

SCEPTREPLUS

Final Trial Report

Trial code:	SP 21
Title:	Root rot control in deep-water hydroponic culture of lettuce
Crop	Lettuce
Target	<i>Phytophthora cryptogea</i> and, potentially, other oomycete root rot pathogens
Lead researcher:	Dr Martin McPherson
Organisation:	Stockbridge Technology Centre
Period:	February – May 2018
Report date:	September 2018
Report author:	Kirsty Wright
ORETO Number: (certificate should be attached)	ORETO 372

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

21.02.2019



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Date

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Authors signature

Trial Summary

Introduction

Phytophthora cryptogea, and other oomycete root rot pathogens, can cause severe deterioration of roots of deep-water hydroponic lettuce plants, leading to reduced vigour and yield. UK hydroponic lettuce growers currently have no access to fungicides (conventional or biopesticide) that are approved for application into hydroponic growing solution for direct control of root rot disease. A selection of conventional and biopesticide products were tested, in a novel hydroponic test system, for efficacy against root rot in lettuce caused by *P. cryptogea*.

Methods

Lettuce cv. Alega, propagated in peat blocks, was planted into carriers placed into floating rafts in discreet hydroponic tanks. Five conventional pesticides and four biopesticides were selected for the trial. Two of these products were novel while the other seven are already approved for foliar application to lettuce or similar crops.

All products were applied into the nutrient solution, with some products also being applied to blocks in propagation, according to manufacturer's directions. Following the first application of products into the solution, the pathogen was introduced via infector plants and by plugs of agar-grown cultures put directly into the nutrient solution. Assessments were made of root length and root colour during the trial and yield assessments made at harvest.

Results

Trt. no.	Treatment code	% control of disease symptoms (root discolouration) relative to untreated control		
		06.3.18 (1 day after application E)	13.3.18 (1 day after application F)	24.4.18 (21 days after application I)
1	Untreated			
2	AHDB 9942	100.0	98.3	60.9
3	AHDB 9941	3.3	16.4	-5.5
4	AHDB 9940	100.0	100.0	85.9
5	AHDB 9958	25.0	68.8	15.6
6	AHDB 9939	96.7	98.3	35.9
7	AHDB 9938	0.0	13.1	4.7
8	AHDB 9937	1.7	4.9	-9.4
9	AHDB 9967	6.7	1.7	-27.5
10	AHDB 9936	0.0	9.8	-4.7
		Not significantly different from untreated control ($p>0.05$)		
		Significantly different from untreated control ($p<0.05$)		

Conclusions

Two conventional fungicides (AHDB 9942 and AHDB 9940) gave excellent control of disease symptoms and one other (AHDB 9939) gave some control. No biopesticides were effective at reducing the symptoms of root rot, although one that caused phytotoxicity did seem to reduce the number of zoospores present in the nutrient solution and might be useful at a lower, non-phytotoxic, application rate.

Take home message:

Root rot disease in deep water hydroponic systems, caused by *P. cryptogea*, can be managed using fungicides applied directly into nutrient solution, although approvals for this method of application will need to be sought.

Objectives

To assess a selection of novel biopesticides and conventional fungicides for activity against *Phytophthora* root rot in glasshouse lettuce grown in a deep-water hydroponic system.

Trial conduct

UK regulatory guidelines were followed but EPPO guidelines took precedence. The following EPPO guidelines were followed:

Relevant EPPO guideline(s)		Variation from EPPO
PP 1/152(3)	Design and analysis of efficacy evaluation trials	None
PP 1/135(3)	Phytotoxicity assessment	None
PP 1/181(3)	Conduct and reporting of efficacy evaluation trials including GEP	None

There were no deviations from EPPO guidance.

Test site

Item	Details
Location address	Stockbridge Technology Centre, Stockbridge House, Cawood, Selby YO8 3TZ
Crop	Lettuce (LACSA)
Cultivar	Alega
Soil or substrate type	Peat blocks
Agronomic practice	Each individual tank filled with nutrient solution. EC and pH of each tank checked regularly and adjusted as necessary. No herbicides or insecticides used
Prior history of site	No previous crop.

Trial design

Item	Details
Trial design:	Randomised complete block
Number of replicates:	6
Row spacing:	20cm
Plot size: (w x l)	111cm x 90cm
Plot size: (m ²)	1.0m ²
Plot (hydroponic tank) volume (l)	330
Number of plants per plot:	30
Leaf Wall Area calculations	N/A

Treatment details

Trt. No.	AHDB Code	Active substance	Product name/ manufacturers code	Formulation batch number	Content of active substance in product	Formulation type	Adjuvant
1	Untreated	Untreated (Inoculated Control)	-	-	-	-	
2	AHDB 9942	N/D	N/D	N/D	N/D	N/D	None
3	AHDB 9941	N/D	N/D	N/D	N/D	N/D	None
4	AHDB 9940	N/D	N/D	N/D	N/D	N/D	None
5	AHDB 9958	N/D	N/D	N/D	N/D	N/D	None
6	AHDB 9939	N/D	N/D	N/D	N/D	N/D	None
7	AHDB 9938	N/D	N/D	N/D	N/D	N/D	None
8	AHDB 9937	N/D	N/D	N/D	N/D	N/D	None
9	AHDB 9967	N/D	N/D	N/D	N/D	N/D	None
10	AHDB 9936	N/D	N/D	N/D	N/D	N/D	None

Application schedule

Trt. No.	Treatment: AHDB Code	Rate of active substance (ml or g a.s./ha)	Rate of product (l or kg/ha)	Application code
1	Untreated			
2	AHDB 9942	1250 g/ha	2.5 kg/ha	D F H
3	AHDB 9941	9300 g/ha + 15900 g/ha	30 l/ha	A
3	AHDB 9941	775 g/ha + 1325 g/ha	2.5 l/ha	D F H
4	AHDB 9940	1163 g/ha	2.5 l/ha	D F H
5	AHDB 9958	240 g/ha + 960 g/ha	3.2 l/ha	D F H
6	AHDB 9939	1250 g/ha	5.0 l/ha	D F H
7	AHDB 9938	8638 g/ha	86.38 kg/ha	C
7	AHDB 9938	90 g/ha	9.0 kg/ha	D
7	AHDB 9938	45 g/ha	4.5 kg/ha	E F G H I
8	AHDB 9937	56320 g/ha	176 kg/ha	B
8	AHDB 9937	2400 g/ha	7.5 kg/ha	D E F G H I
9	AHDB 9967	6000 g/ha	100 l/ha	D E F G H I
10	AHDB 9936	8120.8 g/ha	8.0 kg/ha	A D E F G H I

Application details

	Application A	Application B	Application C	Application D
Application date	20.02.18	20.02.18	20.02.18	26.02.18
Time of day	11:00	11:00	11:00	14:00
Crop growth stage (BBCH)	14	14	14	16
Crop height (cm)	3	3	3	4
Crop coverage (% of foliage)	95	95	0	0
Application Method	Spray	Spray	Dip	Poured
Application Placement	Foliage	Foliage	Block	Nutrient soln.
Application equipment	OPS	OPS	N/A	N/A
Nozzle pressure	2 Bar	2 Bar	N/A	N/A
Nozzle type	Flat fan	Flat fan	N/A	N/A
Nozzle size	Hardi 4110-20	Hardi 4110-20	N/A	N/A
Application water volume/ha	30000 l/ha	35200 l/ha	10ml/plant	50ml/tank
Temperature of air - shade (°C)	19.9	19.9	19.9	10.4
Relative humidity (%)	45.4	45.4	45.4	52
Wind speed range (m/s)	N/A	N/A	N/A	N/A
Dew presence (Y/N)	N	N	N	N
Temperature of soil - 2-5 cm (°C)	N/A	N/A	N/A	N/A
Wetness of soil - 2-5 cm	N/A	N/A	N/A	N/A
Cloud cover (%)	100	100	100	40

	Application E	Application F	Application G	Application H	Application I
Application date	05.03.18	12.03.18	19.03.18	26.03.18	03.04.18
Time of day	14:00	12:00	14:30	14:00	11:30
Crop growth stage (Max, min average BBCH)	18	19	41	43	45
Crop height (cm)	5	8	10	12	12
Crop coverage (% of foliage)	0	0	0	0	0
Application Method	Poured	Poured	Poured	Poured	Poured
Application Placement	Nutrient solution				
Application equipment	N/A	N/A	N/A	N/A	N/A
Nozzle pressure	N/A	N/A	N/A	N/A	N/A
Nozzle type	N/A	N/A	N/A	N/A	N/A
Nozzle size	N/A	N/A	N/A	N/A	N/A
Application water volume/ha	50ml/tank	50ml/tank	50ml/tank	50ml/tank	50ml/tank
Temperature of air - shade (°C)	14.1	9.7	12.8	18.5	16.0
Relative humidity (%)	63.9	87.6	55.4	51.7	79.0
Wind speed range (m/s)	N/A	N/A	N/A	N/A	N/A
Dew presence (Y/N)	N	N	N	N	N
Temperature of soil - 2-5 cm (°C)	N/A	N/A	N/A	N/A	N/A
Wetness of soil - 2-5 cm	N/A	N/A	N/A	N/A	N/A
Cloud cover (%)	100	100	40	10	90

Untreated levels of pests/pathogens at application and through the assessment period

Common name	Scientific Name	EPPO Code	Infestation level pre-application	Infestation level at start of assessment period	Infestation level at end of assessment period
<i>Phytophthora</i> root rot	<i>Phytophthora cryptogea</i>	PHYTCR	None	Moderate	Severe infection in root zone but no plant losses

Plots were artificially inoculated two days after Application D (the first application of all products into the nutrient solution). Inoculation was done in two ways: firstly young plants in peat blocks were inoculated in the root zone using macerated agar cultures of *P. cryptogea*. Two of these plants were then planted into the centre of each plot. Secondly, cultures of *P. cryptogea* were raised on agar and plugs of these cultures added to the nutrient solution at a rate of twenty 5mm plugs per tank (this rate being determined during pre-trial pathogenicity tests).

Assessment details

Evaluation date	Evaluation Timing (DA)*		Crop Growth Stage (BBCH)	Evaluation type (efficacy, phytotox)	Assessment
	After conventional pesticides	After biopesticides			
06.03.18	8	1	18	Efficacy	Root length/root discolouration
13.03.18	1	1	19	Efficacy	Root length/root discolouration
24.04.18	28	21	49	Efficacy	Plant vigour/plant colour
				Efficacy	Root length/root discolouration
				Efficacy	Harvest yield (head weight untrimmed and trimmed (kg), and root fresh weight (g))
24.04.18-26.04.18	28	21	49	Efficacy	Root dry weight (g)

* DA – days after application

Assessments were carried out on 10 central plants in each tank. Observations of phytotoxicity were made during routine crop visits and efficacy assessments commenced once symptoms of root disease were seen in the crop.

Root discolouration was assessed using the following scale:

Score 0: No root discolouration. Roots healthy and white, potentially some darker roots close to the peat block but not disease-related.

Score 1: Some small areas of root discolouration, including dark root tips. Not more than 10% of root discoloured.

Score 2: Significant areas of discoloration visible. 10-25% of root area affected.

Score 3: Severely discoloured roots. > 25% of roots affected

Root discolouration assessments were converted to a disease index score as follows:

$$\text{Disease Index} = \frac{1(\text{no. scored } 1) + 2(\text{no. scored } 2) + 3(\text{no. scored } 3)}{10 (\text{No. of plants assessed})} \times \frac{100}{3}$$

Percentage control was calculated as follows:

$$\text{Percentage control} = 1 - \frac{\text{Disease index of treatment}}{\text{Disease index of untreated}} \times 100$$

Assessments were made of tank parameters such as temperature, EC and pH of the nutrient solution. These were used to adjust the environment in the tanks as necessary.

Statistical analysis

This trial was designed as a randomized complete block with 10 treatments and 6 replicates and was approved by Andrew Mead at Rothamsted Research. The majority of data were analysed by ANOVA using the Minitab (v17) program by David George at STC. Prior to analysis data were checked for normality and homoscedasticity, being transformed if required. Where ANOVA reported a statistically significant effect of treatment, *post-hoc* testing was conducted by calculating one-tailed LSDs to allow treatments to be compared against the untreated control for demonstration of efficacy. In some cases, transformation was not sufficient to meet the assumptions for parametric testing. In these instances, data were analysed using non-parametric tests (Kruskal-Wallis tests for main effects, followed by pairwise comparisons via Mann-Whitney tests to compare the negative control to all other treatments).

Results

Phytotoxicity

AHDB 9967 caused excessive foaming following application into the tanks. This subsequently led to some scorching on foliage of leaves that were in contact with the foam. The quantity of foam varied from plot to plot and therefore the amount of scorching also varied. The manufacturer advised that a defoamer could be added to reduce this problem, but no product was made available during the period of the trial. The effect of the foam on the foliage suggested that the product may also be having a detrimental effect on the roots. Assessments of root colour and root length for this treatment initially indicated that the product was not effective in controlling the disease, but laboratory tests on nutrient solution samples from all of the tanks found no evidence of *Phytophthora* colony forming units in tanks treated with AHDB 9967. This suggests that the root discolouration, poor root length and reduced harvest yield seen with this product may actually be caused by phytotoxicity and not by disease.

Efficacy

Data summaries and analysis of assessments are shown below. Cells shaded green indicate treatments that are significantly better than the untreated control (e.g. have longer root length, lower disease index, higher yield).

Table 1: Root Length and Disease Index- results and analysis

		Root length (cm)	Root length (cm)	Root length (cm)	Disease index (0-100)	Disease index (0-100)	Disease index (0-100)
Trt	Trt name	06.03.18	13.03.18	24.04.18	06.3.18	13.3.18	24.4.18
1	Untreated	14.93	14.56	24.78	33.33	33.89	71.11
2	AHDB 9942	22.85	42.28	65.19	0.00	0.56	27.78
3	AHDB 9941	13.94	14.06	26.16	32.22	28.33	75.00
4	AHDB 9940	24.57	46.18	74.29	0.00	0.00	10.00
5	AHDB 9958	20.57	26.37	40.04	25.00	10.56	60.00
6	AHDB 9939	27.89	47.72	66.31	1.11	0.56	45.56
7	AHDB 9938	13.43	13.55	27.48	33.33	29.44	67.78
8	AHDB 9937	14.43	14.48	25.71	32.78	32.22	77.78
9	AHDB 9967	12.24	15.68	21.28	31.11	33.33	90.67
10	AHDB 9936	14.00	13.95	27.93	33.33	30.56	74.44

F / H	15.93	122.58	38.34	49.97	42.85	11.78
P	0	0	0	0	0	0
df	40	38	39	9	9	39
lsd	3.326	3.118	7.847	*	*	17.181

tcrit(df) one tailed	1.684	1.686	1.685	NA	NA	1.685
MSE	11.7	10.26	65.06	NA	NA	311.9
LSD	3.3256	3.117961	7.8469	NA	NA	17.18094

* NA - treatments compared to control using Mann Whitney Tests (adjusted for ties)

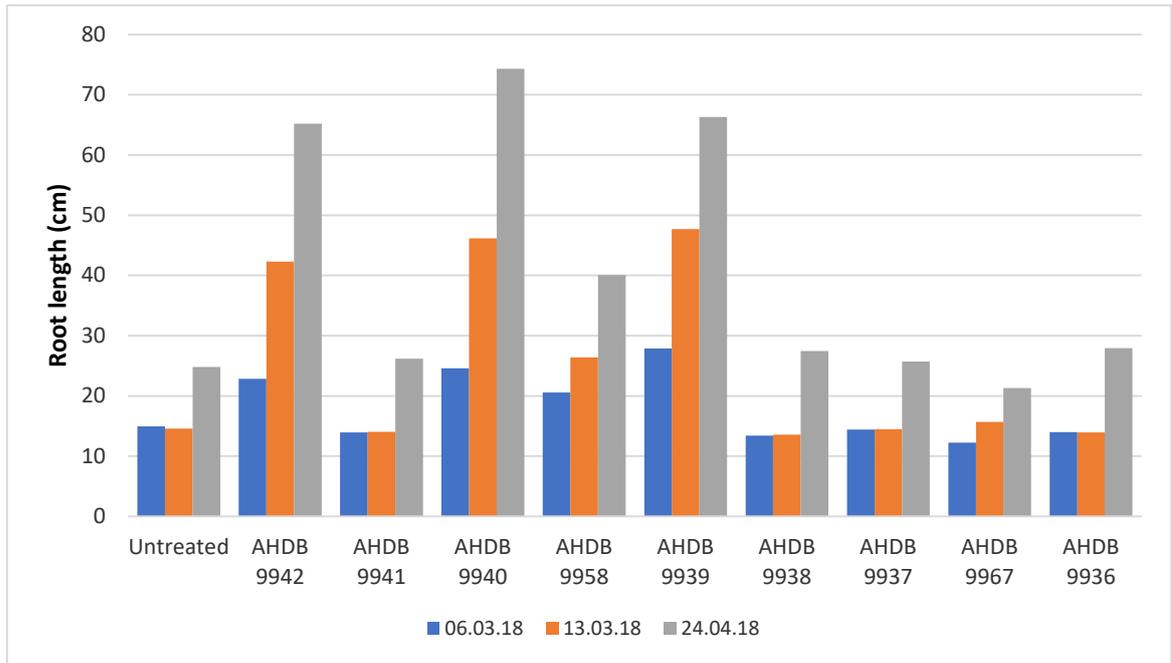


Figure 1: Average root length (cm)

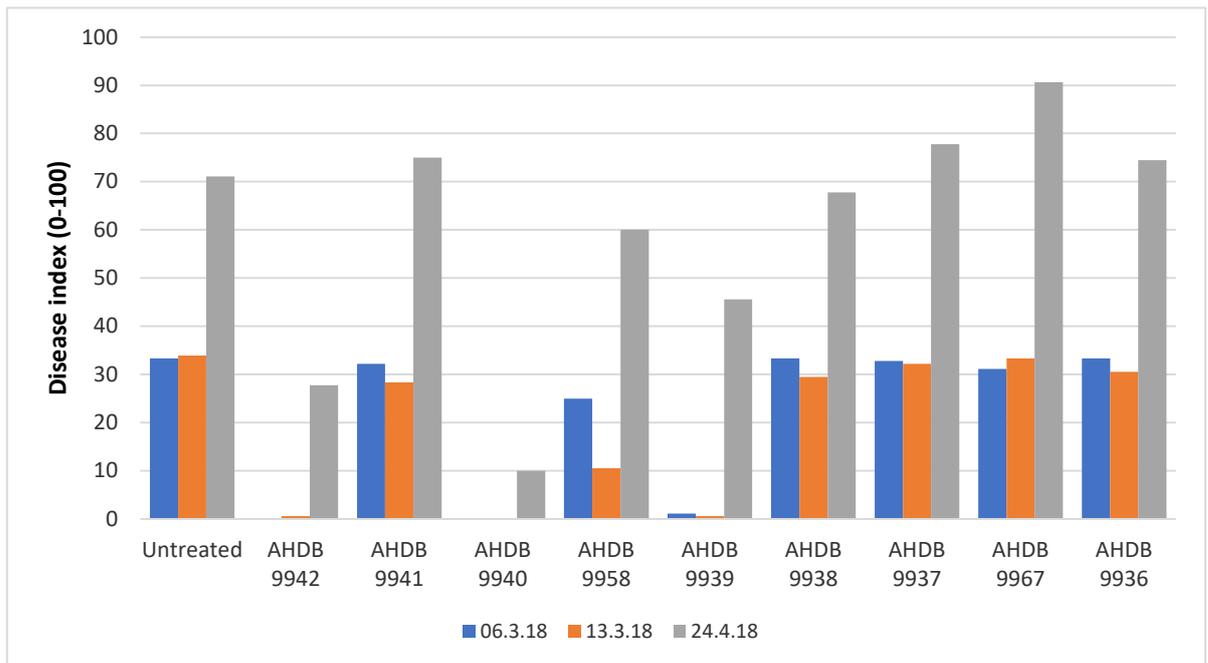


Figure 2: Disease Index (0-100) based on root discoloration

Table 2: Percent control of disease symptoms (root discoloration) relative to the untreated control

Trt	Trt name	% efficacy of products relative to untreated control		
		06.3.18	13.3.18	24.4.18
1	Untreated	-	-	-
2	AHDB 9942	100.0	98.3	60.9
3	AHDB 9941	3.3	16.4	-5.5
4	AHDB 9940	100.0	100.0	85.9
5	AHDB 9958	25.0	68.8	15.6
6	AHDB 9939	96.7	98.3	35.9
7	AHDB 9938	0.0	13.1	4.7
8	AHDB 9937	1.7	4.9	-9.4
9	AHDB 9967	6.7	1.7	-27.5
10	AHDB 9936	0.0	9.8	-4.7

Table 3: Harvest data summary and analysis

Trt	Trt name	Total fresh yield (kg)	Trimmed fresh yield (kg)	Total root fresh weight (g)	Total root dry weight (g)
		24.04.18	24.04.18	24.4.18	26.4.18
1	Untreated	2.62	2.45	45.30	2.78
2	AHDB 9942	3.18	2.92	138.57	6.25
3	AHDB 9941	2.57	2.39	50.91	2.98
4	AHDB 9940	3.31	3.02	133.23	5.67
5	AHDB 9958	2.90	2.70	87.09	4.62
6	AHDB 9939	3.11	2.86	115.96	5.57
7	AHDB 9938	2.41	2.27	73.06	3.11
8	AHDB 9937	2.59	2.43	47.08	2.84
9	AHDB 9967	2.18	2.04	32.15	2.04
10	AHDB 9936	2.69	2.52	50.42	2.93

F / H	13.34	12.86	25.07	24
P	0	0	0	0
df	40	40	39	39
lsd	0.235	0.205	18.43	0.719

tcrit(df) one tailed	1.684	1.684	1.685	1.685
MSE	0.0584	0.04431	358.89	0.5455
LSD	0.2350	0.2047	18.4298	0.7185

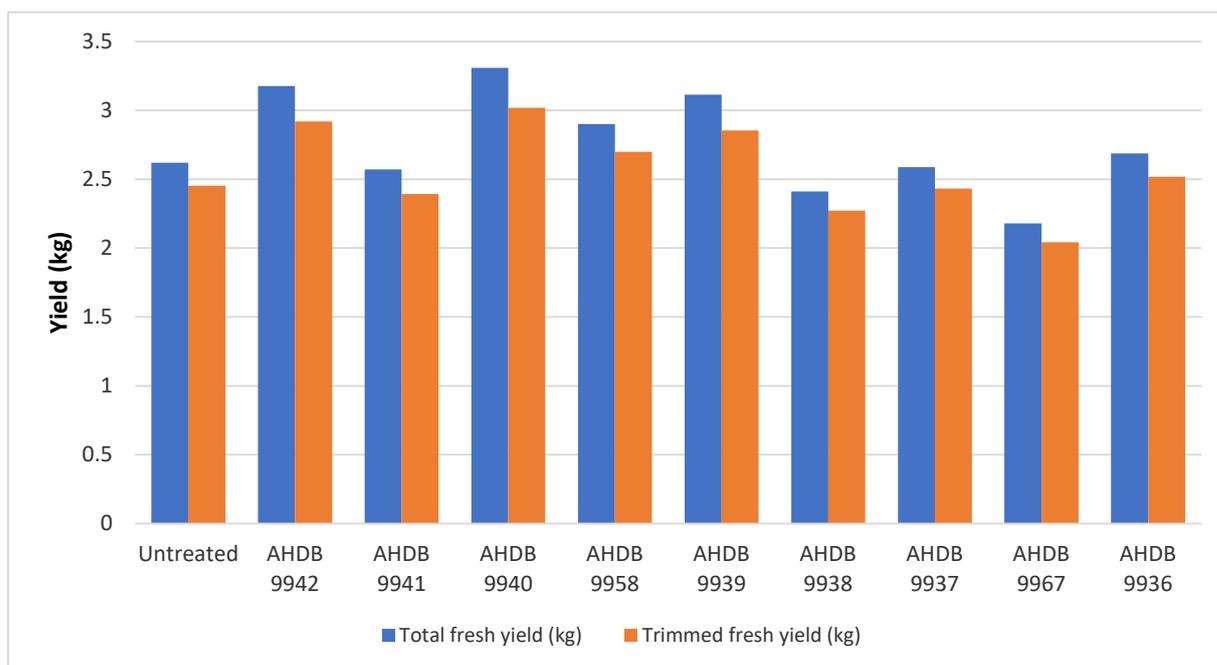


Figure 3: Harvest yield (total and trimmed)

Discussion

The trial was conducted as described in the original protocol with the following exceptions:

- Trial plots were inoculated via infector plants in addition to agar-grown cultures. This was to increase the likelihood of successful infection in the trial. This reduced the number of plants available for assessments from 12 to 10.
- Ten plants per plot were harvested instead of 30.

Disease levels were moderate during the trial and severe in untreated plots by the end of the trial. In a commercial situation, such a level of inoculum would be expected to cause plant losses in subsequent plantings, but no plant death was seen in the period of this trial.

No standard product was available for use in this trial, as no products are approved for application into deep water hydroponic systems. Prior experience with AHDB 9942 suggested that some disease control was likely with this product in this situation, and so AHDB 9942 was included as a standard product. Good disease control was seen with AHDB 9942 in early assessments, dropping to moderate control by the end of the assessment period. Based on this, the trial can be considered valid.

Root phytotoxicity was seen with AHDB 9967 and this may have caused the reduced yields seen at harvest under this treatment. However, laboratory tests on nutrient solution samples from the hydroponic tanks suggest that there was some control of disease by this product. No colony forming units (CFUs) of *Phytophthora* spp. were found in nutrient solution samples taken on 21.03.18 after four applications of AHDB 9967 into the tanks, whereas 350 CFUs per litre were found in untreated tanks. Further work is needed to ascertain whether this product could be used at a lower rate without causing phytotoxicity and whether disease control could be achieved at such a rate.

Of the other products tested in the trial, one (AHDB 9940) gave excellent disease control throughout the trial period, suggesting either some persistency of the product in the hydroponic environment, or more complete control of the inoculum sources during the application period. AHDB 9939 gave excellent disease control at assessments made during the application period, but this control was reduced by the time of harvest. This suggests that repeated applications of this product throughout the life of the crop may be required to achieve increased disease control. AHDB 9958 gave some control of disease and could be useful in a programme of treatments if required.

Rates of product use were not readily available for the application of plant protection products into nutrient solution in the current trial. As such, determining the rates of product use for this trial was difficult. The lack of phytotoxicity seen with most products suggests that the selected rates were crop safe, and the disease control achieved by a number of the products suggests sufficiently high rates were selected for those products. Further work could potentially fine-tune application rates for use in deep water hydroponics, in order to achieve either improved disease control or lower minimum doses.

Conclusions

- Disease levels were moderate to severe in the untreated plots.
- The 'standard' product (AHDB 9942) worked well, giving good control of root rot symptoms.
- One test product (AHDB 9940) gave good control of root rot symptoms which lasted through until harvest, whilst another test product (AHDB 9939) gave good control during the period of application only.
- One product (AHDB 9967) caused severe phytotoxicity effects in the root zone and, as a result of application issues, it also caused phytotoxicity on foliage where contact was made.
- Calculating appropriate product rates for use in deep water hydroponic systems is difficult, as no product approvals exist for extrapolation. Further work can be recommended in this area to determine optimal rates.

Acknowledgements

We would like to thank AHDB and the participating crop protection companies for project funding and CHAP for establishing the deep-water hydroponic trial system. We would like to thank Premier Plants for supplying the lettuce plants, Dr Tim Pettit for assisting with *Phytophthora cryptogea* cultures and Derek Hargreaves for providing a suitable nutrient solution recipe and associated advice. We would also like to thank those growers who helped with the design of the hydroponic system and gave advice during the trial.

Appendix A- Crop Diary

Date	Action
12.12.17	Seed sown by propagator (Premier Plants)
12.02.18	Plants collected from propagator and placed on benches in STC glasshouse MFU 4
20.02.18 – 21.02.18	Tanks filled with nutrient solution, pH measured and all tanks adjusted to approximately pH 5.7
23.02.18	Plants placed in carriers in rafts in tanks
26.02.18	Temperatures of nutrient solution measured in all tanks and heaters adjusted where necessary
27.02.18	pH and temperature of nutrient solution measured in all tanks and adjusted where necessary
28.02.18	pH and temperature of nutrient solution measured in all tanks and adjusted where necessary
02.03.18	pH and temperature of nutrient solution measured in all tanks and adjusted where necessary
06.03.18	pH and temperature of nutrient solution measured in all tanks and adjusted where necessary
09.03.18	EC, pH and temperature of nutrient solution measured in all tanks and adjusted where necessary
12.03.18	EC, pH and temperature of nutrient solution measured in all tanks and adjusted where necessary
15.03.18	EC, pH and temperature of nutrient solution measured in all tanks and adjusted where necessary
16.03.18	pH of nutrient solution measured in all tanks
19.03.18	pH of nutrient solution measured in all tanks
23.03.18	EC, pH and temperature of nutrient solution measured in all tanks
27.03.18	pH and temperature of nutrient solution measured in all tanks
24.04.18	Crop harvested
25.04.18	pH and EC measured in all tanks

Appendix B- Trial Diary

Date	Action
20.02.18	Drench/dip treatments applied to lettuce in blocks
26.02.18	Application of all products to hydroponic tanks
28.02.18	Inoculum added to tanks- 20 5mm agar discs of actively growing cultures and 2 pre-infected inoculator plants added to each tank
05.03.18	Application of biopesticides only to tanks
06.03.18	Assessment of root length and root colour
12.03.18	Application of all products to tanks
13.03.18	Assessment of root length and root colour
19.03.18	Application of biopesticides only to tanks
21.03.18	Nutrient solution sampled and tested for pathogen presence
26.03.18	Application of all products to tanks
24.04.18	Harvest assessments: total yield, trimmed yield, root length, root fresh weight, root dry weight.
01.05.18	Nutrient solution sampled and tested for pathogen presence

Appendix C- photographs

Discreet hydroponic tanks (facility funded by CHAP) were used to keep treatments separate.



Healthy root system (top) and infected roots (below):



Photos of detached root systems from all plots were taken at harvest. Colour and length differences are shown in the photos below.



T1: Untreated



T2: AHDB 9942



T3: AHDB 9941



T4: AHDB 9940



T5: AHDB 9958



T6 AHDB 9939



T7: AHDB 9938



T8: AHDB 9937



T9: AHDB 9967



T10: AHDB 9936

Appendix D- climatological data

Glasshouse MFU 4 (STC propagation phase)

	Maximum temp °C	Minimum temp °C	Average RH %
12/02/2018	18.11	4.1	74.18
13/02/2018	11.18	3.5	79.60
14/02/2018	11.7	3	79.82
15/02/2018	19.12	5.9	71.90
16/02/2018	18.67	4.9	73.78
17/02/2018	19.47	5.3	79.72
18/02/2018	19.42	4.79	80.68
19/02/2018	14.11	9.2	88.63
20/02/2018	20.93	7.82	76.07
21/02/2018	19.74	8.32	77.34
22/02/2018	19.1	4.73	74.31
23/02/2018	17.52	3.9	78.37

Glasshouse M17 (crop in hydroponic tanks)

	Maximum temp °C	Minimum temp °C	Average RH %
23/02/18	16.4	9.9	55.00
24/02/18	16.4	9.63	58.82
25/02/18	16.3	9.65	57.17
26/02/18	11.76	9.43	57.49
27/02/18	15.02	9.37	59.63
28/02/18	14.13	9.3	54.63
01/03/18	10.69	9.51	49.90
02/03/18	12.59	9.72	50.68
03/03/18	10.28	9.8	59.71
04/03/18	10.69	9.7	74.29
05/03/18	16.17	9.82	75.00
06/03/18	15.25	9.62	78.97
07/03/18	18.2	9.57	69.04
08/03/18	17.72	7.4	68.83
09/03/18	17.83	4.5	71.26
10/03/18	16.58	8.6	87.17
11/03/18	17.27	6	79.88
12/03/18	10.05	7.7	88.54
13/03/18	17.65	6.8	78.01
14/03/18	17.2	5.5	74.08
15/03/18	10.52	8	85.66
16/03/18	10.31	5.32	88.63
17/03/18	13.29	2.44	74.40
18/03/18	8.02	2.11	72.48
19/03/18	15.73	3.69	67.33
20/03/18	16.68	4.78	79.16
21/03/18	16.82	2.71	72.71
22/03/18	19.23	8.2	72.73
23/03/18	18.12	8.8	74.40
24/03/18	16.52	8.8	79.56
25/03/18	21.33	5.3	69.91
26/03/18	18.83	5.5	69.82
27/03/18	16.28	8.4	81.68
28/03/18	18.02	7.23	77.58
29/03/18	18.1	4.6	76.21
30/03/18	18.68	7.9	82.38
31/03/18	10.18	6.57	87.67
01/04/18	12.1	5.51	87.27
02/04/18	9.71	6.19	91.59
03/04/18	18.23	7.7	86.12

	Maximum temp °C	Minimum temp °C	Average RH %
04/04/18	17.3	6.92	86.92
05/04/18	20.6	4.6	72.31
06/04/18	17.1	7.52	77.44
07/04/18	18.63	9.89	85.63
08/04/18	17.54	9.2	83.21
09/04/18	22.08	9.5	84.29
10/04/18	12	9.2	91.49
11/04/18	11.3	8.7	91.17
12/04/18	10.39	8.4	91.32
13/04/18	15.22	8.4	91.14
14/04/18	23.86	10.3	81.67
15/04/18	20.18	8.1	85.03
16/04/18	22.51	11	78.53
17/04/18	21.19	11.8	81.66
18/04/18	27.48	13.2	79.05
19/04/18	33.26	13.37	74.68
20/04/18	27.29	13.3	76.62
21/04/18	27.56	11	78.41
22/04/18	24.43	13.18	82.69
23/04/18	21.34	12.42	81.41
24/04/18	19.28	12.1	86.13

Appendix E- raw data

Assessments with 10 subsamples per plot:

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
1	1	23.0	0	47.5	0	68	0
1	2	21.0	0	42.0	0	70	0
1	3	26.5	0	50.5	0	53	0
1	4	30.0	0	47.5	0	54	0
1	5	30.0	0	50.0	0	64.5	0
1	6	30.5	0	43.5	0	68	0
1	7	21.5	0	48.0	0	50	0
1	8	31.0	0	40.0	0	64	0
1	9	19.0	0	37.5	0	52	0
1	10	30.0	0	46.0	0	63.5	0
2	1	15.0	1	18.5	2	20.5	2
2	2	18.0	1	9.5	1	26.5	2
2	3	22.0	1	11.0	1	13	2
2	4	12.0	1	11.0	1	19.5	2
2	5	10.5	1	19.5	1	24	2
2	6	11.5	1	16.5	1	17.5	2
2	7	19.0	1	13.0	1	28.5	2
2	8	0.0		16.5	1	19	2
2	9	4.0	1	8.0	1	19	2
2	10	6.5	1	0	-	21.5	2
3	1	19.0	1	12.0	1	19.5	3
3	2	10.0	1	12.0	1	19.5	2
3	3	10.5	1	15.0	1	17.5	2
3	4	7.5	1	16.5	1	22	2
3	5	10.0	1	11.5	1	16.5	2
3	6	16.0	1	16.0	1	27	2
3	7	17.5	1	12.5	1	9.5	2
3	8	12.5	1	19.5	1	24.5	2
3	9	15.5	1	13.0	1	16	3
3	10	13.0	1	12.0	1	19.5	2
4	1	24.5	0	34.5	0	50	1
4	2	18.0	1	37.0	0	39.5	2
4	3	19.5	0	42.0	0	73	1
4	4	27.5	0	35.0	0	36	2
4	5	20.5	0	37.5	0	61	0
4	6	20.0	0	41.0	0	63	2
4	7	16.5	1	47.5	0	57	2
4	8	19.5	0	45.0	0	43	3
4	9	25.5	0	40.0	0	64.5	2
4	10	25.0	0	39.0	0	74.5	2

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
5	1	14.0	1	13.0	1	29.5	2
5	2	10.5	1	14.0	1	29	2
5	3	13.5	1	18.0	1	36	2
5	4	13.5	1	11.0	1	46.5	2
5	5	17.0	1	18.0	1	42	2
5	6	11.0	1	12.5	1	27.5	2
5	7	18.5	1	12.5	1	32	2
5	8	13.0	1	13.0	1	30.5	1
5	9	14.0	1	13.5	1	30	2
5	10	14.0	1	13.0	2	22.5	2
6	1	18.0	1	13.0	1	23	3
6	2	20.0	1	15.5	0	22	3
6	3	12.5	1	19.0	1	21	3
6	4	11.0	1	21.0	1	19.5	3
6	5	19.0	1	25.0	1	16.5	3
6	6	21.0	1	13.5	1	25	3
6	7	24.5	1	13.5	1	22.5	3
6	8	13.5	1	11.5	1	25.5	3
6	9	13.0	1	18.5	1	19.5	3
6	10	13.0	1	13.0	1	24.5	3
7	1	15.5	1	26.5	1	32	2
7	2	21.5	1	16.0	1	45.5	1
7	3	18.0	1	18.5	1	32.5	1
7	4	15.5	1	16.0	1	28	3
7	5	16.5	1	16.0	1	35	1
7	6	19.0	1	19.0	1	36.5	1
7	7	15.0	1	20.5	1	40.5	2
7	8	22.0	1	20.5	1	48	2
7	9	19.5	1	26.0	1	29	3
7	10	26.5	1	18.0	1	33.5	1
8	1	12.5	1	14.0	1	43	1
8	2	9.0	1	9.0	1	23	3
8	3	14.0	1	10.0	1	25	2
8	4	16.0	1	13.0	1	22	3
8	5	9.5	1	10.0	1	19	3
8	6	13.0	1	13.5	1	27.5	3
8	7	19.5	1	19.5	0	24.5	3
8	8	9.0	1	9.0	0	26.5	3
8	9	14.5	1	15.0	0	26.5	3
8	10	12.0	1	12.5	1	23	0
9	1	17.5	1	17.0	1	22	3
9	2	23.0	1	23.0	1	26.5	3

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
9	3	15.5	1	15.0	1	29.5	3
9	4	16.0	1	14.5	1	17	3
9	5	8.0	1	10.0	1	27	2
9	6	15.0	1	14.5	1	23	2
9	7	17.0	1	16.0	0	25	3
9	8	10.5	1	10.0	1	21	3
9	9	20.0	1	19.0	1	29.5	2
9	10	26.0	0	29.0	0	22.5	3
10	1	26.5	0	42.5	0	67	0
10	2	22.5	0	32.5	0	50	2
10	3	34.5	0	47.0	0	58	1
10	4	27.0	0	36.5	0	65	0
10	5	23.5	0	37.0	0	65.5	1
10	6	27.0	0	44.0	1	68	0
10	7	33.5	0	46.0	0	57	1
10	8	26.0	0	41.0	0	44.5	2
10	9	19.0	0	48.0	0	65	0
10	10	22.0	0	38.5	0	63	1
11	1	13.0	1	14.0	1	29	2
11	2	11.5	1	11.5	1	27.5	2
11	3	11.5	1	11.5	1	25	2
11	4	12.0	1	11.0	1	24	2
11	5	14.0	1	14.5	1	33.5	2
11	6	12.0	1	12.0	1	26	2
11	7	13.5	1	13.5	1	39.5	2
11	8	10.0	1	11.0	1	32.5	2
11	9	13.0	1	12.5	1	31.5	2
11	10	16.5	1	15.5	1	27.5	2
12	1	14.0	1	11.5	0	24.5	1
12	2	20.0	1	19.0	1	37.5	1
12	3	11.5	1	10.5	1	32	1
12	4	11.5	1	11.0	1	27	2
12	5	14.0	1	13.5	1	26	2
12	6	13.5	1	12.5	1	29.5	2
12	7	15.0	1	14.0	1	42	1
12	8	10.5	1	10.5	1	31	2
12	9	18.0	1	18.5	0	33	2
12	10	13.0	1	12.5	1	34	1
13	1	22.5	1	14.5	1	27.5	3
13	2	20.5	1	12.0	1	37.5	3
13	3	12.0	1	22.0	0	29	3
13	4	19.0	1	19.5	0	32	2

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
13	5	19.5	1	11.5	1	23.5	3
13	6	13.5	1	18.0	1	24.5	2
13	7	13.0	1	20.5	0	23	3
13	8	13.0	1	13.5	0	24	3
13	9	14.5	1	12.5	1	35	2
13	10	13.5	1	16.5	0	35.5	3
14	1	14.5	1	14.5	1	23	3
14	2	23.5	1	31.0	0	33.5	2
14	3	28.0	1	25.5	0	40	2
14	4	12.0	1	13.0	1	30.5	3
14	5	16.5	1	17.5	1	35	2
14	6	14.5	1	15.5	1	35	2
14	7	24.0	1	18.5	1	23.5	2
14	8	18.5	1	16.5	1	34.5	3
14	9	17.0	1	21.0	0	32.5	2
14	10	18.5	1	21.5	1	42	2
15	1	23.0	0	43.5	0	120.5	1
15	2	24.5	0	52.5	0	80	1
15	3	23.5	0	44.0	0	75	1
15	4	33.0	0	57.0	0	73.5	1
15	5	25.0	0	49.5	0	111	1
15	6	35.0	0	53.5	0	77.5	1
15	7	23.0	0	44.5	0	73	1
15	8	28.0	0	51.5	0	62	1
15	9	21.0	0	42.0	0	94	1
15	10	33.0	0	50.0	0	86.5	0
16	1	11.5	1	21.0	1	22	3
16	2	16.0	1	13.0	1	28.5	3
16	3	13.5	1	16.5	1	23	3
16	4	15.0	1	15.0	1	27	3
16	5	18.5	1	18.0	1	32	3
16	6	17.5	1	14.5	1	19.5	3
16	7	15.0	1	12.5	1	18	3
16	8	12.0	1	16.0	1	19.5	2
16	9	20.0	1	11.5	1	18	3
16	10	19.0	1	19.0	1	27.5	3
17	1	23.0	0	40.0	0	56	3
17	2	17.0	0	43.0	0	53	3
17	3	18.0	0	50.5	0	48	3
17	4	18.0	0	43.5	0	41	1
17	5	19.0	0	38.5	0	49	1
17	6	19.0	0	37.5	0	52.5	3

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
17	7	28.0	0	37.5	0	36.5	2
17	8	24.0	0	34.5	0	64	2
17	9	24.5	0	44.5	0	54.5	2
17	10	26.0	0	46.5	0	63.5	2
18	1	24.0	0	32.0	0	51	0
18	2	22.5	0	28.0	0	40.5	0
18	3	14.5	0	22.0	0	55.5	0
18	4	12.5	0	22.5	0	35	0
18	5	4.0	0	10.0	1	56.5	0
18	6	26.0	0	33.0	0	40	0
18	7	14.0	1	20.5	0	48	2
18	8	19.5	1	30.0	0	39	0
18	9	25.5	1	31.5	0	48.5	1
18	10	12.5	1	20.0	0	41.5	0
19	1	17.0	1	12.5	2	26.5	3
19	2	16.5	1	12.0	1	35	2
19	3	12.0	1	21	0	34.5	2
19	4	15.5	1	14.5	1	37	3
19	5	19.0	1	16.5	1	33	2
19	6	16.5	1	17.0	1	38	3
19	7	20.0	1	15	1	31	2
19	8	13.5	1	15.5	1	26.5	3
19	9	12.5	1	15.5	1	33	3
19	10	16.0	1	16.0	1	23	3
20	1	27.0	0	50.5	0	59.5	1
20	2	41.3	0	49.5	0	72	0
20	3	34.0	0	41	0	34	1
20	4	32.5	0	53.5	0	51	3
20	5	33.0	0	53	0	72.5	0
20	6	35.0	0	51.5	0	39	2
20	7	22.5	0	55.5	0	45	2
20	8	32.0	0	53.0	0	64	2
20	9	27.0	0	42	0	44	1
20	10	31.5	0	52.0	0	53	1
21	1	25.0	1	14	1	30.5	3
21	2	17.0	1	21.0	1	26	2
21	3	13.5	1	14.5	1	37	2
21	4	19.5	1	15.5	1	21.5	2
21	5	20.5	1	19.5	1	33	2
21	6	13.5	1	11.5	1	23	2
21	7	12.0	1	11	1	32	2
21	8	11.5	1	11.5	1	23	2

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
21	9	21.0	1	20.5	1	36	2
21	10	15.0	1	13.5	1	33	2
22	1	18.5	0	36.5	0	78.5	1
22	2	21.0	0	56.5	0	81	1
22	3	22.5	0	51	0	67	1
22	4	26.0	0	57.0	0	64	1
22	5	19.5	0	42.5	0	47.5	1
22	6	19.0	0	42.0	0	80	0
22	7	20.5	0	48.5	0	71	0
22	8	21.0	0	49.0	0	61.3	0
22	9	18.0	0	44	0	76	0
22	10	20.5	0	44.5	0	58.5	0
23	1	11.0	1	9	1	30	2
23	2	16.5	1	12.0	1	37.5	1
23	3	13.5	1	12	1	23	2
23	4	13.0	1	16.5	1	26.5	2
23	5	13.5	1	12.5	1	31	2
23	6	16.5	1	13.5	2	27	2
23	7	13.0	1	13.5	1	41.5	2
23	8	12.0	1	16.0	1	37.5	1
23	9	10.0	1	12	1	30.5	2
23	10	14.0	1	14.0	1	39	0
24	1	31.5	0	49.5	0	48.5	1
24	2	21.0	0	40.5	0	92.5	1
24	3	33.0	0	52	0	34.5	3
24	4	34.0	0	47.5	0	52	1
24	5	30.0	0	55	0	50	1
24	6	34.0	0	52.0	0	67	2
24	7	30.5	0	45	0	68	1
24	8	29.0	0	46.0	0	35	3
24	9	30.5	0	50	0	80	1
24	10	26.0	0	46.0	0	98	1
25	1	5.0	1	10	1	10.5	2
25	2	6.5	1	10.5	1	9	2
25	3	6.5	1	6.5	1	16.5	2
25	4	7.0	1	7.0	1	12	2
25	5	6.5	1	9	1	7	1
25	6	6.0	1	10.5	1	19	2
25	7	7.0	1	9.5	1	10	2
25	8	8.5	1	6.0	1	15.5	2
25	9	7.0	1	5	1	15.5	2
25	10	8.5	1	7.5	1	23	2

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
26	1	8.0	1	8.5	2	7	3
26	2	12.0	1	16.0	1	10.5	3
26	3	10.0	1	17	1	17	3
26	4	14.0	1	16.0	1	5	3
26	5	17.5	1	13	1	12.5	3
26	6	11.0	1	19.0	2	10.5	3
26	7	12.0	1	10.5	2	15.5	3
26	8	17.5	1	15.0	2	9	3
26	9	9.5	1	8	2	13.5	3
26	10	16.0	1	12.0	2	11	3
27	1	11.5	1	16	1	35	2
27	2	16.5	1	11.0	1	28.5	2
27	3	11.5	1	16.5	1	31	2
27	4	12.0	1	11.0	1	25	2
27	5	11.5	1	13.5	1	28.5	2
27	6	11.0	1	12.5	1	31.5	2
27	7	13.5	1	10.5	1	22	2
27	8	13.0	1	15.0	1	32	2
27	9	17.0	1	14.5	1	29.5	2
27	10	16.0	1	16.0	1	41	2
28	1	23.0	0	34	0	60.5	0
28	2	34.0	0	38.0	0	73.5	0
28	3	23.5	0	41	0	89	0
28	4	26.5	0	42.0	0	58	0
28	5	22.5	0	35	0	44	1
28	6	23.5	0	38	0	56	0
28	7	20.0	0	46	0	101	0
28	8	13.5	0	44	0	78	0
28	9	29.5	0	31	0	82	0
28	10	24.5	0	47.5	0	76.5	1
29	1	15.0	1	20.5	1	18	3
29	2	13.5	1	16.5	1	23.5	2
29	3	22.0	1	17.5	1	20	3
29	4	16.5	1	14	1	20	2
29	5	18.0	1	17	1	18	2
29	6	14.5	1	21	1	23	2
29	7	18.0	1	22.5	2	18.5	2
29	8	21.0	1	19	2	17.5	2
29	9	22.5	1	14	2	19.5	2
29	10	20.0	1	12.5	1	28.5	2
30	1	34.0	1	28	0	30	3
30	2	27.0	0	13.5	0	43	3

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
30	3	25.0	1	28	0	30	3
30	4	25.0	0	25	0	41.5	2
30	5	27.5	0	40.5	0	28	2
30	6	28.0	1	35	0	24.5	3
30	7	31.0	1	31	0	27.5	3
30	8	24.0	1	25.5	0	32.5	3
30	9	21.0	0	26.5	0	37.5	3
30	10	36.0	1	27	0	36.5	3
31	1	16.0	1	13	1	22	2
31	2	21.0	1	18.5	1	16	2
31	3	13.0	1	16.5	1	22	2
31	4	18.0	1	14	1	30.5	2
31	5	16.0	1	13.5	1	31.5	2
31	6	15.5	1	10	1	29	2
31	7	14.0	1	15	2	31	2
31	8	10.5	1	17	0	30	2
31	9	15.0	1	16	1	34.5	2
31	10	13.5	1	21.5	1	29.5	2
32	1	14.5	1	23.5	1	35.5	2
32	2	10.5	1	15	1	38	2
32	3	13.0	1	10.5	1	31	2
32	4	16.5	1	12.5	1	45	2
32	5	16.5	1	16.5	1	23	2
32	6	16.0	1	15.5	1	37.5	2
32	7	16.0	1	15.5	1	34	2
32	8	19.5	1	16	1	28	2
32	9	12.5	1	18	1	29	3
32	10	25.0	1	12	1	31	2
33	1	19.0	0	50	0	67	1
33	2	20.5	0	47	0	82	0
33	3	31.0	0	44.5	0	57.5	0
33	4	31.0	0	54	0	97	1
33	5	25.0	0	46.5	0	61	0
33	6	24.5	0	40.5	0	65	0
33	7	23.0	0	46.5	0	77.5	0
33	8	33.5	0	37	0	61	0
33	9	24.5	0	43.5	0	68	0
33	10	31.5	0	53	0	94.5	1
34	1	24.0	0	44	0	59	1
34	2	34.5	0	48	0	61	1
34	3	26.5	0	47	0	66	1
34	4	33.0	0	41	0	58	2

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
34	5	30.5	0	45	0	58	0
34	6	25.0	0	46	0	45	2
34	7	25.0	0	53	0	62	1
34	8	24.0	0	46	0	24.5	3
34	9	35.5	0	56	0	67	1
34	10	27.0	0	46	0	50	1
35	1	7.0	1	10	2	21.5	3
35	2	8.5	1	7.5	1	19	3
35	3	13.5	1	12.5	1	27.5	2
35	4	14.5	1	13.5	2	18	2
35	5	10.5	1	14	2	17	2
35	6	8.0	1	10	2	24	3
35	7	13.5	1	9.5	2	20	3
35	8	12.5	1	14	1	23	3
35	9	15.0	1	11	1	21.5	3
35	10	8.5	1	15	1	19.5	3
36	1	25.0	0	35	0	71	0
36	2	18.5	0	36.5	0	71.5	0
36	3	22.5	0	41	0	79	0
36	4	15.5	0	45	0	73	0
36	5	29.0	0	50.5	0	64	0
36	6	24.0	0	36	0	89	0
36	7	23.0	0	47.5	0	84	0
36	8	26.5	0	46	0	70	0
36	9	24.0	0	49	0	70	0
36	10	25.5	0	49	0	77.5	0
37	1	7.5	1	20	1	52	0
37	2	11.0	1	17	0	50	1
37	3	17.0	1	19	0	38	2
37	4	21.0	1	15	0	48	1
37	5	25.0	0	25	0	63.5	1
37	6	22.0	0	27	0	36.5	2
37	7	27.0	0	25	0	47	1
37	8	26.0	1	26.5	0	39	2
37	9	15.5	1	40	0	46.5	1
37	10	17.5	1	15.5	0	47	1
38	1	14.5	1	14	1	30.5	2
38	2	11.5	1	15	1	27	3
38	3	15.5	1	14	1	28	2
38	4	12.0	1	16	1	21	3
38	5	14.5	1	13	1	24	2
38	6	18.0	1	11.5	1	26	3

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
38	7	12.0	1	10	1	24.5	2
38	8	12.0	1	10.5	1	19.5	2
38	9	10.5	1	14	1	26	2
38	10	11.0	1	11.5	1	18.5	2
39	1	17.5	1	11.5	1	33.5	1
39	2	15.5	1	15	1	27	3
39	3	13.0	1	20	0	27	3
39	4	14.5	1	13.5	1	29	3
39	5	17.0	1	13	1	27	2
39	6	13.0	1	13.5	1	32	3
39	7	13.0	1	12.5	1	28.5	2
39	8	13.5	1	12.5	1	27.5	2
39	9	13.0	1	17.5	1	20.5	2
39	10	12.5	1	16	1	24.5	2
40	1	19.0	1	18	1	29.5	3
40	2	9.0	1	8.5	1	27	2
40	3	10.0	1	10.5	1	27	3
40	4	18.0	1	17.5	1	26.5	3
40	5	26.0	1	25	1	21.5	2
40	6	14.0	1	16	1	28	3
40	7	14.5	1	14.5	1	27	3
40	8	12.5	1	12.5	1	29	2
40	9	20.5	1	20	1	28	3
40	10	12.5	1	12	1	32	2
41	1	11.5	1	11	1	25	3
41	2	13.0	1	11.5	1	23.5	2
41	3	14.0	1	12	1	33	2
41	4	13.0	1	14.5	1	23	3
41	5	13.0	1	13.5	1	22	2
41	6	14.0	1	14	1	31	2
41	7	14.5	1	13.5	1	28	2
41	8	11.0	1	15	1	36.5	2
41	9	11.0	1	12	1	35.5	3
41	10	11.5	1	10	1	33	2
42	1	13.5	1	14.5	1	46	1
42	2	20.5	1	14.5	1	22	2
42	3	12.0	1	22	0	28	2
42	4	18.5	1	11	1	32	2
42	5	14.0	1	17	1	22	2
42	6	9.5	1	13	1	25	2
42	7	11.0	1	9	1	24	3
42	8	14.0	1	11	1	15	3

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
42	9	9.5	1	12.5	0	34	2
42	10	14.0	1	12.5	0	23	2
43	1	12.0	1	17	1	25.5	2
43	2	11.5	1	12	0	15	2
43	3	12.5	1	11.5	0	25	3
43	4	20.0	1	10	0	23.5	2
43	5	12.5	1	17	0	12	3
43	6	9.0	1	12.5	1	15	2
43	7	10.5	1	11	0	16	2
43	8	10.5	1	11	0	16.5	2
43	9	11.0	1	10.5	0	28.5	2
43	10	17.0	1	12.5	0	19	2
44	1	15.5	1	14.5	1	47	1
44	2	12.0	1	12.5	1	21.5	3
44	3	11.5	1	11.5	1	22.5	3
44	4	15.0	1	15	1	25	2
44	5	15.0	1	14	1	20.5	3
44	6	10.5	1	10.5	1	21	2
44	7	10.5	1	12	1	23.5	3
44	8	14.0	1	14	1	37	2
44	9	13.0	1	11	1	20	2
44	10	12.5	1	12.5	1	19	3
45	1	22.0	0	37	0	59	1
45	2	15.0	1	39	0	63	0
45	3	14.5	1	32	0	51.5	2
45	4	13.5	0	28	0	49	0
45	5	18.0	0	28	0	62.5	1
45	6	14.0	1	34.5	0	35	1
45	7	20.0	0	24	0	43	1
45	8	18.0	0	37	0	77.5	1
45	9	27.0	0	30	0	31	0
45	10	14.5	1	45	0	53	1
46	1	39.0	0	60	0	93	0
46	2	45.0	0	64	0	89.5	0
46	3	19.5	0	44.5	0	70	1
46	4	25.0	0	45.5	0	73.5	1
46	5	18.0	0	37	0	81	1
46	6	24.0	0	45.5	0	100	0
46	7	18.0	0	37.5	0	91.5	1
46	8	28.0	0	59.5	0	88.5	1
46	9	32.0	0	39.5	0	117	1
46	10	36.5	0	57	0	60	1

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
47	1	25.0	0	46.5	0	44	0
47	2	25.0	0	47.5	0	68.5	1
47	3	28.0	0	44.5	0	67	0
47	4	27.5	0	36	0	49	0
47	5	25.5	0	33	0	83	1
47	6	24.5	0	36.5	0	59	0
47	7	25.0	0	43	0	62	0
47	8	22.5	0	44	0	70	0
47	9	22.5	0	43.5	0	64	1
47	10	20.0	0	42	0	72	1
48	1	15.0	1	14.5	1	16.5	3
48	2	11.5	1	15	1	9.5	3
48	3	14.0	1	6	1	16.5	3
48	4	12.0	1	9	1	12.5	3
48	5	12.0	1	13	1	12	3
48	6	7.5	1	9.5	1	14	3
48	7	13.5	1	13.5	0	16	3
48	8	6.5	1	15.5	1	11.5	3
48	9	14.0	1	16	1	15.5	3
48	10	14.5	1	12	1	15.5	3
49	1	23.5	0	41	0	80	1
49	2	25.5	0	45	0	86.5	0
49	3	33.5	0	51	0	69	1
49	4	29.0	0	51.5	0	147.5	0
49	5	29.5	0	55	0	76.5	0
49	6	27.0	0	55.5	0	82	1
49	7	24.0	0	45	0	105	0
49	8	28.5	0	51	0	81.5	0
49	9	25.0	0	51.5	0	80	0
49	10	22.0	0	39	0	25.5	1
50	1	9.0	1	12	1	33	0
50	2	9.5	1	13	1	37	2
50	3	11.0	1	17	0	40	0
50	4	13.0	1	12.5	1	29.5	3
50	5	18.0	1	16	1	33	3
50	6	12.0	1	18	0	34.5	3
50	7	16.0	1	23	1	34.5	3
50	8	18.5	1	16	1	27	3
50	9	22.0	1	9	1	36	3
50	10	16.5	1	8.5	1	45.5	3
51	1	21.0	0	44	0	80	0
51	2	17.5	0	38	0	88.5	0

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
51	3	19.5	0	51.5	0	100	0
51	4	16.0	0	38.5	0	60	0
51	5	29.5	0	34	0	68	0
51	6	24.5	0	38.5	0	64	0
51	7	20.5	0	42	0	57.5	0
51	8	27.5	0	50.5	0	45	0
51	9	34.0	0	52	0	85	0
51	10	25.0	0	48.5	0	82	0
52	1	16.5	1	14.5	1	28.5	2
52	2	21.0	1	14.5	1	23	2
52	3	21.0	1	14.5	1	40	3
52	4	13.5	1	13	1	26.5	2
52	5	19.0	1	17	1	22	2
52	6	13.0	1	13.5	1	26.5	2
52	7	16.0	1	21	1	20	2
52	8	14.5	1	20	1	20	2
52	9	15.0	1	16	1	34	2
52	10	29.0	1	27	1	38	2
53	1	28.0	0	61	1	45.5	3
53	2	30.5	0	48	0	32	3
53	3	29.0	0	60	0	44	3
53	4	17.0	0	58	0	33	3
53	5	33.0	0	58	0	25.5	3
53	6	34.5	0	38	0	65.5	2
53	7	34.5	0	49	0	70	2
53	8	27.0	0	53	0	57	3
53	9	31.0	0	54	0	37.5	3
53	10	28.5	0	48	0	46	2
54	1	20.0	1	18.5	1	25	3
54	2	20.5	1	13	1	18	1
54	3	14.0	1	12	1	16	2
54	4	16.0	1	16	1	26	3
54	5	16.5	1	16.5	1	26.5	2
54	6	14.0	1	14	1	18.5	2
54	7	13.0	1	14	1	20	3
54	8	16.5	1	16	1	21	2
54	9	17.5	1	11.5	1	21	2
54	10	12.0	1	12.5	1	14	0
55	1	12.5	1	17.5	1	23.5	2
55	2	18.0	1	21	0	25	2
55	3	18.5	1	12	1	22	2
55	4	19.0	1	13.5	1	14	2

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
55	5	11.5	1	12	1	44.5	2
55	6	14.0	1	13	1	18.5	2
55	7	9.5	1	20	1	28	3
55	8	14.0	1	14.5	1	15	2
55	9	17.5	1	13.5	1	26.5	2
55	10	10.5	1	18.5	1	22	2
56	1	2.0	2	5	1	16.5	2
56	2	3.5	2	3.5	1	11	3
56	3	3.0	1	4	1	15.5	2
56	4	3.5	1	1.5	1	13	1
56	5	5.5	1	3.5	1	19	2
56	6	5.0	1	5	1	12.5	2
56	7	3.5	1	5	1	11	2
56	8	2.5	1	1.5	1	17	2
56	9	2.0	1	5	1	14	2
56	10	4.0	1	2	1	10.5	1
57	1	11.0	1	13	1	22.5	3
57	2	11.0	1	12.5	1	23	2
57	3	12.0	1	12.5	1	23	2
57	4	8.5	1	17.5	1	15.5	3
57	5	10.5	1	11	1	24.5	3
57	6	15.5	1	11.5	1	37	2
57	7	8.5	1	11	1	21.5	2
57	8	11.0	0	12.5	1	18	2
57	9	9.0	1	12	1	23	2
57	10	12.5	1	11.5	1	18.5	2
58	1	8.0	1	9	1	24.5	2
58	2	10.0	1	11	1	24	2
58	3	14.0	1	12.5	1	19.5	2
58	4	15.0	1	13.5	1	22	2
58	5	10.5	1	20	1	23	2
58	6	21.0	1	16.5	1	24.5	3
58	7	16.0	1	11	1	24	2
58	8	11.0	1	13.5	1	29	2
58	9	14.0	1	10.5	1	34.5	2
58	10	7.5	1	13.5	1	26	2
59	1	14.5	1	38.5	0	55	1
59	2	21.5	1	44.5	0	48	2
59	3	22.0	0	34	1	38	2
59	4	23.5	0	38.5	0	37.5	2
59	5	24.0	1	36.5	0	28	2
59	6	25.5	1	40	0	38	1

		06.03.18	06.03.18	13.03.18	13.03.18	24.04.18	24.04.18
Tank/ Plot	Plant/ subsample	root length	root colour	root length	root colour	root length	root colour
59	7	23.5	1	20	0	31	3
59	8	25.5	1	36	0	37	3
59	9	10.5	1	24	0	42	1
59	10	23.0	1	34	0	35	3
60	1	13.0	0	23.5	0	65	0
60	2	10.0	0	19.5	0	87	0
60	3	14.5	0	17.5	0	80	1
60	4	10.5	0	21	0	100	0
60	5	13.0	0	20	0	98	0
60	6	9.5	0	24.5	0	73	0
60	7	12.0	0	19	0	100	0
60	8	14.5	0	23	0	91	0
60	9	14.5	0	19	0	93	0
60	10	10.5	0	24.5	0	96	0

Appendix E continued: raw data

Assessments with one subsample per plot:

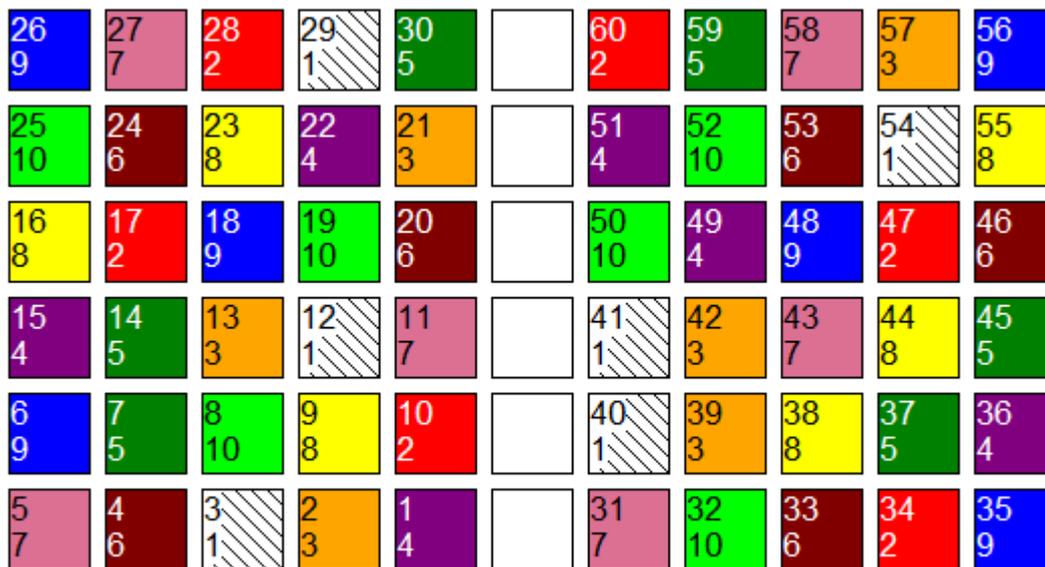
			24.4.18	24.4.18	24.4.18	24.4.18	26.4.18	06.3.18	13.3.18	24.4.18
Tank/ Plot	Trt. No.	Block	number plants harvested	Total fresh yield (kg)	trimmed fresh yield (kg)	total root fresh weight (g)	total root dry weight (g)	disease index	disease index	disease index
1	4	1	10	3.23	3.04	135.55	5.58	0.00	0.00	0.00
2	3	1	9	2.34	2.33	38.68	2.29	30.00	33.33	66.67
3	1	1	10	2.67	2.54	23.99	1.74	33.33	33.33	73.33
4	6	1	10	3.12	2.92	112.8	5.74	6.67	0.00	56.67
5	7	1	10	2.81	2.66	88.75	3.8	33.33	36.67	63.33
6	9	1	10	2.56	2.47	47.49	2.85	33.33	30.00	100.00
7	5	1	10	3.12	3	94.48	4.78	33.33	33.33	56.67
8	10	1	10	2.78	2.66	57.6	3.05	33.33	23.33	80.00
9	8	1	10	2.71	2.62	41.47	2.28	30.00	26.67	90.00
10	2	1	10	3.2	2.97	151.06	6.35	0.00	3.33	26.67
11	7	1	10	2.42	2.29	109.66	4.15	33.33	33.33	66.67
12	1	1	10	2.83	2.61	66.42	3.78	33.33	26.67	50.00
13	3	1	10	2.7	2.33	65.1	3.58	33.33	16.67	90.00
14	5	1	10	2.75	2.53	88.9	5.22	33.33	23.33	76.67
15	4	1	10	3.52	3.15	142.07	5.78	0.00	0.00	30.00
16	8	1	10	2.75	2.57	54.2	3.43	33.33	33.33	96.67
17	2	1	10	2.92	2.76	110	5.59	0.00	0.00	73.33
18	9	1	10	2.88	2.67	138.08	5.74	13.33	3.33	10.00
19	10	1	10	2.9	2.65	51.05	3.12	33.33	33.33	86.67
20	6	1	10	3.07	2.85	113.75	5.55	0.00	0.00	43.33
21	3	1	10	2.69	2.49	52.67	3.03	33.33	33.33	70.00
22	4	1	10	3.48	3.21	125.43	5.31	0.00	0.00	16.67
23	8	1	10	2.59	2.45	53.73	3.08	33.33	36.67	53.33
24	6	1	10	3.08	2.81	102.48	5.05	0.00	0.00	50.00
25	10	1	10	3.01	2.77	34.47	2.08	33.33	33.33	63.33
26	9	1	10	2.11	1.95	12.04	0.86	33.33	53.33	100.00
27	7	1	10	2.42	2.25	76.57	3.68	33.33	33.33	66.67
28	2	1	10	3.52	3.21	151	6.61	0.00	0.00	6.67
29	1	1	10	2.84	2.63	33.75	2.15	33.33	43.33	73.33
30	5	1	10	3.05	2.78	82.57	4.74	20.00	0.00	93.33
31	7	2	10	2.51	2.34	72.94	2.91	33.33	33.33	66.67
32	10	2	10	2.51	2.46	61.79	3.29	33.33	33.33	70.00
33	6	2	10	3.47	3.07	128.9	5.63	0.00	0.00	10.00
34	2	2	10	2.76	2.54	98.67	4.65	0.00	0.00	43.33
35	9	2	10	2.09	1.96	55.06	2.83	33.33	50.00	90.00
36	4	2	10	3.21	2.9	143.33	6.27	0.00	0.00	0.00
37	5	2	10	3.09	2.84	104.44	4.98	23.33	3.33	40.00
38	8	2	10	2.52	2.34	63.24	3.79	33.33	33.33	76.67
39	3	2	10	2.77	2.63	59.33	3.29	33.33	30.00	76.67

			24.4.18	24.4.18	24.4.18	24.4.18	26.4.18	06.3.18	13.3.18	24.4.18
Tank/ Plot	Trt. No.	Block	number plants harvested	Total fresh yield (kg)	trimmed fresh yield (kg)	total root fresh weight (g)	total root dry weight (g)	disease index	disease index	disease index
40	1	2	10	2.48	2.39	53.18	3.21	33.33	33.33	86.67
41	1	2	10	2.65	2.43	58.64	3.12	33.33	33.33	76.67
42	3	2	10	2.39	2.23	52.03	3.07	33.33	23.33	70.00
43	7	2	10	2.15	2.04	36.12	1.63	33.33	6.67	73.33
44	8	2	10	2.59	2.4	37.37	2.26	33.33	33.33	80.00
45	5	2	10	2.69	2.51	73.75	3.66	13.33	0.00	26.67
46	6	2	10	3.35	3.08	145.43	6.58	0.00	0.00	23.33
47	2	2	10	3.32	3.06	128.53	6.09	0.00	0.00	13.33
48	9	2	10	1.8	1.65	28.16	2.19	33.33	30.00	100.00
49	4	2	10	3.59	3.22	137.27	6.08	0.00	0.00	13.33
50	10	2	10	2.63	2.46	54.72	3.14	33.33	26.67	76.67
51	4	2	10	2.83	2.59	115.74	5.01	0.00	0.00	0.00
52	10	2	10	2.3	2.11	42.88	2.91	33.33	33.33	70.00
53	6	2	10	2.59	2.4	92.39	4.89	0.00	3.33	90.00
54	1	2	10	2.25	2.12	35.79	2.69	33.33	33.33	66.67
55	8	2	10	2.37	2.21	32.49	2.18	33.33	30.00	70.00
56	9	2	10	1.64	1.55	17.99	1.45	40.00	33.33	63.33
57	3	2	10	2.53	2.34	37.65	2.61	30.00	33.33	76.67
58	7	2	10	2.16	2.05	54.29	2.5	33.33	33.33	70.00
59	5	2	10	2.71	2.54	78.41	4.34	26.67	3.33	66.67
60	2	2	10	3.34	2.97	192.17	8.21	0.00	0.00	3.33

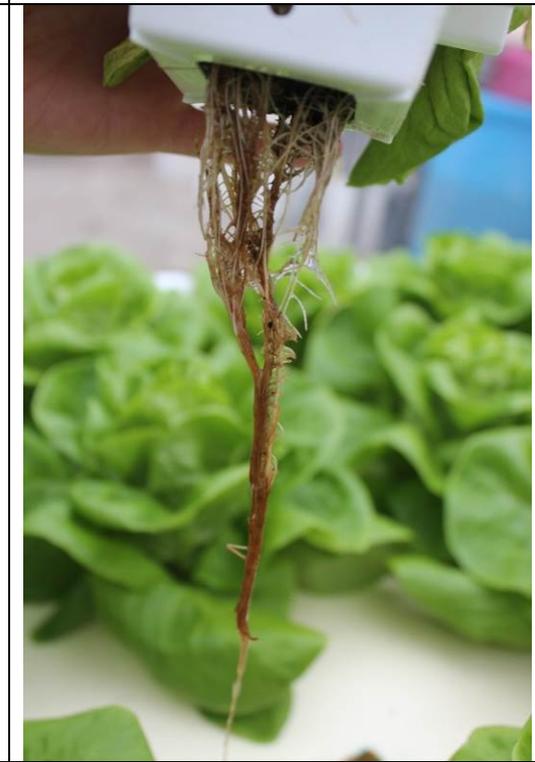
Appendix F- trial layout

Trial Map Treatment Description

Trt no.	AHDB Code	Product
1	Untreated	Untreated
2	AHDB 9942	Paraat
3	AHDB 9941	Previcur Energy
4	AHDB 9940	SL567A
5	AHDB 9958	BAS 657 ADF
6	AHDB 9939	Revus
7	AHDB 9938	Triatum P
8	AHDB 9937	Prestop WG
9	AHDB 9967	030-S-3D
10	AHDB 9936	Serenade ASO



Appendix F- Assessment key for root discolouration

 A photograph showing a dense network of fine, white roots hanging from a white container. The roots are clean and appear healthy. Below the container is a brown peat block.	 A close-up photograph of a single root against a blue background. The root is mostly white, but the tip is dark brown, indicating some discolouration.
<p>Score 0 No root discolouration. Roots healthy and white, potentially some darker roots close to the peat block</p>	<p>Score 1 Some small areas of root discolouration, including dark root tips. Not more than 10% of root discoloured.</p>
 A photograph of a root against a blue background. A significant portion of the root, particularly the lower half, is dark brown, showing more extensive discolouration.	 A photograph of a root system against a blue background. The majority of the roots are dark brown, indicating severe discolouration. Some green leaves are visible in the background.
<p>Score 2 Significant areas of discoloration visible. 10-25% of root area affected.</p>	<p>Score 3 Severely discoloured roots. > 25% of roots affected</p>

Appendix H- ORETO certificate



Certificate of

Official Recognition of Efficacy Testing Facilities or Organisations in the United Kingdom

This certifies that

Stockbridge Technology Centre

complies with the minimum standards laid down in
Regulation (EC) 1107/2009 for efficacy testing.

The above Facility/Organisation has been officially
recognised as being competent to carry out efficacy trials/tests
in the United Kingdom in the following categories:

**Agriculture/Horticulture
Biologicals and Semiochemicals
Stored Crops**

Date of issue: 19 July 2016
Effective date: 1 April 2016
Expiry date: 31 March 2021

Signature


Authorised Signatory

Certification Number

ORETO 372



Chemicals Regulation Division



Department of
**Agriculture and
Rural Development**