Project title:	Vegetable crops: Development of a screening programme for plant growth enhancement products.
Project number:	FV 394a
Project leader:	Pat Croft, STCRF
Report:	Final report, March 2013
Previous report:	None
Key staff:	Pat Croft Catherine Jones Chantel Davies Julie Langdale
Location of project:	STCRF, Cawood, Selby, North Yorkshire YO8 3TZ
Industry Representative:	Martin Evans
Date project commenced:	March 2012
Date project completed (or expected completion date):	March 2013

PLEASE NOTE: The HDC, whilst reporting the results of this independent work, does not advocate or promote the use of the products reviewed in this study for crop protection. It is important to note that:

a) The trials reported in this study are not specifically designed regulatory trials to support a product claim and they have not been through any regulatory scrutiny to assess consistency, level of control and appropriate dose of the products.

b) It is important for growers to remember that before using any product for plant protection purposes always check whether the product is currently approved for the intended use and situation.

AUTHENTICATION

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

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Project Leader
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CONTENTS

GROWER SUMMARY

Headlines

- A wide selection of speciality crop nutrition products were applied to lettuce, carrots and peas, and their effects on yield, and pest and disease damage, were assessed during the 2012 season.
- As in the first year of the trial in 2011, the most significant, beneficial effects were particularly seen in lettuce.

Background

Vegetable growers are faced with increased demand for UK-grown produce in an arena of reduced pesticide availability, increased fertiliser costs, pressure to reduce greenhouse emissions, and demands to improve productivity and quality, whilst protecting the environment and improving biodiversity. High yields require the management and optimisation of all resources, including nitrogen (N), phosphorus (P), potassium (K) and micronutrient availability.

This project is a repeated trial of project FV 394, which was conducted in 2011, and focuses on screening plant growth enhancers (non-NPK macro and micronutrient products). The aim of the project is to provide a service to the UK horticultural sector that uses recent science, known expertise and grower consultations to better inform vegetable growers on the options available for crop improvement using plant enhancers.

Summary of the results and main conclusions

- Tables 1–3 below summarise the recorded effects of the different treatments for each of the three crops (lettuce, carrots and peas) and compares the findings to the previous year (2011).

- The tables provide a simple comparison of the treatments against the control (NPK only), indicating where the treatments gave a better performance than the control (**>**) or not (**x**). The tables also indicate where these differences are significant after statistical analysis ($p<0.05$) (**+**).

- As previously recorded in the 2011 trials, significant treatment effects were recorded on lettuce for fresh weight. Weights (dry and fresh) were recorded at harvest; Omex Biomex Plus, TTL Plus and Phos-Star produced statistically significant increases in yield (Table 1a). Due to the wet climate in 2012, downy mildew appeared quickly throughout the lettuce crop; therefore assessment on percentage of leaves affected was recorded. *Botrytis cinerea*, *Sclerotinia sclerotiorum* and tip-burn were not recorded in 2012.

- In the pea crop some treatments did improve measurements marginally in comparison to the control plots (Table 2a), but there were no statistically valid improvements. Root nodules were very poor in 2012 and it is possible this is because the peas had been flooded due to the wettest year on record. Generally the pea crop was poor due to this heavy rainfall and made comparisons of treatments difficult.

Table 1a: Lettuce (Frisco) 2012

	Treatments	**Means per plot (20 plants per plot)**		
		Fresh Weight (g)	Dry weight (g)	Disease (Downy mildew)
1	Commercial NPK	*	*	*
2	InCa	**>**	**X**	**>**
3	Wormcast	**X**	**X**	**X**
4	Omex Biomex Starter	**>**	**X**	**>**
5	Omex Biomex Plus	**+**	**+**	**>**
6	PHC Colonise AG	**X**	**X**	**+**
7	PHC Complete Plus	**>**	**X**	**X**
8	TTL Plus	**+**	**X**	**X**
9	Serenade	**>**	**X**	**X**
10	Bactolife DP104	**X**	**X**	**X**
11	Bactolife A10	**>**	**X**	**X**
12	Phos-Star	**+**	**X**	**>**

Table 1b: Lettuce (Frisco) 2011

	Treatments	Means per plot (20 plants per plot)			
		Weight (g)	No. with *Botrytis*	No. with *Sclerotinia*	No. with tip burn
1	Control (NPK only)	*	*	*	*
2	InCA	**>**	**+**	**>**	**>**
3	Wormcast Pro	**>**	**+**	**X**	**>**
4	Omex Biomex Starter	**>**	**>**	**>**	**>**
5	Omex Biomex Plus	**>**	**+**	**>**	**>**
6	PLC Colonize AG	**X**	**+**	**>**	**>**
7	PHC Complete Plus	**X**	**>**	**>**	**X**
8	TTL Plus	**X**	**+**	**>**	**X**
9	Serenade	**+**	**+**	**>**	**>**
10	HYT b	**>**	**+**	**>**	**>**
11	HYTb + a + c	**>**	**+**	**>**	**>**
12	Phos-Star	**+**	**+**	**>**	**>**

Table 2a: Peas 2012

	Treatments	Means per sample		
		Numbers of pods	Stem length	Pod weights
1	Control (NPK only)	*****	*****	*****
2	InCa	**X**	**X**	**X**
3	Wormcast	**X**	**X**	**X**
4	Omex Biomex Starter	**>**	**>**	**>**
5	Omex Biomex Plus	**>**	**>**	**>**
6	PHC Colonise AG	**X**	**X**	**X**
7	PHC Complete Plus	**X**	**>**	**X**
8	TTL Plus	**X**	**>**	**X**
9	Serenade	**X**	**>**	**X**
10	Bactolife DP104	**>**	**X**	**>**
11	Bactolife A10	**>**	**X**	**X**
12	Phos-Star	**X**	**>**	**X**

Table 2b: Peas 2011

	Treatments	Means per sample (2 x 0.5 m)			
		Numbers of pods	Stem length	Pod weights	Nodule score
1	Control (NPK only)	*	*	*	*
2	InCa	>	>	>	>
3	Wormcast	>	>	X	X
4	Omex Biomex Starter	>	X	>	>
5	Omex Biomex Plus	>	>	>	>
6	PHC Colonise AG	>	X	>	X
7	PHC Complete Plus	X	>	X	X
8	TTL Plus	>	X	>	X
9	Serenade	>	X	>	X
10	HYTb	X	x	>	X
11	HYT abc	>	>	>	>
12	Phos-Star	>	>	>	X

- 2012 demonstrated that some treatments did improve marketable yield in carrots compared to the control plots (PHC Complete plus, TTL plus, Serenade and Wormcast), but results were not statistically significant. Cavity spot and carrot root fly levels were low as in the previous year.

Table 3a: Carrots 2012

	Treatments	Means per m^2			
		Cavity spot score	No. of carrots with carrot root per m^2	Weight per m^2	Marketable weight per m^2
1	Control (NPK only)	*	*	*	*
2	InCa	>	X	>	X
3	Wormcast	X	X	>	>
4	Omex Biomex Starter	X	X	>	X
5	Omex Biomex Plus	X	>	X	X
6	PHC Colonise AG	>	X	X	X
7	PHC Complete Plus	>	>	>	>
8	TTL Plus	>	>	>	>
9	Serenade	X	>	>	>
10	Bactolife DP104	>	>	>	X
11	Bactolife A10	X	X	>	X
12	Phos-Star	>	X	X	X

Table 3b: Carrots 2011

		Means per sample (60 carrots)			
	Treatments	Cavity spot score	Carrot root fly score	Diameter	Length
1	Control (NPK only)	*	*	*	*
2	InCa	**>**	**X**	**X**	**X**
3	Wormcast	**X**	**X**	**X**	**X**
4	Omex Biomex Starter	**X**	**>**	**X**	**X**
5	Omex Biomex Plus	**>**	**X**	**>**	**>**
6	PHC Colonise AG	**>**	**>**	**X**	**X**
7	PHC Complete Plus	**>**	**X**	**X**	**X**
8	TTL Plus	**>**	**X**	**X**	**X**
9	Serenade	**>**	**X**	**X**	**X**
10	HYTb	**X**	**>**	**>**	**>**
11	HYT abc	**X**	**>**	**X**	**X**
12	Phos-Star	**X**	**X**	**X**	**X**

- The second year data have showed some marginal improvements in yield for carrots and lettuce with some products. The results from two years of trials do not as yet provide clear indications of the efficacy of these plant growth enhancing products. However weather conditions for the two years were very different, with the 2012 being the wettest year on record.

- Additional data would provide a clearer effect of the products on yield and disease. It has been also suggested that introducing an additional control treatment with no NPK application would be useful, as scientific evidence suggests that the addition of NPK may counteract the potential benefits that some of the products are trying to achieve in their promotion of beneficial microbes within the soil.

Research is needed to address the complex interactions of micronutrients and their role in sustainable crop production before recommendations can be made to growers.

Financial benefits

It is possible that micronutrient treatments may provide sustainable methods of maintaining, or even increasing, yield and quality. It is important for the horticultural industry to begin to understand the evidence on micronutrient nutrition and whether these plant growth-enhancing products are useful tools in crop production.

Action points for growers

- Growers can use the results of this project to make more informed decisions on the nutritional products applied to their crops

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SCIENCE SECTION

Introduction

With increasing pressure on growers to produce larger yields or maintain current yields using fewer inputs, there has been an increase in the market for yield-enhancing products. These products exploit existing knowledge of macronutrients other than nitrogen (N), phosphorus (P) and potassium (K) (e.g. magnesium, sulphur and calcium), micronutrients (copper, manganese, boron and molybdenum) and microbials (mycorrhizal fungi).

There is currently no screening programme to provide information on the efficacy of these plant growth enhancers. The aim of this project is to provide a first step towards understanding the role that these products can play in helping growers achieve increased yield and better quality crops.

Materials and methods

All work conducted for the project was undertaken at the Stockbridge Technology Centre Research Foundation (STCRF).

Lettuces were propagated at STCRF before being transplanted; peas and carrot were directly drilled.

Crop diaries

Table 4: PEAS 'Ambassador'

Date	Action
Apr	Applied P + K to trial area in field J (166 kg/ha).
24 May	Harrowed and rolled land. Marked out trial area.
24 May	Drilled Ambassador @ 1 seed/cm with Oyjard Drill. 4 rows/1.83 m bed @ 37.5 cm.
25 May	Applied herbicide Cirrus @ 0.2 L/200 L water/ha. (Very windy).
20 Jun	Applied all micronutrient treatments @ three true leaves. **Spray 1.**
9 Jul	Removed cover. Applied micronutrient treatments**. Spray 2.**
18 Jul	Applied micronutrient treatments. **Spray 3.**
23 Jul	Flowering commencing
3 Aug	Applied micronutrient treatments. **Spray 4.**
22 Aug	Harvested two middle rows x 0.5 m long. Recorded number of pods and weight.
23 Aug	Stem length/root nodule assessment.

Table 5: CARROTS ‘Nairobi’

Date	Action
Apr	Applied P and K to trial area in field J.
23 May	Applied nitrogen @ 100 kg/ha. Harrowed and rolled seedbed.
24 May	Drilled Nairobi @ 150–180 seeds/m^2. 4 rows/1.83 m bed @ 37.5 cm.
24 May	Applied herbicide. Linuron @ 1.2 L/200 L water/ha.
20 Jun	Applied micronutrient treatments @ 2^{nd} true leaf. **Spray 1.**
24 Jun	Carrots hand weeded.
9 Jul	Applied micronutrient treatments. **Spray 2.**
18 Jul	Applied micronutrient treatments. **Spray 3.**
3 Aug	Applied micronutrient treatments. **Spray 4.**
16 Aug	Applied micronutrient treatments. **Spray 5.**
12 Nov	Harvested middle 2 m rows and assessed.

Table 6: LETTUCE ‘Frisco’

Date	Action
Apr	Applied P and K to trial area in field J.
Jun	Lettuce cv. Frisco sown into blocks.
30 Jul	Applied micronutrient treatments to run-off as a **pre-planting** drench. **Spray 1.**
30 Jul	Applied nitrogen @ 100 kg/ha. Harrowed and rolled trial area.
30 Jul	Marked out 4 rows/1.83 m bed @ 37.5 cm x 30 cm within rows.
1 Aug	Planted lettuce. Irrigated 15 mm.
16 Aug	Applied micronutrient treatments. **Spray 2.**
22 Aug	Top dressed nitrogen @ 100 kg/ha
30 Aug	Applied micronutrient treatments. **Spray 3.**
13 Sep	Applied micronutrient treatments. **Spray 4.**
10 Oct	Harvested.

Treatment application

Treatments were applied to the three crops using an Oxford Precision Sprayer at a pressure of 2 bar.

Table 7: Treatments and rates

	Product	Rate	Volume in 4 L of Water	Application
A	Commercial NPK (Control)			**4x at 14 day intervals**
B	InCa	1 L/ha	19.4 ml	**4x at 14 day intervals**
C	Wormcast Pro-Tea	10 L/ha	195 ml	**4x at 14 day intervals**
D	Omex Biomex Starter	0.5 L/ha	9.7 ml	**4x at 14 day intervals**
E	Omex Biomex Plus	2.5 L/ha	48.7 ml	**4x at 14 day intervals**
F	PHC Colonize AG	2 kg/ha	38.6 g	**4x at 14 day intervals**
G	PHC Complete Plus	2 kg/ha	38.6 g	**4x at 14 day intervals**
H	TTL Plus	4 L/ha	78.5 ml	**4x at 14 day intervals**
I	Serenade	10 L/ha	195 ml	**4x at 14 day intervals**
J	Bactolife DP104	2 kg/ha	38.6 g	**4x at 14 day intervals**
K	Bactolife A10	2.0 L/ha	40 ml	**4x at 14 day intervals**
L	Phos-Star PO3-PO4	1 L/ha	19.4 ml	**4x at 14 day intervals**

Each of the twelve treatments (including commercial NPK) was replicated four times. The plots measured 9 m in length and 1.8 m in width. Treatments were applied at 200 L/ha.

Yield assessments:

Lettuce: At harvest each plant was assessed for fresh weight, dry weight and rated as either marketable or non-marketable.

Peas: Peas were assessed for root nodulation, stem length and number and weight of pods.

Carrots: At harvest 2 x 1 m per plot were taken from middle rows and were scored for diameter, length and weight.

Disease assessments:

Lettuce: At harvest, twenty lettuces were removed from the centre two rows of each plot and assessed for disease.

Carrots: Harvested carrots were assessed for carrot root fly damage and cavity spot.

Peas: No disease was observed.

Data analysis

Analysis of Variance (ANOVA) was performed. Data sets with percentages were transformed with angular transformations. Means were compared using least significant difference (LSD) at the 5% level of significance.

Results

Lettuce (Frisco)

Dry weight

The average dry weight for each treatment is presented in Figure 1. Treatment with Omex Biomex Plus gave the greatest mean dry weight. ANOVA results suggested no significant differences between treatments at the 5% confidence level, but significant differences at the 10% level (*p* 0.07) were seen.

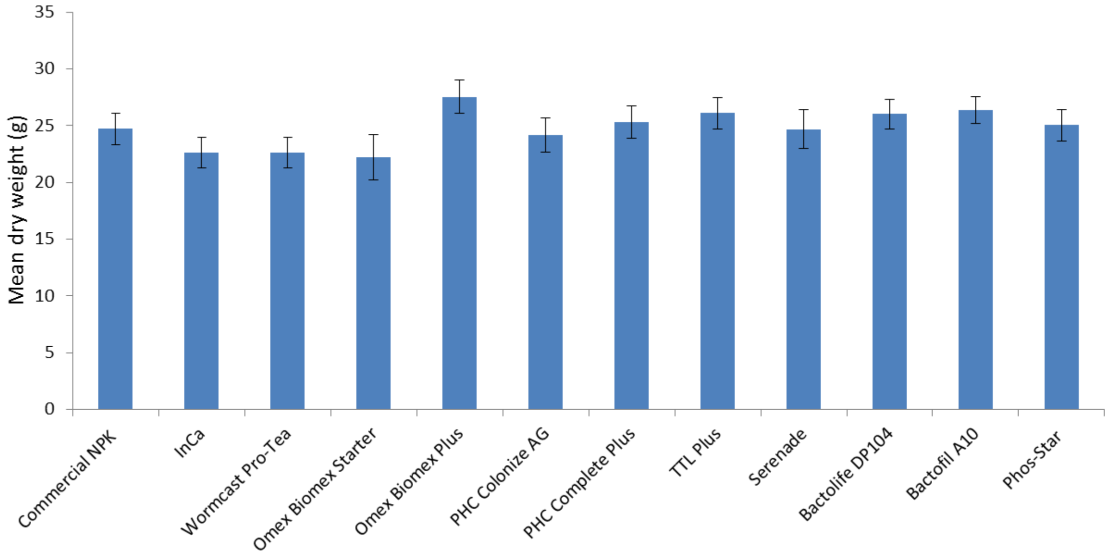

Fig. 1: Mean dry weight of lettuces in each treatment (+/- SE)

Fresh weight

Average marketable yield (fresh weight) for each treatment is shown in Figure 2. Treatment with Phos-Star PO3-PO4 gave highly significant lettuce yield compared to the control (273.23 g ± 12.56 and 214.75 g ± 9.14 respectively, p <0.001); this result was also established in 2011 (FV 394). Omex Biomex Plus and TTL Plus also had significantly higher fresh weights (p 0.02) compared to the control. An increase in fresh weight that does not correspond to an increase in dry weight, as observed in treatments with Phos-Star or TTL Plus and Phos-Star, reflects an increase in moisture content that may result in reduced shelf-life. However, it may also be because of the inherent variability within the data set due to extreme weather conditions.

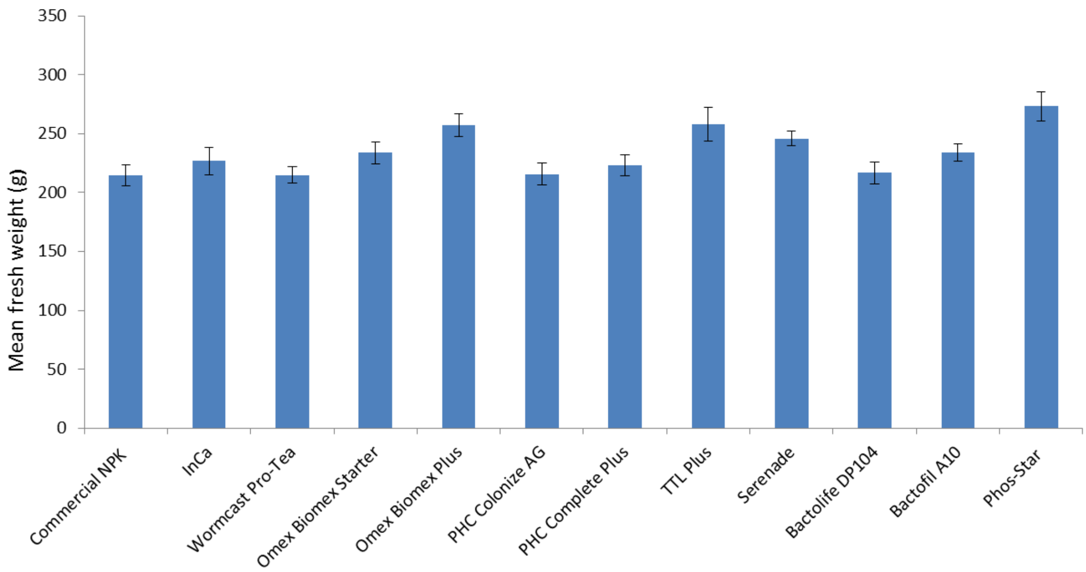

Fig. 2: Mean fresh weight (yield) of lettuces in each treatment (+/- SE)

Disease

Due to the high rainfall experienced in 2012, tip-burn was not observed during the trial, however, downy mildew appeared rapidly and evenly throughout the crop. To assess this impact, the numbers of infected leaves per lettuce were recorded. Mean infection extent for each treatment is shown in Figure 3. Treatment with PHC Colonize AG and Omex products gave the lowest mean infection rates, but values were not significantly better than the control.

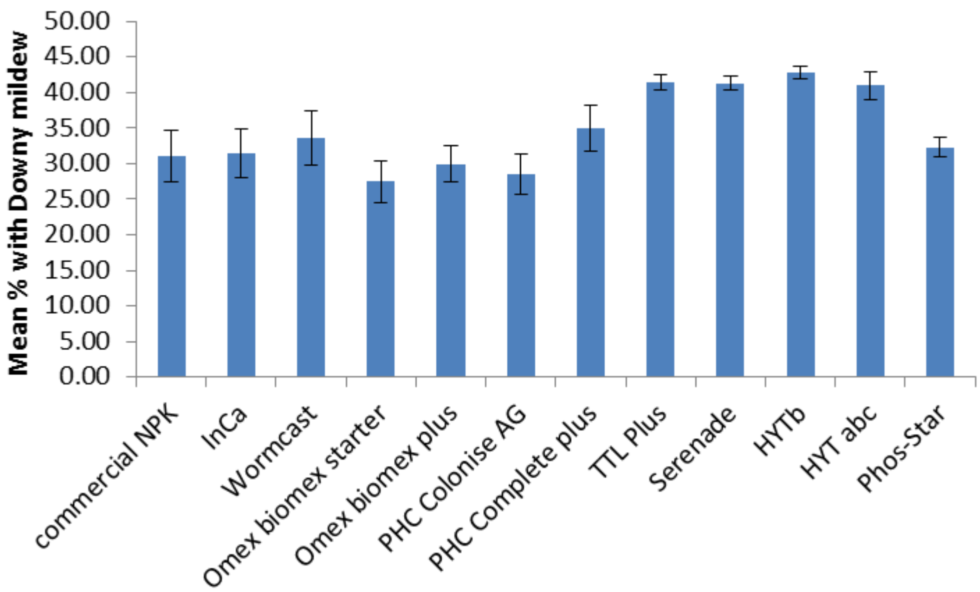

Fig 3: Treatment differences in mean percentage of lettuce leaves infected with downy mildew (+/- SE).

Carrots (Nairobi)

Marketable yield

High within-treatment variation suggests that few treatments have an effect on yield compared to the NPK control treatment. Greatest mean marketable yields were found in the PHC Complete Plus, TTL Plus and Serenade treatments; however, there was no statistically significant difference in means of these treatments compared to the NPK control. Figure 4 outlines these results.

Unmarketable yield

See Figure 5 for comparisons of mean unmarketable weight per metre. Greatest mean unmarketable weight was found with the Wormcast treatment, but plots were highly variable.

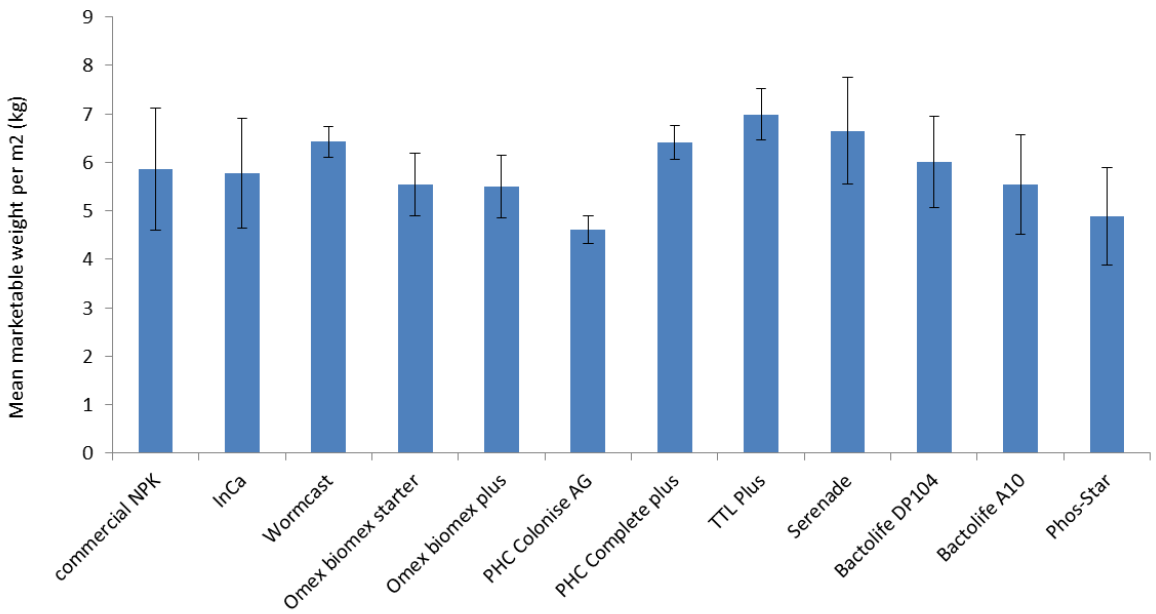

Fig. 4: Mean weight of carrots per metre of each plot for all treatments (+/- SE)

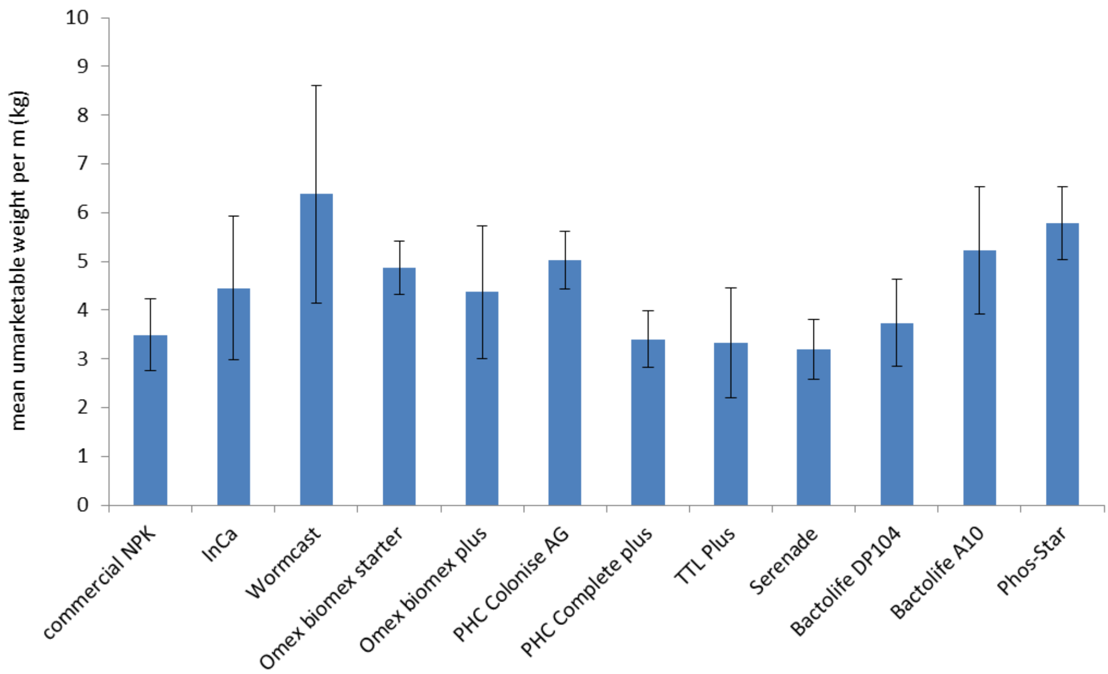

Fig. 5: Mean unmarketable weight per metre for each treatment (+/- SE).

Disease and pest damage

Cavity spot

The incidence of cavity spot was too low to measure any treatment effect. A maximum of two carrots per plot were found to have the disease, and the majority had none. It was not appropriate to calculate mean scores of cavity spot damage but total mean numbers of infected carrots per treatment are given below.

Table 8: Mean number of carrots infected with cavity spot (numbers were very low across all treatments).

Treatment	Mean number of carrots infected with cavity spot
Commercial NPK	0.5
InCa	0
Wormcast	0.5
Omex Biomex Starter	1
Omex Biomex Plus	0.5
PHC Colonise AG	0
PHC Complete Plus	0.25
TTL Plus	0
Serenade	0.5
Bactolife DP104	0.25
Bactolife A10	1.25
Phos-Star	0

Carrot root fly

Carrot root fly incidence was also lower than in the previous year and, as a consequence, damage assessment scores per carrot were replaced with mean numbers of carrots showing signs of damage. Figure 6 shows the results of this assessment. No significant difference in carrot fly incidence was identified following any of the treatments when compared to commercial NPK. Slight but non-significant decreases in carrot root fly, compared to the control plots, were found in Serenade, TTL Plus and PHC Complete Plus treatments. Treatments showing greater incidence of carrot root fly than NPK have higher within-treatment variability than other treatments; this is likely to be due to an edge effect, whereby low numbers of carrot fly moved into the crop but kept close to the perimeter.

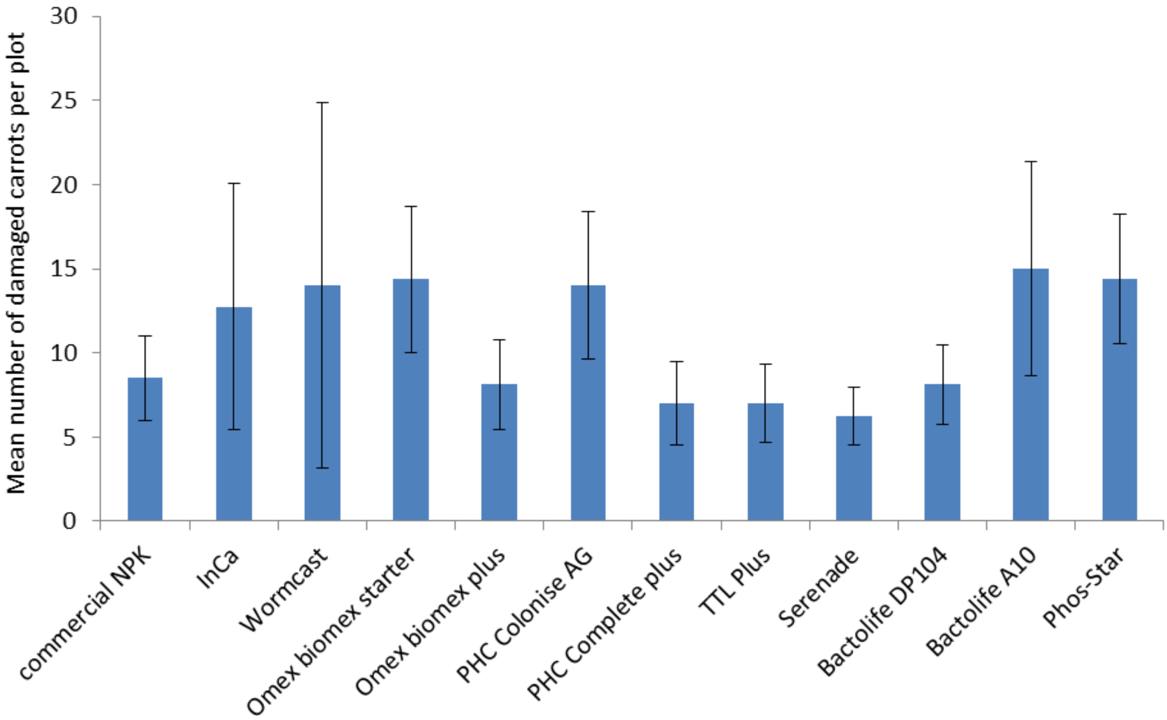

Fig 6: Mean number of carrots infected with carrot root fly per meter for each treatment.

Peas (Ambassador)

Stem length

Mean stem length amongst all treatments was fairly uniform (Fig. 7).

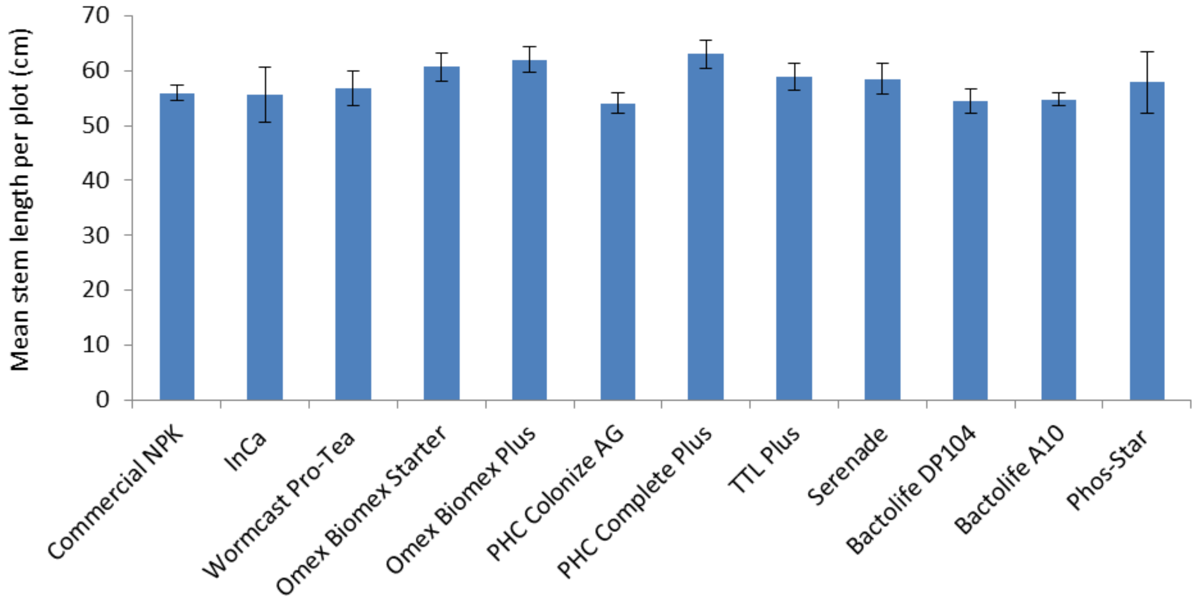

Fig. 7: Mean stem length of peas for each treatment (+/- SE)

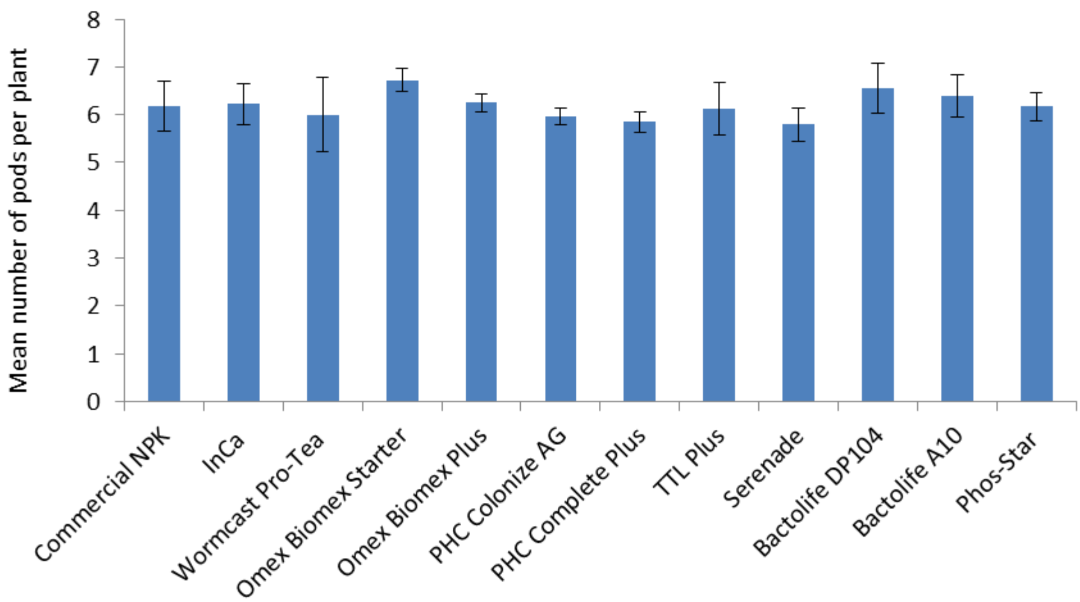

Fig.8: Mean number of pods per plant for each treatment (+/- SE).

Figure 8 shows the comparison of mean numbers of pods per plant for the different treatments. No treatments had a strong or significant effect on yield in terms of pod numbers.

Table 9: Mean weight of pods (kg) per ha

Product	Weight pods per ha (kg)
Commercial NPK (Control)	40040
InCa	38445
Wormcast Pro-Tea	38087.5
Omex Biomex Starter	42955
Omex Biomex Plus	41965
PHC Colonize AG	35942.5
PHC Complete Plus	36712.5
TTL Plus	36877.5
Serenade	35062.5
Bactolife DP104	40975
Bactolife A10	38472.5
Phos-Star PO3-PO4	39875

Table 9 provides the mean weights of pods per ha, with Omex Biomex Starter producing the greatest weight. However, the data in Figure 9 demonstrates how the variability in the mean weight of pods per plant (standard error bars) results in a failure to establish any statistically significant values when treatment means are close in value.

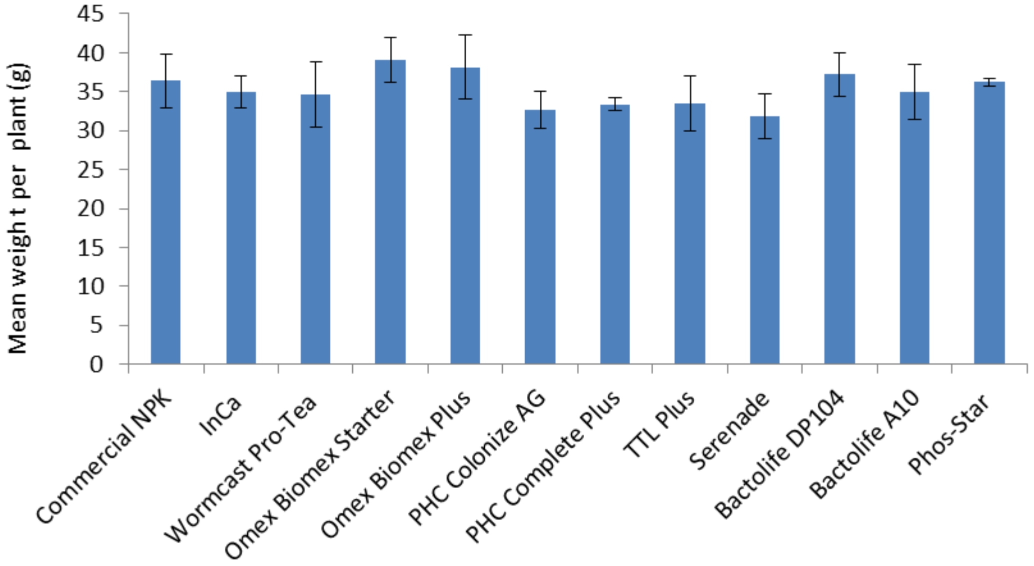

Figure 9: Mean weight of pods (g) (±SE) per plant per plot.

Root nodule formation for all plants – regardless of treatment – was lower than expected compared to the 2011 data. The maximum score for any plant was 6. There was no significant treatment effect. Figure 10 highlights these results.

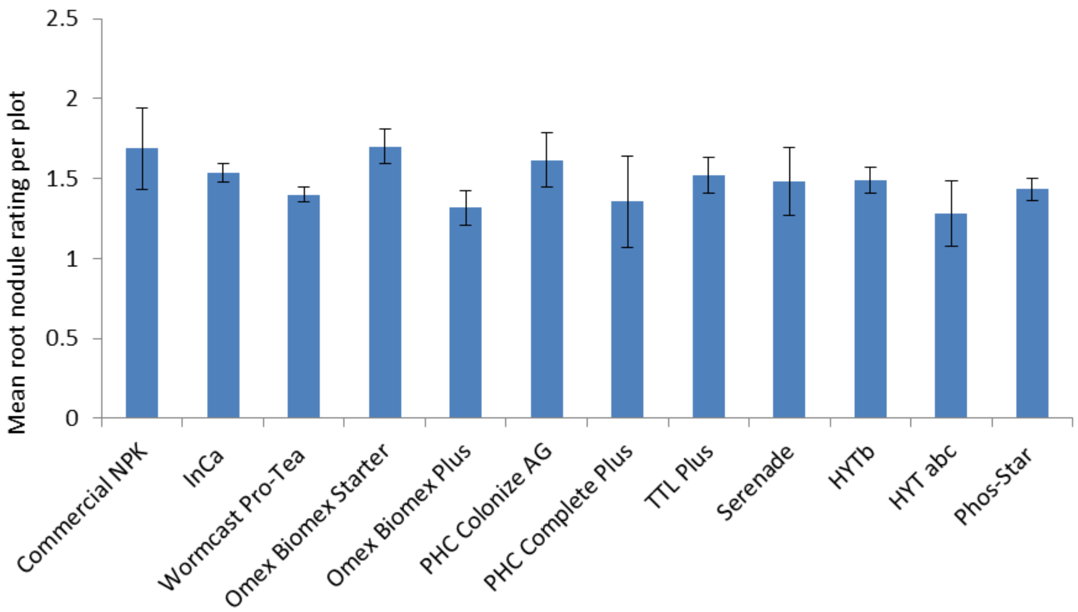

Fig. 10: Mean root nodule score for each treatment (+/- SE). The highest score possible for a plant was 10.

Conclusions

- The trial results for 2012 show significant increases in the fresh and dry weights of lettuce. Dry and fresh weights recorded at harvest showed statistically significant increases in yields with treatments of Omex Biomex Plus, TTL Plus and Phos-Star. Treatment with Phos-Star produced similar results in trials conducted in 2011.

- Due to wet weather in 2012 downy mildew appeared quickly through the lettuce crop; therefore assessment of the percentage of leaves affected was recorded. *Botrytis cinerea*, *Sclerotinia sclerotiorum* and tip-burn were not recorded in 2012.

- It was demonstrated in 2012 that some treatments improved marketable yield in carrots compared to the control plots, but there were no statistically valid results. Cavity spot and carrot root fly levels were low as in the previous year.

- In the pea crop, some treatments did improve yield measurements marginally in comparison to the control plots (Table 2a). Omex Biomex Starter produced the largest yield, but the results were not statistically significant in comparison to the NPK control plots. Root nodules were very poor in 2012 and it is possible this is due to the very wet year. Generally, the pea crop was poor due to this heavy rainfall and made treatment comparisons difficult.

Overall, a wide selection of products have been tested over two growing seasons although both years were subjected to extreme record breaking weather conditions: 2011 had the driest spring and 2012, the wettest summer. There has been statistical evidence that some products have provided benefits in yield and disease control, especially in association with lettuce crops. However, the data is very variable and it is suggested that a further year of trials is required to collect data that will provide a clearer picture. It would also be interesting to understand the effects of these products on other parameters such as post-harvest quality. An understanding of the interactions of the best candidate products would also be useful to test for cumulative benefits.

In addition, there is much scientific evidence to suggest that fertilisers can reduce the beneficial effects that mycorrhizal fungi and other microbes can play in crop growth. It is has been suggested that the testing of vigour-enhancing products needs to be determined in the absence of fertilisers.