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Potato blight control using components of indigenous non-food waste plants

Final report

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Executive summary

The project aims to trial the effectiveness of a new, environmentally sensitive biopesticide for control of late blight in potatoes to replace formulations of copper, a highly toxic spray currently used by organic farmers.

Alpha-hederin, a saponin occurring in common ivy, *Hedera helix*, was extracted and formulated as spray for blight control. In addition, Emerald Crop Science Ltd. have developed OptiYield Diamond (OptD) a novel biostimulant product, based on phosphonate that could help plants grow more vigorously and potentially increase their resistance to pests and diseases and increase yield. OptD was tested on its own and in combination with Hederin to explore its efficacy with respect to managing blight on potato crops and whether there is a synergistic relationship between the two products.

Field trials were carried out at two sites in 2017:

- Ty'n yr Helyg, an organic farm near Aberystwyth, which compared the efficacy of two different concentrations of Hederin and Cuprokylt (a copper oxycholoride fungicide permitted in organic systems) and a control (tap water).
- Henfaes Research Centre, near Bangor, which compared the efficacy of Hederin, OptD, and a combination of Hederin and OptD to standard synthetic fungicides and a control (no treatment)

In light of the data and experiences from 2017, the methodology was changed in 2018 to include higher concentrations of Hederin, a less pure (90% Hederin) extract, and an adjuvant 'Crusade' which improves leaf coverage and controls spay drift.

Treatments were applied to plots, arranged in a randomised block design, at weekly intervals before blight symptoms were observed and as set out below:

	Henfaes		**Ty'n yr Helyg**	
	2017	**2018**	**2017**	**2018**
1	Hederin @ 0.1%	Hederin @ 0.1%***	Hederin (1g/l)	Hederin 0.1%
2	OptD	90% pure Hederin @ 0.2%	Cuprokylt*	Cuprokylt*
3	Hederin and OptD	Hederin @ 0.1% + Crusade	Hederin (0.1%)	Hederin 0.3%
4	Shirlan or Ranman**	OptiYield Diamond	Tap water	Tap water
5	No treatment	Mancozeb **		
6		Tap Water		

* Standard copper based fungicide in organic systems
** Synthetic fungicides commonly used conventional systems
*** 0.1% = 1g/l

The efficacy of the treatments were assessed by measuring the progression of the blight epidemic in each of the trial plots, as well as the yield and health of tubers in each plot post harvest.

At 0.1 %, Hederin had little or no effect compared to tap water at either site in either year. The addition of the adjuvant Crusade did not substantially increase the efficacy of Hederin at this concentration.

At concentrations of 0.2 % (90 % pure extract) and 0.3 % (100 % pure), Hederin was able to slow down, but not halt, the progression of blight at all sites in both years. However, it was less effective than standard fungicide treatments (copper containing 'Cuprokylt' at Ty'n yr Helyg and Mancozeb/ Shirlan/ Ranman or Mancozeb at Henfaes).

OptD, on the other hand, tested each year at the Henfaes site, was consistently the most effective treatment. It outperformed the standard fungicide and the Hederin treatments, both in terms of controlling the spread of the disease on the foliage and controlling tuber blight, resulting in the best marketable yield. In 2018, only an

average of 3 % of foliage was blighted at the end of the trial, compared to 47.5 % for Mancozeb and between 91 % and 100 % for all other treatments. In 2017, OptD was combined with Hederin, and gave better management of blight compared to OptD alone, in terms of slowing the progression of the epidemic.

In cases where Hederin showed a slowing down in the blight epidemic, this was not reflected as clearly in the yield data as might be expected, suggesting that on the whole, control of the epidemic was not sufficiently effective to translate into increased tuber yield. However, there were some differences that can be highlighted:

- In 2018 at Ty'n yr Helyg, the total yield and the proportion of tubers above 45 mm in the 0.3 Hederin treatment was comparable to that in Cuprokylt and higher than those in 0.1 % Hederin and tap water.
- In 2018 the total yield in the OptD plots was comparable to other treatments (despite achieving much better blight control), the marketable yield was clearly higher.

The results suggest that, on its own, Hederin at the concentrations tested does not give comparable control to standard fungicide programmes in conventional systems and to copper in organic systems. However, it may have a role to play in integrated disease management programmes, for example, in combination with resistant potato varieties or when mixed with OptD or similar products.

Contents

1. Overview of the project

The project aimed to trial the effectiveness of a new, environmentally sensitive biopesticide for control of late blight in potatoes. The product Hederin is a saponin extracted from common ivy, *Hedera helix*, and was developed by Naturiol Bangor Ltd.

Naturiol Bangor Ltd., a company dedicated to the development and supply of naturally sourced performance chemicals has recently developed a method for isolating a single saponin called Alpha hederin (known henceforth as 'Hederin') in bulk quantities from ivy. Hederin has been shown to be active in trials against other organisms, and initial work by Naturiol Bangor Ltd. has indicated that a crude extract can protect foliage against late blight and improve marketable yield. This trial tested:

- The efficacy of different concentrations of pure Hederin
- The efficacy of 100% and 90% pure extracts of Hederin
- If 'Crusade', which improves leaf coverage and controls drift of the spray, can increase efficacy of 90% pure Hederin

In addition, Emerald Crop Science Ltd. have developed a novel biostimulant product, *OptiYield Diamond, (also known as OptD or Phi Diamond).* This is a plant stimulant based on potassium phosphite, humic acids and mineral salts, that could help plants grow more vigorously and potentially increase their resistance to pests and diseases and increase yield. The project assessed its efficacy for blight management alone and in combination with Hederin.

Trials were carried out at two sites in 2017 and 2018:

- Ty'n yr Helyg, an organic farm near Aberystwyth, which compared the efficacy of two different concentrations of Hederin to Cuprokylt (a copper oxycholoride fungicide permitted in organic systems) and to a control (tap water)
- Henfaes farm, near Bangor which compared the efficacy of Hederin alone; of OptD plus Hederin; of a low concentration of Hederin with Crusade; of standard synthetic fungicide programmes and of a control (no treatment or tap water)

2. Methodology

2.1 Preparation and formulation of ivy extract treatments

Ivy foliage was collected from various sites and extracts prepared. The results of the 2017 trials informed the development of the product in 2018, and therefore the formulations were slightly different in the two years.

- Data form 2017 suggested a slightly less pure extract was more effective, so a 90 % pure extract was added to the trial in 2018
- Crusade (adjuvant), a new spreader and anti-drift agent, said to improve coverage of foliage, was added to the pure Hederin

2.2 Field trials

2.21 Treatments

The following treatments were applied at each of the sites as described in Table 1 below:

	Henfaes		Ty'n yr Helyg	
	2017	**2018**	**2017**	**2018**
1	Hederin @ 0.1%	Hederin @ 0.1 %	Hederin (1 g/l)	Hederin 0.1 %
2	OptD	90 % pure hederin @ 0.2 %	Cuprokylt*	Cuprokylt*
3	Hederin and OptD	Hederin @ 0.1% + Crusade	Hederin (0.1 %)	Hederin 0.3 %
4	Shirlan or Ranman**	OptiYield Diamond	Tap water	Tap water
5	No treatment	Mancozeb**		
6		Tap Water		

* Standard copper based fungicide as used in organic systems
** Synthetic fungicides commonly used conventional systems
*** 0.1% = 1g/l

Table1: Summary of treatments

Differences between the treatments at the two sites were a reflection of:

- Different practices and regulations in organic and non-organic systems. Organic standards prohibit 'synthetic' fungicides and therefore the standard treatment at Ty'n yr Helyg was a copper oxychloride product, Cuprokylt, instead of the synthetic fungicide at Henfaes.
- Available staff time for data collection. More staff time and resources were available at Henfaes compared to Ty'n yr Helyg. It was therefore possible to include additional treatments at Henfaes.

2.22 Trial layout and management

The number of treatments and replicates in both years at each site are detailed below in Table 2 and Figure 1. Treatments were arranged in a randomised block design, details of which can be found in Appendix 1.

	Henfaes		Ty'n yr Helyg	
	2017	**2018**	**2017**	**2018**
No. treatments	5	6	4	4
No. Replicates	4	4	4	5
Total no. of Plots	20	24	16	20

Table 2: Summary of treatment replication

Figure 1: Plots at Henfaes, 2017

The plots were managed as described in Table 3 below.

Operation/ Characteristics	Ty'n yr Helyg	Henfaes
Ground preparation	Ploughed, cultivated and fertilised and ridged up	
Variety	**Maris piper** and **King Edward**	
Spreader rows (to facilitate the spread of blight)	Two untreated rows between rows of plots	Two rows of Blue Danube longitudinally. 1 row of Blue Danube and 1row of **Maris Piper** or **King Edward** laterally
No. plants/ plot	**20** and **30**	**20** and **28**
Plant spacing	0.75 m between ridges, 0.33 m within the row	
Planting date & seed size	35 – 45 mm seed planted on **08/05/2017** and **01/06/2018**	35 – 45 mm seed planted on **08/05/2017** and **01/06/2018**
Crop management	Hand–weeded until the haulm canopy covered the rows **Irrigation from field main supply using T-tape drip irrigation from 10 July** **Post emergence top-dressing with 20kg organically approved pelleted chicken Manure at a rate of 100g per sq. m. Analysis: 5 % N, 3 % P2O5, 3 % K2O**	Residual herbicide applied one week after planting. **Weeds, mainly Black Nightshade and Fumitory, which escaped herbicide control, were hand weeded in early July** **Irrigation from field main supply using T-tape drip irrigation from 20 July**
Date of haulm removal	**01/09/2017**, **13/09/2018**	**15/09/2017**, **10/10/2018**
Harvesting and storage	Tubers were harvested on **27 -28 September 2017** and **8-10 October 2018**. They were stored in potato chitting trays in a dry shed.	Tubers were harvested on **5-15 October 2017** and **18 -20 October 2018**. They were stored in nets in a dry shed

Green text *relates to 2017,* ***red*** *to 2018 and* ***black*** *is common to both years*

Table 3: Plot management operations/ characteristics

2.23 Application of treatments

Treatments were applied at weekly intervals as per Table 4 at rate of 5 L/plot using a knapsack sprayer to runoff

Ty'n yr Helyg		Henfaes	
2017	**2018**	**2017**	**2018**
17 July*	24 July	13 July	25 July
24 July	31 July	20 July	1 August
31 July	7 August	27 July	8 August
7 August	16 August	3 August	17 August
	22 August		23 August
	29 August		30 August
	4 September		6 September
			13 September

*Due to delays in obtaining a derogation for the use of copper, Cuprokylt was not applied until week 2

Table 4: Timetable for application of treatments

2.25 Assessing blight pressure

The number of days in which full Hutton Period alerts were issued by the AHDB 'Fight Against Blight' service for the postcodes at each of the trial sites (SY23 for Tyn yr Helyg and LL33 for Henfaes) are shown. A full Hutton Period occurs when the following criteria are met on two consecutive days: Minimum air temperatures are at least 10°C, Relative Humidity is 90 % or above for at least 6 hours.

2.26 Assessing foliar blight

The amount of foliar blight was estimated by the percentage of the foliage visibly affected by blight. Each plot was scored on the dates set out in Table 5 below.

Ty'n yr Helyg		Henfaes	
2017	**2018**	**2017**	**2018**
25 July	24 July	07 August	25 July
02 August	31 July	14 August	1 August
08 August	8 August	18 August	6 August
15 August	16 August	12 September	14 August
	22 August		22 August
	29 August		29 August
	4 September		3 September
			8 September
			13 September

Table 5: Timetable for foliar blight assessments

2.27 Assessing yield and tuber health

Tubers were harvested by hand on the dates set out in Table 3. Tubers in each plot were weighed and graded for size. The number and mass of blighted/ rotted tubers were recorded for each plot at each site as follows:

- At Ty'n yr Helyg, healthy tubers between 40 mm – 70 mm were counted and weighed. Tubers less than 40 mm with soft rot and/or tuber blight were counted but not weighed because the rot was so far advanced the latter was impractical.
- At Henfaes, tubers were harvested into nets and stored in a dry shed to dry. When dry, both healthy tubers larger than 45 mm (marketable yield) and healthy tubers less than 45 mm were weighed. Tubers with blight and/or soft rot were weighed.

3. Results

3.1 Ty'n yr Helyg

3.11 Blight pressure

The details of the Full Hutton Period alerts issued for postcode SY23 in 2017 and 2018 are given below in Table 6. A Hutton Criteria occurs when two consecutive days with a minimum temperature of 10°C, and at least six hours of relative humidity (90%).

2017						
Jun			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		
Jul					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						
Aug	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			
Sep				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

2018						
Jun				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	
Jul						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					
Aug		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		
Sep					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Table 6: Hutton Period alerts for postcode area SY23

Blight pressure patterns differed between years. Blight appeared much earlier in 2018 compared to 2017 and there were more Hutton periods in July 2018 compared to July 2017. August 2017 had 18 periods compared to 11 in August 2018. Anecdotally this is surprising because the UK as a whole experienced very dry conditions in early summer 2018.

3.12 Foliar blight

The progression of late blight at Ty'n yr Helyg was scored and is shown in Figure 2 for 2017 and Figure 3 for 2018. The two years are not directly comparable because:

- The concentrations of the Hederin formulations are different in 2018 based on experience of the previous year
- The varieties of potato were different, switching from Maris Piper in 2017 to the more susceptible Kind Edward in 2018.

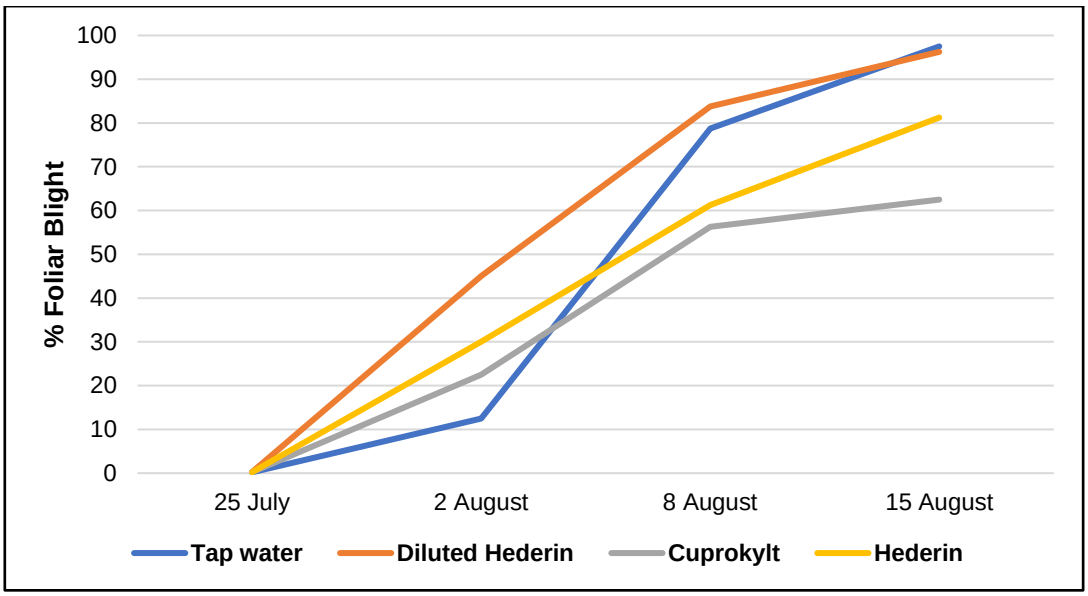

Figure 2: Average scores of late blight, Ty'n yr Helyg 2017

Diluted Hederin = 0.1% (1g/l)

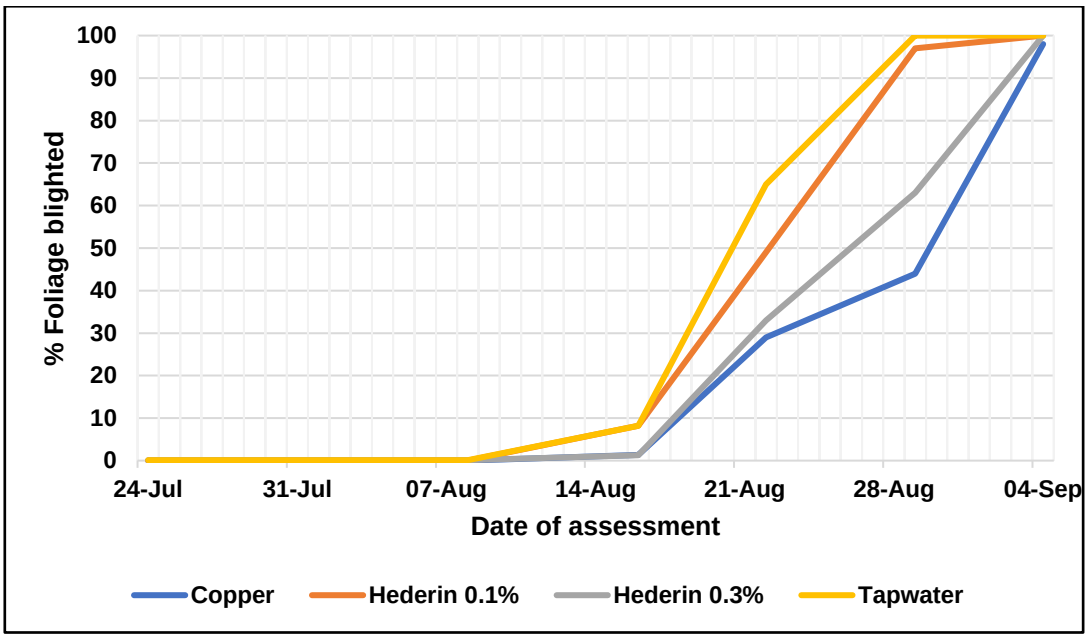

Figure 3: Average scores of late blight, Ty'n yr Helyg 2018

In 2017, the blight infection advanced rapidly. Some blight control was noticeable by week 3 particularly for the copper (56 % blighted) and 0.3% Hederin (61 % blighted) plots compared to the control treatment (79 % blighted). By week 4 of the epidemic, blight control was most noticeable for the copper treatment (63 % blighted) but control for full strength Hederin (81 % blighted) remained greater than for tap water control treatment (98 % blighted) and for diluted Hederin (also 98 % blighted).

Sample pictures of plots from each treatment are presented below in Figure 4

Hederin

Cuprokylt

Dilute hederin

Tap Water/ Control

Figure 4: Images of plots from each treatment at Ty'n yr Helyg (taken 8 August 2017)

In 2018, the blight infection was later (first detected on 7 August) but advanced rapidly thereafter, the control plot reaching 100 % blighted foliage 3 weeks later. The 0.1% Hederin followed a similar pattern to the tap water control. The 0.3 % Hederin was comparable to the copper treatment. Both these treatments delayed the onset of blight by a week compared to tap water and 0.1 % Hederin. On 21 August, the copper and 0.3 % Hederin gave very similar levels of control, but a week later 44 % of foliage was blighted in copper plots compared to 63 % in the 0.3 % Hederin. By 4 September practically all foliage was blighted in both treatments (100 % in the 0.3% Hederin and 98 % in the copper plots).

3.13 Yield

The average weight of tubers per plot in each treatment, broken down by size bracket, is provided for each of the years below.

Results for 2017 are shown below in Table 7 and Figure 6.

Treatment	**Average mass of tubers (Kg)**					**% total yield in control plot**
	< 40 mm	**40 – 65 mm**	**66 – 70 mm**	**>70mm**	**Total**	
Hederin	1.05	7.48	0.35	1.09	9.97	84
Cuprokylyt	1.03	7.7	0.3	1.33	10.36	87
Diluted Hederin	1.11	8	0.25	0.65	10.01	84
Tap water	0.8	8.65	1.35	1.1	11.9	

Table 7: Average total tuber mass/ plot at Ty'n yr Helyg 2017

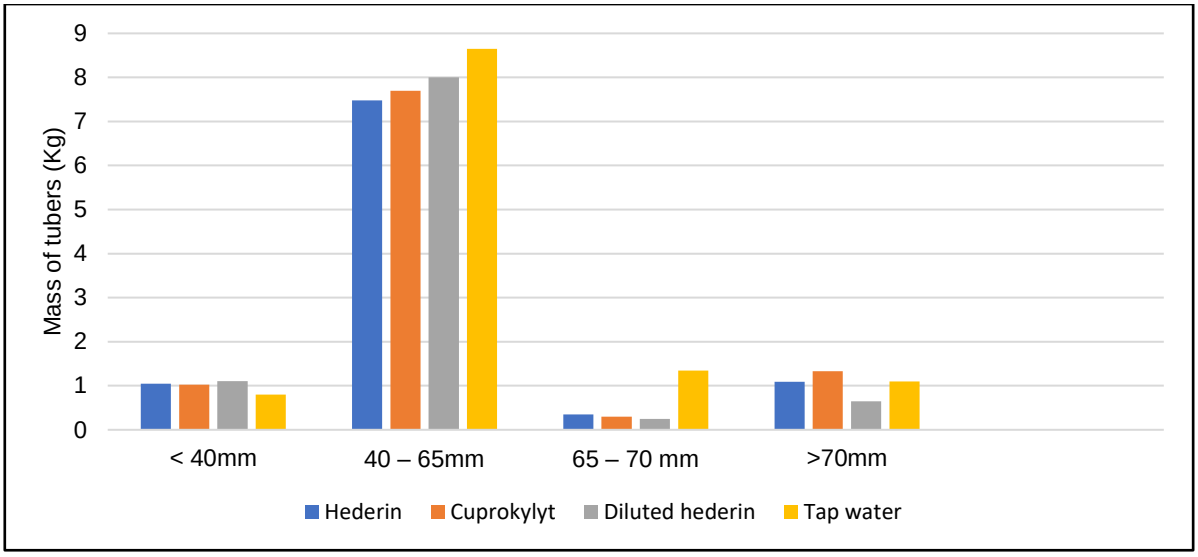

Figure 6: Average total tuber mass per plot, Ty'n yr Helyg, 2017

The results indicate that the yield was highest in the untreated, control plots. This is surprising given the proven efficacy of Cuprokylt, at least, and suggests a site effect rather than a treatment effect.

In 2018 (Table 8 and Figure 7), there were clearer differences between the treatments, possibly as a result of improved experimental design and the reduction of site effects. Table 9 shows that the tap water and 0.1 % Hederin had similar yields and distributions between under and over 45 mm tubers. In comparison, average yield from the copper and 0.3 Hederin were approximately 25 % higher compared to the tap water treatment, with a greater proportion of tubers over 45 mm.

Treatment	**Average yield/ plot (Kg)**			**% total yield in control plots**
	<45 mm	*>45 mm*	*Total*	
Copper	5.30	6.87	12.17	127
Hederin 0.1%	5.76	4.48	10.24	107
Hederin 0.3%	5.50	6.34	11.84	124
Tap water	5.56	4.02	9.58	

Table 9: Average tuber mass/ plot, Ty'n yr Helyg 2018

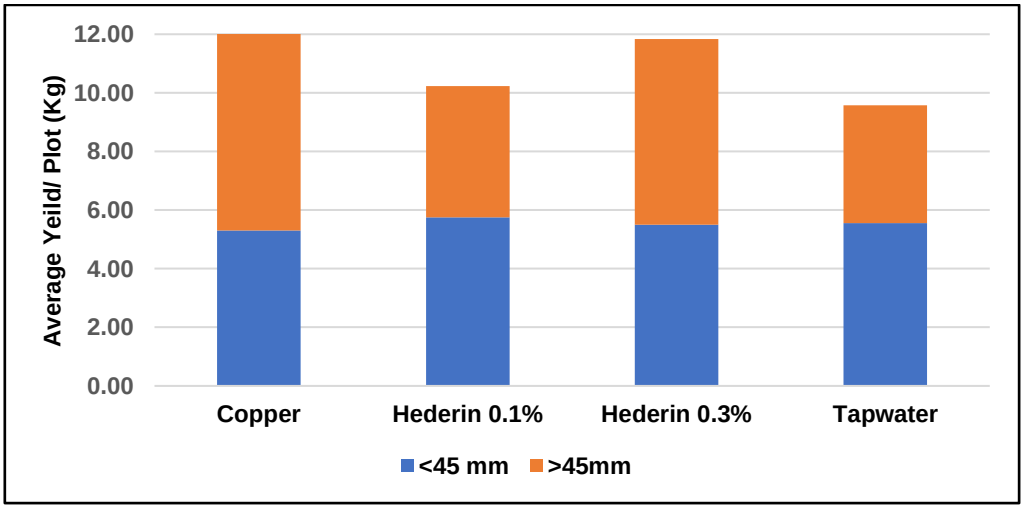

Figure 7: Average tuber mass per plot, Ty'n yr Helyg, 2018

3.14 Tuber Quality

The results with respect to tuber health are less clear cut. For 2017, Figure 8 shows the number of blighted tubers and figure the distribution of the mass of blighted tuber across the different size brackets

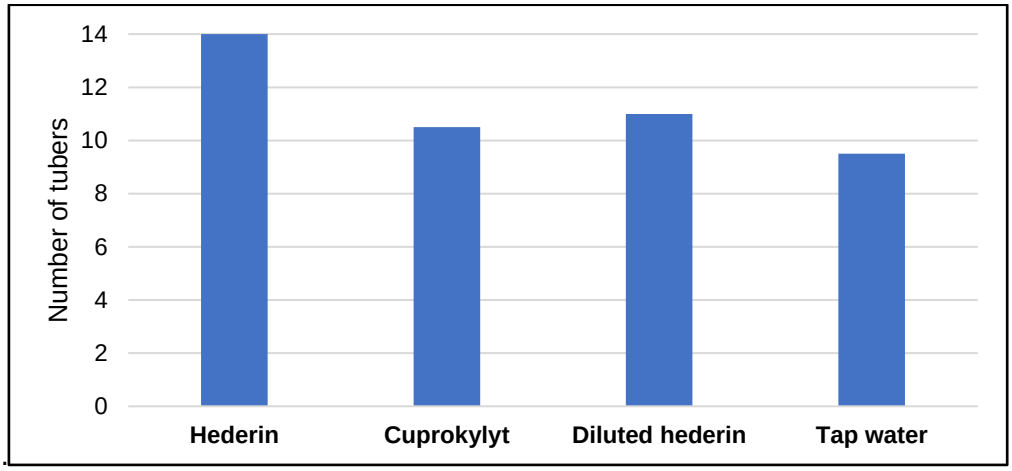

Figure 8: Average number of tuber blights/ rots 2017

On the face of it, the tap water treatment had the lowest number of blighted tubers and the Hederin treatment had a higher number of rotted tubers, but the data needs to be interpreted with care. It is suspected that some of the rotted tubers were actually the remains of mother tubers that were planted rather than soft rot.

This is borne out to some extent by the results for 2018 (Table 10). The number of blighted tubers was similar across all treatments, but the mass of blighted tubers was much higher in the copper and 0.3 % Hederin treatments. This is to be expected to some degree, because these treatments had a greater proportion of larger tubers.

Treatment	**Tuber blight**		**% Tap water**
	Number	*Mass grams*	
Copper	11.8	935.8	207
Hederin 0.1%	11.6	503.6	111
Hederin 0.3%	12.2	650.6	144
Tap water	12.2	452.6	

Table 10: Average number and mass of tuber blight/ rots 2018

3.2 Henfaes

3.21 Blight pressure

Hutton Periods logged for Henfaes, LL33 postcode are shown in Table 11 below.

Month	Date	Total for month (days)
May	Last 2 weeks	2
June	Last 2 weeks	6
July	First 2 weeks	4
August	Throughout the month	8
September	Throughout the month	6

Table 11: Hutton Period alerts for postcode area LL33 for 2017

This represents moderate pressure compared to the Ty'n yr Helyg site, particularly towards the end of the growing season. There were only eight Hutton Period alerts at Henfaes in August compared to 18 in the same month at Ty'n yr Helyg.

3.22 Foliar blight

Average scores of late blight in four replicate plots of each treatment in 2017 are shown in Figure 9. Raw data are presented in Appendix III.

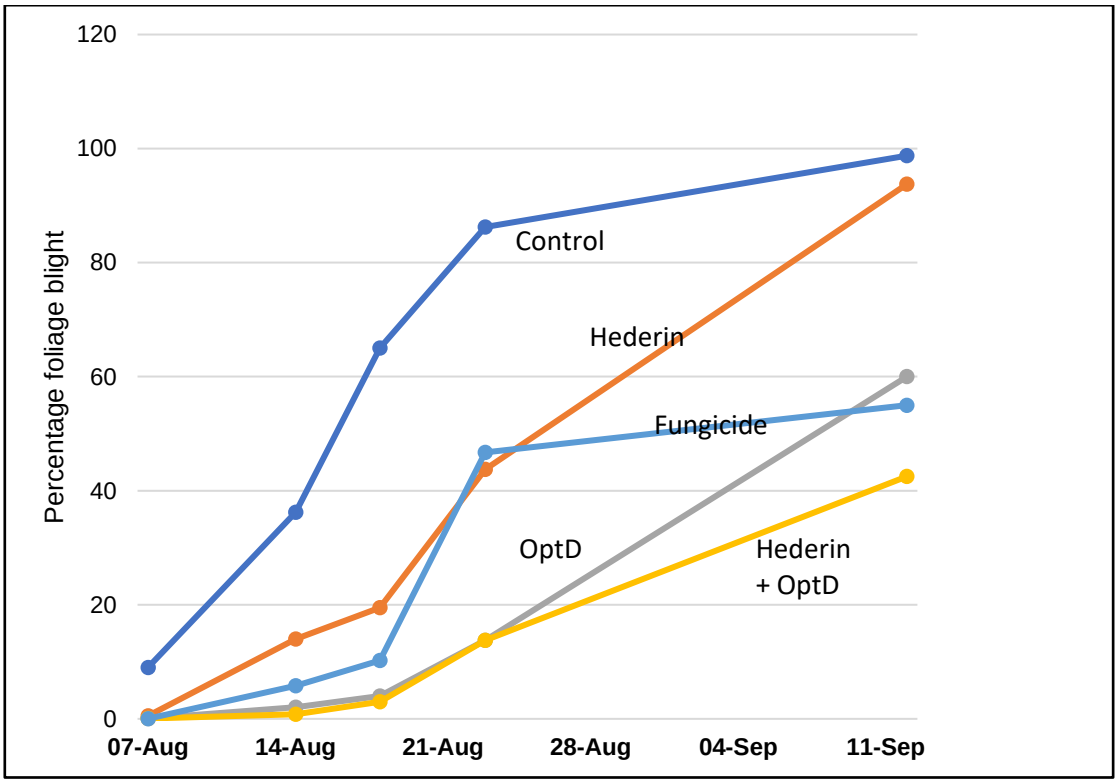

Figure 9: Average scores of late blight, Henfaes 2017

Control values show a typical rapid increase of blight reaching 100 % defoliation) by 11 September.

Commercial fungicides slowed the progression of blight; levels were around 50 % by 11 September. There was evidence that new growth was not protected in the middle part of the progression, allowing more blight to develop subsequently.

Hederin treatment slowed the early development of blight so that values at 23 August were very close to that of commercial fungicide. The final score showed that the progression after that date was steady and achieved nearly 100 % by 12 September.

Progression with OptD increased slowly and was clearly lower than Hederin and commercial fungicide treatments on 23 August but increased steadily to around 60 % by 12 September.

Combined Hederin and OptD resulted in the slowest progression of all treatments. Levels were similar to OptD up until the last score of around 40 % by 12 September. Thus there was some evidence that Hederin with OptD is more protective than OptD alone.

Although Hederin treatments were less effective than commercial fungicide treatments by the end of the trial, there was no evidence that they differed from commercial fungicide in the earlier part of the progression.

Blight progression for 2018 is shown below in Figure 10.

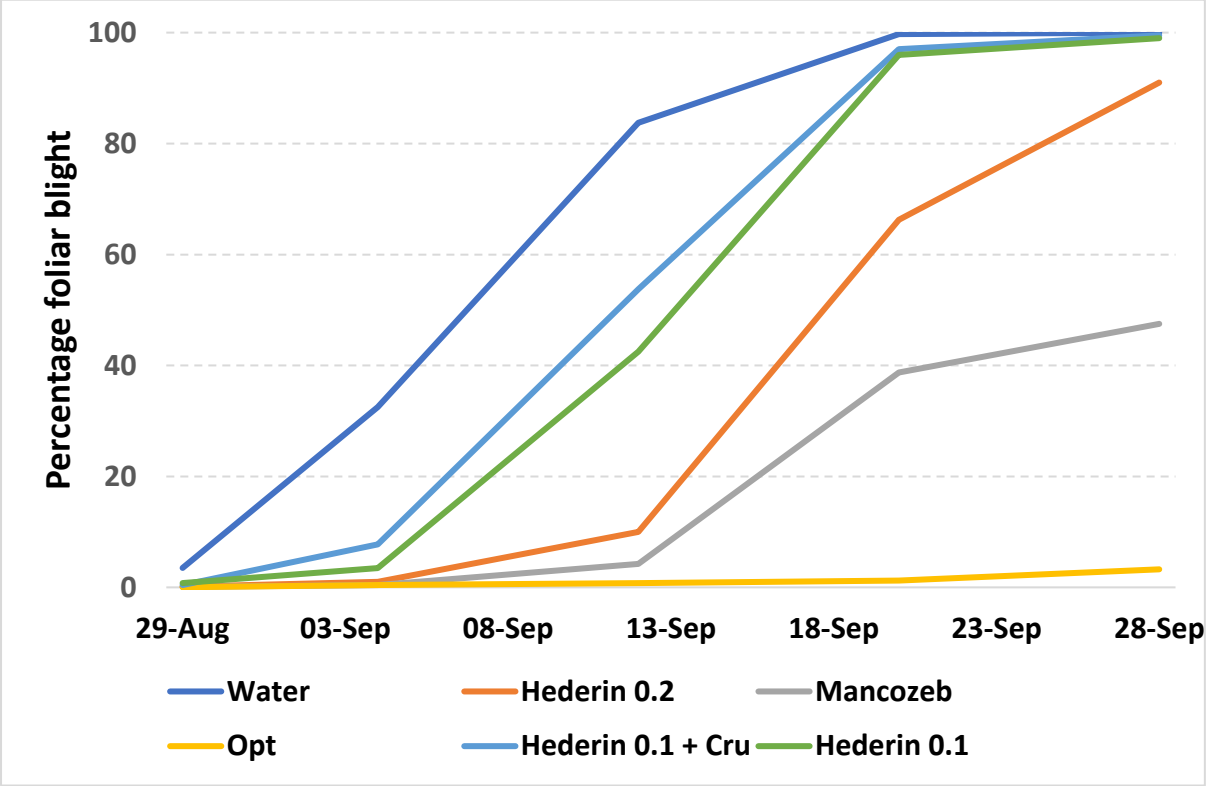

Figure 10: Average scores of late blight in four replicate plots of each treatment, 2018

Progression of foliar blight: plots sprayed with water as a control showed a typical rapid increase of blight on the foliage to 100 % (defoliation) by 12 September.

Commercial fungicide slowed the progression of blight until September 13. After that date, the average percentage foliage blight increased at a low rate to 47 % on 28 September after which scoring ceased.

Hederin treatment (0.1 %) slowed the early development of blight. The rate of progression was less than that in the control plots but greater than the Mancozeb treatments. By 28 September foliar blight had reached 99 %. Hederin, 0.1 % supplemented with spreader 'Crusade' followed a very similar progression but the values (although not significantly different) were consistently more than those of Hederin 0.1 % alone.

Hederin at 0.2 %, partially purified to 90 %, showed better control of foliar blight than the purified product at 0.1 %. The progression curve was intermediate between Mancozeb and the purified product at 0.1 % but reached 91 % by the last date of scoring.

Plots treated with OptD showed a very slow progression, much slower than that of Mancozeb and only reaching just over 3 % at the last date of scoring.

There was evidence that the spread of blight within the plots was not uniform. Wild blight became established in another trial in the west end of the field on 6 August. The disease spread gradually across the field over the next few weeks, carried by the prevailing south-westerly wind. Scores of foliage blight tended to be greater in the westerly plots (1-8% of visible foliage affected) and less in the easterly plots (17-24% of visible foliage affected).

It was observed that plants in some plots showed evidence of virus disease (stunted and distorted foliage). The foliage canopy did not close over in these plots. The virus symptoms became more prominent as the season progressed. The disease was particularly severe on plots 2 (0.1 % Hederin), 3 (0.1 % Hederin + Crusade) and 4 (water control).

3.23 Yield

The average weight of tubers per plot in each treatment, broken down by size bracket for 2017, is provided in the Table 12 and Figure 11. Raw data is available in Appendix IV.

Treatment	Average tuber mass (kg)		
	Grade <45 mm	Grade >45 mm	Total
Control	3.5	17.3	20.8
Hederin	3.0	12.7	15.6
OptD	2.6	17.9	20.5
Hederin + OptD	3.2	17.0	20.2
Fungicide	2.8	13.6	16.4

Table 12: Average total tuber mass/plot, Henfaes 2017

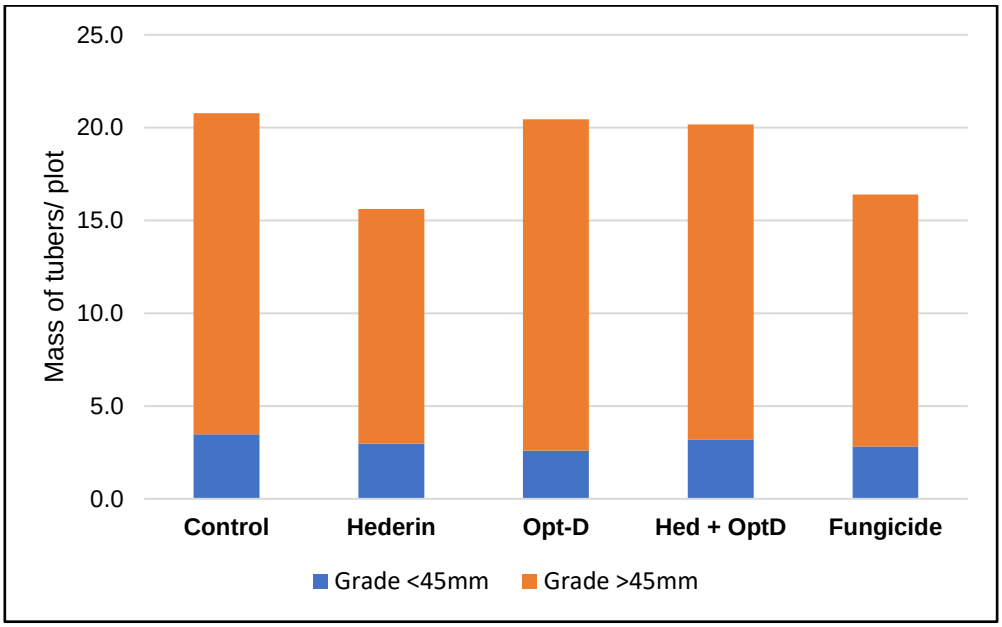

Figure 11: Average total tuber mass/ plot, Henfaes 2017

The yield data from Henfaes is somewhat confusing. Given that all the treatments gave some degree of control of blight (Figure 9), either by reducing the total amount of blighted foliage or by slowing down the progression of the blight epidemic, we would expect yields to be higher in treatment compared to the control plots. In fact, yield in the control plots were higher than the Hederin and fungicide treatments and similar to the 'OptD' and 'Hed + OptD' treatments. This suggests that other factors, which cannot be inferred from the data are at play in this trial.

Yield data for 2018 is shown below in Figure 12

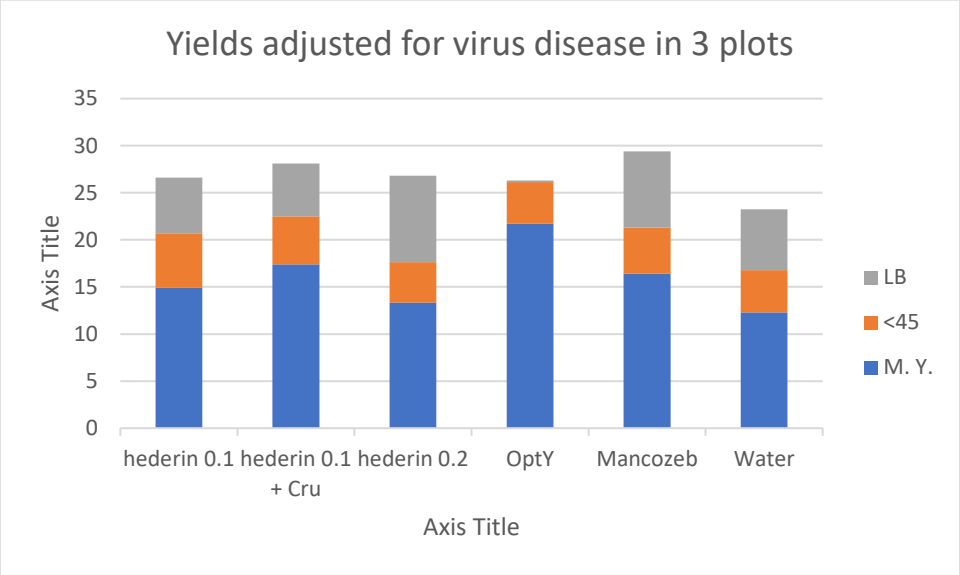

Figure 12: Average total tuber mass/ plot, 2018

The total yields showed that Mancozeb treatments resulted in the highest yields and water control, the lowest. The yields from the other treatments were intermediate (and probably not significant). Opt Dtreatments gave the highest marketable yields (probably significant). Marketable yields for all three Hederin treatments were higher (significantly?) than the control and not different from the Mancozeb treatments. OptD treatments were outstanding in their ability to suppress tuber blight symptoms.

3.24 Tuber quality

Figure 13 shows the average number of rotted tubers and tuber blights for each of the treatments in 2017. At Ty'n yr Helyg, the quality of the tubers was very good. On average, the number of rotted tubers in each treatment and the control was less than 5 per plot. The plots treated with Hederin had the highest number of rotted tubers, but because the absolute number was so low, it is difficult to attach much significant to this result.

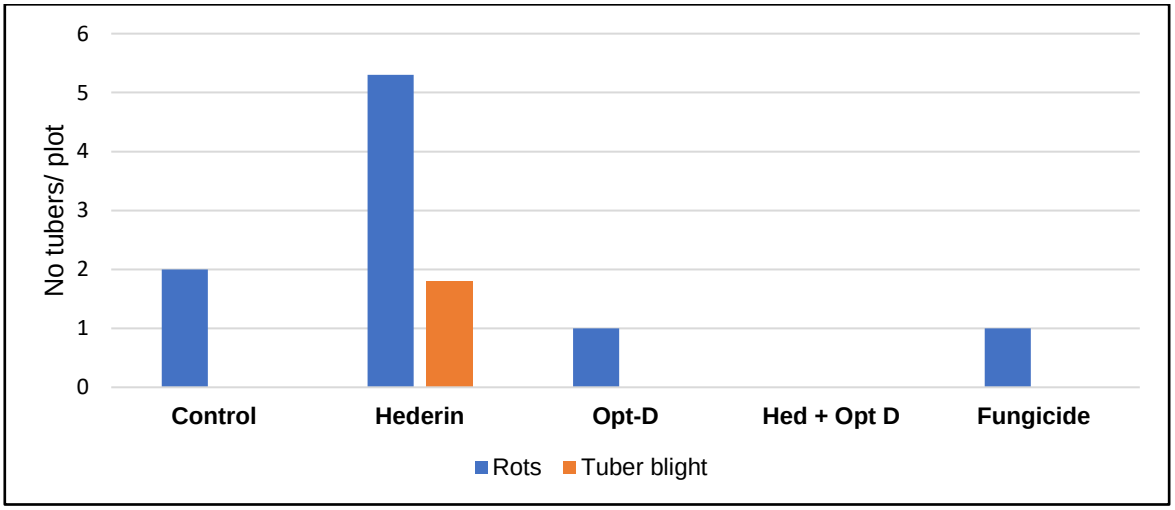

Figure 13: Average number of blighted and rotted tubers, Henfaes 2017

4. Conclusions

4.1 Effect of hederin on blight progression

At concentrations of 0.2 % (90 % pure extract) and 0.3 % (100 % pure), Hederin alone slowed down the progression of the blight epidemic at all sites in both years, compared to the no treatment (tap water). However, it did not prevent blight epidemic reaching 100 % by the end of the monitoring period, exceptions being Ty'n yr Helyg in 2017 where it reached 81 % and Henfaes in 2018 where it reached 91 %. However, at these concentrations Hederin was less effective than standard fungicide treatments (Cuprokylt at Ty'n yr Helyg and Mancozeb/ Shirlan/ Ranman at Henfaes)

At 0.1 %, Hederin had little or no effect compared to tap water at either site in either year. The addition of Crusade, an adjuvant to improve the adhesion of the active ingredient to the foliage, did not substantially increase the efficacy of Hederin at this concentration.

4.2 Effect of OptD on blight progression

OptD, tested only at Henfaes, was consistently the most effective treatment, both in terms of slowing down the progression of the disease and reducing the proportion of foliage blighted at the end of the monitoring period. In 2018, only an average of 3 % of foliage was blighted, compared to 47.5 % for Mancozeb and between 91 % and 100 % for all other treatments.

In 2017, OptD was combined with Hederin, and gave better management of blight compared to OptD alone, both in terms of slowing the progression of the epidemic and reducing the percentage of foliage blighted at the end of the monitoring period.

4.3 Effect of treatments on yield and quality

In cases where Hederin showed a slowing down and/ or a reduction in the blight epidemic, this was not reflected as clearly in the yield data as might be expected, suggesting that on the whole control was not sufficiently effective to translate into increased tuber production. However, there were some differences that can be highlighted. In 2018 at Ty'n yr Helyg, the total yield and the proportion of tubers above 45 mm in the 0.3 % Hederin treatment was comparable to Cuprokylt and higher than 0.1% Hederin and tap water. This is reflected by the blight progression chart (Figure 3). However, it is difficult to pick out similar trends at other sites and in other years. It is important to note that this applies equally to the treatments other than Hederin (i.e. Cuprokylt, synthetic fungicides and OptD). The exception to this is OptD in 2018. In this case although the total yield was comparable to other treatments (despite achieving much better blight control), the marketable yield was noticeably higher.

It is difficult to comment on the impact of the treatments on tuber quality, because the numbers of tubers were low.

4.4 Overall conclusions

The results suggest that, on its own, Hederin at the concentrations tested does not give comparable control to standard fungicide programmes in conventional systems and copper in organic systems. However, it may have a role to play in integrated disease management programmes, for example in combination with resistant varieties or when mixed with OptD or similar products.

Appendix I: Randomised block designs

- Henfaes 2017
- Henfaes 2018
- Ty'n yr Helyg 2017
- Ty'n yr Helyg 2018

Blight progression data, Ty'n yr Helyg

Plot Number	Treatment	% Foliar blight	% Foliar blight	% Foliar blight	% Foliar blight
		25/07/17	**02/08/17**	**08/08/17**	**15/08/17**
1	4	0.2	25	50	95
8	4	0.2	10	95	100
10	4	0.2	10	95	100
15	4	0.2	5	75	95
2	3	0.2	10	50	95
7	3	0.3	95	95	100
12	3	0.2	25	95	95
13	3	0.3	50	95	95
4	2	0.2	10	25	25
5	2	0.2	5	75	75
11	2	0.2	25	50	75
14	2	0.3	50	75	75
3	1	0.2	10	25	75
6	1	0.3	95	95	100
9	1	0.2	10	50	75
16	1	0.2	5	75	75

Appendix II: Yield and quality data, Ty'n yr Helyg

	< 40 mm	40 – 65 mm	65 – 70 mm	>70 mm	Total	No of Discards (soft rot)
Plot No 1 Treatment 4	**0.80**	**10.20**	**2.68**	**0.68**	**14.35**	**6**
Plot No 2 Treatment 3	**1.00**	**10.00**	**0.80**	**0.50**	**12.30**	**7**
Plot No 3 Treatment 1	**1.20**	**8.80**	**1.00**	**2.20**	**13.20**	**15**
Plot No 4 Treatment 2	**0.90**	**9.20**	**1.00**	**2.73**	**13.83**	**20**
Plot No 5 Treatment 2	**1.10**	**7.90**	**0.00**	**1.25**	**10.25**	**4**
Plot No 6 Treatment 1	**1.10**	**5.80**	**0.00**	**0.00**	**6.90**	**17**
Plot No 7 Treatment 3	**1.13**	**5.10**	**0.00**	**0.00**	**6.23**	**17**
Plot No 8 Treatment 4	**0.70**	**7.30**	**0.00**	**1.40**	**9.40**	**17**
Plot No 9 Treatment 1	**1.30**	**8.80**	**0.00**	**1.10**	**11.20**	**18**
Plot No 10 Treatment 4	**1.00**	**8.90**	**1.40**	**0.60**	**11.90**	**10**
Plot No 11 Treatment 2	**0.90**	**8.80**	**0.20**	**1.35**	**11.25**	**12**
Plot No 12 Treatment 3	**1.50**	**10.50**	**0.00**	**1.40**	**13.40**	**12**
Plot No 13 Treatment 3	**0.80**	**6.40**	**0.20**	**0.70**	**8.10**	**8**
Plot No 14 Treatment 2	**1.20**	**4.90**	**0.00**	**0.00**	**6.10**	**6**
Plot No 15 Treatment 4	**0.70**	**8.20**	**1.30**	**1.70**	**11.90**	**5**
Plot No 16 Treatment 1	**0.60**	**6.50**	**0.40**	**1.05**	**8.55**	**6**
Total	15.93	127.30	8.98	16.66	168.86	180.00

Appendix III: Blight Progression data, Henfaes

Raw Data

Treatment	% Foliar Blight				
	07-Aug	14-Aug	18-Aug	23-Aug	12-Sep
Control	0.1	30	85	95	100
Control	1	20	50	70	95
Control	15	35	55	85	100
Control	20	60	70	95	100
Hederin	0.01	1	8	40	95
Hederin	1	15	20	50	95
Hederin	1	20	25	55	100
Hederin	0.1	20	25	30	85
OptYD	0.01	1	5	10	50
OptYD	0.01	0.1	1	5	65
OptYD	0.1	5	5	20	75
OptYD	0.1	2	5	20	50
H + O	0.01	0.1	1	10	45
H + O	0	0.1	3	10	25
H + O	0.1	2	5	20	50
H + O	0.1	1	3	15	50
Fungicide	0.01	5	10	55	50
Fungicide	0	0.1	1	7	35
Fungicide	0.01	15	20	80	80
Fungicide	0.1	3	10	45	55

Appendix IV: Yield and quality data, Henfaes

Bag No.	Treatment	Yield/ plot (kg)			Soft rot (No.)	Tuber blight (No.)
		Grade <45 mm	Grade >45 mm	Total		
11	Control	3.6	10.4	14	1	
18	Control	3.1	26.6	29.7		
20	Control	4.1	20.1	24.2	3	
1	Control	3.1	12.1	15.2		
2	α-hederin	2.8	8.5	11.3		
6	α-hederin	3.5	16.2	19.7	1	9
14	α-hederin	3.3	13.1	16.4	10	
15	α-hederin	2.3	12.8	15.1	5	
9	Opt-Y D	2	21	23	1	
10	Opt-Y D	3.4	17.6	21		
12	Opt-Y D	3	15.2	18.2	1	
19	Opt-Y D	2	17.6	19.6	1	
5	α-h + OYD	3	19.5	22.5		
7	α-h + OYD	3.4	16.8	20.2		
16	α-h + OYD	3.8	14.5	18.3		
17	α-h + OYD	2.6	17.1	19.7		
13	Fungicide	3.5	13.1	16.6	1	
3	Fungicide	3.1	11.1	14.2		
4	Fungicide	2.1	9.8	11.9		
8	Fungicide	2.6	20.3	22.9		