11	*Curzate M* Percos	2.0 0.8	7 7	1 2,3,4,5
12	*Curzate M* Percos + Olie H	2.0 0.8 + 6.25	7 7	1 2,3,4,5
13	*Curzate M* Percos + CropSpray 11E	2.0 0.8+2.5% v/v	7 7	1 2,3,4,5
14	*Curzate M* Percos + Fortune	2.0 0.8+0.5% v/v	7 7	1 2,3,4,5
15	*Curzate M* Invader	2.0 2.4	7 7	1 2,3,4,5
16	*Curzate M* Invader + CropSpray 11E	2.0 2.4 +2.5% v/v	7 7	1 2,3,4,5
17	*Curzate M* Invader + Fortune	2.0 2.4 + 0.5% v/v	7 7	1 2,3,4,5
18	*Curzate M* Valbon + ZinZan	2.0 1.6+0.075% v/v	7 7	1 2,3,4,5
20	*Curzate M* Valbon + ZinZan + Olie H	2.0 1.6+0.075%+ 6.25	7 7	1 2,3,4,5

[1] Four commercial-in-confidence treatments are omitted

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Table 3.3.16 Fungicide application dates and intervals for the rapid canopy trial (2013)

Application Number	1	2	3	4	5	6	7	8	9	10
Date	15 July	22 July	31 July	08 Aug	16 Aug	25 Aug	3 Sep	10 Sep	18 Sep	25 Sep
Actual Interval (days)	-	7	9	8	8	9	9	7	8	7

Assessments of yield and tuber blight post storage were made for both of the blight trials. Both middle two drills of each plot were harvested and the yield of all tubers recorded. Tuber blight was assessed by external inspection of two random samples of 50 tubers per plot (400 tubers per treatment). The tubers were thoroughly washed prior to assessment. The samples were taken at harvest and the assessment made in January 2014, after storage at ambient temperature in a frost-free store. For the canopy stable trial the assessment was also carried out in January 2014.

Stable canopy trial 2013

Details of the test products are given in Table 3.3.17. The programmes evaluated and the dates of application are given in Tables 3.3.18 and 3.3.19.

Table 3.3.17 Details of fungicides for the 2013 stable canopy trial

Fungicide	Active ingredient(s)		Rate (kg or L/ha)
	Common name	**composition**	**Product**
Consento	propamocarb-HCl + fenamidone	375 g/L + 75 g/L	2.0
. Curzate M	cymoxanil + mancozeb	4.5 + 68%	2.0
Percos	ametoctradin + dimethomorph	300 + 225 g/L	0.8
Invader	mancozeb + dimethomorph	66.7% + 7.5%	2.4
Olie H	paraffinic mineral oil	96.0%	6.5
Infinito	propamocarb-HCl+ fluopicolide	625 + 62.5 g/L	1.6

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Table 3.3.18 Treatment summary for the stable canopy trial (2013). ***Maintenance applications which were applied to all plots are shown in italics.***

Tr Number	Product	Dose Rate (l or kg/ha)	Planned Interval (Days)	Application Number
1	*Curzate M* *Consento* Untreated	2.0 2.0 -	7 7-10 -	1 2,3,4 5-11
7	*Curzate M* *Consento* Invader	2.0 2.0 2.4	7 7-10 7-10	1 2,3,4 5-11
8	*Curzate M* *Consento* Invader + Olie H	2.0 2.0 2.4 + 6.25	7 7-10 7-10	1 2,3,4 5-11
9	*Curzate M* *Consento* Infinito	2.0 2.0 1.6	7 7-10 7-10	1 2,3,4 5-11
10	*Curzate M* *Consento* Infinito + Olie H	2.0 2.0 1.6 + 6.25	7 7-10 7-10	1 2,3,4 5-11

Table 3.3.19 Fungicide application dates and intervals for the stable canopy trial (2013)

Application Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Date	1 July	8 July	18 July	26 July	5 Aug	14 Aug	22 Aug	29 Aug	6 Sep	13 Sep	20 Sep
Actual Interval (days)	-	7	10	8	10	9	8	7	8	7	7

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4. Methods of Statistical Analysis

4.1. Virus Transmission Trials

Methods of statistical analysis

Statistical analyses of the field trials evaluating virus transmission carried out by Scottish Agronomy Ltd (Fife), NIAB (Yorkshire & Cambridge) and SASA (Edinburgh) was conducted by BioSS. Since the response data is essentially different between the trials (Scottish Agronomy Ltd and NIAB versus SASA), they required different methods of statistical analysis.

SASA's trials were analysed using a logistic regression model for binomial response data (this is a form of generalised linear model). Here, both block effects and treatment effects were estimated.

For the trials from NIAB and Scottish Agronomy Ltd, it was considered more appropriate to use a complementary log-log model for a binomial response with an offset to allow for the bulk size. This approach allowed block effects to be taken into account, and also dealt more satisfactorily with the extreme results (e.g. 100% estimates but with wide confidence intervals). The approach also allowed the calculation of confidence intervals and test specific differences between treatments. However more between-plot variability than expected was found in many of the trials. In these cases a beta-binomial distribution was used instead.

For SASA results, standard errors are quoted whereas confidence intervals were given for the NIAB and Scottish Agronomy Ltd results. This was because the distribution of the estimates was expected to be highly skewed, due to the use of bulks.

Analyses of the virus transmission trials were analysed in GenStat 15th Edition using the standard General Linear Model Fitting procedures and the RBETABINOMIAL procedure from the Biometris library. The plot yield and tuber number data were analysed with an ANOVA analysed using Agricultural Research Manager software by Scottish Agronomy Ltd and NIAB.

Methods of statistical analysis_over years' data

For SASA, the over-years trial data was analysed for each virus by variety combination. A logistic mixed model was used for a binomial response, with year, block and year-by-treatment as random effects and treatment as a fixed effect. This enables estimation of the over-year effect of treatment given, in particular, the consistency in its effect over years. An allowance was made for overdispersion.

4.2. Seed Crop Inspection Trials

The data gathered from these trials was largely qualitative in that it reflected the perception of the statutory inspectors' ability to identify the trueness to type and health status of seed crops. This is an essential element of generating outcomes from this project that can be implemented in commercial

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seed production but does not generate results appropriate for statistical analysis.

4.3. Blight Control Trials

Data from the blight control trials were subjected to analysis of variance using Genstat 15th Edition by SRUC. AUDPC values were calculated after angular transformation of the foliar blight severity data for each plot. The untreated control was included in the initial analyses but the analyses were repeated with the untreated control excluded to provide more appropriate LSD values for comparison of fungicide treatments.

5. RESULTS

5.1. Vector and Transmission Pressure

Measurements of aphid numbers were made on the Fife and Edinburgh sites in all three years of the project. This also included using published vector efficiency values to create a weekly PVY infection index. At the Yorkshire and Cambridge sites aphid numbers were recorded in 2012 and 2013.

Tables 5.1.1 to 5.1.7 demonstrate that vector and infectivity pressure was variable at the Fife, Yorkshire and Cambridge sites throughout each trial period. Significant peaks in flights of individual aphid species can be noted in a number of cases, resulting in spikes in PVY infection index around individual application dates. These peaks create a disproportionate importance for these timings in the sequence of treatments.

At the Fife site in 2011, Rose-Grain Aphids (*M. dirhodum*) accounted for 56% of the PVY Index. 44% of the cumulative vector pressure occurred during the week ending 13th of July which corresponds with the period following application timing (T)4.

At the Fife site in 2012, Peach-Potato Aphids (*M. persicae*) and Bird Cherry-Oat Aphids (*R. padi*) accounted for 34% and 44% of the vector pressure index, respectively. The majority of the vector pressure for the trial period in 2012 occurred in one 7 day period from the 4th to 11th of July.

At the Fife site in 2013, the Grain aphid (*S. avenae*) accounted for 27% of the pressure index from emergence to desiccation. A peak in vector pressure was recorded in the week ending 25th of July which accounted for 24% of the vector pressure from the 9 week period from emergence to desiccation.

At Cambridge and Yorkshire, yellow water traps were not included in 2011. Colonising aphids (*M. persicae*) were first seen on plants at the Cambridge site on the 8th June, and increased rapidly to 5-6 aphids on 50% of mid canopy leaves by the end of June. At the Yorkshire site, colonising aphids were not observed until 21st July, and remained at very low levels (estimated at about 10% of plants with less than 5 aphids per plant). These observations do not allow for quantification of non-colonising vector species which, where they occur in large numbers, are important for potyvirus transmission.

At the Cambridge site in 2012 the Peach-Potato aphid (*M. persicae*) accounted for 98% of the vector pressure index. 58% of the cumulative vector

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pressure for the trial period occurred in one week from the 13th to 20th of June corresponding to the period following T4.

At the Cambridge site in 2013, the Peach-Potato aphid accounted for 89% of the total cumulative PVY index over the trial period.

At the Edinburgh site the same treatment was applied at each timing which reduces the significance of peaks in activities for individual timings and products. However, monitoring of aphid catches from the 4 yellow water traps showed that mineral oil treatments correspondingly covered the period of highest aphid vector pressure and virus transmission at the earlier stage of plant growth and also within the last week of the trial prior to haulm desiccation (Figures 5.1.1 -5.1.3).

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Table 5.1.1: Aphid species contribution to the PVY Index from all four yellow water traps during the trial period Fife 2011

			Aphid Numbers and PVY Index to Week Ending									
Aphid Species	**Common Name**	**PVY Vector Efficiency**	**08 June**	**15 June**	**22 June**	**29 June**	**06 July**	**13 July**	**20 July**	**27 July**	**02 Aug**	**10 Aug**
Acyrthosiphon pisum	Pea aphid	0.70						4	3		3	
Aphis fabae grp.	Black Bean aphid	0.10					1	8			1	2
Aulacorthum solani	Glasshouse potato aphid	0.20					1			1		
Brachycaudus helichrysi	Leaf-curling Plum aphid	0.21	2	1	1	3	13	15	8	5	11	1
Brevicoryne brassicae	Cabbage aphid	0.01										
Hyperomyzus lactucae	Currant-Sowthistle aphid	0.16							1			1
Macrosiphum euphorbiae	Potato aphid	0.20						4	2	1	3	3
Metopolophium dirhodum	Rose-Grain aphid	0.30		1	4	34	51	268	150	58	19	3
Myzus ornatus	Violet aphid	0.20										
Myzus persicae	Peach-Potato aphid	1.00			1	1	7	36		1	3	
Rhopalosiphoninus latysiphon		0.20								1		
Rhopalosiphum padi	Bird Cherry-Oat aphid	0.40	6	10	14	22	8	39	19	21	6	13
Sitobion avenae	Grain aphid	0.01	1		6		39	41	4	1	2	1
	Weekly PVY Index		**2.83**	**4.51**	**8.28**	**20.63**	**28.92**	**139.96**	**56.98**	**28.46**	**16.23**	**7.28**
	Cumulative PVY Index			7.34	15.62	36.25	65.17	205.13	262.11	290.57	306.8	314.08
				Treatment Application Timings								
				T0	T1	T2	T3	T4	T5	T6	T7	T8 Desic.
				10 June	**17 June**	**23 June**	**30 June**	**07 July**	**14 July**	**21 July**	**27 July**	**03 Aug**

Note: Aphid traps were not included on the Yorkshire or Cambridge sites in 2011

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Table 5.1.2: Aphid species contribution to the PVY Index from all four yellow water traps during the trial period Fife 2012

			Aphid Numbers and PVY Index to Week Ending									
Species	**Common Name**	**PVY Vector Efficiency**	**20 June**	**27 June**	**4 July**	**11 July**	**18 July**	**25 July**	**1 Aug**	**8 Aug**	**15 Aug**	**30 Aug**
Acyrthosipon pisum	Pea aphid	0.70	1					1				
Aphis fabae	Black-Bean aphid	0.10			1					1	1	23
Brachycaudus helichrysi	Leaf-curling Plum aphid	0.21	1						1			
Brevicoryne brassicae	Cabbage aphid	0.01	1									
Cavariella aegopodii	Willow-Carrot aphid	0.50	7	2	2	1	1			1		
Macrosiphum euphorbiae	Potato aphid	0.20	1									
Metopolophium dirhodum	Rose-Grain aphid	0.30			1	3		1				
Myzus persicae	Peach-Potato aphid	1.00		1	2	4	1		1	2		
Rhopalosiphum padi	Bird Cherry-Oat aphid	0.40		10	1	35	1			1	1	3
Sitobion avenae	Grain aphid	0.60*		1	1	7					2	
		Weekly Index	**4.62**	**6.60**	**4.40**	**23.60**	**1.90**	**1.00**	**1.21**	**3.00**	**1.70**	**3.50**
		Cumulative Index		11.22	15.62	39.22	41.12	42.12	43.33	46.33	48.03	51.53
			Treatment Application Timings									
				T0	T1	T2	T3	T4	T5	T6	T7	T8 Desic.
				20 June	**26 June**	**03 July**	**12 July**	**19 July**	**25 July**	**31 July**	**08 Aug**	**16 Aug**

*Note change in vector PVY index for 2013 season from the 2011 value of 0.01

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Table 5.1.3: Aphid species contribution to the PVY Index from all four yellow water traps during the trial period Yorkshire 2012

			Aphid Numbers and PVY Index to Week Ending										
Aphid Species	**Common Name**	**PVY Vector Efficiency**	**10 July**	**17 July**	**24 July**	**31 July**	**7 Aug**	**14 Aug**	**21 Aug**	**28 Aug**	**5 Sept**	**11 Sept**	
Myzus persicae	Peach-Potato aphid	1.0	37	20	3	2			1				
Acyrthosiphon pisi	Pea aphid	0.7	2	1									
Cavariella aegopodii	Willow-Carrot aphid	0.5		1									
Ropalosiphum padi	Bird Cherry-Oat aphid	0.4	1			1							
Metopolophium dirhodum	Rose-Grain aphid	0.3				1							
Hyperomyzus lactucae	Currant -Sowthistle aphid	0.16					1						
Aphis fabae	Black-Bean aphid	0.1	10	9	4								
Brevicoryne brassicae	Cabbage aphid	0.01					2						
Sitobion avenae	Grain aphid	0.01		1									
Aulacorthum solani	Glasshouse potato aphid	0.2				1	1						
		Weekly PVY Index	**40**	**42**	**3.4**	**2.3**	**0.9**	**0.2**	**1.3**	**0.2**	**0.6**	**0.3**	
		Cumulative PVY Index	40	62.3	65.7	67	69	69	70	70.5	70.5	73.2	
			Treatment Application Timings										
			T0	T1	T2	T3	T4	T5	T6	T7	T8		Desic.
			3rd July	**9th July**	**18th July**	**25th July**	**31th July**	**7th Aug**	**15th Aug**	**21th Aug**	**28th Aug**		**13th Sept**

Table 5.1.4: Aphid species contribution to the PVY Index from all four yellow water traps during the trial period Cambridge 2012

			Aphid Numbers and PVY Index to Week Ending										
Species	**Common Name**	**PVY Vector Efficiency**	**30 May**	**06 June**	**13 June**	**20 June**	**27 June**	**04 July**	**11 July**	**18 July**	**25 July**	**01 Aug**	**08 Aug**
Myzus persicae	Peach-Potato aphid	1.0	99	254	311	2991	793	406	150	21	14	-	2
Acyrthosipon pisum	Pea aphid	0.7	1	4	3	3	5	1	1			-	
Cavariella aegopodii	Willow-Carrot aphid	0.5	42	50	15	4	3	3	4			-	
Ropalosiphum padi	Bird Cherry-Oat aphid	0.4	2		2			1					
Metopolophium dirhodum	Rose-Grain aphid	0.3	1		3	4	2	2	8	1			
Brachycaudus helichrysi	Leaf-curling Plum aphid	0.21	8	41	9	2	4	2					
Aulacorthum solani	Glasshouse potato aphid	0.2									5		
Macrosiphum eurphorbiae	Potato aphid	0.2	1	2	3	3							
Hyperomyzus lactucae	Currant -Sowthistle aphid	0.16	1	2			1				1		
Aphis fabae	Black Bean aphid	0.1	7	3	3	7	23	10	1	2			
Brevicoryne brassicae	Cabbage aphid	0.01	146	61	97	35	5	3	4				
Sitobion avenae	Grain aphid	0.01	1			1	1	6	3	2	2		
	Weekly Index		**129**	**286**	**332**	**2999**	**798**	**411**	**156**	**21.4**	**16.8**		**2.9**
	Cumulative Index		124.9	411	744	3744	4543	4954	5051	5132	5148		5152
			Treatment Application Timings										
			T0	T1	T2	T3	T4	T5	T6	T7	T8		Desic.
			24th May	**31st May**	**6th June**	**13th June**	**20th June**	**29th June**	**5th July**	**12th July**	**19th July**		**31st July**

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Table 5.1.5 Aphid species contribution to the PVY Index from all four yellow water traps during the trial period Fife 2013

			Aphid Numbers and PVY Index to Week Ending									
Species	**Common Name**	**PVY Index**	**19 June**	**26 June**	**3 July**	**10 July**	**17 July**	**25 July**	**31 July**	**7 Aug**	**14 Aug**	**21 Aug**
Myzus persicae	Peach-Potato aphid	1.00		3		2	1	3	2	2		
Acyrthosiphon pisum	Pea aphid	0.70	1	2	1		3	5	3			
Sitobion avenae	Grain aphid	0.60*	1	1	2	4	5	16	10	5	3	1
Cavariella aegopodii	Willow-Carrot aphid	0.50	3	5	3	6	4	6		5		3
Rhopalosiphum padi	Bird Cherry-Oat aphid	0.40	3			1	2	3	4	1	2	2
Metopolophium dirhodum	Rose-Grain aphid	0.30	2	4	2	2	11	1	4			
Brachycaudus helichrysti	Leaf-Curling Plum aphid	0.21	3	4	2	2	11	8		5	2	1
Aulacorthum solani	Glasshouse potato aphid	0.20		1								
Macrosiphum euphorbiae	Potato aphid	0.20	3	4		3	10	8	1	2	1	2
Hyperomyzus lactucae	Currant-Sowthistle aphid	0.16			1			1			1	
Aphis fabae	Black Bean aphid	0.10		1			7	11	20	12	1	3
Brevicoryne brassicae	Cabbage aphid	0.01		1								
	Weekly Index		**5.83**	**10.65**	**4.58**	**9.42**	**17.21**	**25.14**	**15.10**	**10.55**	**3.48**	**3.81**
	Cumulative Index		-	16.48	21.06	30.48	47.69	72.83	87.93	98.48	101.96	105.77
			Treatment Application Timings									
				T0	T1	T2	T3	T4	T5	T6	T7	T8 Desic.
				25 June	03 July	09 July	16 July	22 July	30 July	06 Aug	13 Aug	20 Aug

*Note change in vector PVY index for 2013 season from the 2011 value of 0.01

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Table 5.1.6 Aphid species contribution to the PVY Index from all four yellow water traps during the trial period Yorkshire 2013

			Aphid Numbers and PVY Index to Week Ending										
Species	**Common Name**	**PVY Vector Efficiency**	**19 Jun**	**26 Jun**	**3 Jul**	**10 Jul**	**17 Jul**	**24 Jul**	**31 Jul**	**7 Aug**	**14 Aug**	**21 Aug**	
Myzus persicae	Peach-Potato aphid	1.0	`			4	11	5	4	4	1		
Acyrthosiphon pisum	Pea aphid	0.7					4	1					
Sitobion aveane	Grain aphid	0.6					4	4	2	5	1		
Cavalliera aegopodii	Willow-Carrot aphid	0.5	9	1	1	6	11	7	23	5			
Rhopalosiphum padi	Bird Cherry-Oat aphid	0.4				1	1	1	2				
Metopolophium dirhodum	Rose Grain aphid	0.3				1	7	9	2	1			
Brachycaudus helichrysi	Leaf-Curling plum aphid	0.21	8	4			8	1	1				
Macrosiphum euphorbiae	Potato aphid	0.2	1			1	7	19	6	5			
Hyperomyzus lactucae	Currant- Sowthistle aphid	0.16			1		2	3		3			
Aphis fabae	Black Bean aphid	0.1				3	18	3	6	4		1	
	Weekly Index Cumulative Index		**6.3** 6.3	**1.3** 7.6	**0.7** 8.3	**5.2** 12.7	**29.9** 44.5	**17.6** 62.1	**20.1** 82.2	**11.5** 93.7	**1.6** 95.5	**0.1** 95.7	
			Treatment Application Timings										
			T0	T1	T2	T3	T4	T5	T6	T7	T8		Desic.
			11 Jun	19 Jun	26 Jun	3 Jul	10 Jul	17 Jul	24 Jul	31 Jul	07 Aug		16 Aug

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Table 5.1.7 Aphid species contribution to the PVY Index from all four yellow water traps during the trial period Cambridge 2013

			Aphid Numbers and PVY Index to Week Ending										
Species	**Common Name**	**PVY Vector Efficiency**	**29 May**	**05 Jun**	**13 Jun**	**19 Jun**	**26 Jun**	**03 Jul**	**10 Jul**	**17 Jul**	**26 Jul**	**02 Aug**	
Myzus persicae	Peach Potato aphid	1.0				28	30	103	336	243	290	287	
Carvalieria aegopidiae	Willow-Carrot aphid	0.5	1	6	14	17	2	10	6	11		2	
Brachycaudus helichrysti	Leaf-Curling plum aphid	0.21	5	5	14	39	21	19	18	9		1	
Acyrthosiphum pisum	Pea aphid	0.7				1	1	1	1	6	2		
Sitobion avenae	Grain aphid	0.6							1		5	12	
Metopolophium dirhodum	Rose-Grain aphid	0.3			1	3	5	4	15	9	11	10	
Aphis fabae	Black-Bean aphid	0.1			1	8	7	3	55	72	34	36	
Rhopalosiphum padi	Bird Cherry-Oat aphid	0.5	1			2	3	7	9	17	4	19	
Brevicoryne brassicae	Cabbage aphid	0.01					1	4	27	4	6		
Macrosiphum euphorbiae	Potato aphid	0.2	1			2	2	7	14	9	5	6	
Aulacorthum solani	Glasshouse potato aphid	0.2						1	2	5			
Hyperomyzus lactucae	Currant Sowthistle aphid	0.16						1	1	1			
Ropalosiphoninus latysiphon	Bulb and Potato aphid	0.20						1					
	Weekly Index		**2.1**	**1.5**	**10.8**	**48.3**	**40.6**	**116**	**309**	**272**	**313**	**312**	
	Cumulative Index		2.1	3.6	14.4	63	103	220	583	875	1161	1470	
			Treatment Application Timings										
			T0	T1	T2	T3	T4	T5	T6	T7	T8		Desic.
			26 May	31 May	7 Jun	17 Jun	27 Jun	05 Jul	12 Jul	18 Jul	27 Jul		7 Aug

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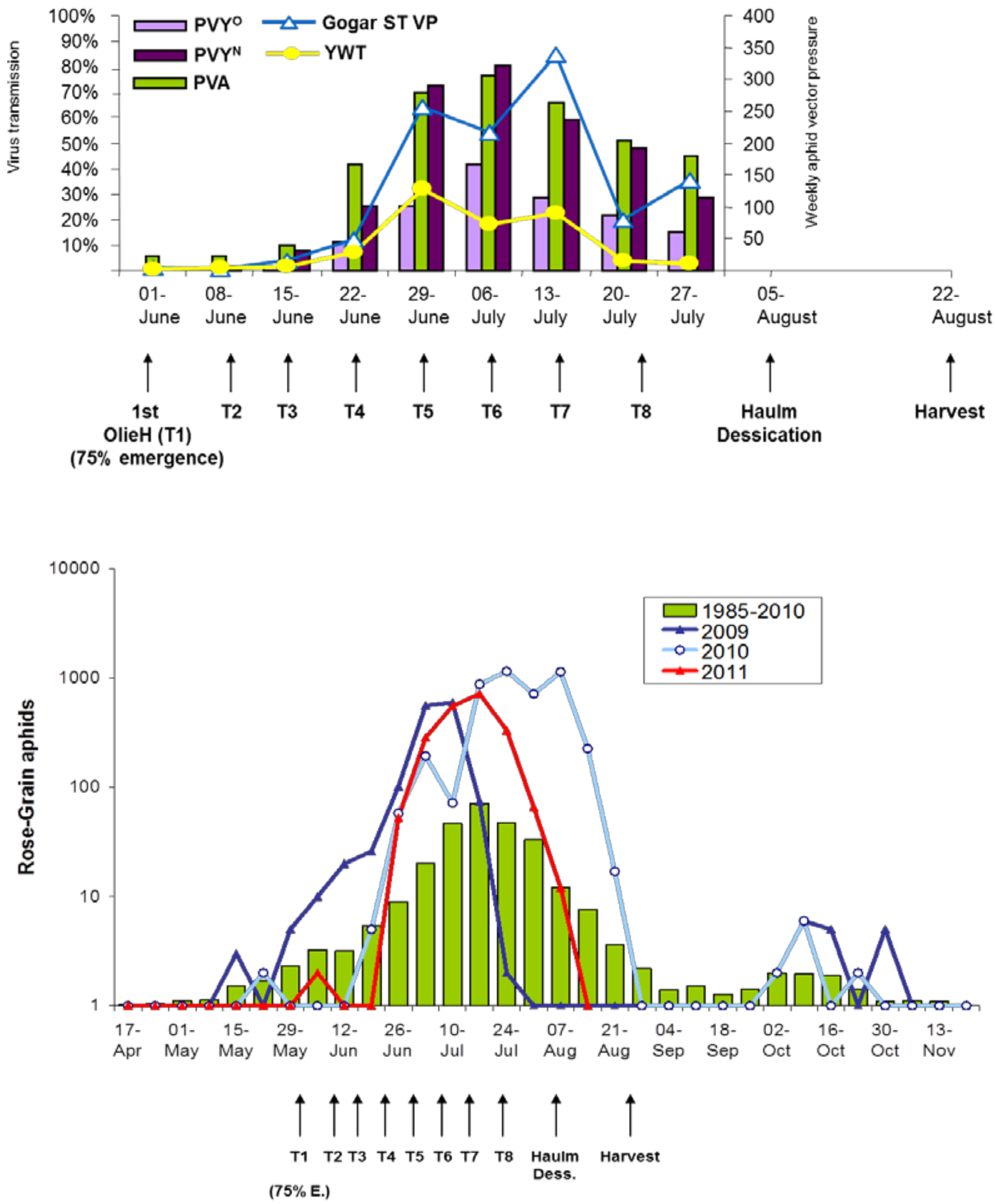

Figure 5.1.1. Aphid vector pressure measured by 4 yellow water traps and suction trap at the vicinity of the experimental plot at Edinburgh 2011 (upper panel) and aphid catches from suction trap (lower panel).

Lines represent *M. dirhodum* catches in 2011 (red) and previous years (2010 and 2009 respectively light- and dark- blue). Bars are averaged catches for 1985-2010). The timing of treatments (T1 to T8), haulm desiccation and harvest are indicated below.

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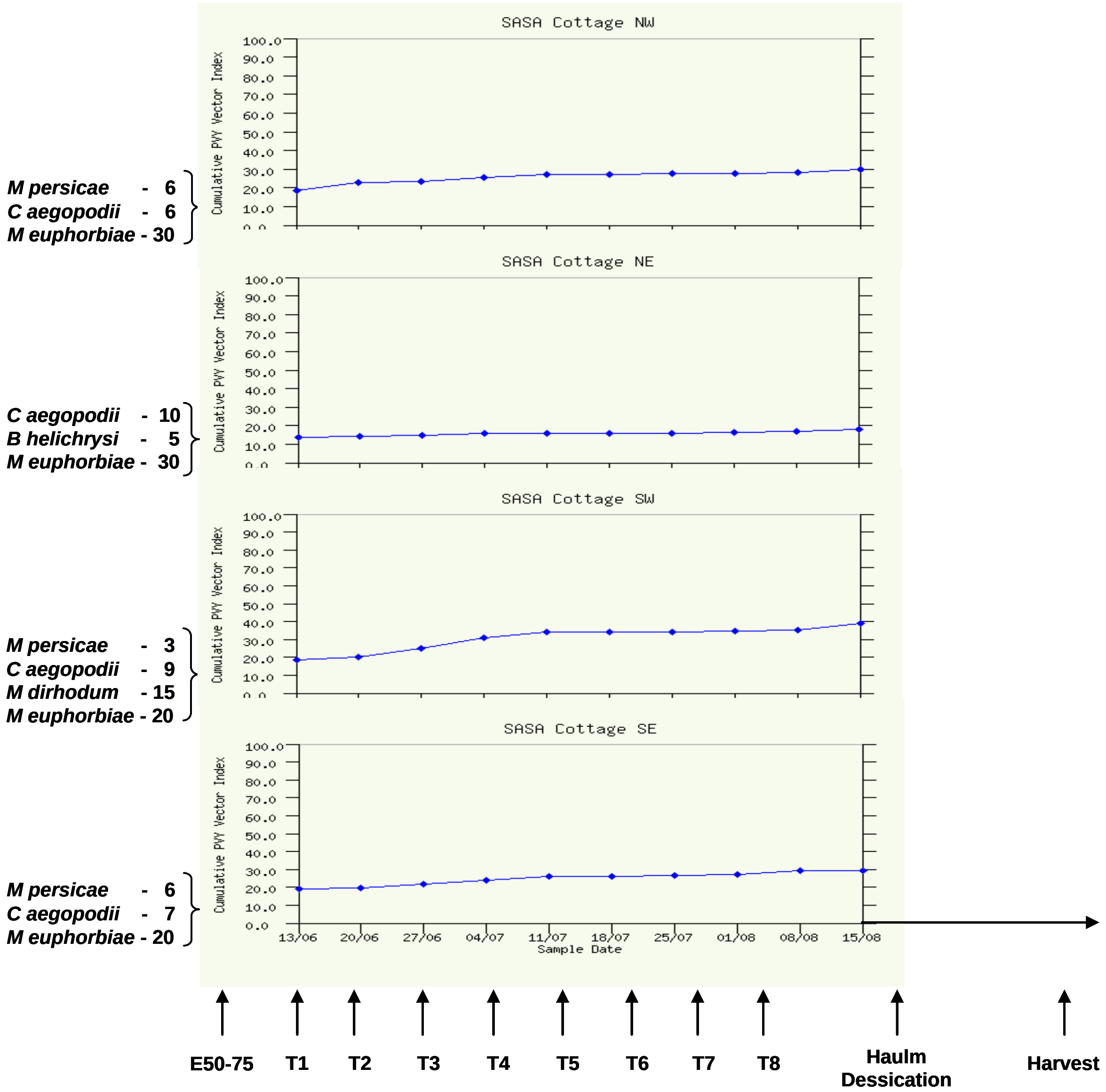

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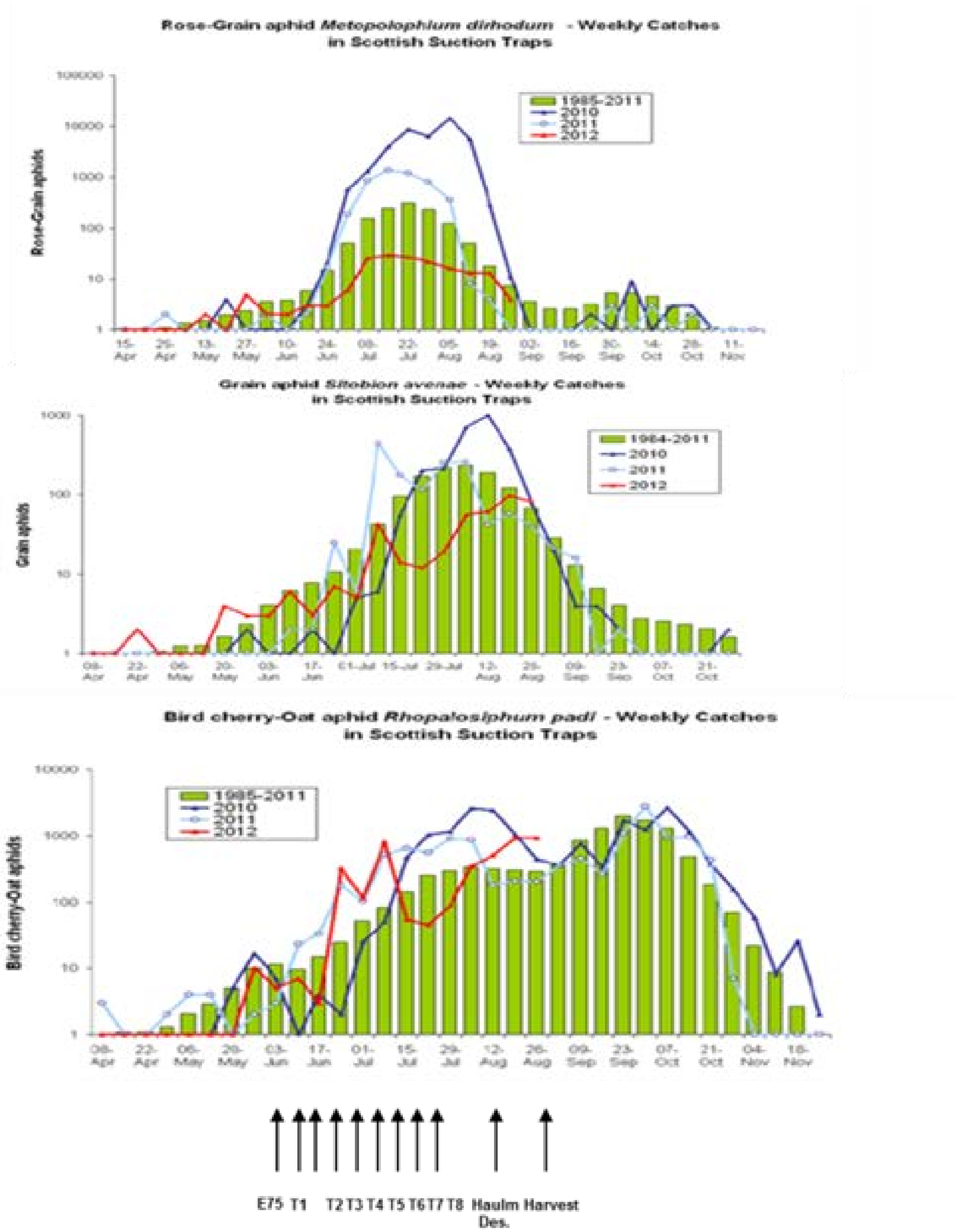

Figure 5.1.2. Cumulative aphid vector pressure measured by 4 yellow water traps within the experimental plots at Edinburgh in 2012. Upper panel – the number of aphid catches known to transmit PVY identified at T1 are indicated on the left. Lower panels- aphid catches from suction trap for *M. dirhodum* (Rose-Grain aphid), *R. padi* (Bird Cherry-Oat aphid) and *S. avenae* (Grain aphid) in Edinburgh in 2012 (red line in each graphs) and previous years. The timing of treatments (T1 to T8), haulm dessication and harvest are indicated.

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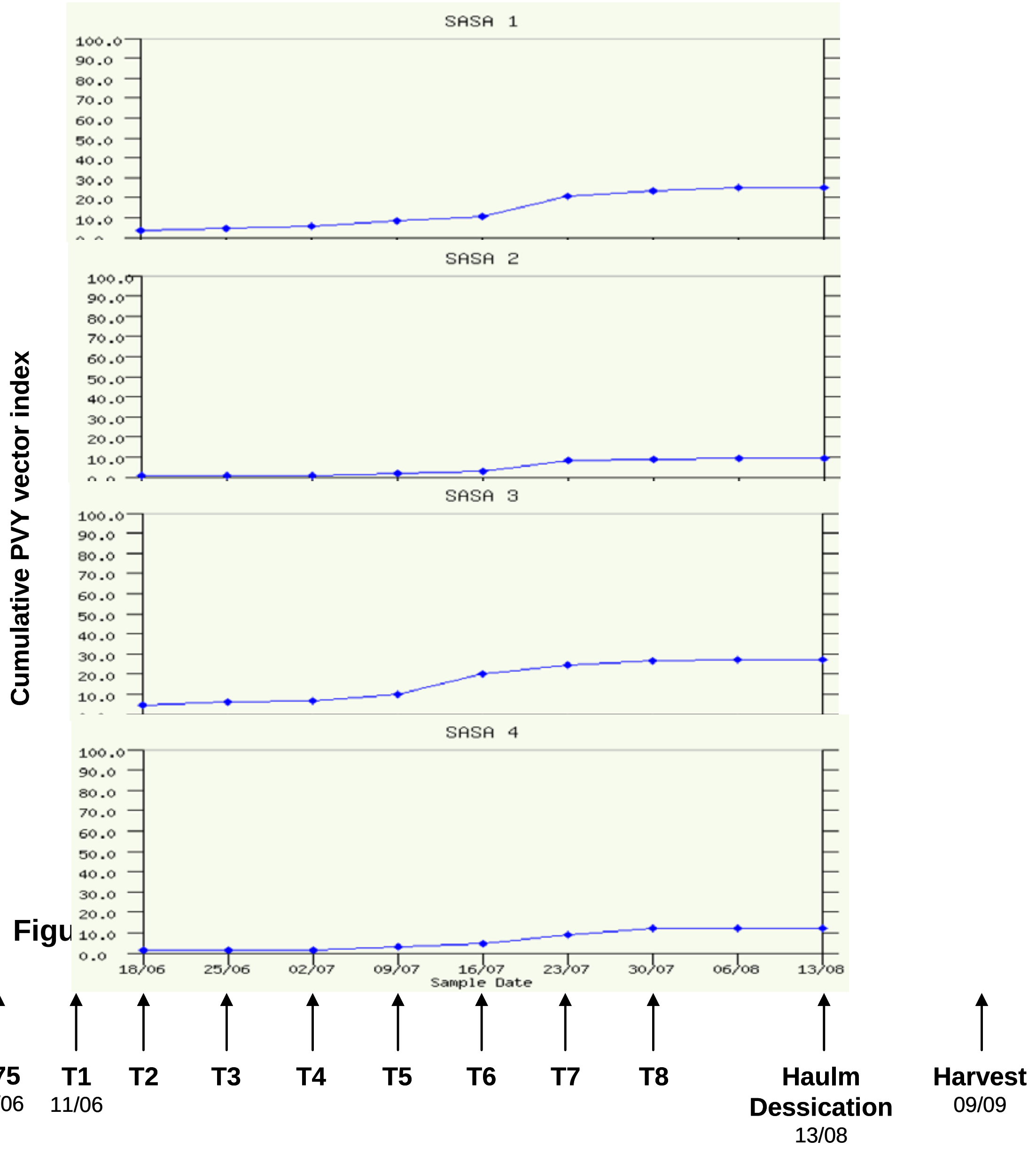

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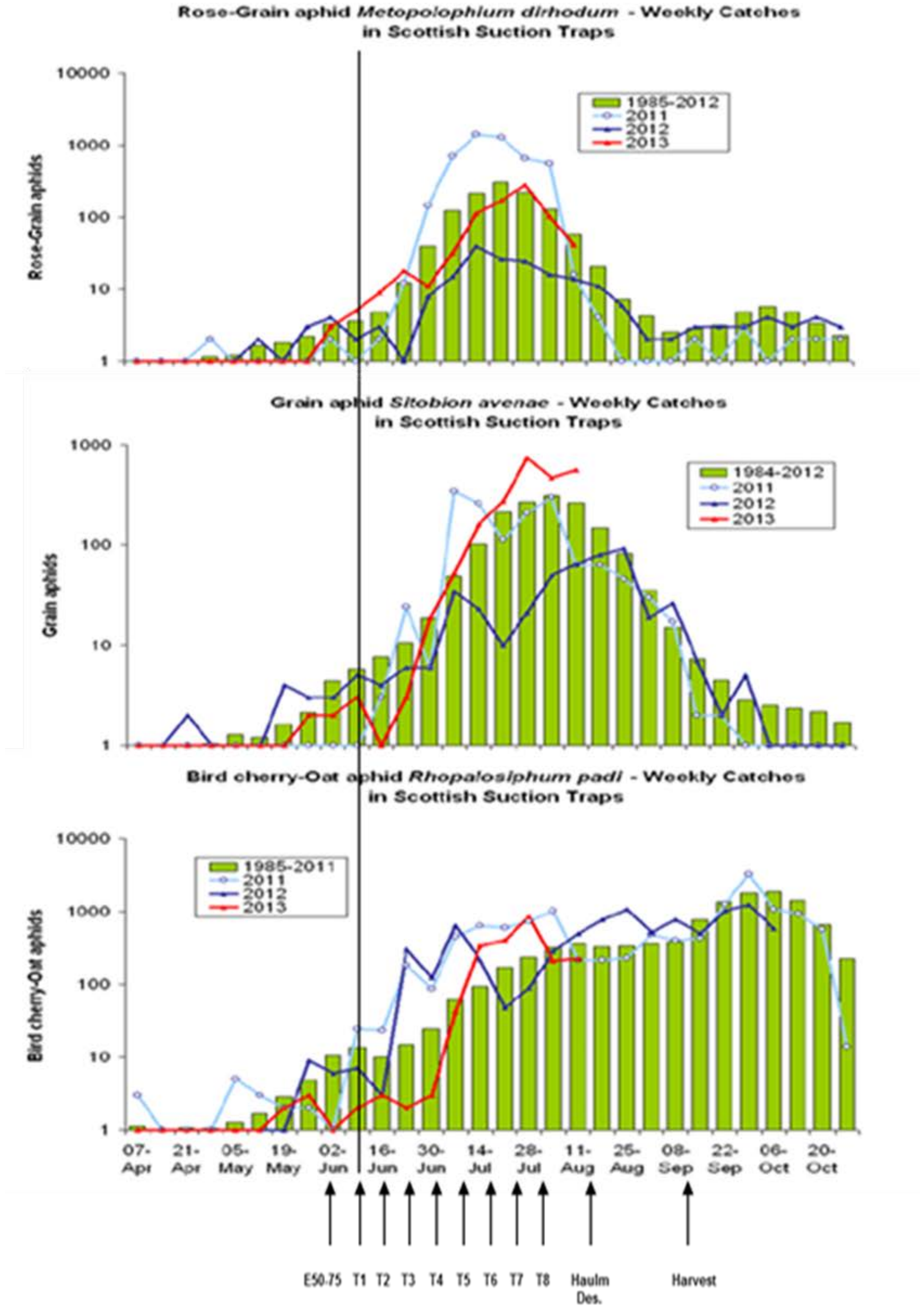

Figure 5.1.3: Cumulative aphid vector pressure measured by 4 yellow water traps within the experimental plots at Edinburgh 2013 (upper panels) and aphid catches from suction trap (lower panels), for *M. dirhodum* (Rose-Grain aphid), *R. padi* (Bird Cherry-Oat aphid) and *S. avenae* (Grain aphid) in Edinburgh in 2013 (red line) and previous years. The timing of treatments (T1 to T8), haulm desiccation and harvest are indicated

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5.2. Virus Transmission

Virus testing for all viruses was carried out on tuber samples taken from each individual trial. Tables 5.2.1 to 5.2.14 present the results for sites where sufficient levels of individual or total virus was found to allow reliable analysis and evidence of statistically significant treatment differences. Accordingly, data is not presented for every site, season and virus combination.

For most viruses at the Fife site in 2011, only low numbers of infected bulks were found. This makes inference using generalised linear models unreliable. The only results that are presented are those from PVA and the combined total of all viruses. In these cases, differences between treatments were not evident. In 2012 PVA and PVY^{N} was found in the test material. Again, statistical differences between treatments were not evident. In 2013 the proportion of infected bulks was higher (apart from $PVY^{o/c}$ where only 1.2% of bulks were infected) Overall, significant differences between treatments were evident (Table 5.2.9). Plots treated with Olie H at 6.2% had a lower rate of infection than the control overall (%) as did this treatment for PVY^{N} and PVA compared to their control. The treatment Programme Sumi/Hallmark numerically performed worse than the control but was not significantly different.

In 2011, only low numbers of infected bulks were found on the Yorkshire site. The only virus for which the results are given are PVA and PVY^{N} (partial); even these should be treated with caution. For example, the estimated infection levels with “Hallmark” were raised considerably by the results for one plot, which was at odds with the other three plots. This is consistent with the lack of infector plants and relatively low vector pressure (Tables 5.1.2, 5.1.5 & 5.1.8) on this site, resulting in low infectivity pressure. No results are presented for the Yorkshire site in 2012 or 2013 due to low virus levels, again this can be attributed to the decision to omit infector rows on this site.

At the Cambridge site in 2011, differences between treatments were evident for PVA and PLRV. For PVA, there was evidence that all treatments apart from “Hallmark/Biscaya/Sumi Alpha/Plenum” had lower proportions of infected tubers than the control. For PLRV, the treatments “Hallmark Fortune”, “Hallmark Olie H” and “Hallmark/Biscaya/Sumi Alpha/Plenum” were found to be more effective than the control.

In 2012, the proportions of infected bulks at Cambridge were lower than in 2011 (though the bulk sizes were smaller in 2012). The infection rates were quite high for PVA and PVY^{N} but low for PLRV and $PVY^{o/c}$ and so the results for the latter should be treated with caution. Differences between treatments were evident only for PVY^{N}. Here the treatments “Olie-H” and “Hallmark Olie-H” were found to be more effective than the control. These results were different from the 2011 results. Variable seasonal results were anticipated during the project as a result of the inherent variability in the temporal and spatial distribution of aphid vector pressure.

In 2013, the proportions of PVA and PLRV infected bulks at Cambridge were lower than in previous years. In the case of PLRV, the level was too low to allow appropriate analysis. For PVA, no evidence of differences between

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the treatments was found. For PVY^N, the proportion of infected bulks was high enough to cause difficulties with the analysis and discrimination between treatments. The proportion of bulks infected with $PVY^{o/c}$ was higher than in previous years. There was strong evidence for differences between treatments for $PVY^{o/c}$, with several having lower rates of infection than the control, including “Olie H” and “Crop Spray 11E”. In light of the high rates of infection seen for PVY^N and $PVY^{o/c,}$ 30 tubers from 30 plants from each plot were tested individually. The same method of analysis as for data from the epidemiology trial at Edinburgh was applied. The results are summarised in Table 5.2.13. As might be expected from the analysis of bulks, there were only low proportions of infected plants for PVA and PLRV and no evidence of differences between the treatments was found. For PVY^N, strong evidence was found for differences between the treatments. In particular, the “Hallmark Olie H” and “Crop Spray 11E” treatments clearly performed better than the control, though, even with these, the proportion of infected plants was still high. For $PVY^{o/c}$, unlike for the bulks, no overall evidence for differences between the treatments was found, though the analysis did indicate that “Crop Spray 11E” performed better than the control. The disparity in result might be explained in part by the higher estimate of infection level in the control based on bulks than based on individual plants.

A summary of the data from sites where statistically significant treatment difference were observed is presented in Tables 5.2.16 & 5.2.17. The individual trial results should be referred to for the statistical significance of the control achieved by individual treatments within this.

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Table 5.2.1: Results for Fife 2011 – PVA & PVY^N

	PVA			PVY^N		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	5.6%			3.2%		
Method of analysis	BB					
Dispersion factor	1.9					
Treatment effect p-value	†0.10					
Estimated propn. infected tubers:						
Untreated	1.8%	0.8%	3.7%			
Fortune	1.1%	0.4%	2.8%			
Olie-H 3.1%	0.9%	0.3%	2.7%			
Hallmark	1.4%	0.6%	3.4%			
Hallmark/ Fortune	0.7%	0.2%	2.2%			
Hallmark/ Olie-H	1.7%	0.8%	3.7%			
Programme 1	*0.2%	0.0%	1.5%			
Programme 1/ Olie-H 3.1%	0.5%	0.1%	1.9%			
Crop Spray 11E 2%	2.3%	1.2%	4.4%			
Hallmark/ Crop Spray 11E	1.7%	0.8%	3.6%			
T11	1.4%	0.5%	3.6%			
T12	2.1%	1.0%	4.4%			

† A large outlier was found in the first replicate of Hallmark/Olie H/Biscaya/Sumi Alpha/Plenum, where more infected bulks were found than expected.
†† Borderline overdispersed but sparsity of results indicated use of binomial model.
Asterisks indicate the level of significance for the comparison between the treatment and the control.
* indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.
B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

Table 5.2.2: Fife 2011. PVV & Total over all viruses

	PVV			Total		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	2.4%			10.6%		
Method of analysis				BB		
Dispersion factor				1.4		
Treatment effect p-value				0.13		
Estimated propn. infected tubers:						
Untreated				2.6%	1.5%	4.4%
Fortune				3.3%	2.0%	5.5%
Olie-H 3.1%				1.4%	0.6%	3.0%
Hallmark				2.0%	1.0%	3.7%
Hallmark/ Fortune				1.6%	0.8%	3.3%
Hallmark/ Olie-H				3.4%	2.0%	5.6%
Programme 1				1.3%	0.6%	2.9%
Programme 1/ Olie-H 3.1%				2.3%	1.2%	4.1%
Crop Spray 11E 2%				3.1%	1.8%	5.1%
Hallmark/ Crop Spray 11E				3.3%	2.0%	5.4%
T11				3.9%	2.4%	6.3%
T12				4.0%	2.5%	6.4%

Asterisks indicate the level of significance for the comparison between the treatment and the control.
* indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.
B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

Table 5.2.3: Results for Yorkshire 2011 – PVA & PVY^N

	PVA			PVY^N		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	8.5%			5.3%		
Method of analysis	BB			BB		
Dispersion factor	2.2			2.3		
Treatment effect p-value	0.004			0.21		
Estimated propn. infected tubers:						
Untreated	2.2%	1.0%	4.9%			
Fortune	2.4%	1.0%	5.5%			
Olie-H 3.1%	*0.5%	0.1%	2.3%			
Hallmark	*5.6%	3.2%	9.5%			
Hallmark/ Fortune	*0.3%	0.0%	2.3%			
Hallmark/ Olie-H	*0.7%	0.2%	2.3%			
Programme 1	0.7%	0.2%	2.7%			
Programme 1/ Olie-H 3.1%	0.7%	0.1%	3.5%			

Asterisks indicate the level of significance for the comparison between the treatment and the control.

* indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

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Table 5.2.4: Results for Cambridge 2011 – PVA & PVY^N

	PVA			PVY^N		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	71.2%			85.2%		
Method of analysis	BB			BB		
Dispersion factor	5.6			5.7		
Treatment effect p-value	†0.017			0.93		
<u>Estimated propn. infected tubers:</u>						
Untreated	53.6%	26.7%	85.0%	38.2%	24.9%	55.5%
Fortune	**15.7%	9.1%	26.4%	27.1%	15.0%	46.0%
Olie-H 3.1%	*19.0%	9.7%	35.5%	36.1%	20.7%	57.7%
Hallmark	*19.2%	11.6%	30.8%	34.0%	21.4%	51.2%
Hallmark/ Fortune	*20.9%	11.1%	37.3%	31.1%	16.8%	53.1%
Hallmark/ Olie-H	**17.5%	10.3%	28.8%	30.2%	20.0%	43.9%
Programme 1	31.1%	18.4%	49.4%	29.3%	19.2%	43.1%
Programme 1/ Olie-H 3.1%	*25.3%	16.5%	37.7%	28.6%	18.7	42.2%

† A large outlier was found in plot 201 (last treatment) where there was fewer infected bulks than expected.

Asterisks indicate the level of significance for the comparison between the treatment and the control.

* indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

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Table 5.2.5: Results for Cambridge 2011 – PLRV & PVY$^{o/c}$

	PLRV			PVY$^{o/c}$		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	30.9%			54.8		
Method of analysis	BB			BB		
Dispersion factor	5.2			6.5		
Treatment effect p-value	0.004			0.509		
<u>Estimated propn. infected tubers:</u>						
Untreated	9.3%	4.7%	18.1%	22.0%	11.7%	39.0%
Fortune	5.8%	2.6%	12.3%	*8.6%	4.1%	17.7%
Olie-H 3.1%	5.8%	2.8%	11.8%	16.9%	9.5%	29.1%
Hallmark	10.0%	5.0%	19.3%	14.9%	7.2%	29.5%
Hallmark/ Fortune	**1.0%	0.2%	4.4%	10.5%	5.1%	20.8%
Hallmark/ Olie-H	**1.9%	0.7%	5.1%	19.1%	11.1%	31.8%
Programme 1	*2.2%	0.8%	5.9%	16.6%	9.3%	28.7%
Programme 1/ Olie-H 3.1%	15.5%	8.4%	27.5%	15.5%	8.3%	28.1%

Asterisks indicate the level of significance for the comparison between the treatment and the control.

* indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

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Table 5.2.6: Results for Fife 2012 –Total over all viruses

	Total		
		95% Confidence interval	
		Lower	Upper
Overall proportion infected bulks	16.5%		
Method of analysis	BB		
Dispersion factor	4.7		
Treatment effect p-value	0.97		
Estimated propn. infected tubers:			
Untreated	6.7%	3.7%	11.8%
Fortune	4.2%	2.0%	8.6%
Olie-H 3.1%	5.8%	2.9%	11.2%
Hallmark	5.1%	2.6%	9.8%
Hallmark / Fortune	4.3%	2.1%	8.5%
Hallmark/Olie-H	4.1%	2.0%	8.3%
Programme 2	4.1%	1.9%	8.7%
Programme 2 / Olie-H 3.1%	3.6%	1.6%	7.7%
Programme 2/ Olie-H 6.2%	5.2%	2.6%	10.1%
Olie-H 6.2%	4.1%	2.0%	8.4%

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.
B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

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Table 5.2.7: Results for Cambridge 2012 – PVA & PVY^N

	PVA			PVY^N		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	21.0%			41.1%		
Method of analysis	BB			BB		
Dispersion factor	3.6			2.7		
Treatment effect p-value	0.16			<0.001		
<u>Estimated propn. infected tubers:</u>						
Untreated	5.7%	3.0%	10.8%	16.9%	11.8%	23.9%
Fortune	7.6%	4.3%	13.4%	12.1%	7.9%	18.2%
Olie-H 3.1%	3.9%	1.7%	8.6%	***4.5%	2.4%	8.6%
Hallmark	7.5%	4.2%	13.3%	15.9%	10.9%	22.8%
Hallmark / Fortune	7.9%	4.5%	13.8%	15.7%	10.8%	22.5%
Hallmark/Olie-H	2.3%	0.9%	6.1%	***4.4%	2.3%	8.4%
Programme 2	4.7%	2.2%	9.9%	16.3%	11.2%	23.3%
Programme 2 / Olie-H 3.1%	3.3%	1.5%	7.3%	15.2%	10.4%	21.9%

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

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Table 5.2.8: Results for Cambridge 2012 – PLRV & PVY$^{o/c}$

	PLRV			PVY$^{o/c}$		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	9.5%			11.0%		
Method of analysis	BB			BB		
Dispersion factor	5.5			3.0		
Treatment effect p-value	0.049			0.26		
<u>Estimated propn. infected tubers:</u>						
Untreated	2.1%	0.5%	8.0%	2.7%	1.1%	6.5%
Fortune	6.2%	2.8%	13.4%	1.2%	0.4%	3.8%
Olie-H 3.1%	1.0%	0.2%	4.8%	1.6%	0.5%	4.9%
Hallmark	4.5%	1.9%	10.6%	2.4%	1.0%	5.8%
Hallmark / Fortune	1.9%	0.5%	7.5%	4.8%	2.5%	9.2%
Hallmark/Olie-H	1.3%	0.3%	5.6%	1.6%	0.6%	4.4%
Programme 2	0.6%	0.1%	5.2%	4.6%	2.3%	9.3%
Programme 2 / Olie-H 3.1%	0.4%	0.0%	3.9%	1.8%	0.7%	4.6%

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

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Table 5.2.9: Results for Fife 2013 –Total over all viruses and PVA

	Total			PVA		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	52.6%			14.1%		
Method of analysis	BB			BB		
Dispersion factor	3.2			4.6		
Treatment effect p-value	<0.001			0.029		
<u>Estimated propn. infected tubers:</u>						
Untreated	17.5%	12.6%	24.0%	5.2%	2.8%	9.8%
Fortune	18.7%	13.6%	25.4%	4.8%	2.6%	9.0%
Olie-H 3.1%	19.2%	14.0%	26.0%	*1.6%	0.5%	5.3%
Hallmark	17.9%	12.8%	24.7%	*1.6%	0.5%	5.5%
Hallmark / Fortune	18.8%	13.5%	25.8%	7.2%	4.0%	12.9%
Hallmark/Olie-H	11.6%	7.8%	17.3%	*1.3%	0.4%	4.1%
Programme 2	*28.0%	21.0%	36.8%	6.3%	3.5%	11.2%
Programme 2 / Olie-H 3.1%	17.4%	12.4%	24.0%	4.5%	2.3%	8.8%
Crop Spray 11E 2.5%	17.5%	12.9%	23.7%	3.4%	1.6%	7.2%
Programme 2/Olie-H 6.2%	13.9%	9.6%	19.8%	3.6%	1.8%	7.4%
Olie-H 6.2%	***6.6%	3.9%	11.1%	*1.5%	0.5%	4.5%

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.
B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

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Table 5.2.10: Results for Fife 2013 –PVY^N and PVV

	PVY^N			PVV		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	40.4%			8.8%		
Method of analysis	BB			QB		
Dispersion factor	3.0			1.7		
Treatment effect p-value	0.009			<0.001		
Estimated propn. infected tubers:						
Untreated	11.5%	7.9%	16.5%	1.1%	0.4%	2.7%
Fortune	11.2%	7.7%	16.3%	*2.8%	1.6%	5.0%
Olie-H 3.1%	16.2%	11.7%	22.3%	1.5%	0.7%	3.3%
Hallmark	15.9%	11.3%	22.1%	0.4%	0.1%	1.7%
Hallmark / Fortune	9.4%	6.1%	14.4%	2.5%	1.3%	4.6%
Hallmark/Olie-H	8.7%	5.6%	13.6%	0.5%	0.1%	1.9%
Programme 2	*17.6%	12.8%	24.0%	**5.3%	3.4%	8.1%
Programme 2 / Olie-H 3.1%	12.7%	8.7%	18.2%	1.5%	0.7%	3.3%
Crop Spray 11E 2.5%	9.8%	6.7%	14.2%	2.4%	1.3%	4.5%
Programme 2/Olie-H 6.2%	10.4%	7.0%	15.3%	0.0%	†	†
Olie-H 6.2%	**4.8%	2.7%	8.4%	1.2%	0.5%	2.9%

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed), QB indicates model based on quasi-binomial analysis (overdispersion – BB did not converge).

† sensible confidence intervals not estimable using glm.

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Table 5.2.11: Results for Cambridge 2013 bulks – PVA & PVY^N

	PVA			PVY^N		
		95% Confidence interval			95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	11.2%			93.4%		
Method of analysis	BB			BB†		
Dispersion factor	2.5			4.3†		
Treatment effect p-value	0.29			0.28†		
<u>Estimated propn. infected tubers:</u>						
Untreated	3.1%	1.5%	6.4%	59.6%		
Fortune	3.5%	1.7%	7.1%	36.7%		
Olie-H 3.1%	2.5%	1.2%	5.4%	57.2%		
Hallmark	1.9%	0.8%	4.7%	51.2%		
Hallmark / Fortune	3.5%	1.8%	6.8%	63.5%		
Hallmark/Olie-H	1.1%	0.3%	3.6%	42.4%		
Programme 2	3.4%	1.7%	6.7%	44.4%		
Programme 2 / Olie-H 3.1%	4.3%	2.3%	8.0%	60.0%		
Crop Spray 11E 2.5%	1.4%	0.5%	3.9%	58.9%		

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

† The BB model did not converge. Values given are for a quasi-binomial model with overdispersion. Given the lack of convergence is caused by the high proportion of infected bulks, it was not sensible to give confidence intervals.

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Table 5.2.12: Results for Cambridge 2013 bulks – PLRV & PVY$^{o/c}$

	PLRV	95% Confidence interval		PVY$^{o/c}$	95% Confidence interval	
		Lower	Upper		Lower	Upper
Overall proportion infected bulks	2.1%			80.3%		
Method of analysis	B†			BB		
Dispersion factor	1.2			1.9		
Treatment effect p-value	†			<0.001		
<u>Estimated propn. infected tubers:</u>						
Untreated	1.1%			48.7%	39.1%	59.2%
Fortune	0.0%			48.9%	38.9%	59.9%
Olie-H 3.1%	0.0%			***26.5%	20.6%	33.7%
Hallmark	8.2%			**32.0%	25.0%	40.3%
Hallmark / Fortune	9.5%			*33.6%	25.7%	43.2%
Hallmark/Olie-H	10.7%			**28.4%	21.9%	36.3%
Programme 2	1.1%			40.6%	32.4%	49.9%
Programme 2 / Olie-H 3.1%	0.0%			*37.5%	29.8%	46.4%
Crop Spray 11E 2.5%	3.4%			***24.5%	18.7%	31.8%

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. BB indicates model based on beta-binomial distribution (over-dispersed).

† analysis unreliable due to low proportions of infected bulks observed combined with patchy occurrence.

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Table 5.2.13: Results for Cambridge 2013 individual plants – PVA & PVY^N

	PVA		PVY^N	
Overall proportion infected	4.4%		79.8%	
Method of analysis	QB		QB	
Dispersion factor	1.6		1.6	
Treatment effect p-value	0.37		0.003	
Estimated propn. infected tubers:	Mean	Standard error	Mean	Standard error
Untreated	1.7%	1.5%	91.7%	3.2%
Fortune	5.0%	2.5%	*76.0%	4.9%
Olie-H 3.1%	2.5%	1.8%	**75.2%	5.0%
Hallmark	7.5%	3.0%	86.8%	3.9%
Hallmark / Fortune	8.3%	3.2%	81.0%	4.5%
Hallmark/Olie-H	2.5%	1.8%	**68.5%	5.3%
Programme 2	4.4%	2.7%	93.9%	3.3%
Programme 2 / Olie-H 3.1%	5.8%	2.7%	83.5%	4.3%
Crop Spray 11E 2.5%	1.7%	1.5%	***66.0%	5.4%

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. QB indicates model based on quasi-binomial analysis (over-dispersed).

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Table 5.2.14: Results for Cambridge 2013 individual plants – PLRV & $PVY^{o/c}$

	PLRV	$PVY^{o/c}$	
Overall proportion infected	0.8%	35.0%	
Method of analysis	B†	QB	
Dispersion factor	†	1.7	
Treatment effect p-value	†	0.52	
Estimated propn. infected tubers:	Mean	Mean	Standard error
Untreated	0.0%	39.9%	5.7%
Fortune	0.8%	42.4%	5.8%
Olie-H 3.1%	0.8%	31.6%	5.5%
Hallmark	2.4%	34.1%	5.6%
Hallmark / Fortune	0.0%	36.6%	5.6%
Hallmark/Olie-H	0.8%	33.3%	5.5%
Programme 2	0.0%	38.6%	6.7%
Programme 2 / Olie-H 3.1%	0.8%	34.9%	5.6%
Crop Spray 11E 2.5%	0.8%	*24.1%	5.0%

Asterisks indicate the level of significance for the comparison between the treatment and the control. * indicates p-value between 0.01 and 0.05; ** between 0.001 and 0.01; *** less than 0.001.

B indicates model based on binomial distribution. QB indicates model based on quasi-binomial analysis (over-dispersed).

† analysis unreliable due to low proportions of infected plants observed.

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Table 5.2.15: 2011-13 Trials showing treatment differences for PVA - Refer to individual data tables for the statistical significance of results. Not all treatments were tested in each of the three years.

Treatment	Cambridge			Yorkshire			Fife		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Untreated	53.6%	5.7%	1.7%	(2.2%)			1.8%		5.2%
Fortune 0.5%	15.7%	7.6%	5.0%	(2.4%)			1.1%		4.8%
Olie H 3.1%	19.0%	3.9%	2.5%	(0.5%)			0.9%		1.6%
Hallmark	19.2%	7.5%	7.5%	(5.6%)			1.4%		1.6%
Hallmark/Fortune 0.5%	20.9%	7.9%	8.3%	(0.3%)			0.7%		7.2%
Hallmark/Olie-H 3.1%	17.5%	2.3%	2.5%	(0.7%)			1.7%		1.3%
Programme 1 OR ***2***	31.1%	***4.7%***	***4.4%***	(0.7%)			0.2%		***6.3%***
Programme 1 OR ***2*** / Olie-H 3.1%	25.3%	***3.3%***	***5.8%***	(0.7%)			0.5%		***4.5%***
Crop Spray 11E 2%							2.3%		
Hallmark/Crop Spray 11E 2%							1.7%		
Crop Spray 11E 2.5%									3.4%
Programme 2/Olie-H 6.2%									3.6%
Olie H 6.2%									1.5%

Results in brackets have shown significant between plot variability

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Table 5.2.16: 2011-13 Trials showing treatment differences for PVY^N - Refer to individual data tables for the statistical significance of results. Not all treatments were tested in each of the three years.

Treatment	Cambridge			Yorkshire			Fife		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Untreated	38.2%	16.9%	91.7%						11.5%
Fortune 0.5%	27.1%	12.1%	76.0%						11.2%
Olie H 3.1%	36.1%	4.5%	75.2%						16.2%
Hallmark	34.0%	15.9%	86.8%						15.9%
Hallmark/Fortune 0.5%	31.1%	15.7%	81.0%						9.4%
Hallmark/Olie-H 3.1%	30.2%	4.4%	68.5%						8.7%
Programme 1 OR ***2***	29.3%	***16.3%***	***93.9%***						***17.6%***
Programme 1 OR ***2*** / Olie-H 3.1%	28.6%	***15.2%***	***83.5%***						***12.7%***
Crop Spray 11E 2.5%									9.8%
Programme 2/Olie-H 6.2%									10.4%
Olie H 6.2%									4.8%

Data shown for Cambridge 2103 are for individual plants.

It should be noted that significant treatment effects were also recorded for $PVY^{o/c}$ but only on the Cambridge site in 2013 (Tables 5.2.12 & 5.2.14).

Virus transmission - Edinburgh

Table 5.2.17 shows that the overall level of PVY^N infection was low in 2011 and no evidence for a difference between the mineral oil and the control was found. However, the level of infection was much higher for PVA and strong evidence was found that the mineral oil reduced the proportion of infected plants.

Table 5.2.17: Results for the virus epidemiology trial 2011

	PVY^N with M Piper		PVA with Estima	
		Standard error		Standard error
Overall proportion	3.1%		24.8%	
Over dispersion found?	No		No †	
Treatment effect p-value	0.192		<0.001 †	
Estimated proportion for <u>untreated</u>	4.4%	1.6%	35.1%	3.9%
Estimated proportion for <u>Olie H</u>	1.9%	1.1%	15.2%	2.9%
Difference in proportion between treated and Olie H	2.5%	1.9%	19.9%	4.9%

† Given the low number of residual degrees of freedom and the small size of the block effect, the analysis was carried out without a block effect. The residual mean deviance was 1.88, which was marginally significant. Accommodating this would increase the standard errors but would not change the conclusion.

The results from the statistical analyses of the 2012 trial are given in Table 5.2.18. In summary, the overall level of PVY^N infection was higher than in 2011. However, although the level of virus incidence was lower in Maris Piper treated by Olie-H than King Edward, no significant difference was found between treatments.

The level of PVA infection was similar between 2011 and 2012. A greater proportion of Estima plants were infected than Desiree. Although there was no sign of overall treatment effect, there was weak evidence of an interaction. There was weak evidence for a decrease in PVA incidence between treatments (p-value=0.081) in Desiree. This seemed to be largely due to a lower infection in plants treated with Olie-H compared to the control.

Table 5.2.18: Results for the epidemiology trial 2012

	PVY^N				PVA			
Overall proportion	13.1%				22.5%			
Over dispersion found?	Yes (p-value=0.017)				No			
Variety effect p-value	<0.001				<0.001			
Treatment effect p-value	0.937				0.636			
Interaction effect p-value	0.554				0.076			
Variety	K Edward		M Piper		Desiree		Estima	
	Mean	Std error	Mean	Std error	Mean	Std error	Mean	Std error
Estimated proportion for untreated	17.5%	4.6%	8.3%	3.2%	19.5%	3.6%	29.1%	4.2%
Estimated proportion for Olie-H	24.0%	5.6%	5.3%	2.7%	8.9%	2.8%	33.1%	3.9%
Estimated proportion for Fortune	20.5%	5.3%	6.2%	3.0%	13.5%	2.9%	28.5%	4.1%

The analysis of virus incidence for different combinations of varieties/virus/treatments obtained in 2013 is presented in Table 5.2.19. In the PVY^N transmission trial, the overall PVY infection level was 30% (higher than the previous year 13.1% in 2012). Significant differences of PVY and PVA incidence between Olie H and Untreated plants were observed (p<0.001). This was consistent for all four varieties tested. PVY incidence in Olie-H-treated plants in comparison to the Untreated control plants was lower for Maris Piper (3-fold decrease 25.7% down to 8.5%) than King Edward (2-fold decrease 53.4% down to 25%). Analysis of the mean incidence per treatment indicated that Olie-H treatment was significantly more effective than Fortune and the Untreated control (5% LSDs).

In the PVA transmission trial, the overall incidence of PVA infection in 2013 was of 4.6%, (lower than previous year 22.5% in 2012). As for previous years, a higher proportion of Estima plants were infected in comparison to Desiree. Significant differences in PVA incidence between treatments and between varieties (albeit not a strong as observed for PVY) were observed. Analysis of the means revealed a higher level of inhibition of virus transmission in Olie-H-treated Estima plants (2.4%), in comparison to Fortune (9.4%) and Untreated control plants (10.9%).

In the PVA trial, 5.5% of plants were found to be infected with PVY^N which is due to the proximity of the PVY^N inoculum from the neighbouring PVY^N trial and aphid-borne

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infection to the Estima and Desiree crops, both varieties displaying significant level of susceptibility to PVY^N. Not surprisingly, no PVA infection was found on King Edward and Maris Piper as both varieties are resistant to PVA. There were no significant differences in PVY incidence between Estima and Desiree, however significant differences between treatments were observed. Overall, Untreated plants had an infection rate of 10.2%, which was significantly reduced in Olie H (2.3%) and Fortune (4.1%) treated plants (p-value<0.001).

Cumulative aphid vector pressure in the plots was measured by weekly monitoring of aphid catches from the 4 Yellow Water Traps. Broadly, increase in cumulative aphid vector pressure followed a similar pattern observed by the neighbouring suction trap (Figure 5.1.3). Mineral oil treatments therefore covered the period of highest aphid vector pressure (and virus transmission) at the earlier stage of plant growth and within the last week of the trial prior to haulm desiccation.

Table 5.2.19: Analysis of virus incidence per variety per treatment per virus (Edinburgh 2013).

	PVY^N				PVA			
Overall proportion	30.1%				4.6%			
Overdispersion found?	No				No			
Variety effect p-value	<0.001				<0.001			
Treatment effect p-value	<0.001				0.049			
Interaction effect p-value	0.070				0.630			
Variety	K Edward		M Piper		Desiree		Estima	
	Mean	Std error	Mean	Std error	Mean	Std error	Mean	Std error
Estimated proportion for <u>untreated</u>	53.4%	4.5%	25.7%	3.5%	2.3%	1.3%	10.9%	3.3%
Estimated proportion for <u>Olie H</u>	24.9%	3.4%	8.5%	2.1%	1.2%	1.0%	2.4%	1.3%
Estimated proportion for <u>Fortune</u>	42.2%	4.0%	32.4%	4.0%	1.8%	1.1%	9.4%	3.4%

A summary of the virus incidence in experimental trials over the period 2011-2013 at the Edinburgh site is presented in Table 5.2.20.

For PVY^N, strong evidence for differences between the treatments was found for Maris Piper (p-value 0.001) with Olie H treatment generating a greater protection to virus infection (estimated mean virus incidence of 4.3%) in comparison to Fortune (10.9%) or Untreated control (10.9%). However, for King Edward, no

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significant differences between treatments were found (p-value 0.762). (Note that the latter was not tested in 2011).

For PVA, no evidence for differences between the treatments was found for Estima (p-value 0.384). However, some evidence was found that infection levels varied between the treatments for Desiree (p-value 0.022) with Olie H treatment reducing infection levels down to 3.3% in comparison to the Untreated control (7.4%). Fortune had an estimated over-year mean of 5.1%.

Taken together, over these three years of trials, our results suggest that mineral oil (Olie H) treatment had an overall beneficial effect in protecting plants against virus infection, however, this was not seen consistently every year and for each variety tested.

Table 5.2.20: Incidence of infected plants in Edinburgh trials (2011-2013).

a. PVY^N trials.

Variety	Treatment	2011	2012	2013
K Edward	Untreated		17.5%	53.4%
	Olie H		24.0%	24.9%
	Fortune		20.5%	42.2%
M Piper	Untreated	4.4%	8.3%	25.7%
	Olie H	1.9%	5.3%	8.5%
	Fortune		6.2%	32.4%

b. PVA trials.

Variety	Treatment	2011	2012	2013
Desiree	Untreated		19.5%	2.3%
	Olie H		8.9%	1.2%
	Fortune		13.5%	1.8%
Estima	Untreated	35.1%	29.1%	10.9%
	Olie H	15.2%	33.1%	2.4%
	Fortune		28.5%	9.4%

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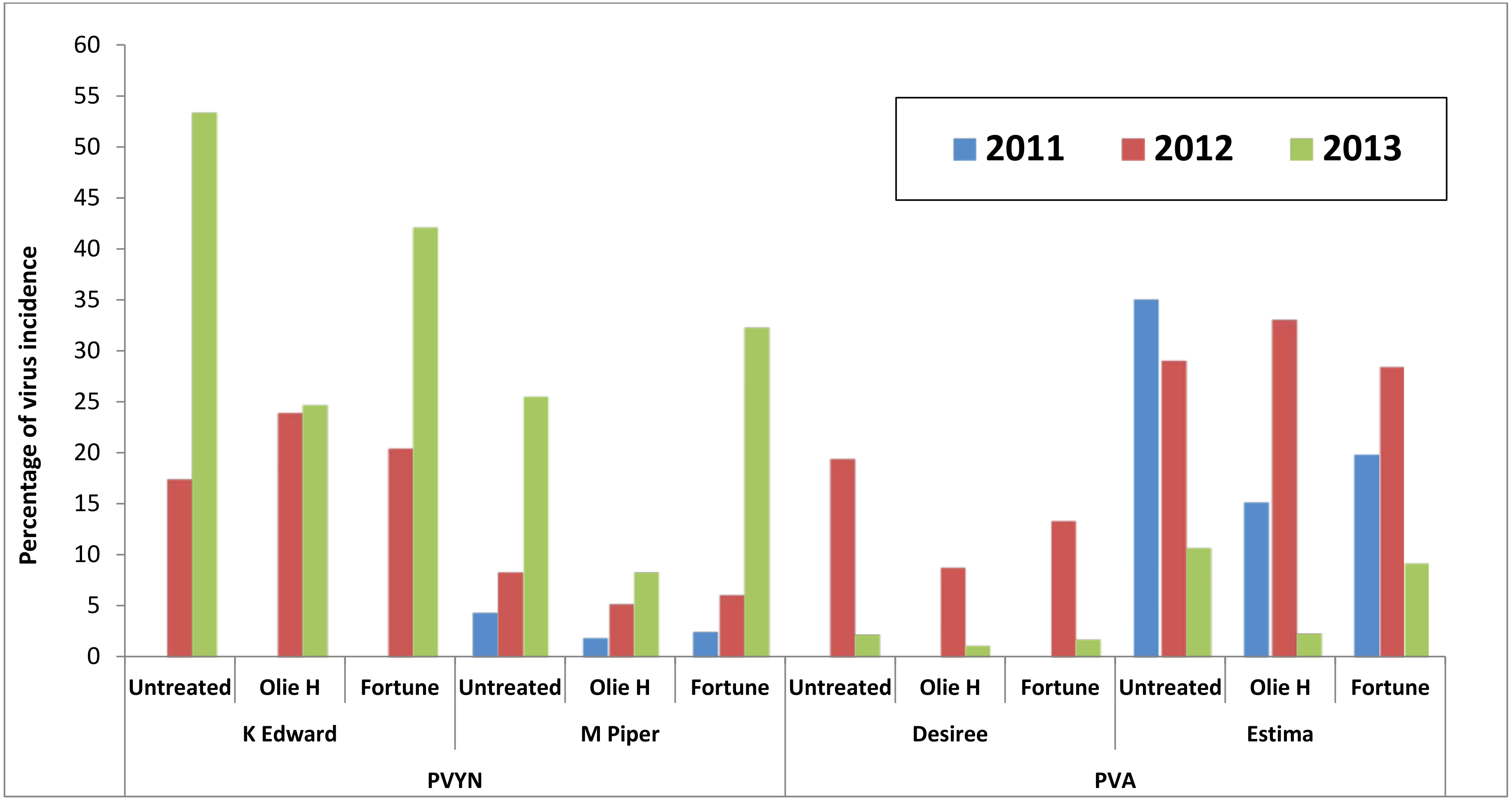

Figure 5.2.4: Virus incidence in Treated (Olie H 3.1%, Fortune 0.5%) and Untreated control plots at the Edinburgh site (%Virus Incidence).

Yield and Canopy Development

Table 5.2.21: Yield – Fife 2011

Treatment	Yield Total T/Ha	Yield <25mm T/Ha	Yield 25-30mm T/Ha	Yield 30-35mm T/Ha	Yield 35-40mm T/Ha	Yield 40-45mm T/Ha	Yield 45-50mm T/Ha	Yield 50-55mm T/Ha	Yield 55-60mm T/Ha	Yield 60-65mm T/Ha	Yield 65-70mm T/Ha	Yield >70mm T/Ha
1- Untreated	43.20	0.33	0.59	2.09	5.43	3.57	13.02	7.30	7.87	2.52	0.48	0
2- Fortune	41.18	0.27	0.57	1.66	5.46	3.13	11.60	6.53	6.94	3.63	1.02	0.37
3- Olie H 3.1%	46.32	0.16	0.53	1.61	4.77	4.67	14.89	6.67	8.21	4.27	0.56	0
4- Hallmark Zeon (HZ)	40.41	0.20	0.51	1.74	4.19	4.06	10.39	5.38	8.22	5.25	0.46	0
5- HZ & Fortune	45.70	0.21	0.37	1.34	4.52	3.47	10.78	7.69	9.29	5.50	0.92	1.62
6- HZ & Olie H	44.67	0.28	0.71	1.19	5.16	3.96	11.71	7.66	8.56	3.96	1.08	0.40
7- Programme 1	47.72	0.27	0.51	1.33	3.75*	4.46	13.30	7.79	8.95	5.23	1.25	0.88
8- Programme 1/Olie-H 3.1%	46.01	0.28	0.42	1.22	3.83*	4.01	12.62	6.93	9.70	4.36	2.64	0
9- Crop Spray 11E 2%	42.40	0.15	0.31	1.27	4.07	4.32	13.43	6.36	7.43	4.35	0.72	0
10- Crop Spray 11E 2%/HZ	40.94	0.23	0.36	1.25	3.59*	3.47	12.67	5.34	7.57	4.83	1.62	0
LSD (P=.05)	6.42	0.19	0.34	0.61	1.65	1.75	3.14	2.71	3.92	3.40	1.77	1.29
Standard Deviation	4.40	0.13	0.23	0.42	1.13	1.20	2.15	1.86	2.68	2.33	1.21	0.89
CV	10.02	53.18	47.42	28.58	25.25	30.57	17.28	27.46	32.42	53.12	112.67	271.26
Grand Mean	43.86	0.24	0.49	1.47	4.48	3.91	12.44	6.76	8.27	4.39	1.08	0.33

*Indicates a significant difference to the untreated control (p = 0.05)

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Table 5.2.22: Tuber Number – Fife 2011

Treatment	Number Total N°/Ha	Number <25mm N°/Ha	Number 25-30mm N°/Ha	Number 30-35mm N°/Ha	Number 35-40mm N°/Ha	Number 40-45mm N°/Ha	Number 45-50mm N°/Ha	Number 50-55mm N°/Ha	Number 55-60mm N°/Ha	Number 60-65mm N°/Ha	Number 65-70mm N°/Ha	Number >70mm N°/Ha
1- Untreated	605556	37037	35185	74074	122223	55556	153704	61111	53704	11112	1852	0
2- Fortune	550000	34259	35185	55556	122222	50000	128704	52778	48148	18519	3704	926
3- Olie H 3.1%	577778	20371	30556	57407	106482	72222	161111	54630	50000	23149	1852	0
4- Hallmark Zeon (HZ)	527778	25000	30556	64815	94445	65741	118519	44444	56482	25926	1852	0
5- HZ & Fortune	505555*	27778	22222	48148*	98148	56482	93518*	63889	59259	28704	2778	4629*
6- HZ & Olie H	569445	30556	40741	40740*	113889	63889	133333	63889	56482	20371	4630	926
7- Programme 1	580556	31481	30556	49074*	87037*	71296	152778	62963	61111	26852	4630	2778
8- Programme 1/Olie-H 3.1%	560494	34568	27161	51852*	85185*	62963	143210	58025	65432	22222	9876	0
9- Crop Spray 11E 2%	525000	18519	18519	48148*	89815	63889	154630	54630	51852	22222	2778	0
10- Crop Spray 11E 2%/HZ	499074*	26852	19445	47222*	82407*	54630	138889	45370	50926	26852	6482	0
LSD (P=.05)	93772	23023	18651	21019	35047	27651	41114	23025	24043	18311	6878	3806
Standard Deviation	64251	15775	12779	14402	24013	18946	28170	15776	16474	12546	4713	2608
CV	12	55	44	27	24	31	20	28	30	56	117	282
Grand Mean	550124	28642	29012	53704	100185	61667	137840	56173	55339	22593	4043	926

*Indicates a significant difference to the untreated control (p = 0.05)

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Table 5.2.23: Yield – Fife 2012

Treatment	Total T/Ha	<25mm T/Ha	25-30mm T/Ha	30-35mm T/Ha	35-40mm T/Ha	40-45mm T/Ha	45-50mm T/Ha	50-55mm T/Ha	55-60mm T/Ha	60-65mm T/Ha	65-70mm T/Ha	70-75mm T/Ha	>75mm T/Ha
1- Untreated	46.60	0.21	0.32	1.42	4.13	3.70	11.52	8.60	10.73	4.81	1.15	0	0
2- Fortune 0.5%	45.69	0.16	0.49	1.53	3.06	3.30	11.92	9.30	11.13	3.83	0.98	0	0
3- Olie-H 3.1%	42.93	0.15	0.43	1.23	2.91	3.65	11.70	9.67	9.86	2.56	0.50	0.27	0
4- Hallmark Zeon (HZ)	46.52	0.30	0.26	1.04	3.37	3.99	12.55	8.56	11.06	2.99	2.12	0.29	0
5- HZ & Fortune	44.54	0.19	0.25	1.26	3.17	4.59	11.67	8.38	10.40	3.32	1.31	0	0
6- HZ & Olie-H 3.1%	45.17	0.18	0.40	1.66	3.07	3.31	10.04	9.02	13.03	3.26	0.89	0.31	0
7- Programme 2	45.46	0.32	0.44	1.56	3.97	3.56	14.11	7.35	9.74	2.96	1.14	0.29	0
8- Programme 2/Olie-H 3.1%	39.75*	0.14	0.25	1.18	3.20	3.73	9.44	8.37	10.16	2.17	1.11	0	0.31
9- Programme 2/ Olie-H 6.2%	47.23	0.29	0.40	0.76	3.78	3.91	11.92	8.24	9.95	5.81	2.19	0	0
10- Olie-H 6.2%	41.33	0.18	0.30	1.07	3.62	4.11	9.83	8.28	10.84	2.04	0.75	0	0
11- Scot Ag 1	39.94	0.20	0.31	1.07	3.79	4.30	10.93	8.56	7.84	1.35	1.58	0	0
12- Scot Ag 2	45.57	0.19	0.31	1.16	2.98	3.27	11.52	7.98	13.09	3.59	1.15	0.32	0
LSD (P=.05)	5.94	0.21	0.27	0.60	1.52	1.60	2.90	2.66	3.50	2.74	1.68	0.56	0.26
Standard Deviation	4.12	0.15	0.19	0.42	1.06	1.11	2.01	1.85	2.42	1.90	1.16	0.39	0.18
CV	9.31	70.94	54.12	33.46	30.85	29.29	17.56	21.65	22.76	58.85	93.83	313.61	692.82
Grand Mean	44.23	0.21	0.35	1.24	3.42	3.79	11.43	8.53	10.65	3.23	1.24	0.12	0.03

*Indicates a significant difference to the untreated control (p = 0.05)

Note – Treatments 11 & 12 were additional treatments included by project collaborators but not released.

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Table 5.2.24: Tuber Number – Fife 2012

Treatment	Total N°/Ha	<25mm N°/Ha	25-30mm N°/Ha	30-35mm N°/Ha	35-40mm N°/Ha	40-45mm N°/Ha	45-50mm N°/Ha	50-55mm N°/Ha	55-60mm N°/Ha	60-65mm N°/Ha	65-70mm N°/Ha	70-75mm N°/Ha	>75mm N°/Ha
1- Untreated	553704	25926	18519	52778	93519	58333	141667	68519	65741	24074	4630	0	0
2- Fortune 0.5%	542593	19445	26852	55555	70370	53704	143519	77778	72222	19445	3704	0	0
3- Olie-H 3.1%	503704	15741	22223	43519	63889	59259	136111	82407	64815	12963	1852	926	0
4- Hallmark Zeon (HZ)	554630	42593	14815	38889	79630	67592	146296	71297	70371	13889	8333	926	0
5- HZ & Fortune	522222	19445	13889	46296	73148	75926	132408	71296	68519	16667	4630	0	0
6- HZ & Olie-H 3.1%	533334	22223	23148	62963	71297	53704	119445	76852	82408	16667	3704	926	0
7- Programme 2	575000	37963	26852	56482	90741	55556	162037	63889	62037	13889	4630	926	0
8- Programme 2/Olie-H 3.1%	470371*	16667	14815	41667	71296	60185	112963	70370	65741	11111	4630	0	926*
9- Programme 2/ Olie-H 6.2%	551852	40741	25000	27778	85185	62963	137963	70371	63889	29630	8333	0	0
10- Olie-H 6.2%	496296	19445	16667	38889	84259	67593	115741	70370	70371	10185*	2778	0	0
11- Scot Ag 1	503704	24074	18519	37037	88889	72222	125926	74074	50000	6482*	6482	0	0
12- Scot Ag 2	516667	22222	18519	41667	67593	50926	142593	67593	82407	17593	4630	926	0
LSD (P=.05)	94469	28063	15434	23407	33785	25757	34265	22305	22765	13761	6595	1747	772
Standard Deviation	65425	19435	10689	16211	23398	17838	23731	15448	15766	9530	4567	1210	535
CV	12	76	53	36	30	29	18	21	23	59	94	314	693
Grand Mean	527006	25540	19985	45293	78318	61497	134722	72068	68210	16049	4861	386	77

*Indicates a significant difference to the untreated control (p = 0.05)

Note – Treatments 11 & 12 were additional treatments included by project collaborators but not released

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Table 5.2.25: Yield – Fife 2013

Treatment	Total T/Ha	<25mm T/Ha	25-30mm T/Ha	30-35mm T/Ha	35-40mm T/Ha	40-45mm T/Ha	45-50mm T/Ha	50-55mm T/Ha	55-60mm T/Ha	60-65mm T/Ha	65-70mm T/Ha	70-75mm T/Ha	75-80mm T/Ha	>80mm T/Ha
1- Untreated	40.25	0.18	0.44	0.60	3.10	2.75	7.97	7.92	6.52	7.84	2.15	0.51	0.28	0
2- Fortune	41.50	0.23	0.64	0.75	3.41	2.15	8.53	7.27	6.95	9.48	1.79	0.32	0	0
3- Olie H 3.1%	42.23	0.23	0.71*	0.98	3.11	2.81	8.58	7.32	7.80	7.15	2.12	1.09	0.34	0
4- Hallmark Zeon (HZ)	40.08	0.21	0.41	0.83	2.74	2.50	6.58	6.79	7.85	7.96	3.66	0.58	0	0
5- HZ & Fortune	39.20	0.21	0.41	0.72	3.29	2.51	9.34	8.40	6.24	6.42	1.12	0.52	0	0
6- HZ & Olie H	40.43	0.23	0.77*	0.97	3.30	2.43	8.84	8.59	5.37	6.78	2.94	0.23	0	0
7- Programme 2	44.50	0.26	0.69	0.80	3.72	2.37	8.57	8.07	7.22	9.09	2.72	0.28	0.71	0
8- Programme 2/Olie-H 3.1%	41.08	0.15	0.60	1.44	2.91	2.07	8.99	5.13*	7.64	8.27	2.96	0.25	0.37	0.32*
9- Crop Spray 11E 2.5%	40.93	0.23	0.78*	1.12	3.53	2.65	8.67	6.56	8.31	6.22	2.86	0	0	0
10- Programme 2/Olie-H 6.2%	39.63	0.21	0.54	0.99	3.09	1.80*	10.92*	6.13	6.42	6.36	2.91	0.28	0	0
11- Olie H 6.2%	38.70	0.24	0.72*	0.93	3.12	2.61	9.06	8.03	6.54	5.63	1.22	0.61	0	0
LSD (P=.05)	4.58	0.14	0.28	0.59	1.31	1.06	1.90	2.88	2.60	3.50	2.62	1.16	0.82	0.27
Standard Deviation	3.17	0.10	0.19	0.41	0.90	0.74	1.32	2.00	1.80	2.42	1.82	0.80	0.57	0.19
CV	7.78	46.39	31.35	44.56	28.17	30.40	15.07	27.37	25.80	32.81	75.53	189.00	365.52	663.33
Grand Mean	40.77	0.21	0.61	0.92	3.21	2.42	8.73	7.29	6.99	7.38	2.40	0.42	0.15	0.03

*Indicates a significant difference to the untreated control (p = 0.05)

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Table 5.2.26: Tuber Number – Fife 2013

Treatment	Total N°/Ha	<25mm N°/Ha	25-30mm N°/Ha	30-35mm N°/Ha	35-40mm N°/Ha	40-45mm N°/Ha	45-50mm N°/Ha	50-55mm N°/Ha	55-60mm N°/Ha	60-65mm N°/Ha	65-70mm N°/Ha	70-75mm N°/Ha	75-80mm N°/Ha	>80mm N°/Ha
1- Untreated	467593	23148	26852	25000	71296	48148	100000	72222	46296	43519	8333	1852	926	0
2- Fortune	493519	38889	35185	26852	71296	37963	106482	65741	50000	52778	7408	926	0	0
3- Olie H 3.1%	524074	32408	40741	36111	76852	46296	115741	68519	55556	37963	9259	3704	926	0
4- Hallmark Zeon (HZ)	463889	30556	24074	30556	65741	42593	91667	62037	54630	44445	15741	1852	0	0
5- HZ & Fortune	498148	33333	24074	37037	77778	44445	117593	76852	45371	35186	4630	1852	0	0
6- HZ & Olie H	524074	27778	42593	37963	84259	45370	114815	77778	39815	39815	12963	926	0	0
7- Programme 2	545370*	42593	33334	31482	89815	42593	110185	75000	52778	52778	12037	926	1852	0
8- Programme/Olie-H 3.1%	494444	29630	35185	51852	65741	35185	111111	47222	55556	47222	12963	926	926	926*
9- Crop Spray 11E 2.5%	526852	39815	43518	41667	83333	47222	106482	56482	60185	36111	12037	0	0	0
10- Programme 2/Olie-H 6.2%	503704	40741	33333	37037	72222	31482*	136111	57408	46296	36111	12037	926	0	0
11- Olie H 6.2%	516667	35185	42593	36111	74074	46296	119445	72222	50000	33334	5556	1852	0	0
LSD (P=.05)	75384	22099	15162	20578	30302	19119	24896	25699	18000	18843	11158	3955	2183	806
Standard Deviation	52208	15305	10500	14251	20986	13241	17242	17798	12466	13050	7727	2739	1512	558
CV	10	45	30	40	28	31	15	27	25	31	75	191	359	663
Grand Mean	505303	34007	34680	35606	75673	42508	111785	66498	50589	41751	10269	1431	421	84

*Indicates a significant difference to the untreated control (p = 0.05)

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Table 5.2.27: Canopy Development Assessments – Fife 2012. Note no phytotoxicity symptoms were present on this trial.

Treatment	Canopy Height 16/08/2012 cm	Plants 08/10/2012 N^{o}/3m row	Stems 08/10/2012 N^{o}/3m row
1- Untreated	56.3	9.5	41.8
2- Fortune 0.5%	55.0	9.5	41.0
3- Olie-H 3.1%	48.8	9.5	37.8
4- Hallmark Zeon (HZ)	55.0	9.3	40.5
5- HZ & Fortune	56.3	9.5	43.0
6- HZ & Olie-H 3.1%	47.5	8.5	36.8
7- Programme 2	56.3	9.0	40.0
8- Programme 2/Olie-H 3.1%	55.0	9.3	40.3
9- Olie-H 6.2% early	46.3	9.8	42.3
10- Olie-H 6.2%	52.5	9.8	41.5
11- Scot Ag 1	45.0	9.8	37.8
12- Scot Ag 2	55.0	9.8	38.0
LSD (P=.05)	4.48	0.94	4.38
Standard Deviation	3.10	0.65	3.04
CV	5.92	6.92	7.58
Grand Mean	52.40	9.42	40.04

A significant reduction in canopy height was noted in all of the treatments where Olie-H was applied in all eight treatments. This effect was not present were Olie-H was included at wider intervals as part of an integrated programme with conventional insecticide products.

Table 5.2.28a: Seed grade yield distribution, Yorkshire 2011, t/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	0.22	0.19	0.12	0.29	6.57	7.80	28.16	43.35
2 Fortune 0.5%	0.25	0.10	0.21	0.30	5.59	9.24	21.23	36.93
3 Olie-H 3.1%	0.23	0.12	0.13	0.27	5.03	6.86	19.05	31.70*
4 Hallmark Zeon (HZ)	0.35	0.17	0.22	0.53	6.41	11.15	29.82	48.67
5 HZ/Fortune	0.33	0.16	0.13	0.60	6.16	9.61	23.66	40.68
6 HZ/Olie-H 3.1%	0.25	0.12	0.34	0.22	5.49	6.51	23.11	36.05
7 Programme 2	0.31	0.21	0.30	0.43	6.31	9.21	17.56*	34.35
8 Programme 2 Olie-H 3.1%	0.28	0.22	0.34	0.45	7.38	9.16	23.00	40.83
LSD (P=.05)	0.252	0.210	0.336	0.335	2.438	3.725	10.011	9.628
Standard Deviation	0.171	0.143	0.229	0.228	1.657	2.532	6.807	6.546
CV	61.79	88.48	102.28	57.2	27.09	29.13	29.34	16.75
Grand Mean	0.28	0.16	0.22	0.39	6.12	8.69	23.20	39.07

Table 5.2.28b: Seed grade number distribution, Yorkshire, 2011, numbers/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	17000	6000	1895	6871	92000	69000	152000	347000
2 Fortune 0.5%	16000	3000	3684	5598	61000	83000	114000	288000
3 Olie-H 3.1%	15000	4000	1895	6621	67000	58000	88000*	243000*
4 Hallmark Zeon (HZ)	24000	6000	4021	13424	90000	96000	164000	400000
5 HZ/Fortune	25000	4000	2932	14767	84000	86000	129000	348000
6 HZ/Olie-H 3.1%	19000	4000	9553	4320	76000	60000	131000	307000
7 Programme 2	22000	7000	4531	10493	88000	82000	98000*	317000
8 Programme 2 Olie-H 3.1%	20000	8000	9899	10760	106000	83000	130000	368000
LSD (P=.05)	17062	7133	10121	7901	36306	33364	47368	71662
Standard Deviation	11600	4850	6882	5372	24685	22685	32206	48724
CV	58.74	92.38	103.87	55.1	29.74	29.41	25.61	14.89
Grand Mean	19750	5250	4801	9107	83000	77125	125750	327250

*Indicates a significant difference to the untreated control (p = 0.05)

Table 5.2.29a: Seed grade yield distribution, Yorkshire 2012, t/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	0.22	0.78	0.98	2.13	2.26	4.08	9.71	20.16
2 Fortune 0.5%	0.54	0.62	1.07	2.14	2.98	4.93	8.48	20.76
3 Olie-H 3.1%	0.34	0.82	1.14	1.97	2.72	3.09	4.56	14.64*
4 Hallmark Zeon (HZ)	0.30	0.82	1.14	2.01	3.01	3.48	7.15	17.91
5 HZ/Fortune	0.48	0.57	1.31	2.49	3.71	3.27	5.32	17.13
6 HZ/Olie-H 3.1%	0.09	0.54	0.86	1.68	2.56	3.89	8.03	17.65
7 Programme 2	0.24	0.52	0.96	1.56	2.33	3.93	8.93	18.48
8 Programme 2 Olie-H 3.1%	0.12	0.29	0.75	1.25	2.54	4.32	8.02	17.29
LSD (P=.05)	0.36	0.60	0.66	1.21	1.44	1.51	5.78	5.51
Standard Deviation	0.24	0.41	0.45	0.82	0.98	1.03	3.93	3.74
CV	82.78	66.36	43.6	43.12	35.42	26.57	52.2	20.8
Grand Mean	0.26	0.57	1.03	1.90	2.76	3.87	7.53	18.00

Table 5.2.29b: Seed grade number distribution, Yorkshire, 2012, numbers/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	15192	17213	23889	36111	31111	37778	56667	220556
2 Fortune 0.5%	19400	22441	29444	38333	37222	46111	48889	245556
3 Olie-H 3.1%	20572	30304	30556	35000	35000	28889	27778*	224444
4 Hallmark Zeon (HZ)	24613	22654	31667	35000	40000	32222	39444	231111
5 HZ/Fortune	26752	20803	35000	42778	46667	30556	31667	247222
6 HZ/Olie-H 3.1%	9155	18277	20556	30000	32222	33333	44444	190000
7 Programme 2	19113	21058	25556	28889	28889	36111	52222	218889
8 Programme 2 Olie-H 3.1%	15192	17213	23889	36111	31111	37778	56667	220556
LSD (P=.05)	21997.5	18452.7	17413.8	21839.7	18542.5	13917.0	27621.9	69614.3
Standard Deviation	14956.3	12546.2	11839.8	14849.0	12607.2	9462.3	18780.4	47331.5
CV	7.17	5.2	43.72	44.45	35.67	26.82	43.2	21.54
Grand Mean	19256	21822	28095	35159	35873	35000	43016	225397

*Indicates a significant difference to the untreated control (p = 0.05)

Table 5.2.30a: Seed grade yield distribution, Yorkshire, 2013, t/ha

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Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	0.23	0.54	1.13	1.82	3.49	6.24	34.61	48.40
2 Fortune 0.5%	0.21	0.63	0.79	1.69	3.33	8.41	35.79	51.27
3 Olie-H 3.1%	0.17	0.56	1.23	2.06	2.54	8.34	33.49	49.34
4 Hallmark Zeon (HZ)	0.18	0.88	1.12	1.81	4.99	6.46	41.83	57.71
5 HZ/Fortune	0.23	0.58	0.86	1.46	2.44	5.28	36.88	47.89
6 HZ/Olie-H 3.1%	0.19	0.74	0.54	1.81	3.12	8.01	31.77	46.33
7 Programme 2	0.18	0.62	0.93	1.79	3.48	5.24	35.34	47.87
8 Programme 2 Olie-H 3.1%	0.21	0.40	1.09	1.67	3.99	7.14	31.04	46.06
9 Crop Spray 11 E	0.08	0.38	0.74	1.53	4.57	5.82	30.48	43.68
LSD (P=.05)	0.13	0.31	0.73	0.92	1.93	3.72	9.40	10.72
Standard Deviation	0.09	0.21	0.50	0.63	1.32	2.55	6.44	7.34
CV	47.42	35.65	35.85	36.22	37.24	15.1	18.62	15.07
Grand Mean	0.19	0.59	0.94	1.74	3.55	6.77	34.58	48.73

Table 5.2.30b: Seed grade number distribution, Yorkshire, 2013, numbers/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	22222	23333	29863	35556	45556	51445	176667	378357
2 Fortune 0.5%	16667	25556	20136	32222	42222	73483	186667	402203
3 Olie-H 3.1%	18889	22222	31717	38889	33333	74559	172222	381257
4 Hallmark Zeon (HZ)	15556	35556	29227	34444	61111	58667	222222	459249
5 HZ/Fortune	21111	24444	19682	25556	32222	50868	192222	365892
6 HZ/Olie-H 3.1%	18889	32222	12285	33333	37778	74739	164444	374996
7 Programme 2	16667	24444	24039	28889	46667	48585	181111	374004
8 Programme 2 Olie-H 3.1%	21111	16667	27425	30000	44444	65412	167778	378161
9 Crop Spray 11 E	6667	17778	19682	28889	55556	54757	152222	335675
LSD (P=.05)	13981.2	12318.4	19720.6	16864.0	24638.8	31922.6	49905.0	96626.9
Standard Deviation	9579.6	8440.3	13512.2	11554.9	16882.0	21872.8	34194.0	66206.9
CV	54.64	34.18	27.02	36.14	38.09	3.1	19.05	1.32
Grand Mean	17531	24691	23784	31975	44321	61391	179506	383310

Table 5.2.31a: Seed grade yield distribution, Cambridge, 2011, t/ha

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Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	0.60	0.32	0.48	0.48	5.36	5.84	23.16	36.24
2 Fortune 0.5%	0.60	0.20	0.40	0.72	5.00	6.96	20.84	34.76
3 Olie-H 3.1%	0.48	0.28	0.32	0.28	5.88	7.12	21.24	35.52
4 Hallmark Zeon (HZ)	0.64	0.48	0.24*	0.72	5.32	5.16	20.8	33.32
5 HZ/Fortune	0.60	0.32	0.16*	0.76	4.72	5.76	22.6	34.92
6 HZ/Olie-H 3.1%	0.60	0.12	0.20*	0.44	3.80	5.28	24.08	34.52
7 Programme 2	0.72	0.44	0.36	0.56	4.76	5.24	23.88	35.92
8 Programme 2 Olie-H 3.1%	0.64	0.20	0.56	0.40	4.44	5.92	25.28	37.36
LSD (P=.05)	0.341	0.239	0.234	0.435	1.673	1.829	6.616	5.636
Standard Deviation	0.232	0.163	0.159	0.296	1.138	1.244	4.498	3.832
CV	38.75	54.72	48.3	54.4	23.18	21.07	19.79	10.85
Grand Mean	0.61	0.29	0.34	0.54	4.91	5.91	22.73	35.32

Table 5.2.31b: Seed grade number distribution, Cambridge, 2011, numbers/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	49000	11000	13000	12000	75000	48000	114000	322000
2 Fortune 0.5%	44000	8000	11000	18000	71000	59000	103000	314000
3 Olie-H 3.1%	45000	10000	9000	6000	84000	57000	111000	322000
4 Hallmark Zeon (HZ)	60000	16000	7000	19000	75000	43000	93000	310000
5 HZ/Fortune	51000	11000	5000*	19000	71000	45000	110000	312000
6 HZ/Olie-H 3.1%	42000	5000	6000*	11000	58000	43000	107000	272000*
7 Programme 2	48000	14000	10000	13000	68000	43000	107000	303000
8 Programme 2 Olie-H 3.1%	48000	7000	16000	9000	64000	50000	117000	311000
LSD (P=.05)	19624.0	8406.2	6842.4	10559.7	23703.7	17116.0	25300.2	45378.0
Standard Deviation	13342.6	5715.5	4652.2	7179.7	16116.4	11637.4	17201.9	30853.0
CV	27.58	55.76	48.33	53.68	22.9	23.99	15.96	10.01
Grand Mean	48375	10250	9625	13375	70750	48500	107750	308250

*Indicates a significant difference to the untreated control (p = 0.05)

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Table 5.2.32a: Seed grade yield distribution, Cambridge, 2012, t/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	0.21	1.79	2.80	5.03	6.31	10.01	5.24	31.41
2 Fortune 0.5%	0.31	1.19	2.61	4.68	7.75	11.22	6.59	34.35
3 Olie-H 3.1%	0.31	1.32	2.20	5.23	5.74	8.84	4.43	28.08
4 Hallmark Zeon (HZ)	0.24	1.63	2.64	5.21	7.46	12.53	7.82	37.54
5 HZ/Fortune	0.31	1.40	2.54	5.39	7.42	10.19	6.00	33.25
6 HZ/Olie-H 3.1%	0.17	1.41	2.01	4.44	5.41	5.64*	1.81	20.89*
7 Programme 2	0.21	1.88	2.30	5.19	7.29	8.73	6.20	31.80
8 Programme 2 Olie-H 3.1%	0.25	1.83	2.13	4.43	5.56	8.10	4.53	26.83
LSD (P=.05)	0.140	0.664	0.937	1.537	2.876	3.689	4.686	7.652
Standard Deviation	0.095	0.452	0.637	1.045	1.956	2.508	3.186	5.203
CV	37.55	29.0	26.51	21.11	29.55	26.66	59.79	17.05
Grand Mean	0.25	1.56	2.40	4.95	6.62	9.41	5.33	30.52

Table 5.2.32b: Seed grade number distribution, Cambridge, 2012, numbers/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	20000	83333	72778	85556	76667	83333	28889	450556
2 Fortune 0.5%	32778	56111	64444	77778	89444	90556	33333	444444
3 Olie-H 3.1%	30556	59444	54444	88333	69444	71667	23333	397222
4 Hallmark Zeon (HZ)	20000	73889	67222	88333	85000	96667	38333	469444
5 HZ/Fortune	23889	67778	63889	89444	87778	83333	31111	447222
6 HZ/Olie-H 3.1%	16667	66111	52778	77778	65000	46667*	9444	334444*
7 Programme 2	25556	86111	58889	89444	84444	69444	32222	446111
8 Programme 2 Olie-H 3.1%	28333	83333	54444	76111	66111	65000	23333	396667
LSD (P=.05)	16291.4	29473.2	24544.2	25175.0	32366.6	28473.2	23097.4	89969.3
Standard Deviation	11076.7	20039.1	16687.8	17116.7	22006.4	19359.3	15704.2	61171.1
CV	44.8	27.8	27.3	20.4	28.2	25.5	57.1	14.5
Grand Mean	24722	72014	61111	84097	77986	75833	27500	423264

*Indicates a significant difference to the untreated control (p = 0.05)

Table 5.2.33a: Seed grade yield distribution, Cambridge, 2013, t/ha

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Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	1.02	1.32	1.83	5.04	7.48	8.94	9.71	35.36
2 Fortune 0.5%	0.81	0.92	2.84*	5.63	7.46	7.00	10.08	34.74
3 Olie-H 3.1%	1.47	1.36	2.18	5.56	7.89	7.63	9.13	35.21
4 Hallmark Zeon (HZ)	0.77	1.21	2.00	5.63	7.81	9.04	9.39	35.86
5 HZ/Fortune	0.98	1.67	2.69*	5.30	6.91	8.41	9.04	35.00
6 HZ/Olie-H 3.1%	1.08	1.39	2.70*	5.79	6.59	7.69	7.92	33.16
7 Programme 2	0.92	1.32	1.91	5.86	6.30	10.36	8.94	35.61
8 Programme 2 Olie-H 3.1%	0.59	1.19	1.92	3.64	7.02	7.28	9.04	30.69
9 Crop Spray 11 E	0.86	1.40	2.23	4.09	6.69	9.24	7.83	32.34
LSD (P=.05)	0.704	0.562	0.693	2.001	2.181	3.306	3.845	4.904
Standard Deviation	0.482	0.385	0.475	1.371	1.494	2.265	2.635	3.360
CV	51.15	29.41	21.04	26.51	20.97	26.97	29.24	9.82
Grand Mean	0.94	1.31	2.26	5.17	7.13	8.40	9.01	34.22

Table 5.2.33b: Seed grade number distribution, Cambridge, 2013, numbers/ha

Treatment	<30mm	30-34mm	35-39mm	40-44mm	45-49mm	50-54mm	>55mm	Total
1 Untreated	107778	55556	54444	92222	103333	86667	60123	564445
2 Fortune 0.5%	90000	41111	80000	101111	98889	67778	64370	547778
3 Olie-H 3.1%	101111	62222	63333	98889	103333	74444	55180	560000
4 Hallmark Zeon (HZ)	87778	54444	55556	106667	107778	91111	62537	567778
5 HZ/Fortune	130000	70000	74444	96667	91111	78889	54792	596667
6 HZ/Olie-H 3.1%	128889	61111	77778*	103333	87778	75556	52186	588889
7 Programme 2	108889	53333	55556	108889	91111	95556	55282	571111
8 Programme 2 Olie-H 3.1%	78889	54444	57778	70000	88889	72222	55684	481111
9 Crop Spray 11 E	96667	62222	63333	74444	90000	86667	47274	524444
LSD (P=.05)	40564.8	21386.2	18208.1	37605.3	28406.4	30752.5	23703.9	86277.3
Standard Deviation	27794.2	14653.4	12475.9	25568.2	19463.5	21071.0	16241.5	59115.6
CV	26.9	25.6	19.3	27.1	20.3	26.0	2.5	10.6
Grand Mean	103333	57160	64691	94691	95802	80988	56381	555803

*Indicates a significant difference to the untreated control (p = 0.05)

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No consistent effects were noted on tuber yield or number at the Fife (Tables 5.2.21 – 5.2.26), Yorkshire or Cambridge sites (Tables 5.2.28a - 5.2.33b). Relatively few significant differences from the untreated control were observed. At the Yorkshire site in 2011, total tuber number and yield were reduced for treatment 3. Olie-H 3.1% and for total yield only in 2012 but not where it was mixed with Hallmark Zeon (treatment 8). The apparent treatment effects were reversed on the Cambridge site in 2011 and 2012 with treatment 3 Olie-H not differing from the untreated control and treatment 8. Olie-H + Hallmark Zeon showing reduced total yield or tuber number.

5.3. Phytotoxicity and the Effects on Visual Seed Crop Inspection

5.3.1. SASA Edinburgh

The plots were assessed to determine any effect of the oil applications on visual crop inspection according to the standard practice for seed certification.

Phytotoxic effects were observed with all three oil treatments. The symptoms observed were necrotic spotting and necrosis of the leaf midrib, and leaflet midrib and veins (Figs. 5.3.1 & 5.3.2). Symptoms were worst in the plots treated with Fortune and least in the plots treated with the lower concentration (3.1%) of Olie-H.

Overall, however, the severity of the phytotoxic symptoms observed were not at a level that would impact on the visual inspection of a commercial seed crop for purity and freedom from disease.

Figure 5.3.1: Phytotoxic symptoms observed on the foliage of cv. Desiree treated with mineral oil.

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Figure 5.3.2: Phytotoxic symptoms observed on the foliage of cv. Desiree treated with mineral oil.

No plant height differences were observed between the treated and untreated portions of each plot. A slight reduction in plant height and spread had been observed with Maris Piper treated with Olie-H @ 3% in 2011 but this effect was not observed in 2012 or in 2013.

During the course of the trial all virus infected plants (Cabaret and Desiree infected with PVA; Estima infected with PVA and PVV; Charlotte, Harmony, Maris Peer and Maris Piper infected with PVY^N; and Saxon, Valor and Wilja infected with PVY^O) were clearly visible and there were no differences in their appearance (symptom expression) between the sprayed (with Olie-H at one of two concentrations or Fortune) and unsprayed portions of each plot.

There was no effect of the oil application on the trueness-to-type of the 10 varieties (Cabaret, Charlotte, Desiree, Estima, Harmony, Maris Peer, Maris Piper, Saxon, Valor and Wilja) used in the trial.

As noted in previous trials using mineral oils, rain water tended to bead on the surface of leaflets and be retained on the foliage of plants for longer compared with untreated plants (Fig. 5.3.3). However, while water beading was observed after rain in the plots treated with Olie-H, there was no water beading observed in the plots treated with Fortune.

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Figure 5.3.3: Beading of rain water on the foliage of cv. Cabaret treated with the mineral oil Olie-H.

No lodging was observed with any of the oil treatments in 2012 or 2013. Transitory lodging was observed in 2011 but both treated and untreated areas recovered. This may have been attributable to the exceptionally heavy downpours of rain which were characteristic of the growing season in 2011. Although there was above average rainfall during the growing season in 2012, it was steadier in nature.

5.3.2. NIAB Cambridge

A descriptive scale was devised to evaluate the incidence and severity of the marking observed, and type reactions are shown in Fig 5.3.4. Lower, mid, and upper canopy layers in the unreplicated demonstration plots were assessed.

Lower, mid, and upper canopy layers in the unreplicated observation plots were assessed. There were differences between dose rates of Olie-H, variety and some indication of a seed stock effect within the same variety (Table 5.3.1). The degree of discolouration, estimated visually by assessing % of leaves affected in each canopy layer also varied between variety and rate of Olie-H treatment (Table 5.3.2).

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1 = few speckles and streaks down veins, < 1% leaf area
2 = specks and streaks more numerous, 1-5% leaf area
3 = larger speckles and streaking, 6-10% leaf area
4 = widespread brown necrotic tissue, 11-20% leaf area

Figure 5.3.4: Representative pictures of the severity of leaf marking associated with Olie-H application (2012)

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Table 5.3.1. Observation on severity (1 to 4 scale) to two rates of Olie-H treatment (3.1% and 6.25%) in different variety, seed -stock and virus combinations in lower, mid and upper canopy layers. Cambridge 2012

Variety/stock	**Lower** 3.1%	**Mid** 3.1%	**Top** 3.1%	**Lower** 6.25%	**Mid** 6.25%	**Top** 6.25%
Estima	1	2	0	3	3	0
Unknown	2	3	0	3	3	0
Sapphire	1	1	0	2	2	0
M. Peer	2	2	0	3	3	0
Unknown	1	1	0	2	2	0
M Peer	1	1	0	2	2	2
M Piper	1	1	0	1	2	0
Charlotte	3	3	0	3	3	0
Harmony	2	2	0	4	4	0
Saxon	1	1	0	3	3	0
M Piper	1	1	0	1	1	0
Bambino	2	2	0	3	3	0
M Piper	1	1	0	1	1	0
Marfona	1	1	0	1	1	0
M Peer	2	2	0	2	2	0
Desiree	3	3	0	4	4	0

The 2012 plots were demonstrated to the PHSI training day delegates at NIAB Cambridge on 14th June after a spray applied on 13th June. The virus infected plants were clearly visible to the inspectors, but there were no phytotoxicity symptoms visible on leaves sprayed by Olie-H or Fortune. Markings subsequently appeared on Olie-H treated plots only on the afternoon of 15th June , and were assessed on 9th July. The same sequence of events took place on the Estima trial plots. No markings were observed at Headley Hall, in contrast to 2011.

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Table 5.3.2: Observation on incidence (% leaflets affected) by foliar markings for two rates of Olie-H treatment in different variety, seed stock and virus combinations in lower, mid and upper canopy layers. Cambridge 2012.

	Canopy Position					
Variety/stock Olie-H treated	**Lower** 3.1%	**Mid** 3.1%	**Top** 3.1%	**Lower** 6.25%	**Mid** 6.25%	**Top** 6.25%
Estima	20	30	0	25	25	0
Unknown	10	10	0	20	20	0
Sapphire	5	5	0	5	5	0
M. Peer	10	10	0	10	10	0
Unknown	5	5	0	5	5	0
M Peer	5	5	0	10	10	0
M Piper	5	5	0	20	20	0
Charlotte	20	20	0	20	20	0
Harmony	20	20	0	20	20	0
Saxon	10	10	0	20	20	0
M Piper	5	5	0	5	5	0
Bambino	25	25	0	20	20	0
M Piper	10	10	0	10	10	0
Marfona	5	5	0	5	5	0
M Peer	10	10	0	20	20	0
Desiree	25	25	0	35	35	0

Table 5.3.4: Mean reaction type and % leaflets affected in Estima trial plots, 9th July, lower half of canopy only.

Treatment	Reaction type (Severity Score 0-4)	% affected
Untreated	0	0
Fortune	0	0
Olie-H	2.5	55
Hallmark Zeon	0	0
HZ/Fortune	0.25	2.5
HZ/Olie-H	1.5	50
Sumi Alpha/HZ/programme	0	0
Sumi Alpha/ HZ/Olie-H/programme	0.62	7.5

The appearance of the markings coincided with a short period of greater sunshine hours in the 48 hours after spray application (see Fig 5.3.5). The leaf layers which were affected were only those exposed at the 13th June spray, and no further symptom development was seen after subsequent sprays which were applied after extended sunshine periods rather than before. The marking severity did not decline or increase after appearance.

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The information presented in tables 5.3.1 & 5.3.2 was collected from the unreplicated observation plots, therefore cannot be analysed statistically. Accordingly, no further conclusions cannot be made from the observations.

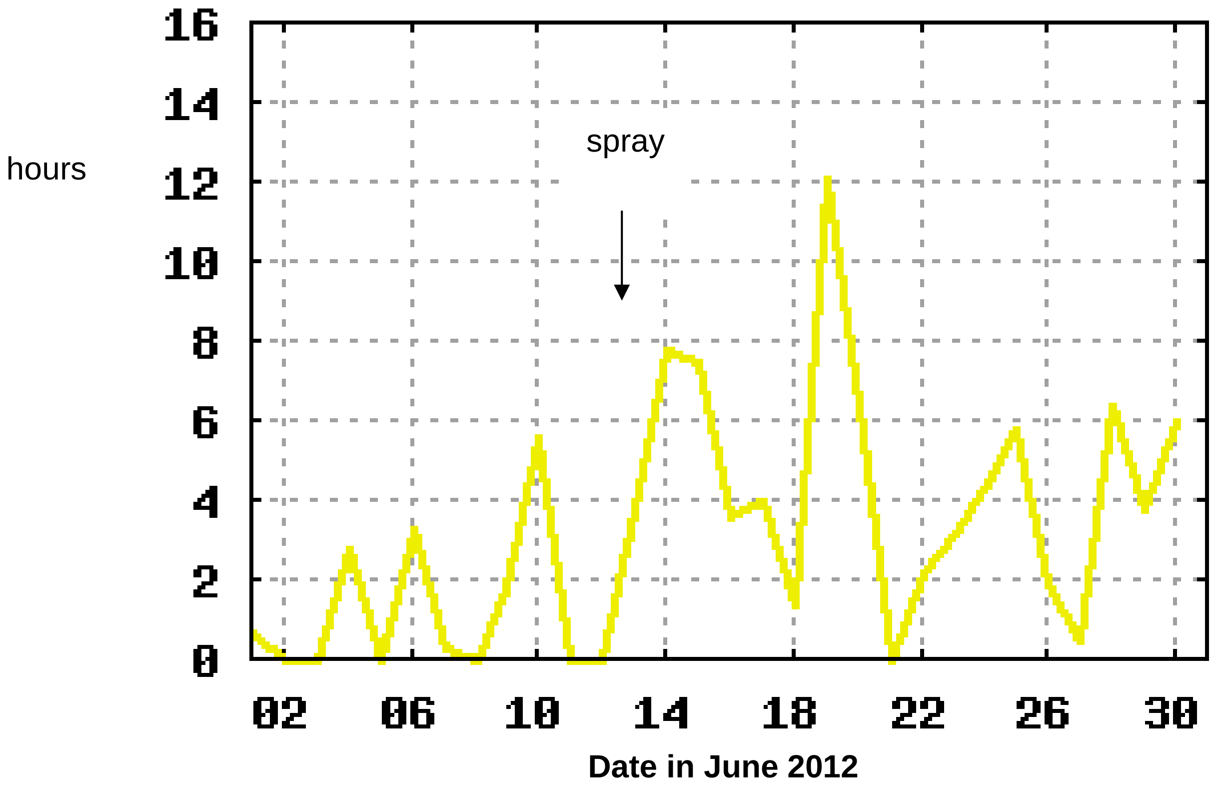

Figure 5.3.5: Sunshine hours recorded 3 miles from Cambridge trial ground, June 2012.

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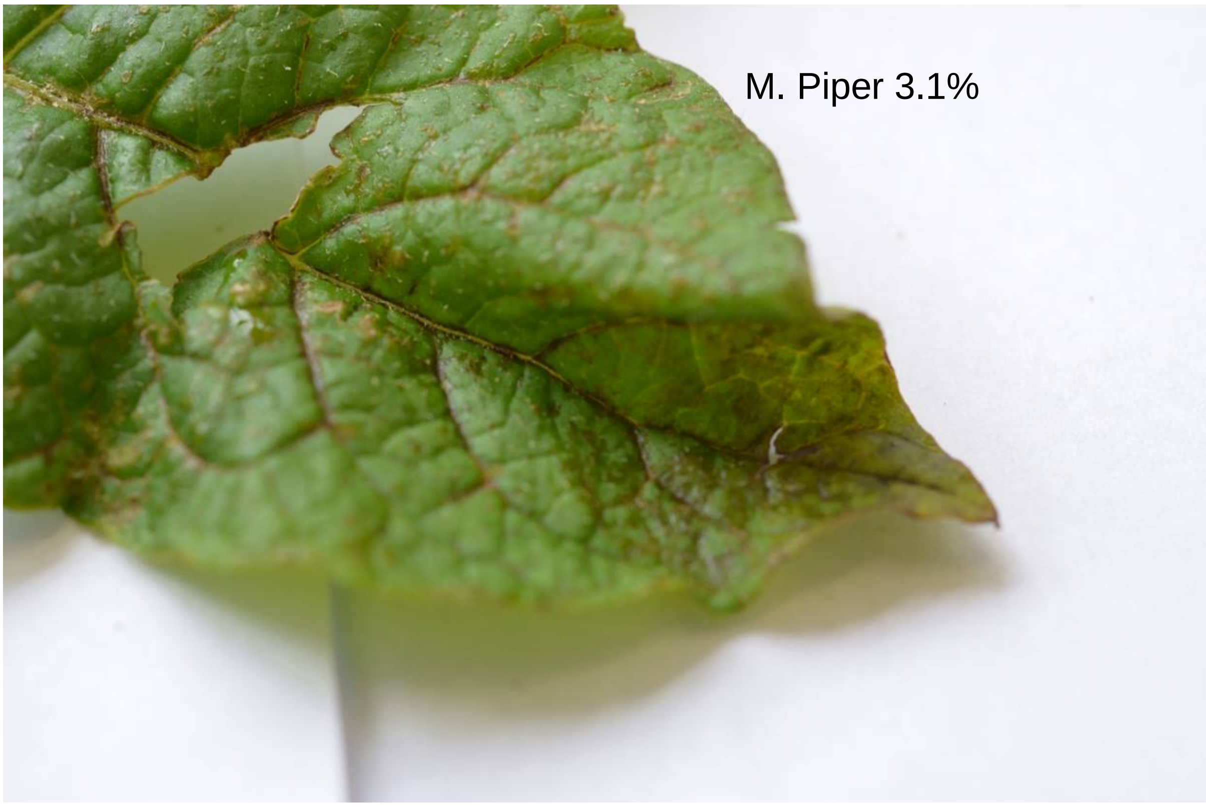

Figures 5.3.6 Typical reactions on a range of varieties in the demonstration plots.

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The 2013 plots were demonstrated to the PHSI training day delegates at NIAB Cambridge on the 11th June after a spray applied on 7th June. Foliar markings at low levels were visible in the oil treated variety plots and in the main Estima trial on some treatments. The inspectors identified virus infected plants correctly and commented that they could see no difficulty in identifying varieties. The foliar markings developed in further leaf layers following subsequent sprays. These layers were all in the lower canopy. The severity of the markings was scored on 11th July using the scale devised previously. At the Yorkshire site symptoms appeared on 2nd July, and were assessed on the same day. Their appearance seemed to be linked to a spray applied on the 26th June since no development was seen prior to this, or after subsequent sprays.

5.4. Results of blight control trials

An overview of the three years of trial work are provided in section 5.4.1. The results for the individual years are described in sections 5.4.2 to 5.4.4.

5.4.1 Trials investigating the effect of tank mixing oils with commonly used fungicides for blight control: overview of results from 3 years (2011 to 2013)

The tables below (Tables 5.4.1 to 5.4.6) list the mean AUDPC values for treatments. The AUDPC values for the 27 paired comparisons of fungicide alone versus fungicide plus oil were used to summarise the 3 years' results. Fungicide plus oil treatments were categorised as having either significantly greater efficacy, significantly worse efficacy or similar efficacy compared with fungicide alone (Table 5.4.7). The 3 years of results were summarised through this categorisation. The same categorisation procedure was used to summarise the impact of oil mixed with fungicide on blight-free yield (Table 5.4.8).

The foliar blight severity results together with those for tuber blight and yield from the individual trials are presented and described in sections 5.4.2 (2011), 5.4.3 (2012) and 5.4.4 (2013).

Table 5.4.1 Effect of oil and fungicide on AUDPC in Rapid Canopy 2011

Treatment[1]	**Mean AUDPC**
1. Ranman A + B	378
2. Ranman A + B + Olie H	1089
3. Revus	270
4. Revus + Olie H	219
5. Resplend[2]	852
6. Resplend + Olie H	450
F pr.	<.001
LSD (*P*=0.05)	220.6

[1] There was no untreated in this trial
2 The name Resplend was discontinued to be replaced by Percos

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Table 5.4.2 Effect of oil and fungicide on AUDPC in Rapid Canopy 2012

Treatment	Mean AUDPC
1. Untreated	9084
2. Ranman Top	3161
3. Ranman Top + Olie H	1583
4. Revus	1494
5. Revus + Olie H	779
6. Percos	2058
7. Percos + Olie H	1141
F pr.[1]	<.001
LSD (*P*=0.05)	544.2
F pr.[2]	<.001
LSD (*P*=0.05)	540.4

[1] All treatments included in analyses
[2] Untreated excluded from analyses

Table 5.4.3 Effect of oil and fungicide on AUDPC in Rapid Canopy trial 2013

Treatment	Mean AUDPC
1. Untreated	3209
2. Ranman Top	1011
3. Ranman Top + Olie H	1043
4. Revus	794
5. Revus + Olie H	414
6. Revus + CropSpray 11E	547
7. Revus + Fortune	401
8. Revus + Axidor	416
9. Revus + Axidor + Olie H	446
11. Percos	1438
12. Percos + Olie H	915
13. Percos + CropSpray 11E	1097
14. Percos + Fortune	1057
15. Invader	849
16. Invader + CropSpray 11E	745
17. Invader + Fortune	634
18. Valbon + Zin Zan	607
20. Valbon + Zin Zan + Olie H	647
F pr.[1]	<.001
LSD (*P*=0.05)	145.4
F pr.[2]	<.001
LSD (*P*=0.05)	148.2

[1] All treatments included in analyses
[2] Untreated excluded from analyses

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Table 5.4.4 Effect of oil and fungicide on AUDPC in Stable Canopy 2011

Treatment	**Mean AUDPC**
1. Untreated	1827.2
2. Shirlan	747.3
3. Shirlan + Olie H	1250.2
4. Infinito	576.5
5. Infinito + Olie H	502.2
6. Invader	522.4
7. Invader + Olie H	301.1
8. Valbon + Zin Zan	374.2
9. Valbon + Zin Zan + Olie H	351.4
F pr.[1]	<.001
LSD (*P*=0.05)	106.27
F pr.[2]	<.001
LSD (*P*=0.05)	107.10

[1] All treatments included in analyses
[2] Untreated excluded from analyses

Table 5.4.5 Effect of oil and fungicide on AUDPC in Stable Canopy 2012

Treatment	**Mean AUDPC**
1. Untreated	2671
2. Curzate M	818
3. Curzate M + Olie H	818
4. Infinito	573
5. Infinito + Olie H	510
6. Invader	668
7. Invader + Olie H	474
8. Valbon + Zin Zan	658
9. Valbon + Zin Zan + Olie H	462
F pr.[1]	<.001
LSD (*P*=0.05)	169.8
F pr.[2]	<.001
LSD (*P*=0.05)	160.6

[1] All treatments included in analyses
[2] Untreated excluded from analyses

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Table 5.4.6 Effect of oil and fungicide on AUDPC in Stable Canopy 2013

Treatment	Mean AUDPC
1. Untreated	2836
7. Invader	376
8. Invader + Olie H	204
9. Infinito	484
10. Infinito + Olie H	688
F pr.[1]	<.001
LSD (P=0.05)	213.9
F pr.[2]	<.001
LSD (P=0.05)	212.6

[1] All treatments included in analyses
[2] Untreated excluded from analyses

Over the 3 years, 14 out of the 27 tank mixes of oil plus fungicide tested resulted in significantly improved control of foliar blight (Table 5.4.7). For 11 tank mixes the oil had no significant effect on foliar blight control by the fungicide partner. Only two combinations of oil plus fungicide significantly impaired blight control. These two tank mixes were Ranman A + B (the Twinpack formulation that was withdrawn from the market during this study) + Olie H in the rapid canopy trial in 2011; and the Shirlan + Olie H tank mix in the stable canopy trial in the same year. The testing of these two tank mixes was therefore discontinued after the first year.

Some core combinations of oil plus fungicide were tested three times to check the repeatability of results in different growing seasons, i.e. Olie H with Infinito, Invader, Percos, Revus or Valbon + ZinZan. The effect of Olie H on the efficacy of individual fungicides was most consistent for Infinito and Percos but also consistent for Invader and Revus (Table 5.4.7). In 2013, the final year of field experiments, tank mixes of an additional mineral oil, Cropspray 11 E, or a vegetable oil, Headland Fortune (Headland Diamond) with Invader, Percos and Revus were tested. The impact of these two additional oils on blight fungicide efficacy was consistent with that obtained with Olie H. When the three oils were compared tank mixed with Revus or Percos all three tank mixes were significantly more effective than straight fungicide. When Cropspray 11E and Fortune were compared tank mixed with Invader, Fortune significantly improved control of foliar blight compared with Invader alone whereas Cropspray 11E gave equivalent control to the fungicide alone. However, because different oils were only compared in 2013 and only in the Rapid Canopy trial, conclusions regarding the relative efficacies of the different oils must be considered to be preliminary.

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Table 5.4.7 Summary of foliar blight results (AUDPC data) across the 3 years (2011 to 2013)

			Compared with fungicide alone the tank mix with oil was:		
Fungicide	**Oil**	**No. of times tank mix tested**	**significantly less effective**	**equally effective**	**significantly more effective**
Curzate M	Olie H	1		Stable 2012	
Infinito	Olie H	3		Stable 2011, 2012 & 2013	
Invader	Olie H	3		Stable 2013	Stable 2011 & 2012
	Cropspray 11 E	1		Rapid 2013	
	Fortune	1			Rapid 2013
Percos	Olie H	3			Rapid 2011, 2012 & 2013
	Cropspray 11 E	1			Rapid 2013
	Fortune	1			Rapid 2013
Ranman A+B	Olie H	1	Rapid 2011		
Ranman Top	Olie H	2		Rapid 2013	Rapid 2012
Revus	Olie H	3		Rapid 2011	Rapid 2012 & 2013
	Cropspray 11 E	1			Rapid 2013
	Fortune	1			Rapid 2013
Revus + Axidor	Olie H	1		Rapid 2013	
Shirlan	Olie H	1	Stable 2011		
Valbon + ZinZan	Olie H	3		Stable 2011 Rapid 2013	Stable 2012

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A similar summary of the blight-free yield results over the 3 years demonstrated that only 3 out of 27 tank mixes of oil plus fungicide resulted in a significantly higher blight-free yield than the comparative straight fungicide: Percos + Olie H and Revus + Olie H in the 2012 rapid canopy trial and Revus + Fortune in the 2013 rapid canopy trial (Table 5.4.8). For 22 tank mixes the inclusion of oil had no significant effect on blight-free yield. Two tank mixes resulted in a significantly reduced yield: Olie H tank mixed with Ranman A + B (the Twinpack formulation that is no longer marketed) in the 2011 rapid canopy trial and the same oil combined with Valbon + ZinZan in the 2013 rapid canopy trial.

The effect of Olie H on blight-free yield was consistent for Infinito, Invader and Ranman Top. Percos or Revus tank mixed with Olie H were not quite as consistent in that the tank mixes either had no significant effect on yield or significantly boosted it. The yield results for Olie H mixed with Valbon plus ZinZan were also inconsistent: a significantly lower blight-free yield with oil in the rapid canopy trial in 2013 and one that was not significantly lower than for Valbon plus ZinZan in the stable canopy trials in 2011 and 2012. In 2013 tank mixes of fungicide with the alternative oils Cropspray 11E or Fortune had similar effects to Olie H tank mixes on blight-free yield (Table 5.4.8).

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Table 5.4.8 Summary of blight-free yield results across the 3 years

			Compared with the blight-free yield for fungicide alone the yield for the tank mix with oil was:		
Fungicide	**Oil**	**No. of times tank mix tested**	**significantly lower**	**not significantly different**	**significantly higher**
Curzate M	Olie H	1		Stable 2012	
Infinito	Olie H	3		Stable 2011, 2012 & 2013	
Invader	Olie H	3		Stable 2011, 2012 & 2013	
	Cropspray 11 E	1		Rapid 2013	
	Fortune	1		Rapid 2013	
Percos	Olie H	3		Rapid 2011 & 2013	Rapid 2012
	Cropspray 11 E	1		Rapid 2013	
	Fortune	1		Rapid 2013	
Ranman A+B	Olie H	1	Rapid 2011		
Ranman Top	Olie H	2		Rapid 2012 & 2013	
Revus	Olie H	3		Rapid 2011 & 2013	Rapid 2012
	Cropspray 11 E	1		Rapid 2013	
	Fortune	1			Rapid 2013
Revus + Axidor	Olie H	1		Rapid 2013	
Shirlan	Olie H	1		Stable 2011	
Valbon + ZinZan	Olie H	3	Rapid 2013	Stable 2011 & 2012	

Symptoms of phytotoxic damage were only observed in the 2011 stable canopy trial for one treatment: Shirlan plus Olie H (see Section 5.4.2). However, a frequently seen effect attributable to mineral oil treatment was the beading of water droplets on the surface of leaflets.

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5.4.2 Trials investigating the effect of tank mixing oils with commonly used fungicides for blight control: 2011

In the 2011 rapid canopy trial the timing of three of the applications of test fungicides, i.e. S2, S4 and S5, were such that they occurred immediately after periods of potential high infectivity pressure therefore products with curative activity may have been favoured (Table 5.4.9).

Table 5.4.9 Smith Period occurrence during test substance application (Rapid Canopy 2011)

Intervals 8, 8, 9, 9

July	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	P	P	P	N								P	P		
			S2								S3				

August	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	P	P	P	P	P		P	P		P	P	P	P	P		N
				S4									S5			

- P Smith criteria (temperature and relative humidity) met on the day
- N Smith criteria almost met on the day but RH short by 1 hour
- PP Full Smith Period

The different fungicides and tank mixes were exposed to a high inoculum challenge in this experiment. In 2011 there was no untreated control but in an adjacent, trial foliar blight in completely untreated plots developed as shown below.

Severity of foliar blight (%)	10-Aug	17-Aug	24-Aug	01-Sep	07-Sep	14-Sep	27-Sep
Untreated	2.75	55.00	77.50	91.25	96.75	100.00	100.00

In the rapid canopy trial, foliar blight was first recorded within 10 days of the first application of the test treatments. Disease severity had increased to 1% in the least effective treatment by the time of the fourth, and final, test fungicide spray on 13th August. The effect of Olie H on the efficacy of fungicides against foliar blight was not consistent across the three fungicides. When the six mineral oil factorial treatments were analysed separately, later in the epidemic highly significant interaction terms for fungicide x Olie H were

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obtained, i.e. the term was not significant on 29th July, 5th and 12th August but <0.001 on 19th and 26th August, 2nd and 9th September. Olie H tank mixed with Ranman TP had a significant deleterious effect on the efficacy of this fungicide (Fig. 5.4.1). The effect was significant from 19th August onwards. The application of Olie H with Resplend improved blight control compared with this fungicide alone; the improvement was significant from 2nd September onwards. The efficacy of Revus was similar with and without Olie H.

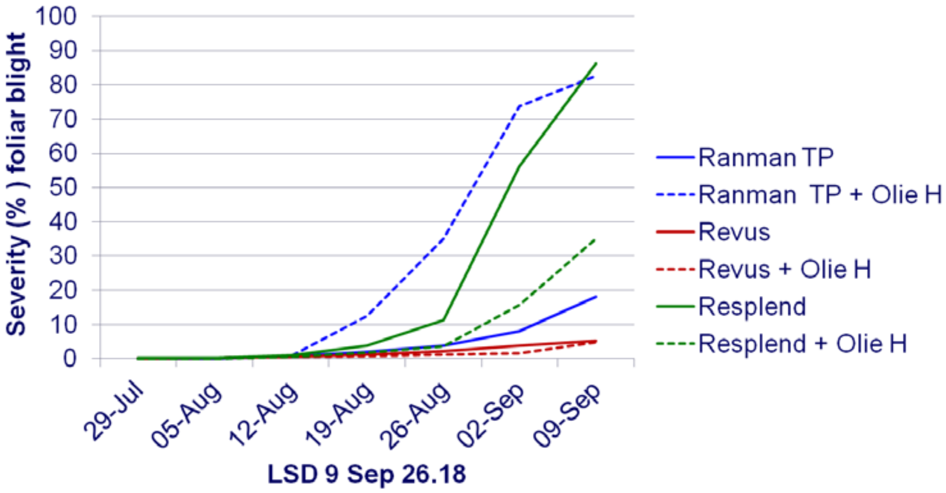

Fig. 5.4.1 - Foliar blight development on cv. King Edward in relation to fungicide treatments applied during rapid canopy (2011).

In general the incidence of tuber blight pre-storage of the tubers was low. This was probably due to all programmes including five applications of Shirlan; one prior to rapid haulm growth and four leading up to desiccation. Tuber blight was only recorded in one treatment, i.e. Resplend + Olie H but there were no significant differences between treatments (Table 5.4.10).

Plots in the 2011 rapid canopy trial were examined for phytotoxic damage on 25th July and 4th, 12th, 19th and 31st August. Phytotoxicity symptoms were only observed in two plots and only on one date, i.e. 19 August. Both plots were Revus + Olie H but the symptoms were limited, 0.5 and 1% severity, and transient. The symptom was yellowing of the middle of the leaf, especially the leaflet margins. Both plots were in the same planted block of potatoes.

On 12th August Olie H-treated plots were obvious due to the very large number of large water droplets remaining on leaves. Plots not treated with Olie H had dry leaves in the upper canopy, lower leaves were wet but moisture was spread thinly over the leaf surface as it normally is after rain. On 12th August oil-treated plots were considerably lower in height and much more open (more soil and plant stem visible). It was considered that the weight of the large water droplets was causing leaves to droop and leaflets to curl down at the edges. One week later the height differences were difficult to discern. By 31st August half the number of plots could not be assessed for damage symptoms because foliar blight was too severe.

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Blight-free yields were calculated taking account of pre-storage tuber blight data (Table 5.4.10). The impact of the inclusion of Olie H was not consistent across the three fungicides. The interaction term for fungicide x Olie H in the analysis restricted to the six mineral oil project treatments was highly significant (F pr. = 0.004). Olie H tank mixed with Ranman TP significantly reduced blight-free yield compared with the straight fungicide treatment (Table 5.4.10).

Table 5.4.10 - Pre-storage tuber blight, yield and blight-free yield on King Edward in relation to fungicide applied at 7-10 day intervals during rapid canopy (2011)

	Pre-storage tuber blight incidence (%)				**Yield**	**Blight-free yield**
Treatment	**By weight**	**By number**	**By weight ***	**By number ***	**(t/ha)**	**(t/ha)**
1. Ranman TP	0.00	0.00	0.00	0.00	24.82	24.82
2. Ranman TP + Olie H	0.00	0.00	0.00	0.00	16.54	16.54
3. Revus	0.00	0.00	0.00	0.00	27.29	27.29
4. Revus + Olie H	0.00	0.00	0.00	0.00	29.38	29.38
5. Resplend	0.00	0.00	0.00	0.00	18.52	18.52
6. Resplend + Olie H	0.36	0.50	1.71	2.03	23.54	23.43
LSD	0.457	0.552	2.028	2.254	5.231	5.238
F pr. (*P*=0.05)	0.161	0.068	0.116	0.069	<0.001	<0.001

* transformed data (angular)

Six applications of test fungicides were applied to the stable canopy trial (Table 5.4.11). Four of the applications were curative, i.e. 9, 17 and 24 August and 22 September. The target spray intervals were 7 to 10 days. The spray dates and intervals are shown below. There was one extended interval due to several days of weather unsuitable for fungicide application.

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Table 5.4.11 Smith Period occurrence during test substance application (Stable Canopy 2011)

Intervals 8, 7, 9, 12, 8

August	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
	P	P	P	P	P		P	P		P	P	P	P	P		N
									S							

August	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
	N			P	P	P		P							
	S							S							

September	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
	P		P			P	P	N				P				
		S												S		

September	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
	P			P					
					S				

September	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
	P			P	P				
						S			

- P Smith criteria (temperature and relative humidity) met on the day
- N Smith criteria almost met on the day but RH short by 1 hour
- PP Full Smith Period
- S Spray application

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Date	09-Aug	17-Aug	24-Aug	02-Sep	14-Sep	22-Sep
Interval (days)	10	8	7	9	12	8

The effect of Olie H on the efficacy of fungicides against foliar blight was not consistent across the four fungicides. When the eight mineral oil treatments were analysed separately highly significant interaction terms for fungicide x Olie H were generally obtained, i.e. 0.273 (15th Aug.), <0.001 (22nd Aug.), 0.002 (29th Aug.), <0.001 (5th, 14th and 29th Sep.).

The trial provided a severe test of the fungicides and tank mixes (Fig. 5.4.2; Table 5.4.12). The severity of foliar blight was not significantly affected by tank mixing Olie H with either Infinito or Valbon + ZinZan. In contrast, the addition of Olie H to Shirlan resulted in significantly more severe foliar blight at all assessments, except the first. The control of foliar blight was significantly greater for the tank mix of Invader than the straight fungicide but only on one of the earlier assessments (22nd August) and the final one on 20th September.

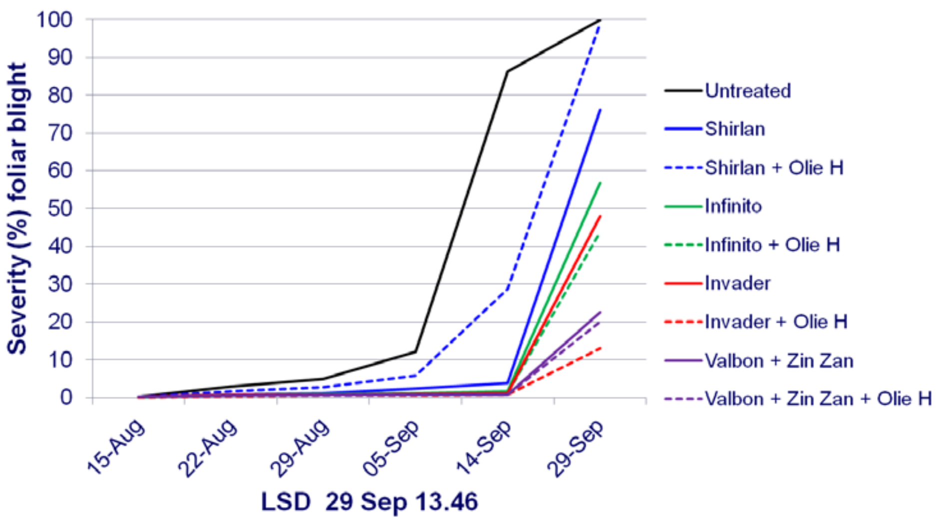

Fig. 5.4.2 - Severity (%) foliar blight on King Edward in relation to fungicide applied during stable canopy at 7-10 day intervals (2011)

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Table 5.4.12 - Severity (%) foliar blight on King Edward in relation to fungicide applied during stable canopy at 7-10 day intervals (2011)

Treatment	**15-Aug**	**22-Aug**	**29-Aug**	**05-Sep**	**14-Sep**	**29-Sep**
1. Untreated	0.15	3.00	4.88	12.12	86.25	100.00
2. Shirlan	0.28	0.73	1.20	2.35	3.75	76.20
3. Shirlan + OH	0.28	1.73	2.75	5.88	28.75	99.00
4. Infinito	0.08	0.68	0.88	1.10	1.62	56.90
5. Infinito + OH	0.08	0.73	0.90	1.13	1.17	43.80
6. Invader	0.20	0.68	0.83	0.93	1.07	48.10
7. Invader + OH	0.03	0.35	0.50	0.65	0.77	13.10
8. Valbon + ZinZan	0.18	0.63	0.70	0.78	0.80	22.50
9. Valbon + ZinZan + OH	0.15	0.55	0.63	0.73	0.75	20.00
LSD	0.183	0.342	0.520	1.305	5.528	13.460
F pr. (*P*=0.05)	0.030	<.001	<.001	<.001	<.001	<.001
LSD	0.186	0.282	0.507	0.863	5.258	13.72
F pr. (Untreated excluded) (*P*=0.05)	0.033	<.001	<.001	<.001	<.001	<.001

Blight-free yields were calculated using the pre-storage tuber blight data (Table 5.4.12). Differences in blight-free yield were not statistically significant. In addition when the eight mineral oil treatments were analysed separately the fungicide x Olie H interaction term was not significant. The lower blight-free yield for the combination of Olie H plus Shirlan compared with straight Shirlan reflects foliar blight control. Additional experiments are required to investigate the yield response to Olie H for Valbon + ZinZan because the lower yield with mineral oil cannot be related to foliar blight severity and/or pre-storage tuber blight. Additional tuber blight developed during storage therefore comments are restricted to the total incidence of tuber blight, i.e. pre- plus post-storage (Table 5.4.14).

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Table 5.4.13 - Pre-storage tuber blight incidence (%), yield and blight-free yield for King Edward in relation to fungicide applied during stable canopy at 7-10 day intervals (2011)

Treatment	By Weight	By Number	By weight*	By number*	Yield (t/ha)	Blight-free yield (t/ha)
1. Untreated	0.00	0.00	0.00	0.00	25.33	25.33
2. Shirlan	0.56	0.76	2.15	2.47	35.46	35.30
3. Shirlan + OH	0.29	0.51	1.53	2.04	28.54	28.47
4. Infinito	0.00	0.00	0.00	0.00	42.92	42.92
5. Infinito + OH	0.00	0.00	0.00	0.00	44.58	44.58
6. Invader	0.25	0.50	1.44	2.03	45.84	45.72
7. Invader + OH	1.39	1.25	4.51	4.48	47.63	46.99
8. Valbon + ZinZan	1.25	1.50	3.75	4.22	42.52	42.12
9. Valbon + ZinZan + OH	0.18	0.26	0.86	1.04	37.84	37.76
LSD	0.854	0.999	2.905	3.408	7.942	7.936
F pr. (*P*=0.05)	0.048	0.009	0.048	0.019	<0.001	<0.001
LSD	-	-	-	-	8.014	8.010
F pr. (Untreated excluded) (*P*=0.05)	-	-	-	-	0.001	0.001

***transformed data (angular)**
OH=Olie H

The fungicide x Olie H interaction terms from the ANOVAs of total tuber blight were all significant, i.e. 0.022 (by weight), 0.020 (by weight, transformed) and 0.033 (by number), indicating that the response to Olie H was different for some of the fungicides. The tuber blight results should be interpreted with caution because of substantial differences in the rate of foliar blight development for some pairs of treatments, e.g. Invader minus and plus Olie H. Excellent control of tuber blight was achieved with Infinito alone or tank mixed with Olie H (Table 5.4.14). With Shirlan, tuber blight control was not significantly affected by Olie H. Mixing the mineral oil with Valbon plus ZinZan consistently and significantly reduced the incidence of tuber blight. However, tuber blight was greater where Olie H was added to Invader; significantly so when tuber blight was expressed as a percentage of tuber weight.

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Table 5.4.14 - Total tuber blight incidence (%) (pre- plus post-storage) for King Edward in relation to fungicide applied at 7-10 day intervals during stable canopy (2011)

Treatment	By weight	By number	By weight*	By number*
1. Untreated	0.00	0.00	0.00	0.00
2. Shirlan	1.07	1.27	2.98	3.23
3. Shirlan + OH	0.44	0.75	1.90	2.47
4. Infinito	0.00	0.00	0.00	0.00
5. Infinito + OH	0.00	0.00	0.00	0.00
6. Invader	0.62	1.00	3.15	4.07
7. Invader + OH	2.42	2.25	7.10	7.27
8. Valbon + ZinZan	2.72	2.99	6.96	7.57
9. Valbon + ZinZan + OH	0.44	0.52	1.35	1.47
LSD	1.319	1.423	3.641	4.096
F pr. (*P*=0.05)	0.002	<0.001	<0.001	<0.001

OH=Olie H
***transformed data (angular)**

The foliar symptoms in Fig. 5.4.3 were photographed on the 23rd of August in the stable canopy trial for the plots treated with Shirlan + Olie H. The photograph was taken 6 days after the second application of the tank mix. Symptoms were clearly visible after the first application but severity was not recorded at this time. The severity (% of leaf surface affected) was on average 13.8% on 18th August (1 day after second application of the tank mix). By 29th August too much foliar blight prevented accurate assessment of plots treated with Shirlan + Olie H. Phytotoxicity symptoms were not recorded for any other canopy stable treatment. Assessments continued until 8th September, 6 days after four applications of the test treatments.

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Fig 5.4.3 – Leaf symptoms Shirlan + Olie H 23rd August 2011

It was also observed that water 'beading' and retention occurred on the surface of leaves treated with Olie H. The two photographs below (Figs 5.4.4 and 5.4.5) were taken on 8 September at 13.30, 6.5 hours after the last recorded rainfall. NB there was trace rainfall just before the photographs were taken which accounts for the small water droplets on the Infinito-treated leaves.

Figs. 5.4.4 & 5.4.5 - Leaf Surface wetness 6.5 hours after last recorded rainfall. Infinito (top) and Infinito + Olie H (bottom) (2011).

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Table 5.4.15 Hourly rainfall at Auchincruive during 24 hours before the photographs in Figs 5.4.4 and 5.4.5 were taken (2011).

Date	Time	Rain (mm)
07-Sep	13:00	0.0
07-Sep	14:00	0.2
07-Sep	15:00	0.0
07-Sep	16:00	0.2
07-Sep	17:00	0.0
07-Sep	18:00	0.4
07-Sep	19:00	1.4
07-Sep	20:00	0.2
07-Sep	21:00	0.8
07-Sep	22:00	0.4
07-Sep	23:00	0.4
07-Sep	00:00	0.6
08-Sep	01:00	0.0
08-Sep	02:00	0.0
08-Sep	03:00	0.0
08-Sep	04:00	0.0
08-Sep	05:00	2.2
08-Sep	06:00	4.2
08-Sep	07:00	0.4
08-Sep	08:00	0.0
08-Sep	09:00	0.0
08-Sep	10:00	0.0
08-Sep	11:00	0.0
08-Sep	12:00	0.0
08-Sep	13:00	0.0
08-Sep	14:00	0.0

5.4.3 Trials investigating the effect of tank mixing oils with commonly used fungicides for blight control: 2012

In 2012 weather conditions were very favourable for the development of foliar blight: six Smith periods were recorded in July, eight in August and two in September (Table 5.4.16). It is acknowledged that the Smith period criteria may not be fully applicable to the strains of blight present in this season. However, the observations do provide an indication that 2012 was a very high blight risk season at the Auchincruive site, especially compared with 2013.

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Table 5.4.16 Blight high-risk conditions 2012 (SRUC, Auchincruive, Diamond Field, Met. Office data) and spray dates for the rapid canopy and stable canopy trials.

June	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
						P		**P**		**P**						
Period																

	17	18	19	20	21	22	23	24	25	26	27	28	29	30
						P	**P**	**P**			**P**	**P**	**P**	**P**
Period												**1**		**2**

July	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		P	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**N**					
Period			**3**		**4**		**5**		**6**							
Rapid													**S**			
Stable											**S**					

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		P	**P**	**P**			**P**	**P**		**P**					
Period			**7**					**8**							
Rapid				**S**							**S**				
Stable	**S**							**S**							**S**

August	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	P	**P**		**P**	**P**	**P**					**P**		**P**	**P**		**P**
Period		**9**			**10**									**11**		
Rapid			**S**							**S**						
Stable				**S**				**S**							**S**	

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	P	**P**		**P**	**P**	**P**	**P**	**P**	**P**	**(P)**	**P**	**P**			
Period	**12**				**13**		**14**		**15**			**16**			
Rapid	**S**							**S**							
Stable						**S**							**S**		

Sept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	P	**P**					**P**	**P**		**P**						
Period		**17**						**18**								
Rapid			**S**								**S**					
Stable						**S**										

	17	18	19	20	21	22	23	24	25	26	27	28	29	30
														N
Rapid														
Stable		**S**								**S**				

26 Aug missed by 0.1 ^{o}C in one hour.

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P Smith criteria (temperature and relative humidity) met on the day
N Smith criteria almost met on the day but RH short by 1 hour
P P Full Smith Period. There were eighteen during the season; six in July, eight in August and two in September.
NP Near Miss.
S Spray application

For the rapid canopy trial there were three Smith Periods during the 22-day period of protection given by the test fungicides (20 July until to 10 August).The first and third applications of test fungicides had the opportunity of curative activity.

The trial was planted late deliberately, so that rapid canopy development took place in the presence of a significant inoculum challenge from other trials in the field. This approach was successful. Foliar blight developed very quickly from the time of inoculation on 19 July. Untreated control plots that were not treated with fungicide on 20 July, 27 July and 3 August were completely killed by blight by 15 August (Table 5.4.17).

The late planting and severe, early attack by blight substantially limited haulm growth where fungicide protection was insufficient. In addition, a period of very wet weather in late June/early July prevented the second part of the planned herbicide programme being applied to this trial. Together these factors resulted in considerable weed growth later in the growing season in the rapid canopy trial. This growth prevented accurate assessments of foliar blight after 22 August and therefore the results of the assessment made on 29 August were discarded.

For all three fungicides tested tank mixing Olie-H improved the control of foliar blight compared with straight fungicide (Table 5.4.17). The improvement was statistically significant for Ranman Top and Percos on the last two dates of assessment. The lack of statistical significance with Revus is most likely due to the better control of foliar blight by this fungicide leaving little scope for significantly improved control.

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Table 5.4.17 Severity (%) foliar blight on King Edward in relation to rapid canopy fungicide (2012)

Treatment	25Jul	01Aug	08Aug	15Aug	22Aug
1. Untreated[1]	0.50	14.38	72.50	100.00	100.00
2. Ranman Top	0.47	0.90	1.50	30.00	41.20
3. Ranman Top + Olie-H	0.40	0.77	0.92	5.25	11.20
4. Revus	0.50	0.90	1.10	6.87	6.20
5. Revus + Olie-H	0.20	0.30	0.55	0.80	2.40
6. Percos	0.22	0.70	0.87	12.62	18.70
7. Percos + Olie-H	0.12	0.25	0.50	2.23	6.10
LSD	0.131	2.850	8.961	7.708	9.980
F pr. (*P*=0.05)	<0.001	<0.001	<0.001	<0.001	<0.001
LSD[2]	0.132	0.200	0.463	8.080	10.540
F pr. (*P*=0.05)	<0.001	<0.001	<0.001	<0.001	<0.001

[1] All treatments comprised Curzate M x 1, test fungicide x 3 then Quell Flo x 5

[2]Treatment 1 (untreated) excluded from analyses

The blight-free yield for treatment 1, which missed only three fungicide applications, was exceptionally low (Table 5.4.18). For all three fungicides, tank mixing Olie-H increased blight-free yield. The increase was statistically significant for Revus and Percos, the two fungicides which resulted in the highest yields when applied alone. Blight-free yields were increased by 24.1%, 34.1% and 34.1% for Olie-H tank mixed with Ranman Top, Revus and Percos respectively.

Table 5.4.18 Yield and blight-free yield in relation to rapid canopy fungicide (2012)

Treatment	Yield (t/ha)	Blight-free Yield (t/ha)
1. Untreated[1]	1.15	1.15
2. Ranman Top	7.44	6.89
3.Ranman Top + Olie-H	8.56	8.55
4. Revus	11.53	11.53
5. Revus+ Olie-H	15.46	15.46
6. Percos	10.33	10.24
7. Percos + Olie-H	13.73	13.73
LSD	2.745	2.575
F pr. (*P*=0.05)	<0.001	<0.001
LSD[2]	2.905	2.726
F. pr. (P=0.05)	<0.001	<0.001

[1] All treatments comprised Curzate M x 1, test fungicide x 3 then Quell Flo x 5

[2]Treatment 1 (untreated) excluded from analyses

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There was no clear effect of tank mixing Olie-H on the incidence of tuber blight, either pre-storage (Table 5.4.19) or for total tuber blight (Table 5.4.20). However, the incidence of tuber blight was low, with no significant differences between treatments.

Table 5.4.19 Incidence (%) pre-storage tuber blight in relation to rapid canopy fungicide (2012)

	% tuber blight			
Treatment	**by weight**	**by number**	**by weight (angular)**	**by number (angular)**
1. Untreated[1]	0.19	0.36	0.88	1.23
2. Ranman Top	2.52	0.48	3.94	1.99
3.Ranman Top + Olie-H	0.05	0.25	0.43	1.01
4. Revus	0.00	0.00	0.00	0.00
5. Revus + Olie-H	0.00	0.00	0.00	0.00
6. Percos	0.84	0.98	3.03	3.45
7. Percos + Olie-H	0.29	0.25	1.09	1.01
LSD	2.112	0.849	3.565	3.036
F pr. (*P*=0.05)	0.472 (NS)	0.382 (NS)	0.424 (NS)	0.440 (NS)

[1] All treatments comprised Curzate M x 1, test fungicide x 3 then Quell Flo x 5

Table 5.4.20 Incidence (%) total tuber blight (pre- plus post-storage) in relation to rapid canopy fungicide (2012)

	% tuber blight			
Treatment	**by weight**	**by number**	**by weight (angular)**	**by number (angular)**
1. Untreated[1]	0.19	0.36	0.88	1.23
2. Ranman Top	2.64	0.72	4.03	2.41
3.Ranman Top + Olie-H	0.22	0.50	1.27	2.02
4. Revus	0.00	0.00	0.00	0.00
5. Revus + Olie-H	0.00	0.00	0.00	0.00
6. Percos	0.84	0.98	3.03	3.45
7. Percos + Olie-H	0.29	0.25	1.09	1.01
LSD	2.222	0.941	3.702	3.256
F pr. (*P*=0.05)	0.492 (NS)	0.446 (NS)	0.488 (NS)	0.469 (NS)

[1] All treatments comprised Curzate M x 1, test fungicide x 3 then Quell Flo x 5

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The early and severe blight pressure in 2012 meant that the blanket fungicide applications made to the stable canopy trial during rapid canopy development had to be modified to limit as much as possible the development of foliar blight until the test fungicide treatments were started. One application of Curzate M (2.0 kg/ha), three applications of Revus + C50 (0.6 l/ha + 0.24 kg/ha) and one application of Consento (2.0 l/ha) were applied to each treatment plot before the first application of test fungicides. This approach was reasonably successful and the average severity of foliar blight in plots on 8 August was limited to 1.5%.

There were eight Smith Periods during the time that the test fungicides protected the crop, i.e. from 8 August until desiccation on 27 September. Six of the Smith periods were in August with only two in September. The timings of the four test fungicide applications during August gave the opportunity for curative activity whereas the four in September did not.

The robust blanket fungicide treatment during rapid haulm growth plus the generally short application intervals of the test fungicides together with their curative activity resulted in a steady blight epidemic. Foliar blight severity only reached double figures in fungicide-treated plots at the final assessment. Control plots left untreated from 8 August onwards became very badly blighted by 27 August and were dead by 18 September (Table 5.4.21). For all four fungicides tested, tank mixing Olie-H improved the control of foliar blight compared with straight fungicide at the final assessment on 25 September. The improvement was statistically significant for Invader and Valbon + Zinzan but only at the final assessment.

Table 5.4.21 Severity (%) foliar blight on King Edward in relation to stable canopy fungicide (2012)

Date	26-Jul	02-Aug	09-Aug	16-Aug	20-Aug	27-Aug	03-Sep	10-Sep	18-Sep	25-Sep
Trt.										
1 UT	0.73	1.45	1.60	1.63	5.00	58.75	90.00	96.25	100.00	100.00
2 CM-	0.53	0.95	1.63	1.63	2.12	4.88	5.62	6.00	15.00	55.00
3 CM+	0.65	0.95	1.75	1.88	2.12	4.38	5.12	11.50	14.62	43.70
4 INFI-	0.50	0.95	1.10	1.38	1.88	3.88	4.25	3.88	5.00	7.60
5 INFI+	0.55	1.00	1.48	1.98	1.32	2.83	2.13	3.49	4.19	3.40
6 INVA-	0.55	1.00	1.15	1.64	2.32	3.83	3.96	6.16	8.35	18.60
7 INVA+	0.58	0.95	1.63	1.75	2.00	2.50	1.87	1.88	2.87	2.70
8 VALB-	0.68	1.08	1.75	2.13	1.75	3.38	4.12	4.13	7.87	21.20
9 VALB+	0.71	1.16	1.68	2.07	1.54	2.36	2.49	1.72	2.38	3.10
F pr. (P=0.05)	**0.023**	**0.817**	**0.047**	**0.605**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.146**	**0.479**	**0.543**	**0.645**	**3.550**	**7.341**	**6.314**	**8.350**	**11.876**	**14.200**
F pr.[1] (P=0.05)	**0.056**	**0.700**	**0.018**	**0.604**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	**0.147**	**0.379**	**0.515**	**0.648**	**3.634**	**6.060**	**6.273**	**8.552**	**6.076**	**14.530**

UT=Untreated, CM=Curzate M, INFI=Infinito; INVA=Invader; VALB=Valbon + Zinzan; +=Olie-H tank mixed; -=straight fungicide

[1]Treatment 1 (untreated) excluded from analyses

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Tank mixing Olie-H with fungicide substantially increased blight-free yield for three of the fungicides, i.e. Infinito, Invader and Valbon + Zinzan, however, the increases were not statistically significant (Table 5.4.22). When the blight-free yield data were reanalysed as a factorial experiment (mineral oil x fungicide) the mineral oil factor was not significant (*P*=0.106). The mean blight-free yields for Olie-H and no Olie-H across all fungicides were 32.78 and 29.74 respectively. In spite of the different yield response to Olie-H for Curzate M compared with the other three fungicides the mineral oil x fungicide interaction was not significant (*P*=0.682).

Incidences of tuber blight were low (Table 5.4.23). There were 45 blighted tubers out of the 9,318 assessed in the complete trial.There was no evidence that tank mixing Olie-H with the fungicides had a deleterious effect on the control of tuber blight.

Table 5.4.22 Yield and blight-free yield in relation to stable canopy fungicide (2012)

Treatment		**Yield (t/ha)**	**Blight-free yield (t/ha)**	**% increase in Blight free yield with Olie-H**
1	Untreated	20.50	20.31	
2	Curzate M	28.70	28.63	-
3	Curzate M + Olie-H	28.27	28.05	-2.1
4	Infinito	33.42	33.38	-
5	Infinito + Olie-H	36.55	36.54	+9.5
6	Invader	30.83	30.82	-
7	Invader + Olie-H	35.24	35.19	+14.2
8	Valbon + Zinzan	26.63	26.45	-
9	Valbon + Zinzan + Olie-H	32.14	31.88	+20.5
LSD		7.404	7.418	
F pr. (*P*=0.05)		<0.001	<0.001	
LSD[1]		7.540	7.555	
F pr. (*P*=0.05)		0.004	0.004	

[1]Treatment 1 (untreated) excluded from analyses

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Table 5.4.23 Incidence (%) tuber blight in relation to stable canopy fungicide (2012; March 2013 assessment)

		% tuber blight			
Treatment		**by weight**	**by number**	**by weight (angular)**	**by number (angular)**
1	Untreated	0.88	1.00	2.69	2.79
2	Curzate M	0.30	0.25	1.10	1.02
3	Curzate M + OH	0.83	0.78	3.11	3.11
4	Infinito	0.11	0.29	0.73	1.18
5	Infinito + OH	0.01	0.01	0.04	0.05
6	Invader	0.25	0.29	1.11	1.20
7	Invader + OH	0.17	0.25	0.83	1.01
8	Valbon + Zinzan	0.65	0.76	2.78	3.06
9	Valbon + Zinzan + OH	0.73	0.83	3.06	3.42
LSD		0.998	1.065	3.405	3.592
F pr. (*P*=0.05)		0.502 (NS)	0.757 (NS)	0.491 (NS)	0.652 (NS)

5.4.4 Trials investigating the effect of tank mixing oils with commonly used fungicides for blight control: 2013

Unlike the previous year, 2012, there were relatively few high risk weather periods (Smith). The first occurred on 15 & 16 August, the day that the final application of the four rapid canopy test fungicide sprays was applied (Table 5.4.24). Consequently only the fourth application of the test fungicides had the opportunity for curative activity. The intervals for the four rapid canopy applications were 9, 8, 8 and 9 days. The second Smith Period was on 22 & 23 August and the third on 24 & 25 September. In spite of the very limited number of Smith Periods during the period of protection by the test fungicides (22 July to 24 August) the rapid canopy fungicide treatments were severely tested. Foliar blight was first recorded on 5 August at a severity of 0.7 %. In plots left untreated during rapid canopy development the severity of foliar blight increased quickly over the next 3 weeks reaching 40%, 92.5% and 100% on 12, 19 and 26 August respectively (Table 5.4.25).

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Table 5.4.24 Blight high-risk conditions 2013 (SRUC, Auchincruive, Diamond Field, Met. Office data) and spray dates: rapid canopy (2013)

May	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
				P										**P**	
Period															

June	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
					P						**N**		**P**				
Period																	

	17	18	19	20	21	22	23	24	25	26	27	28	29	30
												P		
Period														

July	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
				P								**N**	**N**				
Period																	
																S1	

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
			N												
Period															
						S2									**S3**

August	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	P				**P**										**P**	**P**
Period																**1**
								S4								**S5**

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
						P	**P**								
Period							**2**								
									S6						

Sept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
												P				
Period																
			S7							**S8**						

	17	18	19	20	21	22	23	24	25	26	27	28	29	30
				P				**P**	**P**					
Period									**3**					
		S9							**S10**					

October	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
			P	**P**	**P**		**P**									
Period				**4**												

P Smith criteria (temperature and relative humidity) met on the day
N Smith criteria almost met on the day but RH short by 1 hour

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P P Full Smith Period. There were four during the season; two in August, one in September and one in October.
NP Near Miss. There were none during the season
S1 to S10 Spray application for the Rapid Canopy trial

The impact of the oils tank mixed with fungicide on the development of foliar blight is illustrated in Figs 5.4.6 to 5.4.8 and also tabulated (Table 5.4.25).

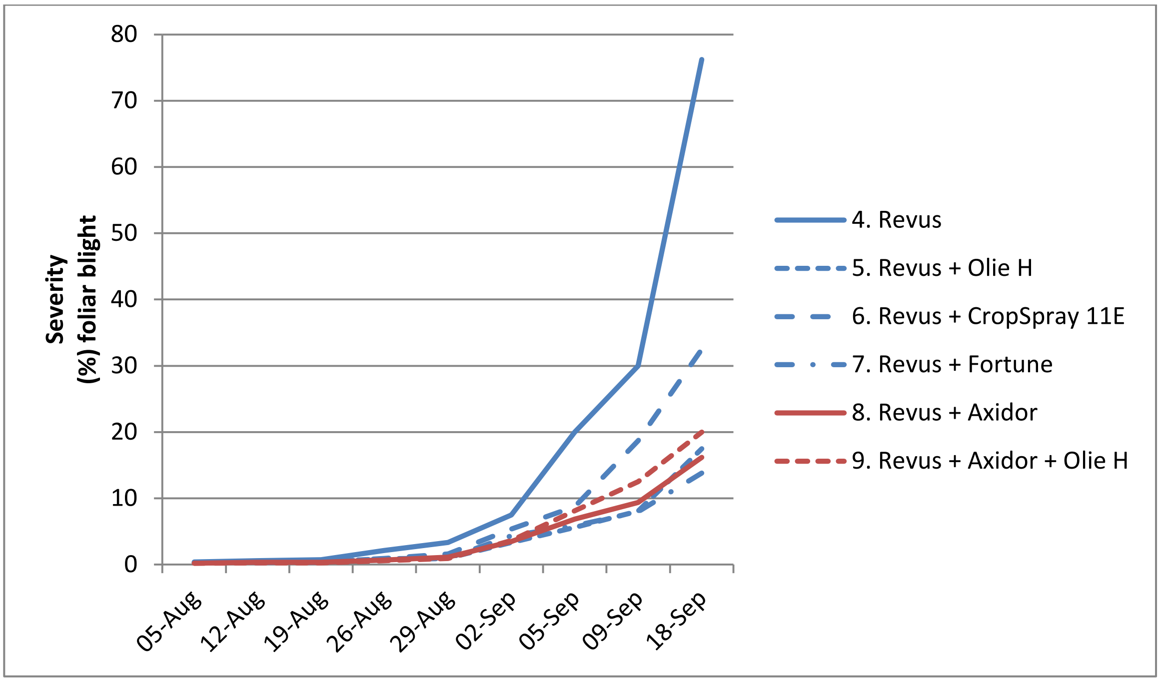

Fig. 5.4.6 Severity (%) foliar blight on King Edward in relation to fungicide without or with oil applied during rapid canopy (2013): Revus and Revus + Axidor

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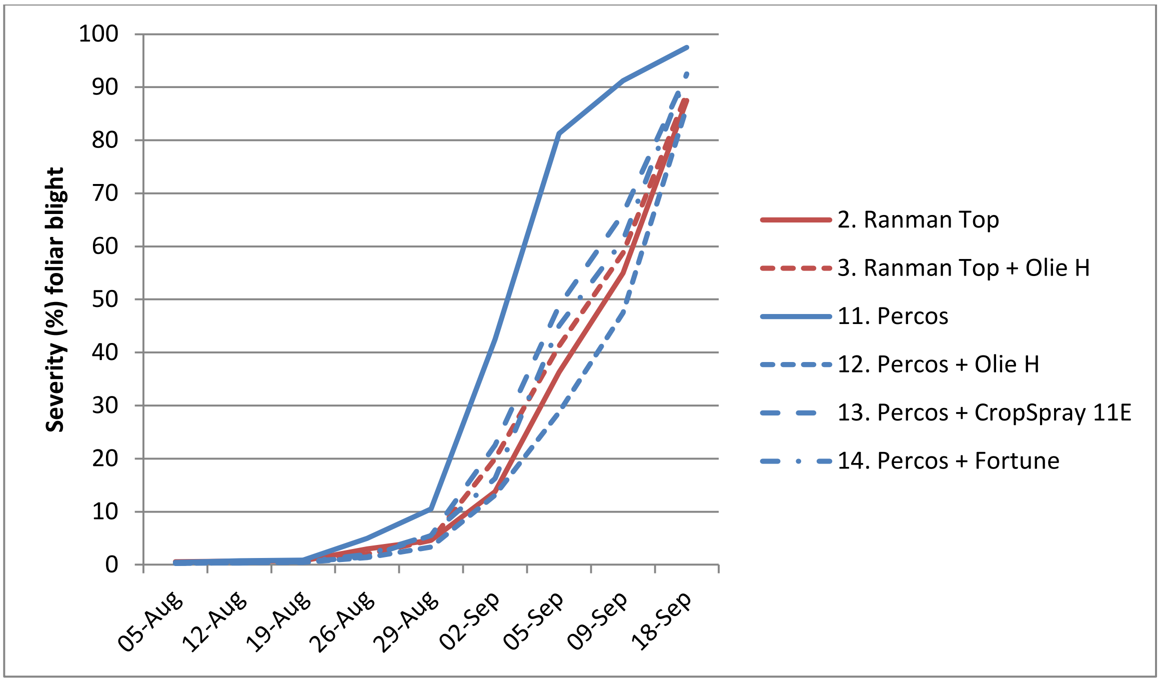

Fig. 5.4.7 Severity (%) foliar blight on King Edward in relation to fungicide without or with oil applied during rapid canopy (2013): Ranman Top and Percos

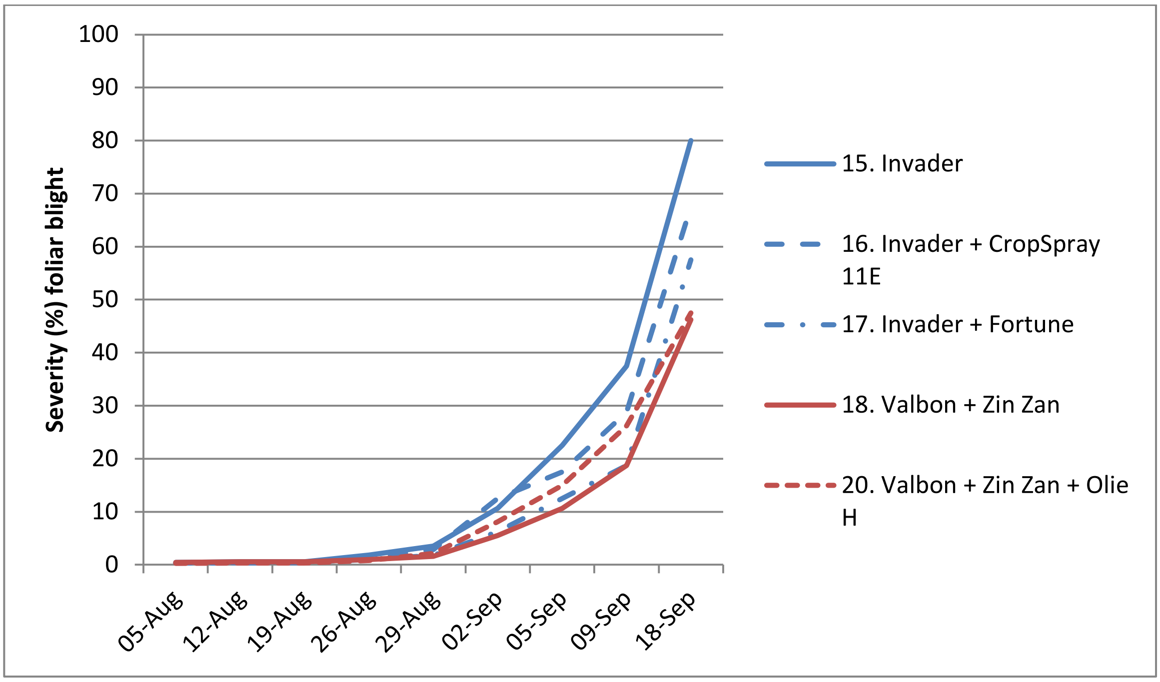

Fig. 5.4.8 Severity (%) foliar blight on King Edward in relation to fungicide without or with oil applied during rapid canopy (2013): Invader and Valbon + ZinZan

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Table 5.4 25 Severity (%) foliar blight on King Edward in rapid canopy (2013)

Treatment	05 Aug	12 Aug	19 Aug	26 Aug	29 Aug
1. Untreated	0.68	40.00	92.50	100.00	100.00
2. Ranman Top	0.55	0.70	0.73	3.00	4.62
3. Ranman Top + Olie H	0.40	0.63	0.75	2.00	4.62
4. Revus	0.40	0.58	0.75	2.13	3.37
5. Revus + Olie H	0.33	0.28	0.45	0.90	1.00
6. Revus + CropSpray 11E	0.35	0.30	0.43	0.95	1.62
7. Revus + Fortune	0.38	0.38	0.38	0.73	0.95
8. Revus + Axidor	0.23	0.35	0.35	0.68	1.12
9. Revus + Axidor + Olie H	0.23	0.25	0.28	0.60	0.95
11. Percos	0.45	0.75	0.88	5.00	10.50
12. Percos + Olie H	0.28	0.38	0.48	1.35	3.37
13. Percos + CropSpray 11E	0.28	0.38	0.58	1.48	5.50
14. Percos + Fortune	0.30	0.35	0.55	1.98	5.62
15. Invader	0.45	0.58	0.58	1.85	3.50
16. Invader + CropSpray 11E	0.30	0.33	0.38	1.25	2.87
17. Invader + Fortune	0.30	0.38	0.43	0.98	1.75
18. Valbon + Zin Zan	0.48	0.58	0.55	1.00	1.62
20. Valbon + Zin Zan + Olie H	0.25	0.30	0.35	0.83	2.12
F pr.[1]	<.001	<.001	<.001	<.001	<.001
LSD (*P*=0.05)	0.131	2.462	0.884	2.083	3.544
F pr.[2]	<.001	<.001	<.001	<.001	<.001
LSD (*P*=0.05)	0.120	0.117	0.159	2.132	3.625

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Table 5.4.25 Severity (%) foliar blight on King Edward in rapid canopy (2013)(continued)

Treatment	02 Sep	05 Sep	09 Sep	18 Sep
1. Untreated	100.00	100.00	100.00	100.00
2. Ranman Top	13.75	36.25	55.0	87.5
3. Ranman Top + Olie H	20.00	41.25	58.8	88.8
4. Revus	7.50	20.00	30.0	76.2
5. Revus + Olie H	3.37	5.62	8.1	17.5
6. Revus + CropSpray 11E	5.37	8.75	18.7	32.5
7. Revus + Fortune	4.37	5.88	8.0	13.8
8. Revus + Axidor	3.50	6.88	9.4	16.2
9. Revus + Axidor + Olie H	3.62	8.12	12.5	20.0
11. Percos	42.50	81.25	91.2	97.5
12. Percos + Olie H	13.12	28.75	47.5	86.2
13. Percos + CropSpray 11E	22.50	48.75	66.2	92.5
14. Percos + Fortune	16.25	45.00	61.2	92.5
15. Invader	10.62	22.50	37.5	80.0
16. Invader + CropSpray 11E	12.50	17.50	28.8	67.5
17. Invader + Fortune	6.25	12.50	18.7	57.5
18. Valbon + Zin Zan	5.50	10.62	18.7	46.2
20. Valbon + Zin Zan + Olie H	8.12	15.00	26.2	47.5
F pr.[1]	<.001	<.001	<.001	<.001
LSD (*P*=0.05)	10.228	12.579	14.62	15.29
F pr.[2]	<.001	<.001	<.001	<.001
LSD (*P*=0.05)	10.457	12.864	14.93	15.65

[1] All treatments included in analyses
[2] Untreated excluded from analyses

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Table 5.4.26 Yield and blight-free yield in rapid canopy (2013)

Treatment	Rate	No. Appl	Yield (t/ha)	Blight-free Yield (t/ha)
1. Untreated	-	4	5.18	5.18
2. Ranman Top	0.5	4	18.38	18.38
3. Ranman Top + Olie H	0.5 + 6.25	4	16.06	16.03
4. Revus	0.6	4	19.32	19.32
5. Revus + Olie H	0.6 + 6.25	4	22.06	22.06
6. Revus + CropSpray 11E	0.6 + 2.5%	4	21.98	21.98
7. Revus + Fortune	0.6 + 0.5%	4	27.58	27.58
8. Revus + Axidor	0.6 + 2.0	4	26.38	26.38
9. Revus + Axidor + Olie H	0.6 + 2.0 + 6.25	4	22.56	22.56
11. Percos	0.8	4	14.44	14.44
12. Percos + Olie H	0.8 + 6.25	4	18.05	18.05
13. Percos + CropSpray 11E	0.8 + 2.5%	4	17.29	17.29
14. Percos + Fortune	0.8 + 0.5%	4	17.31	17.24
15. Invader	2.4	4	17.35	17.35
16. Invader + CropSpray 11E	2.4 + 2.5%	4	20.03	20.03
17. Invader + Fortune	2.4 + 0.5%	4	21.48	21.43
18. Valbon + Zin Zan	1.6 + 0.075%	4	25.79	25.68
20. Valbon + Zin Zan + Olie H	1.6 + 0.075% + 6.25	4	19.41	19.41
F pr.[1]			<.001	<.001
LSD (*P*=0.05)			5.264	5.269
F pr.[2]			<.001	<.001
LSD (*P*=0.05)			5.394	5.399

[1] All treatments comprised Curzate M x 1, test fungicide x 4 then Quell Flo x 5
[2] Untreated excluded from analyses

The following Smith Periods, near misses and single days on which the Smith criteria were met were recorded at the Meteorological Office weather station site at Auchincruive in 2013 (Table 5.4.27). Unlike the stable canopy trials in 2011 and 2012 the timings of test fungicide application did not allow curative activity.

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Table 5.4.27 Blight high-risk conditions 2013 (SRUC, Auchincruive, Diamond Field, Met. Office data) and spray dates: stable canopy trial 2013

May	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
				P										**P**	
Period															

June	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
					P						**N**		**P**				
Period																	

	17	18	19	20	21	22	23	24	25	26	27	28	29	30
												P		
Period														

July	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
				P								**N**	**N**				
Period																	
		S1							**S2**								

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
			N												
Period															
		S3								**S4**					

August	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	P				**P**										**P**	**P**
Period																**1**
					S5									**S6**		

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
						P	**P**								
Period							**2**								
						S7							**S8**		

Sept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
												P				
Period																
						S9							**S10**			

	17	18	19	20	21	22	23	24	25	26	27	28	29	30
				P				**P**	**P**					
Period									**3**					
				S11										

October	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
			P	**P**	**P**		**P**									
Period																

P Smith criteria (temperature and relative humidity) met on the day
N Smith criteria almost met on the day but RH short by 1 hour

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P P Full Smith Period. There were four during the season; two in August, one in September and one in October.
NP Near Miss. There were none during the season
S Spray application for stable canopy trial 2013

The test treatments were applied to the stable canopy trial in 2013 after a blanket fungicide programme of Curzate M x 1 and Consento x 3 was applied to take the plots through rapid haulm growth. The first application of test fungicides at the end of rapid canopy development was on 5 August. At this time foliar blight was present in the trial but at a very low level. The seventh application of test fungicides was on 20 September. The maximum potential period of protection given by the test fungicides was 52 days and the spray intervals were 9, 8, 7, 8, 7 and 7 days. There were three Smith Periods between the first and seventh application (see table 5.4.27). Unlike 2011 and 2012 none of the test fungicide applications were on days when there was the opportunity for curative activity. Foliar blight development was relatively slow during the first half of August but increased considerably from the third week of that month (Fig. 5.4.9 and Table 5.4.28). By 4 September the plots left untreated during stable canopy had been killed by blight.

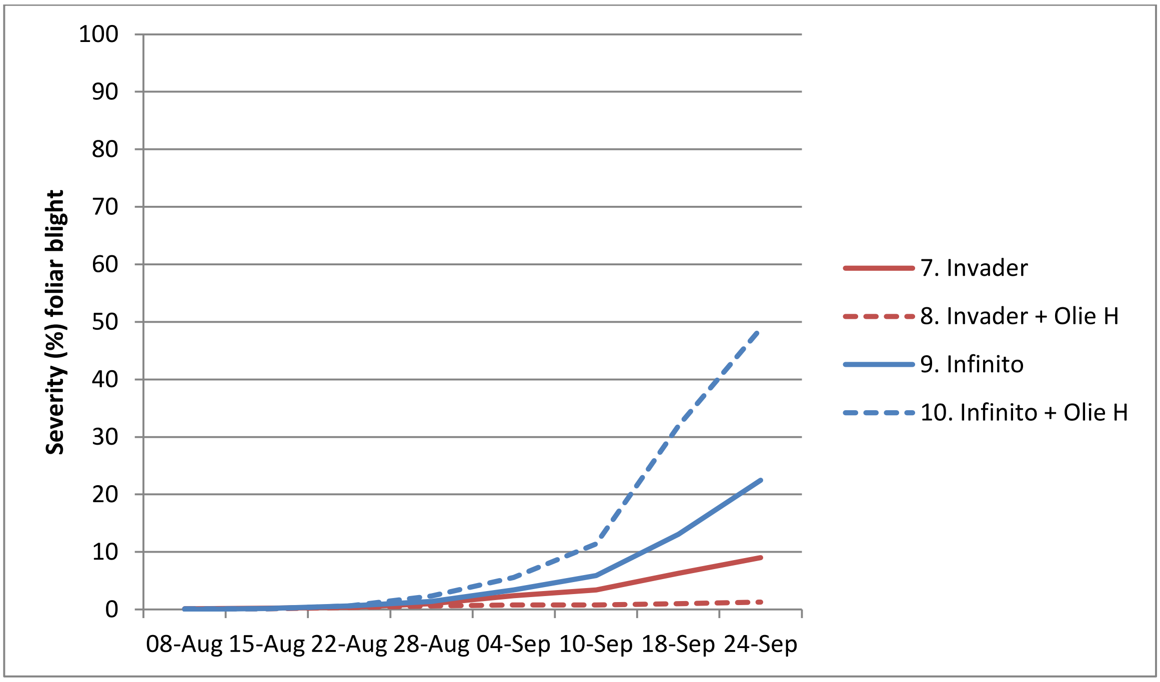

Fig. 5.4.9 Severity (%) foliar blight over time in the stable canopy trial (2013)

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Table 5.4.28 Severity (%) foliar blight on King Edward in the stable canopy trial (2013)

Treatment	**08 Aug**	**15 Aug**	**22 Aug**	**28 Aug**	**04 Sep**	**10 Sep**
1. Untreated	0.18	0.48	14.75	97.50	100.0	100.0
7. Invader	0.15	0.23	0.40	1.03	2.4	3.4
8. Invader + Olie H	0.13	0.10	0.33	0.62	0.8	0.8
9. Infinito	0.03	0.18	0.60	1.38	3.4	5.9
10. Infinito + Olie H	0.13	0.15	0.60	2.35	5.6	11.4
F pr.1	0.077	<.001	<.001	<.001	<.001	<.001
LSD (*P*=0.05)	0.098	0.134	4.808	1.850	10.73	15.69
F pr.2	0.020	0.026	<.001	<.001	<.001	0.036
LSD (*P*=0.05)	0.078	0.109	0.099	0.535	1.910	5.952

Treatment	**18 Sep**	**24 Sep**
1. Untreated	100.0	100.0
7. Invader	6.3	9.0
8. Invader + Olie H	1.0	1.3
9. Infinito	13.1	22.5
10. Infinito + Olie H	31.9	48.8
F pr.[1]	<.001	<.001
LSD (*P*=0.05)	15.87	17.33
F pr.[2]	0.010	<.001
LSD (*P*=0.05)	17.48	19.91

[1] All treatments included in analyses
[2] Untreated excluded from analyses

Tank mixing Olie H with Invader or Infinito did not significantly affect blight-free yield (Table 5.4.29). Tuber samples were harvested and assessed and the data analysed. However, due to very low blight incidence (only 4 tubers had blight out of 5292 tubers assessed) the results were not analysed.

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Table 5.4.29 Stable canopy trial (2013): blight-free yield in relation to treatment

Treatment	Blight-free yield (t/ha)
1. Untreated	28.63
7. Invader	45.97
8. Invader + Olie H	50.49
9. Infinito	47.92
10. Infinito + Olie H	43.26
F pr. [1]	<.001
LSD (*P*=0.05)	4.958
F pr. [2]	<.001
LSD (*P*=0.05)	5.109

[1] Untreated included in analysis
[2] Untreated excluded from analysis

Tuber samples were harvested and assessed. However, due to a very low blight incidence (only 8 tubers had blight out of 8869 tubers assessed) the results were not analysed. There was very little difference between yields and blight-free yields for individual treatments due to the very low incidence of tuber blight. The results for blight-free yield are presented. Deliberate late planting of the rapid canopy trial to boost the chances of high disease pressure during canopy development combined with early and severe foliar blight resulted in relatively low yields (Table 5.4.26). In this trial the addition of oils to most of the fungicides did not significantly affect blight-free yield. The exceptions were the tank mix of Fortune + Revus, which significantly increased blight-free yield compared with straight Revus, and the Olie H with Valbon + ZinZan mixture for which the blight-free yield was significantly lower than that obtained with the fungicide plus recommended adjuvant alone.

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6. Discussion

6.1. Virus Control & Epidemiology

At the Fife site PVA and PVY^N were found but statistically significant differences between treatments were not evident for 2011 and 2012. In 2013 Olie-H 3.1%, Hallmark, Hallmark/Olie-H and Olie H 6.2% all had significantly less PVA than the untreated control. In the same year PVY^N was significantly reduced with Olie-H 6.2%.

Evidence for treatments performing better than the control was also found at Cambridge. In 2011 trial differences were found for PVA with all of the treatments except conventional Programme 1. For Potato Leafroll Virus (PLRV) the treatments Hallmark Fortune, Hallmark Olie H and conventional Programme 1 had a significant effect in reducing incidence. The acknowledged vector for PLRV is the colonising aphid *M. persicae*. The positive effect of oil in reducing transmission was unexpected. No significant effects were recorded for PVY^N. For PVY^N in 2012: the treatments 3 Olie H and 6 Hallmark Olie H were found to be more effective than the control. At Edinburgh for PVA with Desiree: the treatment Olie H was more effective than the control. In 2013 PVY^N was significantly reduced by the application of Fortune, Olie H 3.1%, Hallmark Olie H and CropSpray 11E 2.5%. $PVY^{o/c}$ was also significantly reduced by oil treatments.

The levels of virus infection were too low to make conclusions about treatment effects at the Yorkshire site in all years.

The variability between sites and seasons is likely to be driven by a number of environmental variables for example differences between the vector pressure and timing experienced by each of the sites.

This difficulty is highlighted on the Yorkshire site which differed from the sites at Fife, Edinburgh and Cambridge in that environmental infection sources were not supplemented by infector rows within the trial. Differences in aphid species between sites and seasons also contributes to an explanation of the variance in infectivity pressure. In low infectivity seasons, the infection levels on single sites are less likely to be sufficient to produce treatment effects at the p-values tested.

A literature review (Al-Mrabeh *et al* 2010) of the use of mineral oils indicated a reduction in potyvirus spread in the range of 30 – 60% when oil based treatments were compared to untreated control. Within the data sets generated on the Cambridge, Edinburgh and Fife sites reductions in this range have been observed for treatment means for PVA and PVY^N. These results encourage the continued investigation of integrated programmes where oils are used to replace or supplement pyrethroids in conjunction with insecticides with alternative modes of action such as Biscaya and Tepekki.

It is acknowledged that differences in transmission rate associated with vector activity and virus loading make it difficult to combine results across sites and seasons. This diminishes the potential to determine further significant differences.

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The incidence of potyvirus post-harvest must also be viewed in the context of the nature and timing of the aphids present that contributed to the total vector pressure on each individual site. In particular, this relates to the Fife, Cambridge and Yorkshire site where programmes were applied. For example on the Fife site the weekly vector index for the week 4^{th} - 11^{th} July 2012 was 23.6. This represents circa 50% of the total accumulated vector index recorded to complete haulm destruction. The peak in infectivity pressure was largely associated with catches of the Bird Cherry-Oat Aphid and the occurrence of 4 of the 11 Peach-Potato Aphids caught during the whole of the trial period. On the Yorkshire site in 2012 significant aphid activity only occurred during the first two weeks of trapping which has contributed to the low transmission rates. By contrast at Cambridge in 2012, an average of 1,213 *M. persicae* were caught in each of the four yellow water traps placed within the trial area within the first 6 week post emergence of the crop. In total only three *Sitobion avenae* were caught in the same period. This variability in infection pressure challenges individual treatments rather than the programme as a whole and increases the potential for large variability within individual treatments between both seasons and sites.

The O and P genotypes dominate the *M. persicae* population in the UK (Fenton, personal communication). Testing of 16 *M. persicae* from the Edinburgh and Elgin suction traps in 2012 found that 7 were P type and 8 O type, with the final sample suffering a testing failure. The O and P genotype carry a resistance gene associated with single point mutation (M918L) in the voltage gated sodium channel gene resulting in 'super-kdr'. The LD_{50} of pyrethroid insecticides associated with this gene appears to be greater than >120mg/litre compared to <0.47 mg/l where the mutation is absent. (Fontaine *et al,* 2011). This research offers an explanation of why the pyrethroid and pyrethroid programmes were ineffective at reducing $PVY^{O/C}$ and PVY^{N} infection at the Cambridge site.

At the Fife site in 2013, the Grain Aphid (*S. avenae*) was a significant contributor to the total PVY Index. Significantly, this species has shown a 5-6 fold shift in sensitivity to pyrethroid insecticides (Fenton *et al* 2014). This shift may not be adequate to affect the control of *S. avenae* achieved at field rates as demonstrated by the reduction in PVA transmission achieved with the Hallmark treatments.

At the Edinburgh site both PVY^{N} and PVA, infection levels varied between the varieties tested over the three years of trial, which reflects the different levels of susceptibility towards the viruses (i.e. King Edward more susceptible to PVY^{N} than Maris Piper but both being immune to PVA and Estima more susceptible to PVA than Desiree). Strong variations were observed between varieties, treatments and years which were not tightly associated to the virus/vector pressure as both significant and non-significant effect of treatments were observed in years of higher and lower incidence of virus transmission (Tables 5.6, 5.7,. 5.8 and Figure 5.9). Vegetable oil (Fortune) treatment did not result in any significant reduction in virus incidence over the three years of trials.

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A relatively high variability was observed between treatments and varieties over the years at the Edinburgh site. This is highlighted in Figure 5.9. As an example, in Year 1 (2011) at the Edinburgh site, a non-significant reduction of PVY^N incidence in Maris Piper was observed between Olie H treated and control plants while a significant effect of Olie H treatment was observed on Estima (2.3-fold reduction). Contrastingly, in 2012 a significant reduction of PVA incidence was observed in Desiree (2.2-fold in comparison to Untreated plants), while no effect on Olie H-treated Estima was observed in 2012. The relative poor performance of treatment in Year 2 (2012) could be explained by a relatively early aphid vector pressure that occurred 2 weeks before the first treatment and potentially associated with virus transmission in Estima and King Edward crops. The reasons for this variability of mineral oil efficacy between varieties and between years are likely to be complex and are not fully understood at present. Several factors might have contributed to these differences such as the heterogeneity of aphid distribution and virus transmission in the field, the relative importance of different aphid species in transmitting PVY^N and PVA, and the developmental differences (emergence, foliage maturity) between plants and varieties that impact on mature plant resistance levels (Beemster, 1987). However, this hypothesis does not hold true for the 2012 trial as significant differences in PVA incidence in both Desiree and Estima plant was observed, in spite of having a comparable emergence and foliage maturity rate. Other reasons for these discrepancies could be explained by the influence of temperature (Simons *et al*, 1977), leaf morphology and other climatic conditions (rainfall) in the performance of oil treatments. While a weekly treatment covering a period of 8 consecutive weeks was adopted, different mineral oil spraying regimes have been adopted in several countries with a higher frequency at the earlier development stages when rapid canopy development is observed resulting in a less efficient surface coverage during spraying (Advice provided to French growers by Federation Nationale des Producteurs de Plants de Pommes de Terre)

6.2. Effects on Visual Crop Inspection for Certification

No treatment effects that could impair the ability of growing crop inspectors to Certify crops were observed at the Fife, Edinburgh, Yorkshire or Cambridge sites. Leaf necrosis associated with applications of vegetable and mineral oils were noted only at the Cambridge & Edinburgh sites in a minority of occasions over all trials undertaken. At Cambridge the appearance of the markings coincided with a short period of greater sunshine hours in the 48h after spray application. The marking severity did not decline or increase after appearance.

It is also noted that the plot sprayers used at Cambridge and Edinburgh are of the same type. They differ to the plot sprayer design used on the Fife site and at Auchincruive. The method of application could be a contributory factor to the occurrence of phytotoxicity. At the Cambridge site the observation plots were sprayed across the drills making it difficult to maintain a constant boom height and speed as the operator moved across the drills.

It is pertinent to note that treatments applied through commercial field sprayers in Perthshire and Norfolk, out with this project in 2012, did not result

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in phytotoxic symptoms. This could support the hypothesis that application methodology is important as well as environmental conditions.

SASA inspectorate staff at Edinburgh concluded that, “despite phytotoxic symptoms being observed with the application of oils, the severity of the symptoms observed were not at a level that would impact on the visual inspection of a commercial seed crop for purity and freedom from disease.”

PHSI officials from FERA visited the virus demonstration plots at Cambridge on after the symptoms had appeared in 2012. They concluded that the markings observed, on the material available, would not compromise either variety identification or virus recognition during crop inspection.

In the 2011 blight control trials it was observed that tank mixing oil treatments with the fungicide Shirlan could result in more severe necrosis that could potentially impair growing crop inspection for seed Certification. This treatment was not repeated in subsequent years. A much more frequent effect and widespread effect attributable to mineral oil treatment was the beading of water droplets on the surface of leaflets.

6.3. Effects on Crop Yield

At the Fife site in 2012 a significant reduction in total yield was recorded in treatment 8 where Olie-H was used on three occasions within a programme. However, no significant yield differences were recorded where Olie-H and Fortune were used repeatedly throughout the trial period indicating that another factor may be responsible. 2012 was a generally overcast season and it is likely that total yield was dictated by limited sunshine hours.

No significant effects were noted on tuber number were recorded in any of the three years at the Fife site.

There were no significant effects of treatment on individual seed grade yield or tuber numbers at any site in any year. There were some statistically significant differences between treatments for total yield and tuber number (all categories), but no consistent trend for oil treatments, or programmes containing oil treatments to be lower than treatments not containing oil products. This is broadly consistent to previous Scottish Agronomy Ltd trials which found that yield effects were related to a delay in tuber bulking rate rather than in total yield potential. In practice, a delay in crop desiccation timing by a few days will offset this effect.

In the blight trials some yield responses to the addition of Olie-H were very high. This was particularly the case in the rapid canopy blight control trial in 2012 and reflected the improved foliar blight control with the mineral oil together with the early and severe impact of blight on crop growth in a very high risk season. In the rapid canopy trial, for all three fungicides tank mixing Olie-H increased blight-free yield. The increase was statistically significant for Revus and Percos, the two fungicides which resulted in the highest yields when applied alone. Blight-free yields were increased by 24.1%, 34.1% and 34.1% for Olie-H tank mixed with Ranman Top, Revus and Percos respectively.

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In the canopy stable blight control trials tank mixing Olie-H with the fungicides Infinito, Invader & Valbon + Zinzan increased blight free yield but the results were not statistically significant.

Overall the yield data indicates that in the absence of disease applications of oils do have the potential to reduce yield at a given point in time but it is by no means a consistent effect of the treatments. Where it is observed the effect is primarily related to bulking rate not total tuber number. A delay in burn down may be necessary under some circumstances to achieve the target tuber size distribution for the intended seed market.

6.4. Effect on Blight Control

It is clear that seasonal factors can influence the impact of using oil with blight fungicides. For example, in each of the three stable canopy trials Infinito was assessed with and without Olie H. Although the result obtained in each year was similar, i.e. oil did not significantly change the AUDPC, the percentage improvement, or decline, in foliar blight control was markedly different in 2013 compared with the two previous years (Table 6.4.1). It can be hypothesised that spray timing relative to infection period will have a confounding effect.

The impact of oil on foliar blight control was influenced greatly by the fungicide product used in the tank mix (Table 6.4.1). In 2011 Olie-H had deleterious effects when tank mixed with Shirlan or Ranman TP. The work with Shirlan was not continued in 2012 and the formulation of Ranman TP was changed by the manufacturer to Ranman Top. In contrast, the oils consistently improved blight control for the three fungicides Percos, Revus and Invader; in 12 out of the 15 comparisons including these fungicides the improvement was statistically significant. Much greater variability in control was evident in the results for Valbon + ZinZan, Ranman Top and to a certain extent Infinito.

The reason for the variability with some fungicides can't be determined from the dataset generated by this study. Additional experiments conducted under controlled environments (i.e. glasshouse) are required to provide the explanation. In theory there should be greater variation in response to added oil from fungicide products with two active ingredients compared with one. This is because the two a.i.s are likely to have different characteristics and also the oil may differentially enhance the contribution of the two active ingredients. However, there is no evidence that this is the case. Although inconsistent control of foliar blight occurred for oil mixed with Infinito (fluopicolide + propamocarb) and Valbon (benthiavalicarb + mancozeb) + ZinZan, it was also evident for Ranman Top (cyazofamid). Foliar blight control was considerably more consistent for oil plus Invader (dimethomorph + mancozeb), Percos (ametoctradin + dimethomorph) and Revus (mandipropamid).

Very different results for foliar blight control were obtained with Ranman TP in 2011 and Ranman Top in 2012. Differences between the blight epidemics in 2011 and 2012 will account for some of this difference but it is likely that much of the discrepancy was due to differences in the formulations of the two products. Both products provided 80 g of the fungicide cyazofamid per hectare.

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Table 6.4.1 Percentage improvement in foliar blight control contributed by tank mixing oil with fungicide

Fungicide	**Oil**	**% improvement[1]**		
		2011	**2012**	**2013**
Infinito	Olie H	12.9[2]	11.0	-42.1
Invader	Olie H	**42.4**	**29.0**	45.7
	Cropspray 11 E	12.2		
	Fortune	**25.3**		
Percos	Olie H	**47.2**	**44.6**	**36.4**
	Cropspray 11 E	**23.7**		
	Fortune	**26.5**		
Ranman A+B	**Olie H**	**-188.1**		
Ranman Top	Olie H	**49.9**	-3.2	
Revus	Olie H	18.9	**47.9**	**47.9**
	Cropspray 11 E	**31.1**		
	Fortune	**49.5**		
Valbon + ZinZan	Olie H	6.1	**29.8**	-6.6

[1] Calculated from the relative AUDPC values for paired treatments of fungicide alone and fungicide plus oil. A negative value indicates poorer control by the tank mix of oil and fungicide.
[2] Values in bold are statistically significant (P<0.05)
Fungicides that were tested with one oil once only are excluded from the above table

The oils Cropspray 11E and Headland Fortune were only tested in one trial in one year with three fungicides. The results were similar to those achieved when they were mixed with Olie H (Table 6.4.1), the oil tested most extensively. It should be noted that Cropspray 11E and Headland Fortune were tested in tank mix with the three fungicides that responded most consistently to mixture with Olie H.

Given the observed importance of the formulation of fungicide products to oil impact it is important to acknowledge the limitations of the data set generated by this study. This study compared fungicide alone with fungicide plus oil. It can't be assumed that the results observed in these experiments will necessarily be replicated if oils are tank mixed with mixtures of blight fungicide plus for example aphicides. The formulation of, and adjuvant in, an aphicide are likely to differ from those of the blight fungicide. Previous work conducted by Scottish Agronomy Ltd found that tank mixing mineral oil with Biscaya (a neonicotinoid insecticide) should not be carried out due to incompatibility in formulation and the occurrence of phytotoxic symptoms.

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Fungicides applied to trials during the rapid canopy phase of development generally have relatively low numbers of sporangia to control but unprotected new haulm is produced between applications. In contrast, plots treated once the canopy growth has stabilised present a different challenge: a considerably higher number of sporangia but generally very little new haulm growth. In this study separate trials were made for the rapid canopy and stable canopy phases. The principle reason for this was that in current practice oils tank mixed with blight fungicides are only approved for application to potato crops up to tuber initiation. This can be as soon as 14 -21 days after emergence.

No conclusion can be made regarding whether oils were more effective if applied during rapid canopy development compared with during the stable canopy phase. The main reason for this is that in fungicide trials treatments applied earlier in the growing season generally result in larger differences between them because they have a longer part of the epidemic to diverge and therefore are more likely to generate statistically significant differences. Another reason is that almost twice as many comparisons were made in the rapid canopy compared with stable canopy trials: 17 and 10, respectively.

For 22 out of the 27 paired comparisons, adding oil to the blight fungicide did not significantly affect blight-free yield. Yield was only significantly reduced for two oil tank mixes compared with the straight fungicide. The first was Olie H plus Ranman TP in the rapid canopy trial in 2011. This reduction was related to the very poor control of foliar blight for the tank mix compared with Ranman TP alone. The second, Valbon + ZinZan + Olie H in the 2013 rapid canopy trial, was not associated with significantly poorer control of foliar blight. For three comparisons the oil tank mix had significantly higher blight-free yields. In all three cases the elevated yields were related to significantly better control of foliar blight. The three were Percos + Olie H and Revus + Olie H (rapid canopy 2012) and Revus + Fortune (rapid canopy 2013).

The incidences of tuber blight in the six trials were low; so low in 2013 that the data were not analysed. In the four earlier trials the incidences of tuber blight did not differ significantly for 11 of the 14 paired comparisons. In the rapid canopy trial in 2012 the addition of Olie H to Ranman Top resulted in significantly less tuber blight. A similar result was obtained for Valbon + ZinZan + Olie H in the stable canopy trial in 2011. However, in the same trial tank mixing OIie H with Invader produced significantly more tuber blight. These limited results prevent a conclusion being reached regarding the impact of mixing oils with blight fungicides on tuber blight control. The impact of Olie H on tuber blight control by Ranman Top, Valbon + ZinZan and Invader can’t be explained by the effect of the added oil treatment on foliar blight control by the respective treatments.

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7. CONCLUSIONS

The conclusions are given below in reference to the individual project objectives.

1. *Determine the effectiveness of treatment programmes utilising mineral oils, vegetable oil and aphicide products in minimising the incidence of potyvirus in daughter tubers.*

Evidence for oil based treatments performing better than the control could be observed in specific sites and seasons for PVA and PVY^N. The overall analysis for the entire three years suggest that mineral oil (Olie H) treatment had an overall beneficial effect, but this was not seen consistently in each year for all varieties tested (see objective 6 below).

It is acknowledged that differences in transmission rate associated with vector activity and virus loading make it difficult to combine results across sites and seasons.

At the Fife, Edinburgh and Cambridge sites the majority of the transmission pressure occurred in different 7 day periods in the different locations. Therefore, the products applied during these periods were placed under the greatest pressure. The results for the entire programme at different locations may hinge on the performance of a single application at a critical time.

2. *Determine the effect of tank mixes of oils and common blight sprays including the identification of any phytotoxic effects in addition to assessment of the effects on levels of foliar & tuber blight.*

Olie H was the oil tested most frequently with the commonly used blight fungicides but Cropspray 11E and Headland Fortune were included in the third year of the study. The oils consistently improved foliar blight control for the three fungicides Percos, Revus and Invader. In 12 out of the 15 comparisons including these fungicides the improvement was statistically significant. However, the impact of oil added to fungicide on leaf blight was greatly influenced by the fungicide product used in the tank mix. In 2011 Olie-H had deleterious effects when tank mixed with Shirlan or Ranman TP. The formulation of Ranman TP was changed, coincidentally, to Ranman Top by the manufacturer during the period of study. Foliar blight control with Olie H added to the mix was not detrimental for the replacement Top formulation. Different blight epidemics and conditions in 2011 compared with 2012 and 2013 may have accounted for some of the changed response to added oil but it is likely that most was due to formulation differences between the two products. Both products provided 80 g of the fungicide cyazofamid per hectare. Seasonal variability in foliar blight control with added Olie H was evident in the results for Valbon + ZinZan, Ranman Top and to a lesser extent Infinito. The reason for the variability with some fungicides can't be determined from the dataset generated by this study.

The oils Cropspray 11 E and Headland Fortune were only tested in one trial in one year but foliar blight results when used with three fungicides were similar to those achieved with Olie H mixes. It should be noted that Cropspray 11E

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and Headland Fortune were tested in tank mix with the three fungicides that responded most consistently to mixture with Olie H.

This study compared fungicide alone with fungicide plus oil. It can't be assumed that the results observed in these experiments will necessarily be replicated if oils are tank mixed with mixtures of blight fungicide plus other crop protection chemicals. The formulation of, and adjuvant(s) in, the additional pesticide are likely to differ from those of the blight fungicide. The quite different results for Olie H with Ranman TP or Ranman Top indicate the importance of formulation.

No conclusion can be made about whether oils were more effective if applied during rapid canopy development compared with the stable canopy phase.

For 22 out of the 27 paired comparisons, adding oil to the blight fungicide did not significantly affect blight-free yield. For three comparisons the oil plus fungicide had significantly higher blight-free yields. For two comparisons yield was significantly reduced in the oil tank mix compared with the straight fungicide. Four out of these five tank mixes with a significant yield response to added oil had an associated statistically significant difference in foliar blight. The exception was the reduction in blight-free yield with the Valbon + ZinZan and Olie H mix.

The incidences of tuber blight in the six trials ranged from low to very low. Such results prevent any conclusion regarding the impact of oil plus fungicide tank mixes on tuber blight control. However, there was no evidence that adding oil to blight fungicides had a substantial detrimental effect on control of this aspect of the disease.

Symptoms of phytotoxicity associated with oil use were only observed with one treatment, i.e. Shirlan + Olie H in the stable canopy trial in 2011. A much more frequent and widespread effect was the beading of water droplets on the surface of leaflets treated with oil.

3. *Quantify the impacts of the treatment programmes on crop yield; and the cost: benefits of the studied treatment programmes.*

Effects on tuber number and total yields were noted in every season of testing. These however have been inconsistent between seasons. It is unclear whether the results have occurred as a result of chance. Overall the cases where improvements in virus control from including oils in the programme outnumber the incidences of reduced yield or tuber number.

It may be more difficult than was initially perceived to calculate a cost/benefit analysis as further information will be needed to quantify with more confidence the effect on virus control and hence benefit of the treatment programmes. The benefit to industry from a reduction in the transmission of potyvirus is more difficult to quantify than if a treatment offered seed growers a quantifiable reduction in downgrades due to virus symptoms.

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4. *Evaluate the impact of the treatments on crop inspection and certification, establishing the acceptability of oil treated crops for phenotype and visual recognition of mild mosaic symptoms.*

The concern within the industry that the use of oils would be detrimental to statutory growing crop inspections has not been borne out by the trials carried out to date. Inspectors from both SGRPID and PHSI concluded that the ability to identify both varieties and virus symptoms were not diminished by treatment with Olie-H or Fortune. These conclusions were drawn in the presence of phytotoxic reactions at the Edinburgh and Cambridge inspection plots.

SASA inspectorate staff at Edinburgh concluded on the two occasions where necrosis was observed that "despite phytotoxic symptoms being observed with the application of oils, the severity of the symptoms observed were not at a level that would impact on the visual inspection of a commercial seed crop for purity and freedom from disease." The number of occasions where phytotoxic symptoms were observed were in the minority and may have related to limitations of the methods of application.

PHSI officials from FERA visiting the virus demonstration plots at Cambridge concluded that the markings observed, on the material available, would not compromise either variety identification or virus recognition during crop inspection.

The method of application could be a contributory factor to the occurrence of phytotoxic symptoms in the observation plots but not elsewhere in this project or in field evaluations carried out in Perthshire and Norfolk out with the project.

5. *Progress towards the development of a sustainable integrated programme for the reduction of potyvirus, as well as control of potato leafroll. This must be within the context of a tank mix with foliar blight control products.*

The sustainability of the control programmes for leaf roll are partially dependant on the resistance status of the clones of Peach-Potato Aphids present in GB. Currently, there is a requirement to include products from the neonicotinoid group of insecticides to achieve satisfactory control. These products have been successfully integrated into the season long programmes included within the virus control trials. The GB clonal population of Peach-Potato aphids currently does not include the neonicotiniod resistant genotypes known to exist in Southern Europe. If a migrant or introduced population successfully establishes in GB the current approach will no longer be successful.

It is recognised that tank mixing mineral oil with Biscaya (a neonicotinoid insecticide) should not be carried out due to incompatibility in formulation and the occurrence of phytotoxic symptoms.

6. *Evaluate the virus incidence in progeny tubers of different cultivars with and without the use of oils.*

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PVY^N and PVA, infection levels in response to each treatment did vary significantly between varieties and between years. While protection by Olie H in particular was found in isolated combination of Variety x Virus species in the order of a 2-fold reduction, no complete protection for all trials was observed in any of the three years of the trial (Figure 5.9), The causes for the variability of mineral oil efficacy between varieties and between years in our trial are not known and require further investigation. One could assume that several factors are likely to have contributed such as differences in aphid distribution and virus transmission within and between plots, the developmental differences such as heterogenous emergence, foliage maturity between plants and varieties that impact on mature plant resistance levels (Beemster, 1987) and the relative importance of different aphid species in transmitting PVY^N and PVA.

This highlights the complexity of the epidemiology of PVY^N and PVA and the influence of environmental conditions that affects PVY^N and PVA transmission by their aphid vectors, their distribution in host plants and varietal differences in potato physiology and growth habits. In addition, the modes of action of mineral oil have yet to be fully elucidated as direct effect on aphids, interference in virus transmission during acquisition-transmission stages and effects on plant physiology have been reported to impact on overall virus incidence in bait plants (Martin-Lopez *et al,* 2006, for a review see Al-Mrabeh *et al,* 2010). Further variability could be explained by the relative contribution of one or several mechanisms in different potato genotypes and as well as environment influences. Previous research has reported the variability of mineral oil performance in protecting different potato varieties against different virus species usually ranging within a 2-fold to 2.5-fold reduction in virus incidence, while in some years no clear protection could be observed (Wrobel, 2012, Wrobel 2014, Martin-Lopez *et al,* 2006).

In the light of these results, we can conclude that while mineral oil(s) can offer significant protection (about 2-fold reduction) to virus infection in some cases, due to the strong variability in treatment efficacy observed within and between sites, thorough management of potato viruses through practices such as roguing, limited field generation seed, managing environmental sources (volunteers, groundkeepers and lower grade crops) remains the most efficient way to control virus health in seed crops.

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