Project title:	AHDB Field Vegetable Centres – Brassicas, Scotland – Broccoli bio-stimulants screen
Project number:	FV 462
Project leader:	Angela Huckle, ADAS Horticulture
Report:	February 2022
Previous report:	Annual Report, December 2020
Key staff:	Angela Huckle, ADAS Horticulture (report editor) Ewan Gage, ADAS Horticulture (report author) Chris Dyer, ADAS Statistician James Rome, East of Scotland Growers Duncan MacLachlan, East of Scotland Growers Duncan Carr, Oxford Agricultural Trials
Location of project:	Moonzie, Scotland (2021) Balmullo, Scotland (2020)
Industry Representative:	James Rome, East of Scotland Growers, Prestonhall Industrial Estate, Cupar, Fife
Date project commenced:	1 April 2020

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

AUTHENTICATION

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

Ewan Gage

Associate Director

ADAS Horticulture

Signature ..  ... Date 4th February 2022

Report authorised by:

Angela Huckle

Associate Director – Crop Health

ADAS Horticulture

Signature .....  .... Date 7th February 2022

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GROWER SUMMARY

Headline

- All treatment programmes in the experiment were safe to use over broccoli with no adverse effects observed on the crop.
- There were no significant differences in head biomass or root biomass between treatments, although some treatments showed small, but insignificant, differences in foliar biomass which may have been attributable to nutrient effects rather than any specific biostimulant effects.
- The lack of any significant differences between treatments may be attributable to the generally good conditions under which the crops were cultivated. However, effects may be clearer when cultivated under conditions of stress (especially drought stress) in other seasons.

Background

An increasing range of biostimulant products are available on the UK market, with a broad range of components, reported modes of action and benefits. With the continued loss of chemical active ingredients, biostimulants continue to be of great interest to horticultural growers due to the benefits claimed by manufacturers with regards to increasing crop health and resilience against pests and pathogens. Furthermore, many products are reported to offer increased crop resilience of abiotic stress (especially drought) which may be of benefit as increasingly unpredictable weather patterns are seen.

This is an area which is expanding rapidly with an increasing number of products available based on a range of different constituents, such as amino acids, seaweed extracts, growth promoting bacteria, phosphites, humic and fulvic substances which are reported to have a wide range of influences on the innate crop biology – for example, acting as analogues of plant hormones to stimulate root growth. These are sometimes now formulated as a combined blend in selected products, and may include supplementary macro- or micronutrients.

In high value horticulture crops even a small increase in yield or shelf-life, or increased tolerance to disease or drought can mean an greater impact on profit margins than is seen in cereals, and therefore many growers are keen to try these products but unsure of their efficacy as claimed by the manufacturers.

The biostimulants market was reviewed for cereals and oilseeds growers by Dr Kate Storer of ADAS (Research Review No. 89. A review of the function, efficacy and value of biostimulant products available for UK Cereals & Oilseeds was prepared by ADAS as part of a nine-month project (2140032125) which started in November 2015).

Trials in the 2020 season with a range of products did not demonstrate any significant differences between individual biostimulant products and the untreated control, although the crops examined were grown under near-ideal conditions free of stress which may have explained the lack of any significant results. To continue to build on the evidence available a further trial was planned into the 2021 season. A range of biostimulant products were chosen to trial in discussion with East of Scotland Growers and Kettle Produce, and shortlisted to ten programmes.

Summary

Methods

The trial took place within a broccoli crop of a commercially grown variety, cv. Parthenon, planted on 4 June 2021. The plots were situated at the East Scotland Growers trial ground located nr Moonzie, Fife. The trial design comprised a fully randomised block design with 11 treatments (**Table 1 and 2**), including one untreated control and was replicated five times. Each replicate plot was a 10m length of 1.94m bed to give a minimum assessment area of 15m^2 per plot. Either side of the trial was a 1 bed width and 10m strip length discard area, giving a total trial area of 130m x 13.6m.

Altogether the trial was seven beds wide including guards either side of the trial. The central row was used for all assessments and excluded the 0.5 m at the end of each plot from the area to be assessed. One half of the plot was used for foliar assessments, while the remaining half was left for destructive assessments.

Table 1. Treatment programmes and timings of applications used in the trial

	Timing 1 – 1 to 2 weeks after planting		Timing 2 – 3 weeks after T1 application		Timing 2- Head initiation (approx. 2-3 weeks after T2 app	
Trt. No.	Product	Rate (L/ha or kg/ha)	Product	Rate (L/ha or kg/ha)	Product	Rate (L/ha or kg/ha)
1	UTC	-	UTC	-	UTC	-
2	Biofarmix 'H' Biofarmix 'M' Biofarmix 'A'	25.0 5.0 5.0	Biofarmix 'A'	15.0	Biofarmix 'A'	15.0
3	Kelpak	2.0	Bio 20	2.0	Calmax Ultra	2.0
4	Bioforge	1.0	Stimulante Plus	1.0	Hold	1.5
5	Hold	1.5	Hold	1.5	Hold	1.5
6	Vit Amino	2.0	Vit Amino	2.0	MDS 602	2.0
7	AF Turret + AF Nurture	0.05 0.032	AF Phosphorous + AF Nurture	5.0 2.0	AF Phosphorous + AF Nurture	5.0 2.0
8	NTS Trio NTS Triple 10	2.0 1.5	NTS Trio NTS Triple 10	2.0 1.5	NTS Trio NTS Triple 10	2.0 1.5
9	TTL+ AF Pulsar	1.0 6.0	TTL+ AF Pulsar	2.5 6.0	TTL+ AF Pulsar	2.5 6.0
10	Yieldon	2.0	Yieldon	2.0	Yieldon	2.0
11	Megafol	3.0	Megafol	3.0	Megafol	3.0

Table 2. The biostimulant product details and constituents from available label data.

Product	Active ingredient (s)	Company
Biofarmix	H- Humic substances + organic substances + microorganisms M - Microbial consortium (more than 100 species) A - Amino acid complex + organic substances + microorganisms	BioFarmix
Kelpak	Organic biostimulant from kelp	Omex
Bio 20	Bio 20 is a suspension concentrate containing macro and micronutrients combined with naturally occurring kelp biostimulant (18.5%). Nitrogen (13.2%), Phosphate (13.2%), Potassium (13.2%) plus Mg, Mn, Fe, B, Cu, Zn and Mo.	Omex
Calmax Ultra	Foliar feed with N (9.6%) and Ca (14.5%) with trace elements including Mg, Mn, Fe, B, Cu, Zn and Mo.	Omex
Bioforge	Foliar spray with N (2%) and K (3%) along with trace elements (Co and Mo).	Stoller

Product	Active ingredient (s)	Company
Stimulante Plus	Foliar spray containing auxins, cytokinins and gibberellins.	Stoller
Hold	Foliar spray containing Ca	Stoller
Vit Amino	Yeast fractions (Saccharomyces cerevisiae)	Microbial distribution
MDS 602	Aqua, Ascorbic Acid, Vitamin P, Acetic Acid, Glycerine, Orange Extract, Seaweed extract, Neem Extract, Garlic Extract,	Microbial distribution
AF Turret	Starter fertiliser – Nitrogen (8.9%) Phosphorous 13.6%), plus Mg, S, Mn and Zn	Aiva Fertilisers
AF Nurture	Fulvic and humic acids plus Potassium (1.1%), Mg, S, Ca and trace elements (So, Cu, Fe, Mn and Zn)	Aiva Fertilisers
AF Phosphorous	Foliar nutrients inc phosphorous. Nitrogen (7%), Phosphorous (13.8%), and Mg, S and Zn	Aiva Fertilisers
NTS Trio	Foliar fertiliser based on 13.73% N, 0.1%K and 15.3% Ca with Mg, B and Fe alongside fulvica acid and mannitol derived from kelp.	Nutri-Tech Solutions
NTS Triple 10	A liquid 10-10-10 fertiliser with trace elements and natural growth promoters.	Nutri-Tech Solutions
TTL Plus	Fulvic and humic acids	Nutrimate
AF Pulsar	Foliar nutrients including N (6%) and trace elements (S, Mg, Mn, Zn, Cu, B, Mo, Co and Na).	Aiva Fertilisers
Yieldon	Foliar nutrients including N (3%), K (3%) and trace elements (Mn, Mo, Zn)	Valagro
Megafol	Foliar nutrients including N (3%), K (8%) and various vitamins, amino acids and proteins, betaines and growth factors	Valagro

The broccoli was netted to protect the crop from bird damage, with the net being removed for each application and replaced afterwards. The net was fully removed at the end of July.

Treatments were applied using a precision knapsack sprayer with a 1.5 metre boom and 02F110 nozzles at medium quality and 200 litres per hectare water volume. All treatments were applied post-planting at the following timings:

- Timing 1: 18th June 2021 - post-emergence, once plants established (3-4 leaves)
- Timing 2: 8th July 2021 - 6-8 leaves
- Timing 3: 23rd July 2021 – 10 mm leading head

The crop growth stage was recorded at each spray application visit.

One destructive assessment was carried out to measure the weights of the plant roots and shoots or foliage at harvest. Samples were taken from the middle row and the top five metres of the plot avoiding the 0.5 m at the plot edges. The top half of the plot was used for destructive assessments and the bottom half was used for visual assessments. Plots were sampled on 10th and 11th August over two days. Five samples were taken per plot at each sampling for measurement. This gave 25 samples per treatment across all five blocks. The plants were dug up and shaken carefully to remove as much soil as possible and to prevent the fine roots from tearing, and a fresh weight was taken of all five plants in the plot separately. A mean was then taken from these measurements per plot. The roots were then cut off to be weighed and the weight of the top of the plant was then extrapolated from total fresh weight minus the weight of roots. At the destructive assessments club root was monitored and recorded, but significant development was not seen. Broccoli head size was also measured as weight in grams, and the number of broccoli with head rot were recorded per plot to give percentage incidence head rot per each plot. Head rot was visually assessed if seen, with the causal pathogen not determined in the lab. No head rot was observed in the plots at the time of harvest.

Results & Discussion

At harvest, there no significant differences in total biomass, foliage, root or head weight between treatments (**Table 3, Figure 1, Figure 2**) . Whilst there were marginal differences in foliage biomass between treatments (NTS Trio + NTS Triple 10 gave the greatest increase at 109% of the control) this was largely due to increases in the foliar biomass, with relatively consistent biomass in the root and head portions. There were also no significant differences in the incidence of clubroot between treatments.

Whilst there were no significant differences between treatments at harvest, there were anecdotal comments provided by the host grower that some differences were evident between treatments following a period of drought stress in July. However, showery weather after this period until harvest gave good levels of growth so that any differences were lost prior to assessments at harvest. This correlates with wider observations that biostimulants offer the greatest benefits to crops that are undergoing stress, and so the near-optimum conditions seen over the majority of the growing period meant that comparatively even growth was seen across both the treatments and the control plants.

Whilst these results have not demonstrated any clear benefits for biostimulant use, it is likely that should this trial be repeated under conditions of greater stress that any distinction between products will be clearer given the conditions of their use.

Table 3. Summary figures for the destructive sampling at harvest. Values are presented per plant.

Treatment		Average Fresh Weight per Plant (kg)				Club Root Total No.
		Foliage	Root	Head	Total	
1	Untreated control	1.55 ± 0.06	0.24 ± 0.02	0.41 ± 0.03	2.21 ± 0.08	1.00 ± 0.20
2	Biofarmix 'H', 'M', 'A' program	1.44 ± 0.07	0.27 ± 0.01	0.39 ± 0.03	2.11 ± 0.08	0.80 ± 0.09
3*	Kelpak fb. Bio20 fb. Calmax Ultra	1.60 ± 0.05	0.26 ± 0.02	0.42 ± 0.03	2.28 ± 0.08	0.00 ± 0.00
4	Bioforge fb. Stimulante Plus fb. Hold	1.59 ± 0.07	0.27 ± 0.02	0.43 ± 0.04	2.28 ± 0.11	0.20 ± 0.09
5	Hold applied 3 times	1.48 ± 0.07	0.24 ± 0.01	0.37 ± 0.02	2.08 ± 0.08	0.20 ± 0.09
6	Vit Amino applied twice then MDS 602	1.48 ± 0.08	0.25 ± 0.02	0.40 ± 0.04	2.12 ± 0.13	1.20 ± 0.26
7	AF Turret + AF Nurture fb. AF Phosphorous + AF Nurture x 2	1.51 ± 0.04	0.25 ± 0.01	0.40 ± 0.03	2.16 ± 0.06	0.80 ± 0.22
8	NTS Trio + NTS Triple 10 Applied 3 times	1.69 ± 0.11	0.30 ± 0.03	0.43 ± 0.02	2.41 ± 0.14	0.40 ± 0.18
9	TTL+ AF Pulsar applied 3 times	1.45 ± 0.06	0.25 ± 0.02	0.40 ± 0.03	2.10 ± 0.09	0.40 ± 0.18
10	Yieldon applied 3 times	1.51 ± 0.10	0.29 ± 0.01	0.40 ± 0.04	2.21 ± 0.13	0.20 ± 0.09
11	Megafol applied 3 times	1.48 ± 0.06	0.23 ± 0.01	0.40 ± 0.03	2.10 ± 0.08	0.20 ± 0.09

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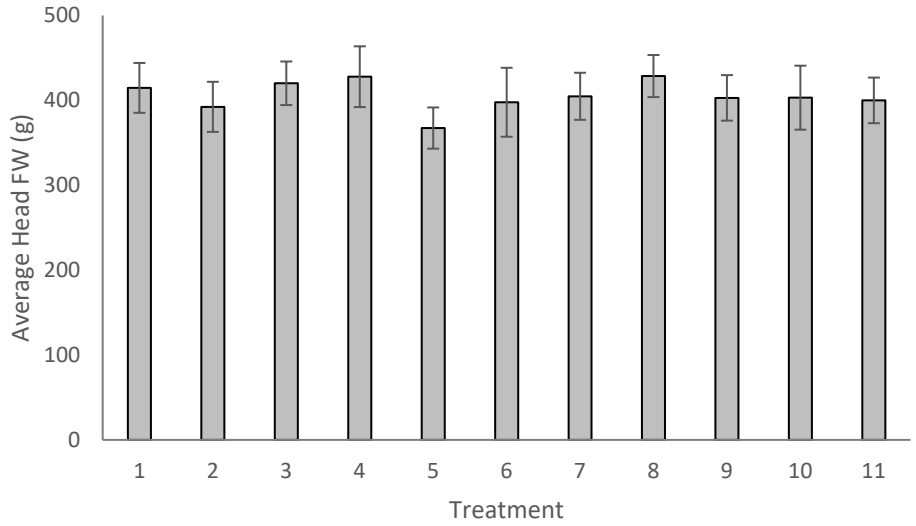

Figure 1. Average head fresh weight at harvest. For treatment numbers see Table 3.

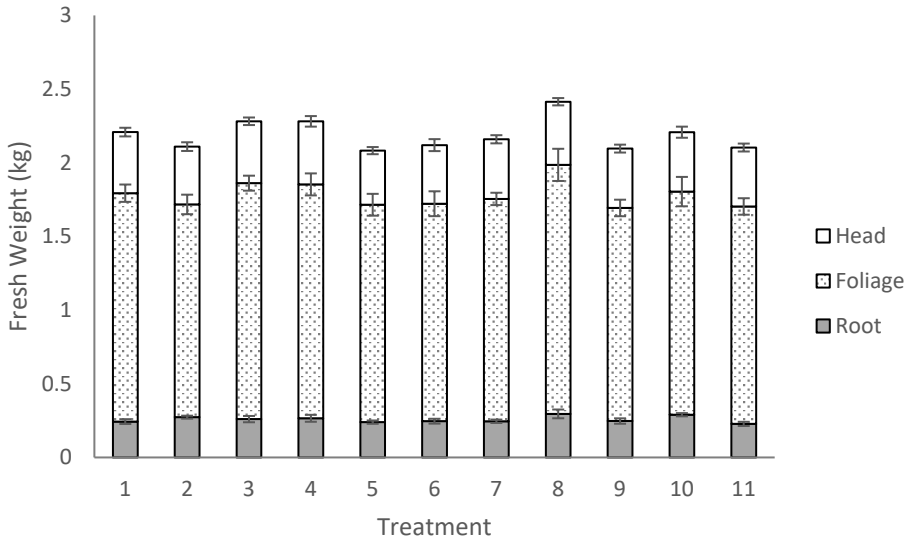

Figure 2. Biomass distribution at harvest. Average head weight at harvest. For treatment numbers see Table 3.

Conclusions

- None of the treatment programmes in the experiment resulted in adverse effects observed on the crop.
- There was no significant increase in root biomass or plant biomass from any of the treatments when compared to the untreated control.
- Whilst biostimulant treatments may offer benefits for field vegetable production, these distinctions may be lessened under conditions where the crop is likely to be subject to reduced levels of stress due to suitable rainfall or irrigation provision.

References

Storer, K. *et al* (2016). A review of the function, efficacy and value of biostimulant products available for UK cereals and oilseeds. AHDB Research Review No. 89

Tiffin, D. (2005). Interpretation of leaf nutrient analysis results – Brassicas (cabbage, Brussels sprouts, cauliflower, broccoli, turnip and swede). AHDB Factsheet 21/05

Financial Benefits

It is difficult to confidently determine the financial benefits of the use of biostimulants from this trial as there were no significant conclusions. However, if more information were available as to the benefits of these products in sub-optimal year it would be possible to provide a more valid financial appraisal of their benefits.

SCIENCE SECTION

Introduction

Biostimulants represent a diverse range of products which are reported to work in a synergistic fashion with crop biology to improve growth, mitigate environmental/biological stresses and aid crops to achieve target yield volume and quality. The modes of action of biostimulant are highly heterogenous, and their benefits may only be seen under certain conditions or during specific stages of crop growth.

With the continued loss of chemical active ingredients, biostimulants continue to be of great interest to horticultural growers due to the benefits claimed by manufacturers with regards to increasing crop health and resilience against pests and pathogens.

This is an area which is expanding rapidly with an increasing number of products available based on a range of different constituents, such as amino acids, seaweed extracts, growth promoting bacteria, phosphites, humic and fulvic substances for example. These are sometimes now formulated as a combined blend in selected products.

In high value horticulture crops even a small increase in yield or shelf-life, or increased tolerance to disease or drought can mean a larger increase in profit margins than is seen in cereals, and therefore many growers are keen to try these products but unsure of their efficacy as claimed by the manufacturers.

For example, products which are reported to drive root growth (e.g. humic and fulvic acids) may improve the ability of the crops to absorb necessary water and nutrients under periods of drought stress. Similarly, foliar application of calcium may reduce the impact of rots (particularly in fruits prone to blossom end rot) under circumstances where the uptake of calcium from the soil is insufficient to meet the demands of crop growth.

The relative novelty of many of these products, combined with the lack of on-label recommendations for specific horticultural crops can constrain the uptake of these products in the commercial horticulture sector.

To address these knowledge gaps, this project was set up to develop an evidence base as to the best practice and benefits of biostimulant use for broccoli. The objective of this trial was to compare a number of commercially available biostimulants and evaluate effects on crop growth and biomass of roots, foliage and head size as well as any effects on crop health, where possible to illustrate their benefits for the wider horticulture sector.

The biostimulants market was reviewed for cereals and oilseeds growers by Dr Kate Storer of ADAS (Research Review No. 89. A review of the function, efficacy and value of biostimulant

products available for UK Cereals & Oilseeds was prepared by ADAS as part of a nine-month project (2140032125) which started in November 2015).

On the cereals monitor farms those biostimulants identified with potential are frequently being chosen as a subject to trial, and field vegetable growers are also keen to see independent trials of these products. The review, crucially, also evaluated a wide variety of literature sources to find evidence of benefits associated with the use of biostimulants. Although product diversity made the process of detecting significant benefits challenging, some positive yield results were identified in cereal experiments. It was also noted that limited data was available for UK conditions. For the most common product categories – seaweed extracts, humic substances, phosphite and plant growth promoting bacteria – statistically significant yield responses were observed for 3/7, 3/4, 4/17 and 13/15 cereal experiments, respectively. Dr Kate Storer was quoted “We need to better understand, however, management requirements of these products under UK field conditions to improve consistency of performance, both under experimental and commercial conditions.”

A range of biostimulant products were chosen to trial in discussion with East of Scotland Growers and Kettle Produce, and shortlisted to ten programmes.

A range of biostimulant products were used for targeted trials in Broccoli that were identified through discussion with East of Scotland Growers and Kettle produce were initially tested in the 2020 season (**Table 1**). All treatment programmes were demonstrated to be safe for use in Broccoli, with no adverse effects. However, there were no significant increases in root or plant biomass of any of the treatments compared with the untreated control. There was also no significant difference in nutrient levels between treatments and the untreated control, except for a significant increase in Zn in plots with one of the treatment programs (Aiva Fertilisers programme of AF Turret plus AF Nurture, then two applications of AF Turret plus AF Phosphorous). Despite the lack of significant differences between treatments and the control, there were non-significant reductions in head rot and increases in biomass (of up to 5%) which suggested that some positive benefits of biostimulant use were seen. For instance, three products (Nutri-Tech Solutions Triacontinol, Aiva Fertilisers products, AF Turret plus AF Nurture and Pharm Fertilisers SupaStandPhos) gave early increases in biomass, potentially as a result of increased early availability in P to drive early growth.

Table 1. Summary of products trials in the 2020 season.

Product	Active ingredient (s)	Company
Bridgeway	Amino acid complex – 18 L-isomer amino acids and peptides, Nitrogen (5%), biological organic carbon (17.5%)	Interagro
Bio 20	Kelp (18.5%) and nutrients – Nitrogen (13.2%), Phosphorous (13.2%), Potassium (13.2%) plus trace elements (Fe, Mn, Cu, Zn, B, Co and Mo)	Omex
TTL Plus	Fulvic and humic acids	Nutrimate
Zenith	Bioeffector – phyto active carbon compounds	Pharm Fertilisers
SupaStandPhos	Plant hormones derived from seaweed plus starter fertiliser – Nitrogen (5%), Phosphorous (18.2%), Potassium (3%) plus trace elements (Fe, Mn, Cu, Zn, Co and Mo)	Pharm Fertilisers
Fortifos 600	Phosphorous acid (600 g/L) as mono and dipotassium phosphonate	Pharm Fertilisers
AF Turret	Starter fertiliser – Nitrogen (8.9%) Phosphorous 13.6%), plus Mg, S, Mn and Zn	Aiva Fertilisers
AF Nurture	Fulvic and humic acids plus Potassium (1.1%), Mg, S, Ca and trace elements (So, Cu, Fe, Mn and Zn)	Aiva Fertilisers
AF Phosphorous	Foliar nutrients inc phosphorous. Nitrogen (7%), Phosphorous (13.8%), and Mg, S and Zn	Aiva Fertilisers
AF Bioflex	Seaweed (*Ascophllum nodosum),* Fulvic and humic acid, Nitrogen (0.95%), Phosphorous (0.14%), Potassium (2.28%), plus Mg, S, So, Cl, Ca and antioxidants	Aiva Fertilisers
Naturamin	Amino acids (80%) and Nitrogen (12.8%)	Novokem
Tri-Kelp	Soluble Organic Seaweed Powder (*Laminaria, Sargassum, Ascophllum nodosum*) – Alginic acid (18%) Nitrogen (0.89%) Potassium (15%) plus trace elements including silicon	Nutri-Tech Solutions
Nutri- Stim Triacontinol	Triacontinol 2.5% - naturally occurring plant growth promoter	Nutri-Tech Solutions

Given the potential benefits of some of the product tests, it was considered beneficial to repeat trials using a subset of products into a second season, supplemented with an additional range of products to broaden the available evidence base for biostimulant use in field brassica production.

Materials and methods

The trial took place within a broccoli crop of a commercially grown variety, cv. Parthenon, planted on 2 June 2021. The plots were situated at Newington Farm, near Moonzie.

The trial design comprised a fully randomised block design with 10 treatments plus an untreated control, each replicated 5 times. Treatments are summarised in **Table 2** and **Table 3** below. Each replicate plot was a 10m length of 1.94m bed to give a minimum assessment area of 15m^2 per plot. Either side of the trial was a 1 bed width and 10m strip length discard area, giving a total trial area of 130m x 13.5m.

Altogether the trial was seven beds wide including guards either side of the trial. The central row was used for all assessments and excluded the 0.5 m at the end of each plot from the area to be assessed. One half of the plot was used for foliar assessments, while the remaining half was left for destructive assessments.

Table 2. Treatment programmes and timings of applications used in the trial.

	Timing 1 – 1 to 2 weeks after planting		Timing 2 – 3 weeks after T1 application		Timing 2- Head initiation (approx. 2-3 weeks after T2 app	
Trt. No.	Product	Rate (L/ha or kg/ha)	Product	Rate (L/ha or kg/ha)	Product	Rate (L/ha or kg/ha)
1	UTC	-				
2	Biofarmix 'H' Biofarmix 'M' Biofarmix 'A'	25.0 5.0 5.0	Biofarmix 'A'	15.0	Biofarmix 'A'	15.0
3	Kelpak	2.0	Bio 20	2.0	Calmax Ultra	2.0
4	Bioforge	1.0	Stimulante Plus	1.0	Hold	1.5
5	Hold	1.5	Hold	1.5	Hold	1.5
6	Vit Amino	2.0	Vit Amino	2.0	MDS 602	2.0
7	AF Turret + AF Nurture	0.05 0.032	AF Phosphorous + AF Nurture	5.0 2.0	AF Phosphorous + AF Nurture	5.0 2.0
8	NTS Trio NTS Triple 10	2.0 1.5	NTS Trio NTS Triple 10	2.0 1.5	NTS Trio NTS Triple 10	2.0 1.5
9	TTL+ AF Pulsar	1.0 6.0	TTL+ AF Pulsar	2.5 6.0	TTL+ AF Pulsar	2.5 6.0
10	Yieldon	2.0	Yieldon	2.0	Yieldon	2.0
11	Megafol	3.0	Megafol	3.0	Megafol	3.0

Table 3. The biostimulant product details and constituents from available label data. Coded product not included in the list due to confidentiality.

Product	**Active ingredient (s)**	**Company**
Biofarmix	H- Humic substances + organic substances + microorganisms M - Microbial consortium (more than 100 species) A - Amino acid complex + organic substances + microorganisms	BioFarmix
Kelpak	Organic biostimulant from kelp	Omex

Product	Active ingredient (s)	Company
Bio 20	Kelp (18.5%) and nutrients – Nitrogen (13.2%), Phosphorous (13.2%), Potassium (13.2%) plus trace elements (Fe, Mn, Cu, Zn, B, Co and Mo)	Omex
Calmax Ultra	Foliar feed with N (9.6%) and Ca (14.5%) with trace elements including Mg, Mn, Fe, B, Cu, Zn and Mo.	Omex
Bioforge	Foliar spray with N (2%) and K (3%) along with trace elements (Co and Mo).	Stoller
Stimulante Plus	Foliar spray containing auxins, cytokinins and gibberellins.	Stoller
Hold	Foliar spray containing Ca	Stoller
Vit Amino	Yeast fractions (Saccharomyces cerevisiae)	Microbial distribution
MDS 602	Aqua, Ascorbic Acid, Vitamin P, Acitic Acid, Glycerine, Orange Extract, Seaweed extract, Neem Extract, Garlic Extract,	Microbial distribution
AF Turret	Starter fertiliser – Nitrogen (8.9%) Phosphorous 13.6%), plus Mg, S, Mn and Zn	Aiva Fertilisers
AF Nurture	Fulvic and humic acids plus Potassium (1.1%), Mg, S, Ca and trace elements (So, Cu, Fe, Mn and Zn)	Aiva Fertilisers
AF Phosphorous	Foliar nutrients inc phosphorous. Nitrogen (7%), Phosphorous (13.8%), and Mg, S and Zn	Aiva Fertilisers
NTS Trio	Foliar fertiliser based on 13.73% N, 0.1%K and 15.3% Ca with Mg, B and Fe alongside fulvica acid and mannitol derived from kelp.	Nutri-Tech Solutions
NTS Triple 10	A liquid 10-10-10 fertiliser with trace elements and natural growth promoters.	Nutri-Tech Solutions
TTL Plus	Fulvic and humic acids	Nutrimate
AF Pulsar	Foliar nutrients including N (6%) and trace elements (S, Mg, Mn, Zn, Cu, B, Mo, Co and Na).	Aviva Fertilisers
Yieldon	Foliar nutrients including N (3%), K (3%) and trace elements (Mn, Mo, Zn)	Valagro
Megafol	Foliar nutrients including N (3%), K (8%) and various vitamins, amino acids and proteins, betaines and growth factors	Valagro

The broccoli was netted to protect the crop from bird damage, with the net being removed for each application and replaced afterwards. The net was fully removed at the end of July.

Treatments were applied using an Azo precision knapsack sprayer with a 1.5 metre boom and 02F110 nozzles at medium quality and 200 litres per hectare water volume. All treatments were applied post-planting at the following timings:

- Timing 1: 18th June 2021 - post-emergence, once plants established (3-4 leaves)
- Timing 2: 8th July 2021 - 6-8 leaves
- Timing 3: 23rd July 2021 – 10 mm leading head

The crop growth stage was recorded at each spray application visit.

Table 4. Application details of the three sprays.

	Application 1	Application 2	Application 3
Application date	18/06/2021	08/07/2021	23/07/2021
Time of day	0950-1210	0545-0800	1050-1255
Crop growth stage (Max, min average BBCH)	13-15	35	41
Crop height (cm)	9	40cm	60 cm
Crop coverage (%)	35	70	90
Application Method	*Spray*	*Spray*	*Spray*
Application Placement	*Foliar*	*Foliar*	*Foliar*
Application equipment	*Azo small plot - 40A & 40B*	*Azo small plot - 40A & 40B*	*Azo small plot - 40A & 40B*
Nozzle pressure	*3*	*3*	*3*
Nozzle type	*Flat fan Hypro*	*Flat fan Hypro*	*Flat fan Hypro*
Nozzle size	*025F110*	*025F110*	*025F110*
Application water volume/ha	*400*	*400*	*400*
Temperature of air - shade (°C)	*17.8*	13.5	17.6
Relative humidity (%)	*53*	86	83
Wind speed range (kph)	*4 - 8 (SE)*	0	0
Dew presence (Y/N)	*N*	Y	N
Temperature of soil - 2-5 cm (°C)	*16.3*	12.6	14.8
Wetness of soil - 2-5 cm	*Dry*	Moist	V. dry
Cloud cover (%)	60	70	100

The trials were harvested on the 10th and 11th August and used to determine crop responses. Samples were taken from the middle row and the top five metres of the plot avoiding the 0.5 m at the plot edges. The top half of the plot was used for destructive assessments and the bottom half was used for visual assessments. Five samples were taken from each plot, giving a total of 25 samples per treatment. The plants were dug up and shaken carefully to remove as much soil as possible and to prevent the fine roots from tearing, and a fresh weight was taken of all five plants in the plot as a single sample. Head weight from each plant were

recorded separately, but a combined sample was recorded for the roots and foliage of all five plants in a plot. The roots were then cut off to be weighed and the weight of the top of the plant was then extrapolated from total fresh weight minus the weight of roots. Clubroot severity was recorded as a percentage of club root severity and number of plants expressing symptoms. Data were analysed using ANOVA and Duncan's post- hoc by the ADAS statistician Chris Dyer.

Results

Season Summary

Soil conditions were moist at planting, with a dry period immediately after planting and showers at the end of June and July. Dry soil conditions were experienced in early June, however, so early fertiliser applications are unlikely to have been fully utilised. Rainfall was consistent throughout July, although overlaid with a significant heat wave at the end of the month where the crop was reported to show stress. Overall, this provided periods of good growing weather against occasionally sub-optimum conditions although good growth was seen overall without any significant periods of stress as a result of the frequent showers. The host growers reported that some differences were seen between treatments when the crop was showing signs of stress in the July heatwave, although no clear differences were seen at the point of harvest and assessment in August. There was no significant impact of any of the treatments of plant health, and no recordable phytotoxicity was recorded for any of the treatments.

Biomass assessments

At harvest, the crop was healthy and produced commercially viable yields. Crop height and vigour varied as changes in underlying soil type changes over the planted area (especially as topography changed across the planted area), particularly with plants in the lower portion of the trial area appearing larger at harvest. The host grower reported that differences were evident between treatments when the crop was displaying significant stress symptoms in the July heatwave, but strong growth in the latter part of the season had levelled out growth giving relatively standard conditions between plots and treatments.

Summary figures for the biomass samples are given in **Table 5** and **Figure 2**. For foliage, there was no significant difference between treatments or between blocks, suggesting that leaf development was consistent between blocks and treatments. For roots there was a significant difference only between blocks (p >0.001) and not between treatments, again showing relatively consistency between treatments. However, there were two treatments that gave a larger (if insignificant) increases in root mass – YieldOn (+19.1%) and NTS Trio/NTS

Triple 10 (+21.3%) compared with the untreated control. There was also no significant difference in the incidence or severity of club root between treatments.

For head weight, there were no significant differences between treatments, although there was a significant difference between blocks (p<0.001) demonstrating that there was significant variability between blocks independent of treatments (**Figure 1**). The majority of treatments gave comparable head weights to the untreated control with the exception of "Hold" (Treatment 5) which achieved a large (but not significant) reduction in head weight of 367.4g vs. 414.7g in the untreated control, although this may have been due to the lack of an appreciable N content compared with the other treatments.

There was no significant development of club root incidence across trial areas. Average severity of symptoms was 3.2% in the untreated control, compared with 4.8% (Vit Amino) and 4.4% (AF Turret + AF Nurture). The lowest incidence of club root severity was seen with Kelpak (0%), Yieldon (0.2%) and Megafol (0.4%).

Table 5. Summary figures for the destructive sampling at harvest. Values are presented per plant.

Treatment		Average Fresh Weight per Plant (kg)				Club Root Total No.
		Foliage	Root	Head	Total	
1	Untreated control	1.55 ± 0.06	0.24 ± 0.02	0.41 ± 0.03	2.21 ± 0.08	1.00 ± 0.20
2	Biofarmix 'H', 'M', 'A' program	1.44 ± 0.07	0.27 ± 0.01	0.39 ± 0.03	2.11 ± 0.08	0.80 ± 0.09
3*	Kelpak fb. Bio20 fb. Calmax Ultra	1.6 ± 0.05	0.26 ± 0.02	0.42 ± 0.03	2.28 ± 0.08	0.00 ± 0.00
4	Bioforge fb. Stimulante Plus fb. Hold	1.59 ± 0.07	0.27 ± 0.02	0.43 ± 0.04	2.28 ± 0.11	0.20 ± 0.09
5	Hold applied 3 times	1.48 ± 0.07	0.24 ± 0.01	0.37 ± 0.02	2.08 ± 0.08	0.20 ± 0.09
6	Vit Amino applied twice then MDS 602	1.48 ± 0.08	0.25 ± 0.02	0.40 ± 0.04	2.12 ± 0.13	1.20 ± 0.26
7	AF Turret + AF Nurture fb. AF Phosphorous + AF Nurture x 2	1.51 ± 0.04	0.25 ± 0.01	0.40 ± 0.03	2.16 ± 0.06	0.80 ± 0.22
8	NTS Trio + NTS Triple 10 Applied 3 times	1.69 ± 0.11	0.3 ± 0.03	0.43 ± 0.02	2.41 ± 0.14	0.40 ± 0.18
9	TTL+ AF Pulsar applied 3 times	1.45 ± 0.06	0.25 ± 0.02	0.40 ± 0.03	2.10 ± 0.09	0.40 ± 0.18
10	Yieldon applied 3 times	1.51 ± 0.10	0.29 ± 0.01	0.40 ± 0.04	2.21 ± 0.13	0.20 ± 0.09
11	Megafol applied 3 times	1.48 ± 0.06	0.23 ± 0.01	0.40 ± 0.03	2.10 ± 0.08	0.20 ± 0.09

fb. = followed by

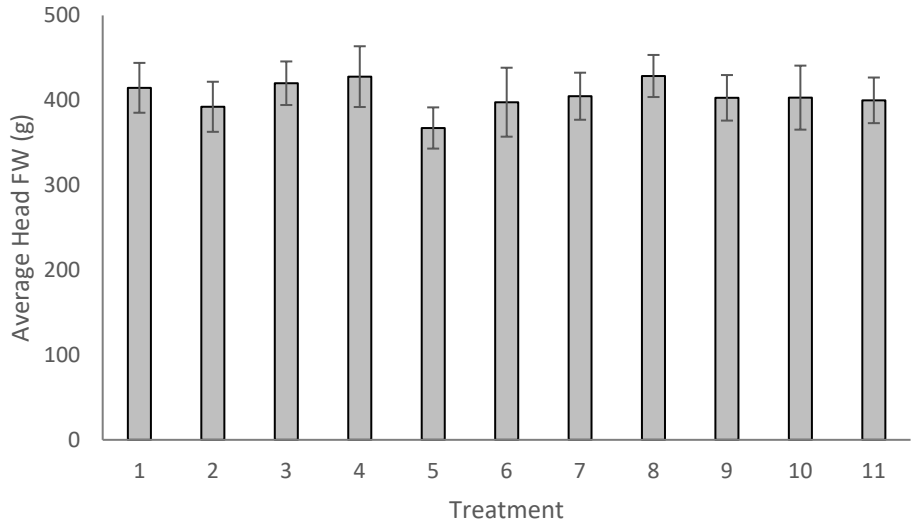

Figure 3. Average head weight at harvest. For treatment numbers see Table 5.

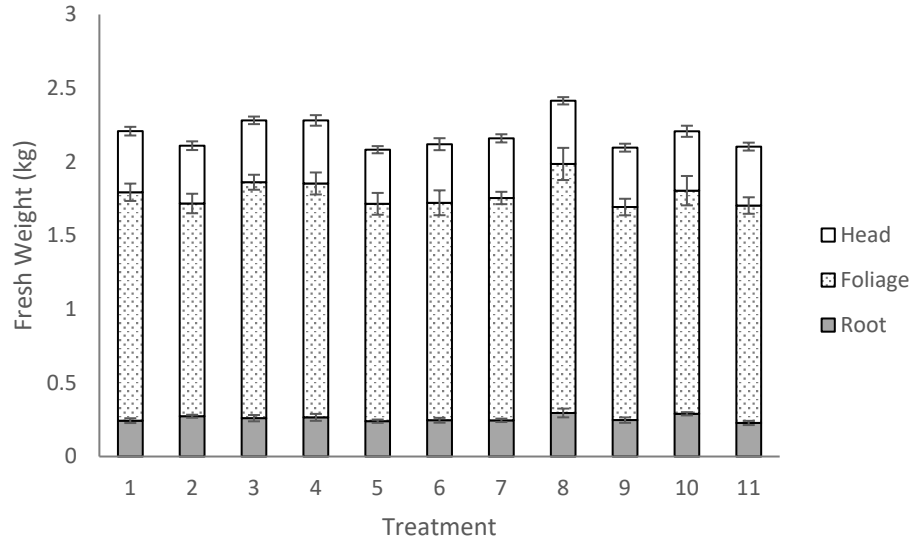

Figure 4. Biomass distribution at harvest. Average head weight at harvest. For treatment numbers see Table 5.

Discussion

All treatment programmes in the experiment were safe to use over broccoli with no adverse effects observed on the crop. There were also no significant differences in crop condition or overall quality at the point of harvest, with only a single incident of a blown head. Similarly, there were no significant developments of club root across the trial – whilst club root incidence can be linked to a variety of environmental factors such as suitable pH balancing and presence of inoculum at planting – overall productivity was good over the trial period with the crop showing strong performance and a general lack of stress symptoms.

Whilst there was significant variation in whole biomass accumulation, there were some differences noted between treatments. Total biomass was marginally increased in the NTS Trio + NTS Triple treatment (8) compared with the untreated control, whilst total biomass was reduced in Hold, Vit Amino, AF Turret + AF Nurture and TTL + AF Pulsar. However, these changes were primarily due to differences in total foliage, with comparable head and root mass at harvest across all treatments and the untreated control.

Focusing specifically on the head, all treatments achieved a head weight relatively comparable with the control, with the exception of Hold (367g vs. 416g in the untreated control). Only three treatments marginally exceeded that of the control: Kelpak (420g), Bioforge program (428g) and NTS Trio + NTS Triple 10 (428g) although none of these differences were significant.

From an overall perspective, there were no significant differences between treatments in either yield or total biomass accumulation. Similarly to the results obtained in 2020, there is a strong potential that the lack of any significant response is due to the relatively healthy, stress free conditions which the crop was cultivated under. A common theme in biostimulant use is that the most notable effects are achieved under conditions where the crop is stressed – most typically under circumstances where either root development or water/nutrient uptake are hindered – leading to suboptimal growth. For example, abiotic stress resistance and promotion of root growth reported by fulvic acid use (Nardi *et al*., 1996; Anjum *et al.,* 2011) is most likely to give identifiable effects in crops grown under drought conditions.

Whilst a brief period of drought was experienced by the crop this year, the long periods of good weather with frequent rainfall are likely to have ensured sufficient growth and an unstressed crop, mitigating any benefits derived from biostimulant products. It is noteworthy that the host growers provided anecdotal evidence of differences between treatments during the heat wave period, indicating that some differences may have been present in the crop during early growth. However, improved growth in the latter stage of production allowed the crop to outpace early stress limits to give suitable yields at harvest.

There were no significant differences between the treated plots and the untreated control regarding any of the other parameters measured – whole plant, foliar or root biomass, head diameter or head rot incidence. The crop upon which the experiment was carried out was very healthy, and unstressed apart from the initial pigeon damage and biostimulants may not have had as great an influence as they would on a stressed crop.

It is noteworthy that the greatest difference in biomass fractions were linked with foliar development – this may indicate that biostimulant provision in these treatments (Kelpak, Bioforge program and NTS Trio + NTS Triple 10) provided extra biomass partitioned to the leaf rather than the head portion. This may be due to the provision of additional N provided by the treatments: for example, there is a high N content of the NTS products, reflected in the greatest foliar biomass of the trial (109% of the control). However, extra nitrogen provision did not directly correlate with increased leaf biomass – the AF Phosphorous and AF Pulsar products both have significant N content but did not lead to increased foliar biomass. Conversely, the Bioforge and Kelpak products do not have significant N content but also achieved increased foliar biomass relative to the control treatments.

It is also noteworthy that there was greatest variation between blocks than between treatments, most notably between exposed plots of the top of a ridge compared with those in more sheltered parts of the field. Overall, these results indicate that none of the treatments tested in the 2021 season gave any significant benefit compared with the untreated control.

Overall, whilst there were no significant benefits demonstrated from the use of the biostimulant products tested in this trial, the good conditions seen throughout the cultivation period may not have provided the conditions under which these products demonstrate their best effects.

Conclusions

- All treatment programmes in the experiment were safe to use over broccoli with no adverse effects observed on the crop.
- There was no significant increase in root biomass or plant biomass from any of the treatments when compared to the untreated control.
- The lack of any significant response may be due to the ideal conditions under which the crops were grown, and whilst benefits may have been clearer under stressed conditions it is not possible to demonstrate any clear benefits from these results.

Knowledge and Technology Transfer

2020

East of Scotland Grower Group day – spoke to small groups of growers in organised slots who came to view the trials – 23 and 24 September 2020

Video of overview of trials at Scottish Strategic Centre for Brassicas – https://www.youtube.com/watch?v=7kj8vNOogg8

Presentation to the Brassica Grower Association – 14 October 2020

2021

Video of overview of trials at Scottish Strategic Centre for Brassicas – 2021

https://www.youtube.com/watch?v=RjXpSooqsTY&t=205s

Presentation to the Brassica Grower Association – 17 November 2021

References

Storer, K. *et al* (2016). A review of the function, efficacy and value of biostimulant products available for UK cereals and oilseeds. AHDB Research Review No. 89

Tiffin, D. (2005). Interpretation of leaf nutrient analysis results – Brassicas (cabbage, Brussels sprouts, cauliflower, broccoli, turnip and swede). AHDB Factsheet 21/05

Nardi, S., G. Concheri, and G. Dell'Agnola, 1996: Biological activity of humic substances. In: A. Piccolo, ed. Humic Substances in Terrestrial Ecosystems, pp. 361–406. Elsevier, Amsterdam

Anjum, S. A., Wang, L., Farooq, M., Xue, L., & Ali, S. (2011). Fulvic acid application improves the maize performance under well-watered and drought conditions. Journal of Agronomy and Crop Science, 197(6), 409-417.

Acknowledgements

AHDB for funding the work, and also the biostimulant companies for their financial contributions as well as providing samples for the trials. Thanks should also be given to East of Scotland Growers (ESG) for hosting the trial and Kettle Produce for their input. Particular thanks should be given to James Rome and Duncan MacLachlan of ESG for their technical input and in-kind support with trial management and assessments.

Appendices

Appendix 1: Summary Metrological Data

	RAINFALL (mm)				T5 SUM (^{0}C)				SOLAR RADIATION (MJ/m^2)				EFFECTIVE DAY DEGREES		
	AVERAGE	ACTUAL	% of Av.		AVERAGE	ACTUAL	% of Av.		AVERAGE	ACTUAL	% of Av.		AVERAGE	ACTUAL	% of Av.
JAN	82.1	80.2	97.7%		19.1	0.7	3.7%		57.3	61.5	107.4%		55.4	23.6	42.6%
FEB	63.5	123.1	193.9%		20.2	35.2	174.2%		109.3	95.3	87.2%		61.4	56.5	92.0%
MAR	61.4	28.6	46.6%		39.1	68.1	174.4%		218.9	221.7	101.3%		110.3	132.5	120.2%
APR	49.6	6.0	12.1%		76.4	34.7	45.4%		336.8	395.6	117.5%		159.7	124.9	78.2%
MAY	59.3	121.2	204.4%		157.2	118.4	75.3%		456.8	387.8	84.9%		224.0	196.6	87.8%
JUN	60.8	18.2	29.9%		233.9	257.3	110.0%		460.3	451.5	98.1%		263.1	271.0	103.0%
JUL	64.5	40.4	62.7%		300.9	358.2	119.1%		454.0	446.7	98.4%		295.2	319.3	108.2%
AUG	73.8	48.8	66.2%		288.7	311.7	108.0%		365.0	365.3	100.1%		269.6	279.6	103.7%
SEP	60.2	39.0	64.8%		218.2	280.1	128.4%		251.6	242.0	96.2%		203.9	216.6	106.2%
OCT	85.9	116.6	135.8%		133.0	174.1	130.9%		144.2	129.9	90.1%		132.2	127.7	96.6%
NOV	76.3	35.0	45.9%		53.1	78.9	148.6%		72.3	86.4	119.6%		66.6	84.9	127.6%
DEC	76.9	0.0	0.0%		27.2	0.0	0.0%		42.9	0.0	0.0%		37.3	0.0	0.0%

Appendix 2: Summary Raw Data from Harvest

	Treatment	Block				
		1	2	3	4	5
Total Head Weight per 5 heads harvested (g)	1	2055.8	1557.1	1400.4	2081.1	1872.9
	2	1793.8	1891.5	1344	1470.5	2086.1
	3	1802.1	1889.4	1860.6	2338.3	1416.9
	4	1519.6	1789.8	1411.4	2168	2376.8
	5	1421.1	2273.9	1878.4	1570.5	1431.1
	6	1362.3	1413.7	1827	1527.4	2479.4
	7	1961.1	1768.8	1632.4	1935.4	1475.4
	8	1598.6	1867.7	3098.4	1481	1882.5
	9	1426.7	1223.4	2077.6	1801.4	1937
	10	1863.7	1611.4	1544.4	1363.4	2638.5
	11	1752.4	1357.1	1505.8	1728.2	2173.4
Total Root Weight per 5 roots harvested (g)	1	202.7	161	285	365	203.7
	2	215.7	220.3	315.4	312.7	302.7
	3	181.8	192.1	346	404	177.1
	4	134.6	202.2	287	449.5	255.5
	5	178.2	212.1	253	328.2	226.9
	6	152.8	166.9	275.7	338.7	296.1
	7	182.1	218.3	242.8	338.2	246.9
	8	161.6	182.9	519.1	369.4	244.8
	9	158.9	158.9	362	316.2	239.5
	10	253.4	216.8	302.4	353.8	323.6
	11	175	132.5	258.8	304.2	268.1
Total Foliage Weight of 5 plants harvested (g)	1	1853.1	1396.1	1115.4	1716.1	1669.2
	2	1578.1	1671.2	1028.6	1157.8	1783.4
	3	1620.3	1697.3	1514.6	1934.3	1239.8
	4	1385	1587.6	1124.4	1718.5	2121.3
	5	1242.9	2061.8	1625.4	1242.3	1204.2
	6	1209.5	1246.8	1551.3	1188.7	2183.3
	7	1779	1550.5	1389.6	1597.2	1228.5
	8	1437	1684.8	2579.3	1111.6	1637.7
	9	1267.8	1064.5	1715.6	1485.2	1697.5
	10	1610.3	1394.6	1242	1009.6	2314.9
	11	1577.4	1224.6	1247	1424	1905.3

	Treatment	Block				
		1	2	3	4	5
Clubroot Development (%)	**1**	1	10	0	0	5
	2	0.5	0	5	2	1
	3	0	0	0	0	0
	4	0	0	0	5	0
	5	0	5	0	0	0
	6	7	15	0	2	0
	7	0	15	7	0	0
	8	5	0	0	0	0
	9	0	0	0	8	0
	10	1	0	0	0	0
	11	0	0	2	0	0
Number of plants with clubroot	**1**	1	2	0	0	2
	2	1	0	1	1	1
	3	0	0	0	0	0
	4	0	0	0	1	0
	5	0	1	0	0	0
	6	2	3	0	1	0
	7	0	2	2	0	0
	8	2	0	0	0	0
	9	0	0	0	2	0
	10	1	0	0	0	0
	11	0	0	1	0	0

