Project title:	AHDB Field Vegetable Centres – Brassicas, Scotland – Swede bio-stimulants screen
Project number:	FV 462
Project leader:	Angela Huckle, ADAS Horticulture
Report:	Final report, February 2021
Previous report:	Annual report, December 2020
Key staff:	Angela Huckle, ADAS Horticulture (report editor and field assessor) Ewan Gage, ADAS Horticulture (report author) Chris Dyer, ADAS Statistician Jeff Layton, Kettle Produce Euan Alexander, Kettle Produce Duncan Carr, Oxford Agricultural Trials James Rome, East of Scotland Growers
Location of project:	Kettlehill, Scotland
Industry Representative:	James Rome, East of Scotland Growers, Prestonhall Industrial Estate, Cupar, Fife
Date project commenced:	1 April 2020

DISCLAIMER

While the Agriculture and Horticulture Development Board seeks to ensure that the information contained within this document is accurate at the time of printing, no warranty is given in respect thereof and, to the maximum extent permitted by law the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

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

Horticultural Consultant

ADAS Horticulture

Signature .... Date ......12 January 2022.

Report authorised by:

Angela Huckle

Associate Director – Crop Health

ADAS Horticulture

Signature .... Date ...... 11 February 2022

CONTENTS

Headline....................1
Background....................1
Summary....................2
Methods....................2
Discussion and Conclusion....................4
Financial Benefits....................6
Introduction....................7
Materials and methods....................8
Results....................11
Season Summary....................11
Biomass assessments....................12
Discussion and Conclusions....................15
References....................16
Knowledge and Technology Transfer....................17
Acknowledgements....................17
Appendices....................18

GROWER SUMMARY

Headline

- All treatment programmes in the experiment were safe to use over swedes with no adverse effects observed on the crop.
- By the conclusion of the trial - one month after the third and final biostimulant application – there were no significant differences in biomass measurements between the biostimulant treatments and the untreated control.
- There was good weather throughout the 2021 season and so it is possible that the potential benefits of biostimulant use were overshadowed by strong growth across the treatments and the control.

Background

Field vegetable production is facing a significant number of pressures including reduced availability of actives for pest/disease control, increased need to optimise fertiliser applications and mitigate increased frequency of climate-related stress. One potential route to addressing these influences could be the use of biostimulants, a heterogenous range of products which are reported to improve yields through a synergistic interaction with crop biology. Product ranges in this area have expanded in recent years, with a range of formulations based on different constituents such as seaweed extracts, growth promoting bacteria, phosphites, humic/fulvic acids or analogues of growth hormones – potentially in combination with a range of plant macro or micronutrients. These are widely reported to enhance plant resistance to abiotic and biotic stress, particularly mitigation for drought. 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. The objective of this trial is to compare a number of commercially available biostimulants and evaluate effects on crop growth and biomass of both roots (including the swede) and shoots, as well as any effects on crop health, where possible.

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

This trial was located in a commercial field of swedes near Kettlehill in Scotland within a crop of the commercially grown variety of swede, Magres, drilled on 29 April. The trial design comprised a fully randomised block design with 10 treatments (Table 4 and 5), including one untreated control and was replicated five times. An area of 11 metres wide gave a total trial area of 11 m x 120 m (1320 m^2). Plots were 10 m of a 2.0 m-wide bed, comprising five rows of swede. Altogether the trial was seven beds wide including guards either side of the trial. A 1 m^2 area across the width of the bed 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 – once seedlings established 3-4 leaves 18/6/21		**Timing 2 – approx. 3 weeks after T1 application 15/7/21**		**Timing 3 – approx. 3 weeks after T2 application 12/8/21**	
Trt no	**Product**	**Rate (L/ha or kg/ha)**	**Product**	**Rate (L/ha or kg/ha)**	**Product**	**Rate (L/ha or kg/ha)**
1	Untreated control	-	Untreated control	-	Untreated control	-
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	Bio 20	2.0
4	Bioforge	1.0	Stimulante Plus	1.0	Hold	1.5
5	Vit Amino	2.0	Vit Amino	2.0	MDS 602	2.0
6	AF Turret + AF Nurture	0.05 0.032	AF Phosphorous + AF Nurture	5.0 2.0	AF Phosphorous + AF Nurture	5.0 2.0
7	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
8	TTL+ AF Pulsar	1.0 6.0	TTL+ AF Pulsar	2.5 6.0	TTL+ AF Pulsar	2.5 6.0
9	Yieldon	2.0	Yieldon	2.0	Yieldon	2.0
10	Megafol	3.0	Megafol	3.0	Megafol	3.0

Table 2. 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
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
Kelpak	Organic biostimulant from kelp	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
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 Pulsar	Foliar nutrients including N (6%) and trace elements (S, Mg, Mn, Zn, Cu, B, Mo, Co and Na).	Aiva Fertilisers
Hold	Foliar spray containing Ca	Stoller
TTL	Fulvic and humic acids	Nutrimate
MDS 602	Aqua, Ascorbic Acid, Vitamin P, Acetic Acid, Glycerine, Orange Extract, Seaweed extract, Neem Extract, Garlic Extract,	Microbial distribution
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

Product	Active ingredient (s)	Company
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

The swedes were netted for insect exclusion, and the treatments were sprayed through the net as per commercial practice. Treatments were applied using a precision knapsack sprayer with a 2.0 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 –post-emergence, once seedlings are established (4-5 leaves)
- Timing 2: 15th July - 30 cm height foliage – early root formation – 4 cm
- Timing 3: 12th August – 40 cm height foliage – roots expanding – 10-15 cm

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

A single destructive assessment was carried out at harvest to assess yield outputs over two days on 28th and 29th September. All roots were lifted, the plants were dug up and shaken carefully to remove as much soil as possible and to prevent the fine roots from tearing, and all plants in each plot were harvested for assessment. Total and marketable root number and weight was recorded, alongside numbers in specific categories of unmarketability (undersized, cabbage fly rot fly damage, club root presence or rots).

Discussion and Conclusion

All treatment programmes in the experiment were safe to use over swedes with no adverse effects observed on the crop. At harvest, there were no significant differences in total or marketable yields between treatments and the untreated control (Figure *1*, Table *1*). Two treatments (AF Turret + AF Nurture and NTS Trio + NTS Triple 10) showed marginally lower yields compared with the control, whilst three treatments (Kelpak, TTL + AF Pulsar and Megafol) gave yields greater than that of the control – although none of these differences were significant. Similarly, when individual marketable root weight was considered, there were no significant differences between treatments. In terms of unmarketable yield, there were also no significant differences in the causes of unmarketable roots between treatments.

These findings are comparable to trial results from 2020 which found no significant difference in yield outputs compared with the untreated control. However, conditions in the 2021 season were similarly good compared with 2020 – July was warm but with frequent rainfall, so that it is unlikely that the crop was subject to any significant stresses. As a result, any differences due to the use of the biostimulant treatments may have been muted compared with the untreated control. However, it is possible that the use of these products under conditions of greater plant stress – especially drought – where the reported abilities of these products may further drive yield performance.

Table 1. Summary figures for assessments taken at harvest from 1 m^2 area.

Treatment		Total Plot Fresh Weight (kg)	Plot Marketable Fresh Weight (kg)	Total Root Number	Marketable Root Number
1	Untreated control	9.2 ± 0.55	8.6 ± 0.63	21.8 ± 0.75	15 ± 1.22
2	Biofarmix ‘H’, 'M', 'A' program	8.9 ± 0.61	8.2 ± 0.77	23.8 ± 1.11	15 ± 1.15
3	Kelpak fb. Bio20 fb. Calmax Ultra	9.9 ± 0.77	8.9 ± 0.98	23.6 ± 2.5	14.6 ± 2.33
4	Bioforge fb. Stimulante Plus fb. Hold	9.5 ± 0.88	9 ± 0.96	21 ± 0.91	15.4 ± 1.85
5	Vit Amino applied twice then MDS 602	9.1 ± 0.84	8.3 ± 0.79	21.4 ± 1.56	17.6 ± 2.22
6	AF Turret + AF Nurture fb. AF Phosphorous + AF Nurture x 2	8.5 ± 0.59	7.6 ± 0.76	21.8 ± 0.63	14.2 ± 0.95
7	NTS Trio + NTS Triple 10 Applied 3 times	8.7 ± 0.61	7.6 ± 0.72	22.2 ± 0.95	14.6 ± 1.39
8	TTL+ AF Pulsar applied 3 times	10.2 ± 0.9	9.5 ± 0.88	21.6 ± 2.82	16.6 ± 1.94
9	Yieldon applied 3 times	9.6 ± 0.37	9.2 ± 0.43	20.8 ± 1.38	15.6 ± 1.26
10	Megafol applied 3 times	10 ± 0.66	9.3 ± 0.57	20.4 ± 1.39	14.6 ± 1.61

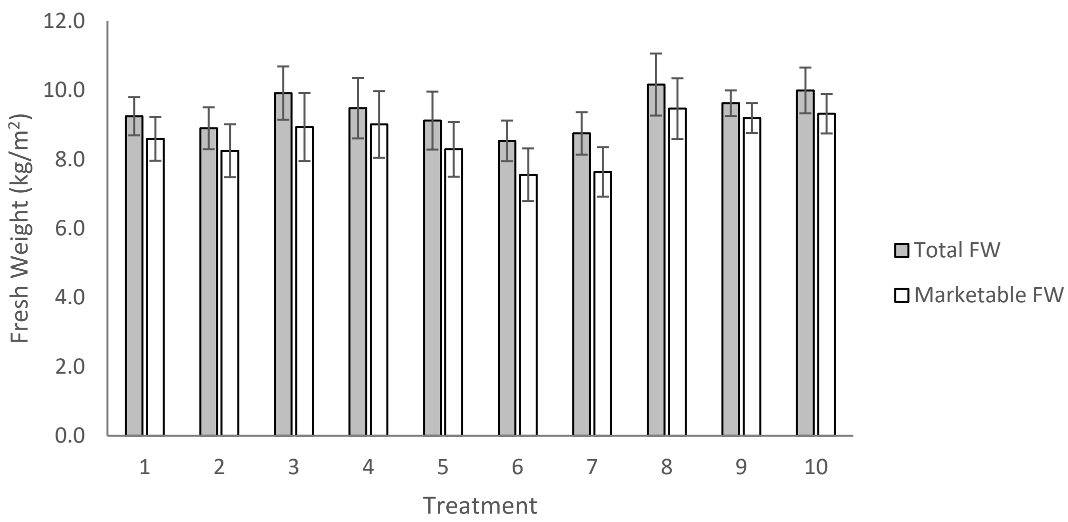

Figure 1. Total and marketable fresh weight yields per plot. For treatment codes see Table 2.

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.

SCIENCE SECTION

Introduction

Field vegetable production is facing a significant number of pressures including reduced availability of actives for pest/disease control, increased need to optimise fertiliser applications and mitigate increased frequency of climate-related stress. One potential route to addressing these influences could be the use of biostimulants, a heterogenous range of products which are reported to improve yields through a synergistic interaction with crop biology.

Product ranges in this area have expanded in recent years, with a range of formulations based on different constituents such as seaweed extracts, growth promoting bacteria, phosphites, humic/fulvic acids or analogues of growth hormones – potentially in combination with a range of plant macro or micronutrients. These are widely reported to enhance plant resistance to abiotic and biotic stress, particularly mitigation for drought. 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 diverse nature of these products, coupled with poorly understood modes of action and best practice for commercial horticulture have limited their uptake. Furthermore, the benefits of these products may be difficult to quantify, and vary between season, crop and location. However, for 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.

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 selected field vegetable products. The objective of this trial was to compare a number of commercially available biostimulants and evaluate effects on crop growth and marketable yield outputs as well as any effects on crop health, where possible to illustrate their benefits for the wider horticulture sector.

The objective of this trial is to compare a number of commercially available biostimulants and evaluate effects on crop growth and biomass of both roots (including the swede) and shoots, as well as any effects on crop health, where possible.

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. This built on trials implemented in the 2020 season which demonstrated that whilst no negative effects were seen from biostimulant use in swedes no significant improvements in yield were demonstrated. As biostimulant use may show strong season responses (especially between good and bad years) these trials were continued into a second season in order to further examine the potential benefits of biostimulant use for field vegetable production in the UK.

Materials and methods

This trial was located in a commercial crop of swedes near Kettlehill, Scotland within a crop of the commercially grown variety, Magres, drilled on 29 April. The trial design comprised a fully randomised block design with 10 treatments (Table 4 and 5), including one untreated control and was replicated five times. An area of 11 metres wide gave a total trial area of 11 m x 120 m (1320 m^2). Plots were 10 m of a 2.0 m-wide bed, comprising five rows of swede. Altogether the trial was seven beds wide including guards either side of the trial. A strip of 0.5 m across the full bed 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 4. Treatment programmes and timings of applications used in the trial

	Timing 1 – once seedlings established 3-4 leaves 18/6/21		Timing 2 – approx. 3 weeks after T1 application 15/7/21		Timing 3 – approx. 3 weeks after T2 application 12/8/21	
Trt no	**Product**	**Rate (L/ha or kg/ha)**	**Product**	**Rate (L/ha or kg/ha)**	**Product**	**Rate (L/ha or kg/ha)**
1	Untreated control	-	Untreated control	-	Untreated control	-
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	Bio 20	2.0
4	Bioforge	1.0	Stimulante Plus	1.0	Hold	1.5
5	Vit Amino	2.0	Vit Amino	2.0	MDS 602	2.0
6	AF Turret + AF Nurture	0.05 0.032	AF Phosphorous + AF Nurture	5.0 2.0	AF Phosphorous + AF Nurture	5.0 2.0
7	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
8	TTL+ AF Pulsar	1.0 6.0	TTL+ AF Pulsar	2.5 6.0	TTL+ AF Pulsar	2.5 6.0
9	Yieldon	2.0	Yieldon	2.0	Yieldon	2.0
10	Megafol	3.0	Megafol	3.0	Megafol	3.0

Table 5. 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
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
Kelpak	Organic biostimulant from kelp	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
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 Pulsar	Foliar nutrients including N (6%) and trace elements (S, Mg, Mn, Zn, Cu, B, Mo, Co and Na).	Aiva Fertilisers
Hold	Foliar spray containing Ca	Stoller
TTL	Fulvic and humic acids	Nutrimate
MDS 602	Aqua, Ascorbic Acid, Vitamin P, Acetic Acid, Glycerine, Orange Extract, Seaweed extract, Neem Extract, Garlic Extract,	Microbial distribution
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
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

The swedes were netted for insect exclusion, with the net being removed for each application and replaced afterwards. Initial crop establishment was good, although there was some damage from deer in the mature crop.

Treatments were applied using an Azo precision knapsack sprayer with a 2.0 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 –post-emergence, once seedlings are established (4-5 leaves)
- Timing 2: 15th July - 30 cm height foliage – early root formation – 4 cm

- Timing 3: 12th August – 40 cm height foliage – roots expanding – 10-15 cm

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

Table 6. Application details

	Application 1	Application 2	Application 3
Application date	18/06/2021	15/07/2021	12/08/2021
Time of day	1325-1520	0830-1110	1055-1245
Crop growth stage (Max, min)	4-5 leaves	4cm root	10-15cm root
Crop height (cm)	12	30cm	40 cm
Crop coverage (%)	45	90	95
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)	*17.5 - 21.8*	17.9 - 23.8	14.9-16.2
Relative humidity (%)	*51*	50	82
Wind speed range (kph)	*3 - 7 (SSE)*	0-5 (S'ly)	10-16 (S'ly)
Dew presence (Y/N)	*N*	N	N
Temperature of soil - 2-5 cm (°C)	*20.1*	20.7	13.5
Wetness of soil - 2-5 cm	*Dry*	Dry	Moist
Cloud cover (%)	80	5	100

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 showers at the end of June and July. Early June showed dry soil conditions, however, so early fertiliser applications are unlikely to have been fully utilised. Rainfall was consistent throughout July, although overlaid with a significant heat wave. 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. There were some minor croplevel effects across the trial area, especially with regards to club root symptom development which may indicate variation in soil infestation or conditions conducive to infection. A summary of the weather per month is included in the Appendix.

Biomass assessments

Whilst there were minor variations between plots, there were no significant differences in the parameters measured (Table 2). There were some non-significant differences in total root number between treatments (Figure 2) – Treatment 2 (Biofarmix - 23.8) and 3 (Kelpak - 23.6) had greater total numbers than the untreated control (21.8 per plot), although other treatments were relatively comparable to each other and the control. Marketable numbers were also relatively comparable, although Treatment 5 (Vit Amino - 17.6) had a greater number of swedes than the control (15) and the other treatments.

Similarly, there were some small, non-significant differences in yield by weight (Figure 2). Total fresh weight in three treatments showed minor increases compared with the control – Treatment 3 (Kelpak - 9.9kg/m^2), Treatment 8 (TTL + AF Pulsar - 10.2kg/ m^2) and Treatment 10 (Megafol - 10.0kg/ m^2) compared with 9.2kg/ m^2 in the control. The majority of treatments gave a marketable yield comparable with that of the untreated control, although two treatments (Treatment 6 – AF Turret + AF Nurture – and Treatment 7 – NTS Trio + NTS Triple, both 7.6kg/ m^2) gave notable (albeit insignificant) reductions compared with the untreated control (8.6kg/ m^2).

Table 2. Summary figures for assessments taken at harvest from an area of 1 m^2

Treatment		Total Plot Fresh Weight (kg)	Plot Marketable Fresh Weight (kg)	Total Root Number	Marketable Root Number
1	Untreated control	9.2 ± 0.55	8.6 ± 0.63	21.8 ± 0.75	15 ± 1.22
2	Biofarmix ‘H’, 'M', 'A' program	8.9 ± 0.61	8.2 ± 0.77	23.8 ± 1.11	15 ± 1.15
3	Kelpak fb. Bio20 fb. Calmax Ultra	9.9 ± 0.77	8.9 ± 0.98	23.6 ± 2.5	14.6 ± 2.33
4	Bioforge fb. Stimulante Plus fb. Hold	9.5 ± 0.88	9 ± 0.96	21 ± 0.91	15.4 ± 1.85
5	Vit Amino applied twice then MDS 602	9.1 ± 0.84	8.3 ± 0.79	21.4 ± 1.56	17.6 ± 2.22
6	AF Turret + AF Nurture fb. AF Phosphorous + AF Nurture x 2	8.5 ± 0.59	7.6 ± 0.76	21.8 ± 0.63	14.2 ± 0.95
7	NTS Trio + NTS Triple 10 Applied 3 times	8.7 ± 0.61	7.6 ± 0.72	22.2 ± 0.95	14.6 ± 1.39
8	TTL+ AF Pulsar applied 3 times	10.2 ± 0.9	9.5 ± 0.88	21.6 ± 2.82	16.6 ± 1.94
9	Yieldon applied 3 times	9.6 ± 0.37	9.2 ± 0.43	20.8 ± 1.38	15.6 ± 1.26
10	Megafol applied 3 times	10 ± 0.66	9.3 ± 0.57	20.4 ± 1.39	14.6 ± 1.61

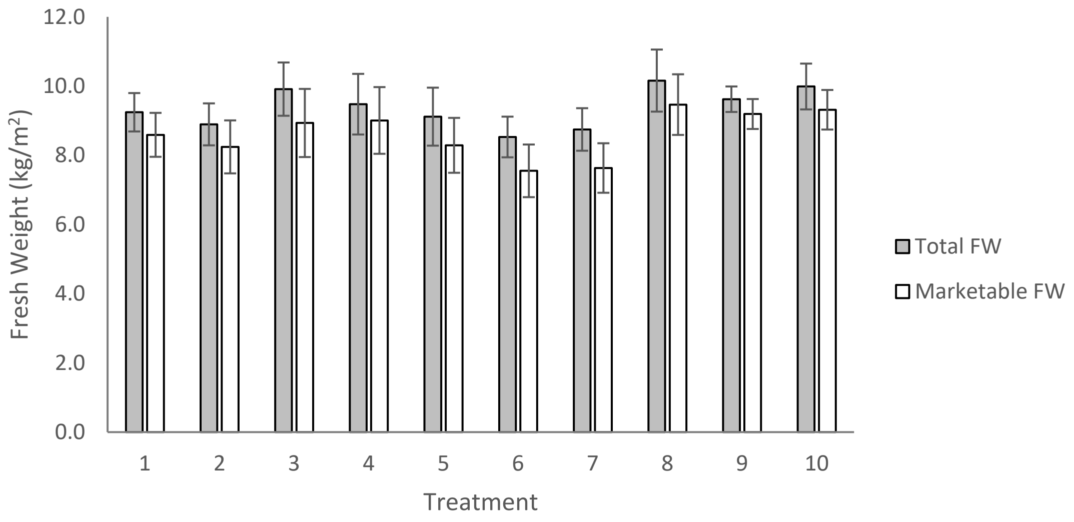

Figure 2. Total and marketable fresh weight yields per plot. For treatment codes see Table 2.

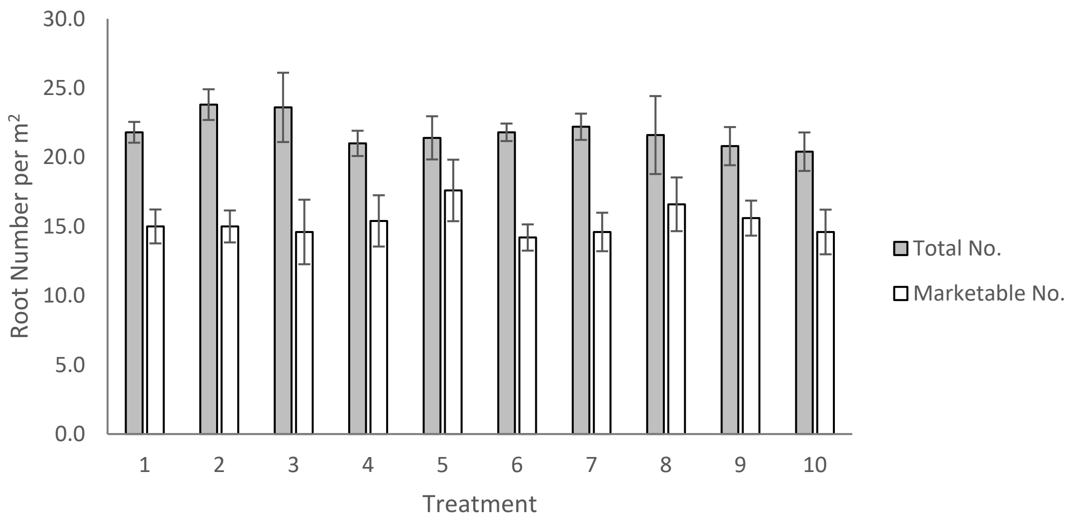

Figure 3. Total and marketable root number per m^2. For treatment codes see Table 2.

Within the marketable root fraction there was no significant difference in average root weight between treatments (Figure *4*). There were marginal differences in average root weight, with Treatment 10 (Megafol) giving the greatest average root weight (647g compared with 575g in the control). The smallest average root weight was achieved in Treatment 5 (Vit Amino - 493g). However, these differences were not significant.

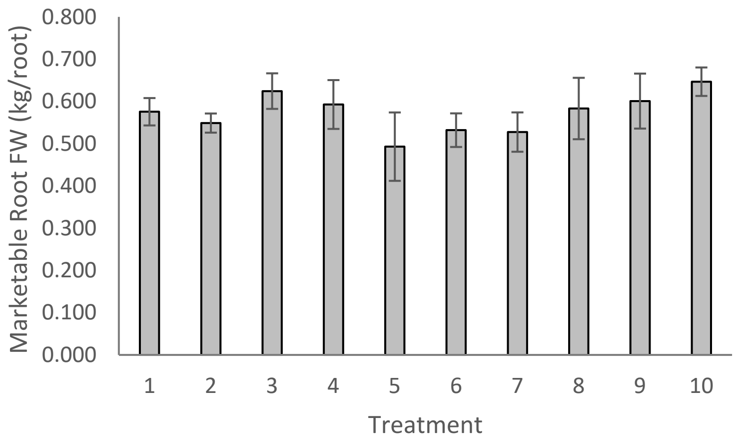

Figure 4. Average individual root weight of marketable roots at harvest. For treatment codes see Table 2.

Whilst there were no significant differences in the proportion of marketable roots between treatments, there were some minor differences demonstrated (Table 3). The greatest percentage of marketable roots was taken from Treatment 5 (Vit Amino) at 82% compared with 68.7% in the untreated control. The smallest percentage of marketable roots was taken from Treatment 3 (Kelpak). The proportion of unmarketable roots was largely due to differences in the number of undersized roots between treatment as the incidence of clubroot, cabbage root fly damage or root rots were negligible across all treatments.

Table 3. Summary figures for unmarketable root fractions.

Treatment		Total Count of Unmarketable Roots per m^2				Percentage Marketable (%)
		Clubroot	Cabbage Root Fly	Rots	Undersized	
1	Untreated control	0 ± 0	0.2 ± 0.26	0 ± 0	6.6 ± 1.05	68.7 ± 4.31
2	Biofarmix ‘H’, 'M', 'A' program	0.4 ± 0.52	0 ± 0	0.4 ± 0.52	8 ± 1.73	63.7 ± 6.87
3	Kelpak fb. Bio20 fb. Calmax Ultra	0.8 ± 0.75	0 ± 0	0.2 ± 0.26	8 ± 1.68	61.5 ± 6.29
4	Bioforge fb. Stimulante Plus fb. Hold	0.4 ± 0.52	0.4 ± 0.52	0 ± 0	4.8 ± 0.63	73 ± 3.84
5	Vit Amino applied twice then MDS 602	0 ± 0	0 ± 0	0.4 ± 0.52	3.4 ± 1.66	82 ± 7.26
6	AF Turret + AF Nurture fb. AF Phosphorous + AF Nurture x 2	0 ± 0	0 ± 0	1 ± 1	6.6 ± 1.66	65.4 ± 7.07
7	NTS Trio + NTS Triple 10 Applied 3 times	0.2 ± 0.26	0.6 ± 0.77	0.2 ± 0.26	6.6 ± 1.33	66 ± 5.33
8	TTL+ AF Pulsar applied 3 times	0 ± 0	0 ± 0	0.2 ± 0.26	4.8 ± 1.25	77.3 ± 3.81
9	Yieldon applied 3 times	0.6 ± 0.52	0 ± 0	0 ± 0	4.6 ± 1.05	75.4 ± 4.44
10	Megafol applied 3 times	0.4 ± 0.52	0 ± 0	0.2 ± 0.26	5.2 ± 1.32	71.9 ± 6.11

Discussion and Conclusions

All treatment programmes followed were safe to be use in swedes, with no adverse effects observed on crop. From a whole plot perspective, there were only minor differences in total and marketable yield from harvest. The majority of treatments were relatively comparable with the untreated control, although two treatments (AF Turret + AF Nurture and NTS Trio + NTS Triple 10) showed a small under performance compared with the control. Similarly, whilst there were minor changes in total and marketable root number, results were relatively comparable between treatments. On an individual root basis, performance was relatively comparable between treatments except Kelpak and Megafol showed increased performance compared with the untreated control, whilst Vit Amino showed roots smaller than average. Similarly, there were no significant differences in the causes of unmarketable roots recovered.

Overall, there appear to be no significant differences between any of the products tested and the untreated control, either in terms of marketability or yield outputs. This corresponds with observations from the 2020 season, and are most likely as a result of the near-optimum conditions under which the crop is grown. Many of the reported benefits of biostimulant products are their ability to reinforce crop performance under conditions of stress. For example, fulvic acid use is reported to drive root growth to enhance the ability of crops to mitigate stress damage (Nardi *et al*., 1996; Anjum *et al.,* 2011), although this effect is only likely to be notable under conditions of significant stress. For crops that are not suffering significant drought stress, more even growth is likely to negate any benefits produced from the biostimulant use.

It is likely that the suitable weather conditions – especially the warm weather with frequent showers in the latter half of the growth when hypocotyl inception and enlargement will have been taking place – are likely to have ensured even and sufficient growth between treatments in the absence of any significant crop stress.

The relatively comparable responses between treatments and the control correspond with observations from the 2020 season, although larger differences were reported in 2020 compared with those seen in 2021. In the 2020 season there was some correlation between increased biomass and the use of products containing higher proportions of N. Interestingly, this effect has not been seen this year – indeed, the products high in N (AF Turret and NTS Trio + NTS Triple 10) gave equal total fresh weight, and lower marketable FW, compared with the other treatments. Furthermore, there may not be a directly correlation between nutrient (especially N) availability and increase in yields – for example, studies in New Zealand have demonstrated that yield increases are not seen above a certain thresholds, with biomass increases seen in the leaves as the crop increases investment in the foliar partition rather than root biomass (Chakwizira *et al*., 2011). As a result, enhancing the nutritional status of the crop beyond optimum thresholds may not translate to increased yields – even if there is an increase in total biomass accumulation.

It is also noteworthy that there was no correlation between harvested root mass and products containing fulvic/humic acids or potential plant hormone analogues (e.g. TTL Plus, Kelpak), corresponding with observations from 2020. As noted above, these actives are reported to stimulate root growth although this has not transitioned to an increase in harvested biomass. However, these products are reported to increase the number and rate of extension of lateral roots (e.g. Abdel-Baky *et al*., 2019) and increasing total root surface area. This would not necessarily correspond to increased growth of the hypocotyl (which constitutes the harvestable portion), which may explain the lack of any significant response to these activities.

Overall, the results from this season do not demonstrate any significant benefits from the use of biostimulant products for swede production. However, this is most likely as a result of the generally good growing conditions this season, and clearer benefits may have been demonstrated under greater conditions of plant stress, especially from droughts. Given that that summer rainfall patterns are becoming increasing unpredictable there may be greater benefits for biostimulant use to help ensure yields can be consistently achieved.

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

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.

Chakwizira, E., Fletcher, A. L., Meenken, E. D., Johnstone, P. R., Maley, S., Arnold, N., ... & Stafford, A. (2011). Dry matter response of swede crops to nitrogen and phosphorus application in Southland and central North Island regions of New Zealand. In Proceedings of the Agronomy Society of New Zealand (Vol. 41, pp. 23-37).

Abdel-Baky, Y. R., Abouziena, H. F., Amin, A. A., El-Sh, M. R., & Abd El-Sttar, A. M. (2019). Improve quality and productivity of some faba bean cultivars with foliar application of fulvic acid. *Bulletin of the National Research Centre*, *43*(1), 1-11.

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

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 Kettle Produce for hosting the trial and for their input. Particular thanks should be given to Jeff Layton for his 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%

Appedix 2: Summary Figures

	Treatment	Block				
		1	**2**	**3**	**4**	**5**
Total Harvested Weight per Plot (kg/m^2)	**1**	10.1	7.9	10.3	8.8	9.1
	2	9.2	9.2	10.4	7.7	8.0
	3	11.8	8.9	8.7	9.4	10.8
	4	9.9	7.7	11.2	10.4	8.1
	5	9.8	7.4	10.2	10.5	7.7
	6	7.9	9.1	8.1	7.5	10.0
	7	9.4	7.2	10.0	8.8	8.4
	8	11.3	11.3	8.1	8.8	11.2
	9	9.2	10.3	8.8	10.1	9.8
	10	11.0	9.4	11.4	8.8	9.4
Total Marketable Weight per Plot (kg/m^2)	**1**	9.4	7.9	10.3	8.8	9.1
	2	9.2	9.2	10.4	7.7	8.0
	3	11.8	8.9	8.7	9.4	10.8
	4	9.9	7.7	11.2	10.4	8.1
	5	9.8	7.4	10.2	10.5	7.7
	6	7.9	9.1	8.1	7.5	10.0
	7	9.4	7.2	10.0	8.8	8.4
	8	11.3	11.3	8.1	8.8	11.2
	9	9.2	10.3	8.8	10.1	9.8
	10	11.0	9.4	11.4	8.8	9.4
Total Root Number per m^2	**1**	21	21	24	21	22
	2	26	25	21	24	23
	3	31	21	21	24	21
	4	21	19	23	22	20
	5	22	24	23	17	21
	6	21	23	21	23	21
	7	22	21	22	21	25
	8	29	21	23	19	16
	9	22	21	24	18	19
	10	23	17	21	19	22
Marketable Root Number per m^2	**1**	14	12	17	15	17
	2	14	16	18	13	14
	3	21	10	14	13	15
	4	12	13	20	17	15
	5	18	24	16	14	16
	6	13	13	14	14	17
	7	12	13	14	18	16
	8	22	17	16	15	13
	9	19	13	16	15	15
	10	18	14	17	12	12

	Treatment	Block				
		1	2	3	4	5
Number of Undersized Roots per m²	1	7.0	9.0	7.0	6.0	4.0
	2	8.0	9.0	3.0	11.0	9.0
	3	10.0	9.0	4.0	11.0	6.0
	4	5.0	6.0	3.0	5.0	5.0
	5	4.0	0.0	7.0	1.0	5.0
	6	8.0	9.0	3.0	9.0	4.0
	7	6.0	7.0	8.0	3.0	9.0
	8	7.0	4.0	7.0	4.0	2.0
	9	3.0	7.0	6.0	3.0	4.0
	10	5.0	3.0	3.0	7.0	8.0
Number of Roots with Clubroot Symptoms per m²	1	0.0	0.0	0.0	0.0	0.0
	2	2.0	0.0	0.0	0.0	0.0
	3	0.0	1.0	3.0	0.0	0.0
	4	2.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	0.0
	7	0.0	1.0	0.0	0.0	0.0
	8	0.0	0.0	0.0	0.0	0.0
	9	0.0	1.0	2.0	0.0	0.0
	10	0.0	0.0	0.0	0.0	2.0
Number of Roots with Cabbage Root Fly Damage per m²	1	0.0	0.0	0.0	0.0	1.0
	2	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0
	4	2.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	0.0
	7	3.0	0.0	0.0	0.0	0.0
	8	0.0	0.0	0.0	0.0	0.0
	9	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.0	0.0	0.0	0.0
Number of Roots with Rots per m²	1	0.0	0.0	0.0	0.0	0.0
	2	2.0	0.0	0.0	0.0	0.0
	3	0.0	1.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	2.0	0.0
	6	0.0	1.0	4.0	0.0	0.0
	7	1.0	0.0	0.0	0.0	0.0
	8	0.0	0.0	0.0	0.0	1.0
	9	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.0	1.0	0.0	0.0

