Project title:	AHDB Field Vegetable Centres – Brassicas, Scotland – Broccoli bio-stimulants screen
Project number:	FV 462
Project leader:	Angela Huckle, ADAS Horticulture
Report:	December 2020
Previous report:	None
Key staff:	Angela Huckle, ADAS Horticulture (report editor) Diana Pooley, ADAS Horticulture (report author) Pete Seymour, 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:	Balmullo, Scotland
Industry Representative:	James Rome, East of Scotland Growers, Prestonhall Industrial Estate, Cupar, Fife
Date project commenced:	1 April 2020

DISCLAIMER

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.

Diana Pooley

Senior Research Technician

ADAS Horticulture

Signature ......Diana Pooley......... Date 12th January 2021

Peter Seymour

Horticulture Consultant

ADAS Horticulture

Signature ... P Seymour .. Date 12th January 2021

Report authorised by:

Angela Huckle

Associate Director – Crop Health

ADAS Horticulture

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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 increases in root biomass or plant biomass from any of the treatments when compared to the untreated control.
- There were no significant differences in nutrient levels between treatments and the untreated control with the exception of Zinc.
    - There was a significant increase in Zinc of 3.8 mg/kg in plots treated with the Aiva Fertilisers programme of AF Turret plus AF Nurture, then two applications of AF Turret plus AF Phosphorous.
- Plots treated with this programme also had a trend for the lowest headrot at the final assessment, and one of the highest biomass measurements at the first destructive assessment, but these were not significant effects.

Background

The objective of this trial is 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.

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.

The biostimulants market was reviewed for cereals and oilseeds growers by Dr Kate Storer of ADAS (AHDB funded 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.

Summary

Methods

The trial took place within a broccoli crop of a commercially grown variety, cv. Parthenon, planted on 4 June 2020. The plots were situated at the East Scotland Growers trial ground located at Balmullo, 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 – though only four replicates were assessed for the final destructive assessment due to time constraints. 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 1.8 m-wide bed, comprising three rows of broccoli. 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 – once crop established 3-4 leaves 2 July		Timing 2 – approx. 3 weeks after T1 application 6 leaves 21 July		Timing 3 – approx. 3 weeks after T2 application, and at 10 mm leading head 12 August	
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	Bridgeway	2.0	Bridgeway	2.0	Bridgeway	2.0
3*	Omex Bio 20	2.0	Omex Bio 20	2.0	Omex Bio 20	2.0
4	TTL plus	1.0	TTL plus	2.5	TTL plus	2.5
5	Zenith	0.15	Zenith	0.15	Zenith	0.15
6	SupaStandPhos	7.0	Fortifos 600	1.5	Fortifos 600	1.5
7	Coded 1	-	Coded 1	-	Coded 1	-
8	AF Turret + AF Nurture	0.05 0.032	AF Phosphorous + AF Nurture	5.0 2.0	AF Phosphorous + AF Nurture	5.0 2.0
9	AF Bioflex + Naturamin	2.0 0.5	AF Bioflex + Naturamin	2.0 0.5	AF Bioflex + Naturamin	2.0 0.5
10	NTS Tri-Kelp	0.4	NTS Tri-Kelp	0.4	NTS Tri-Kelp	0.4
11	NTS Triacontionol	0.032	NTS Triacontionol	0.032	NTS Triacontionol	0.032

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
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

Product	Active ingredient (s)	Company
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

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. However, the initial placement of the nets was delayed by a week and the young broccoli plants subsequently suffered damage from pigeons in the first week after planting. The crop recovered, but the initial biostimulant application was delayed for three weeks to allow enough foliage to be present to absorb the foliar biostimulant sprays.

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: 2 July 2020 – post-emergence, once plants established (3-4 leaves)
- Timing 2: 21 July 2020- 6-8 leaves
- Timing 3: 12 August 2020 – 10 mm leading head

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

Hummingbird Technologies used a drone or unmanned aerial vehicle (UAV) to scan the crop to capture data for normalised difference vegetation index (NDVI). The crops were flown and data collected on two occasions; first, once the crop was at around six to eight leaves and approximately two weeks after the first biostimulant application (20 July), with the second flight at heading, and one week after the final biostimulant application (19 August).

At the final harvest assessment, leaf samples were taken from each plot for nutrient analysis. The newest fully expanded leaf was sampled in each case from at least five plants per plot, and then placed in labelled bags in chilled containers for transport before analysis by NRM for the foliar plant package - Total % Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Manganese (Mn), Copper (Cu), Zinc (Zn), Iron (Fe), and Boron (B).

Two destructive assessments took place to measure the weights of the plant roots and shoots or foliage. 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 July 16th and 17th, two weeks after the first biostimulant application and then on August 20th, eight days after the final biostimulant application. Five samples were taken per plot at each sampling for measurement. This gave 25 samples per treatment in the first sampling, and 20 per treatment in the second sampling as only four replicates were included for the latter sampling due to time restraints. 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 clubroot was monitored for but none seen. At the final assessment, broccoli head size was also measured, 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, with the causal pathogen not determined in the lab.

Discussion

All treatment programmes in the experiment were safe to use over broccoli with no adverse effects observed on the crop. A significant increase in foliar Zinc of 3.8 mg/kg compared to the untreated was observed in the broccoli leaves in plots where the Aiva Fertilisers programme of AF Turret plus AF Nurture, then two applications of AF Turret plus AF Phosphorous were applied. This programme contained the highest concentration of Zinc when compared to the other treatments with AF Phosphorous containing 1.5% Zinc, and this was applied at 5.0 L/ha. Zinc is involved in plant processes such as photosynthesis, and the development and function of growth regulators (auxins), and is a structural and functional element of enzymes.

There were no other significant effects on any of the other elements which were analysed – which were; Total % Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Manganese (Mn), Copper (Cu), Iron (Fe), and Boron (B). It should be highlighted that all samples fell well within acceptable ranges for each nutrient for broccoli with no deficiencies when compared to the table in AHDB factsheet 21/05 – Interpretation of leaf nutrient analysis results.

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 therefore biostimulants may not have had as great an influence as they would on a stressed crop (Figure 1).

Figure 1. Overview of the broccoli trial crop on 20 August exhibiting a vigorous uniform visual appearance. Balmullo, Scotland.

At each biomass assessment there were significant differences between blocks indicating that the differences between individual beds down which the treatments were arranged influenced differences in biomass greater than any effect from treatments. But, there were trends for selected products to increase biomass by greater than 5% in selected assessments, though it should be highlighted that due to the lack of significance these trends cannot be attributed to the effect of a particular biostimulant product or programme with confidence. Therefore it would be valuable to repeat the experiment in a further season to see if any consistent effects are detected. Such as the trend observed for an increase in early biomass by the three treatments which showed the overall highest mean total plant weight in the first assessment. These were Nutri-Tech Solutions Triacontinol, Aiva Fertilisers products, AF Turret plus AF Nurture and Pharm Fertilisers SupaStandPhos (Table 3). The latter two products are based around starter fertilisers which contain a higher percentage of phosphorous which is an element associated with improved rooting as well as a vital role in energy transfer (ATP) and photosynthesis which could have led to the greater investment in root and foliar growth at this early broccoli growth stage (BBCH 16 or 6 true leaves).

Table 3. Results of first destructive harvest on 16 and 17 August, two weeks after the first bio stimulant application. Table showing total mean root and 'shoot' (foliage) weight in grams. Figures highlighted in bold are 5% greater in weight than the untreated control (Treatment 1) in its respective category.

Trt no	Treatment name	First destructive harvest – 16 and 17 July		
		Mean root weight (g)	Mean foliage weight (g)	Mean whole plant weight (g)
1	*Untreated*	13.4	72.1	85.5
2	*Bridgeway*	12.3	67.8	80.1
3	*Omex Bio 20*	**14.3**	72.2	86.4
4	*TTL plus*	12.6	72.0	84.6
5	*Zenith*	13.3	**79.4**	**92.6**
6	*SupaStandPhos*	**14.8**	**82.4**	**97.2**
7	*Coded 1*	**14.6**	**77.8**	**92.4**
8	*AF Turret + AF Nurture*	**14.6**	**84.9**	**99.5**
9	*AF Bioflex + Naturamin*	13.4	75.5	88.9
10	*NTS Tri- Kelp*	12.9	72.4	85.3
11	*NTS Triacontinol*	13.3	**94.1**	**107.3**
	F pr value	0.760 (NS)	0.308 (NS)	0.339 (NS)
	d.f.	10	10	10
	L.S.D	2.987	19.51	20.95

Head rot occurred at harvest in the broccoli at low levels - 5.24% in the untreated control plots, and the incidence was assessed as an indicator for crop health. Head rot was assessed visually by East of Scotland Growers agronomists, and symptoms which appeared to be spear or head rot were recorded, however these were not subsequently confirmed with a lab analysis. There were no significant differences between any of the treatments and the untreated control in the incidence of broccoli head rot (F pr = 0.376, LSD = 3.44). But, despite the lack of significant differences when treatments are compared to the untreated, there was a significant difference between the treatments using Duncan's post-hoc test. The programme - AF Turret and AF Nurture then AF Turret and AF Phosphorous applied twice (Treatment 8) had consistently less incidence of head rot than the plots treated with Omex Bio20 (Treatment 3) with 1.94% head rot compared to 6.43% (Figure 2). But, it should be noted that data for this latter treatment was skewed by one plot with much higher incidence of head rot.

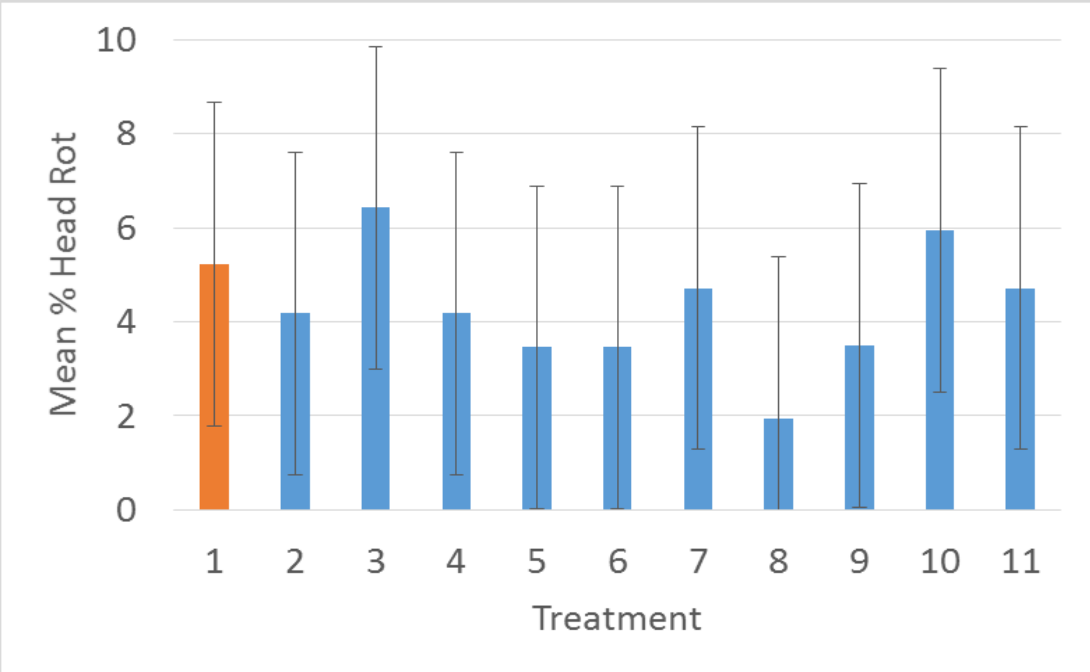

Figure 2. Mean percentage head rot per treatment (F pr = 0.376, LSD = 3.44), 25 August 2020. The orange bar indicates the untreated control.

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.
- There were no significant differences in nutrient levels between treatments and the untreated control with the exception of Zinc.
    - There was a significant increase in Zinc of 3.8 mg/kg in plots treated with the Aiva Fertilisers programme of AF Turret plus AF Nurture, then two applications of AF Turret plus AF Phosphorous.
- Plots treated with this programme also had the lowest headrot at the final assessment, and one of the greatest biomass increases at the first destructive assessment. Though these were not significant effects.

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, a reduction in incidence of headrot by even as little as 3% could equate to an extra 300 kg/ha of marketable heads of broccoli in a typical crop which usually yields 10,000 kg/ha (10 t/ha), and therefore a financial benefit of £240/ha.

SCIENCE SECTION

Introduction

The objective of this trial is 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.

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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.

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

Materials and methods

The trial took place within a broccoli crop of a commercially grown variety, cv. Parthenon, planted on 4 June 2020. The plots were situated at the East Scotland Growers trial ground located at Balmullo, Fife. The trial design comprised a fully randomised block design with 11 treatments (Table 4 and 5), including one untreated control and was replicated five times – though only four replicates were assessed for the final destructive assessment due to time constraints. 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 1.8m-wide bed, comprising three rows of broccoli. 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 4. Treatment programmes and timings of applications used in the trial

	Timing 1 – once crop established 3-4 leaves 2 July		Timing 2 – approx. 3 weeks after T1 application 6 leaves 21 July		Timing 3 – approx. 3 weeks after T2 application, and at 10mm leading head 12 August	
Trt no	**Product**	**Rate (L/ha or kg/ha)**	**Product**	**Rate (L/ha or kg/ha)**	**Product**	**Rate (L/ha or kg/ha)**
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3*	Omex Bio 20	2.0	Omex Bio 20	2.0	Omex Bio 20	2.0
4	TTL plus	1.0	TTL plus	2.5	TTL plus	2.5
5	Zenith	0.15	Zenith	0.15	Zenith	0.15
6	SupaStandPhos	7.0	Fortifos 600	1.5	Fortifos 600	1.5
7	Coded 1	-	Coded 1	-	Coded 1	-
8	AF Turret + AF Nurture	0.05 0.032	AF Phosphorous + AF Nurture	5.0 2.0	AF Phosphorous + AF Nurture	5.0 2.0
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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
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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 di potassium 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

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. However, the initial placement of the nets was delayed by a week and the young broccoli plants subsequently suffered damage from pigeons in the first week after planting. The crop recovered, but the initial biostimulant application was delayed for three weeks to allow enough foliage to be present to absorb the foliar biostimulant sprays.

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: 2 July 2020 – post-emergence, once plants established (3-4 leaves)
- Timing 2: 21 July 2020- 6-8 leaves
- Timing 3: 12 August 2020 – 10 mm leading head

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

Table 6. Application details of the three sprays

	Application 1	**Application 2**	**Application 3**
Application date	02/07/2020	21/07/2020	12/08/2020
Time of day	09:20 AM	08:50 AM	15:00 PM
Crop growth stage (Max, min average BBCH)	BBCH 14	BBCH 16-18	BBCH 41
Crop height (cm)	12	30	60
Crop coverage (%)	20	50	90
Application Method	Spray	Spray	Spray
Application Placement	Foliar	Foliar	Foliar
Application equipment	Azo small plot sprayer	Azo small plot sprayer	Azo small plot sprayer
Nozzle pressure	2.0	2.0	2.0
Nozzle type	Flat fan	Flat fan	Flat fan
Nozzle size	DG Teejet F11002	DG Teejet F11002	DG Teejet F11002
Application water volume/ha	200 L/ha	200 L/ha	200 L/ha
Temperature of air - shade (°C)	14.4	16.4	23.2
Relative humidity (%)	83	64	68
Wind speed range (kph)	0	7KPH	5KPH
Dew presence (Y/N)	N	N	N
Temperature of soil - 2-5 cm (°C)	13.7	12.8	14.4
Wetness of soil - 2-5 cm	Moist	Dry	Wet
Cloud cover (%)	100	10	0

Hummingbird Technologies used a drone or unmanned aerial vehicle (UAV) to scan the crop to capture data for normalised difference vegetation index (NDVI). The crops were flown and data collected on two occasions; first, once the crop was at around six to eight leaves and approximately two weeks after the first biostimulant application (20 July), with the second flight at heading, and one week after the final biostimulant application (19 August).

At the final harvest assessment, leaf samples were taken from each plot for nutrient analysis. The newest fully expanded leaf was sampled in each case from at least five plants per plot, and then placed in labelled bags in chilled containers for transport before analysis by NRM for the foliar plant package - Total % Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Manganese (Mn), Copper (Cu), Zinc (Zn), Iron (Fe), and Boron (B).

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Data were analysed using ANOVA and Duncan's post- hoc by the ADAS statistician Chris Dyer.

Crop Safety

Two weeks after each application timing the crops were checked for crop phytotoxicity or damage and scored using scheme in Table 7. Phytotoxicity was scored using the untreated as a comparison. When any phytotoxicity is suspected the type of symptom was recorded.

Table 7: Crop Phytotoxicity scoring.

Crop tolerance score	Equivalent to crop damage (% phytotoxicity)
0	*(no damage) 0%*
1	10%
*2	20%
3	30%
4	40%
5	50%
6	60%
7	70%
8	80%
9	90%
10	(complete crop kill) 100%

Results

No symptoms of phytotoxicity or crop damage was observed in the crop at the destructive assessments, and no negative impacts on crop vigour were recorded.

NDVI images

The digital image from the multispectral scan on 20 July is included below (Figure 3). The broccoli trial area is shown by the blue box, and it can be seen that there are no clear differences in NDVI between any of the plots as there are no changes in colour associated with treatments. The small red squares in each plot are where the destructive samples have been taken from each plot. The scan from 19 August is not shown as the reflectance had reached saturation due to canopy closure, and no differences could be determined.

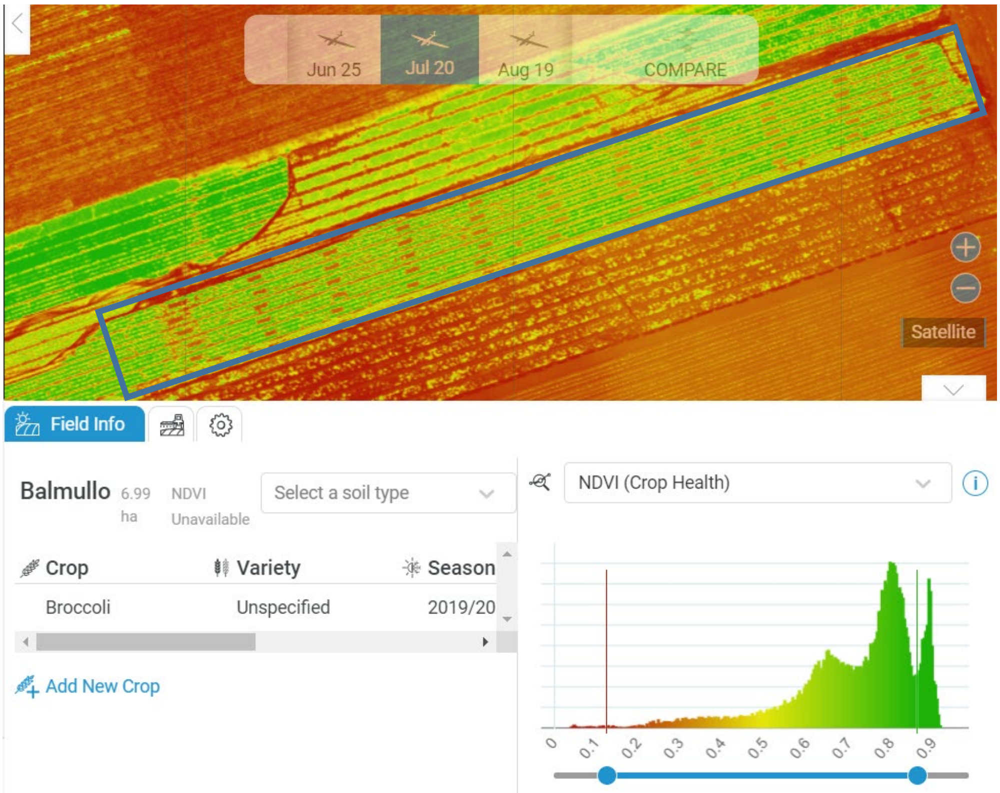

Figure 3. NDVI image of the trial area on 20 July with the broccoli trial area indicated by the blue box. NDVI image supplied by Hummingbird Technologies

Biomass assessments

First destructive harvest

There was a high degree of variability in values for the mean root and foliage (shoot) weights between both the different treatments, and also the five blocks within each treatment (Appendix, Tables A, B and C). Due to this variability no statistically significant differences could be determined between the treated plots compared to the untreated control. The treatments with a biomass at least 5% larger than the untreated plots are shown in bold in Table 8 to demonstrate the plots which indicated a trend for greater biomass, but it should be reminded that this is not significant and cannot be confidently attributed to consistent treatment effect rather than natural background trends in variability. The three treatments which showed the overall highest mean biomass in the first assessment were NTS Triacontinol, followed by the Aiva Fertilisers products, AF Turret plus AF Nurture then Pharn Fertilisers SupaStandPhos (Figure 4). The latter two products are based around starter fertilisers which contain a higher percentage of phosphorous which is an element associated with improved rooting as well as a vital role in energy transfer (ATP) and photosynthesis which could have led to the greater investment in root and foliar growth at this early broccoli growth stage (BBCH 16 or 6 true leaves).

Table 8. Results of first destructive harvest on 16 and 17 August, two weeks after the first biostimulant application. Table showing total mean root and 'shoot' (foliage) weight in grams. Figures highlighted in bold are 5% greater in weight than the untreated control (Treatment 1) in its respective category.

Trt no	Treatment name	First destructive harvest – 16 and 17 July		
		Mean root weight (g)	Mean foliage weight (g)	Mean whole plant weight (g)
1	*Untreated*	13.4	72.1	85.5
2	*Bridgeway*	12.3	67.8	80.1
3	*Omex Bio 20*	**14.3**	72.2	86.4
4	*TTL plus*	12.6	72.0	84.6
5	*Zenith*	13.3	**79.4**	**92.6**
6	*SupaStandPhos*	**14.8**	**82.4**	**97.2**
7	*Coded 1*	**14.6**	**77.8**	**92.4**
8	*AF Turret + AF Nurture*	**14.6**	**84.9**	**99.5**
9	*AF Bioflex + Naturamin*	13.4	75.5	88.9
10	*NTS Tri- Kelp*	12.9	72.4	85.3
11	*NTS Triacontinol*	13.3	**94.1**	**107.3**
	F pr value	0.760 (NS)	0.308 (NS)	0.339 (NS)
	d.f.	10	10	10
	L.S.D	2.987	19.51	20.95

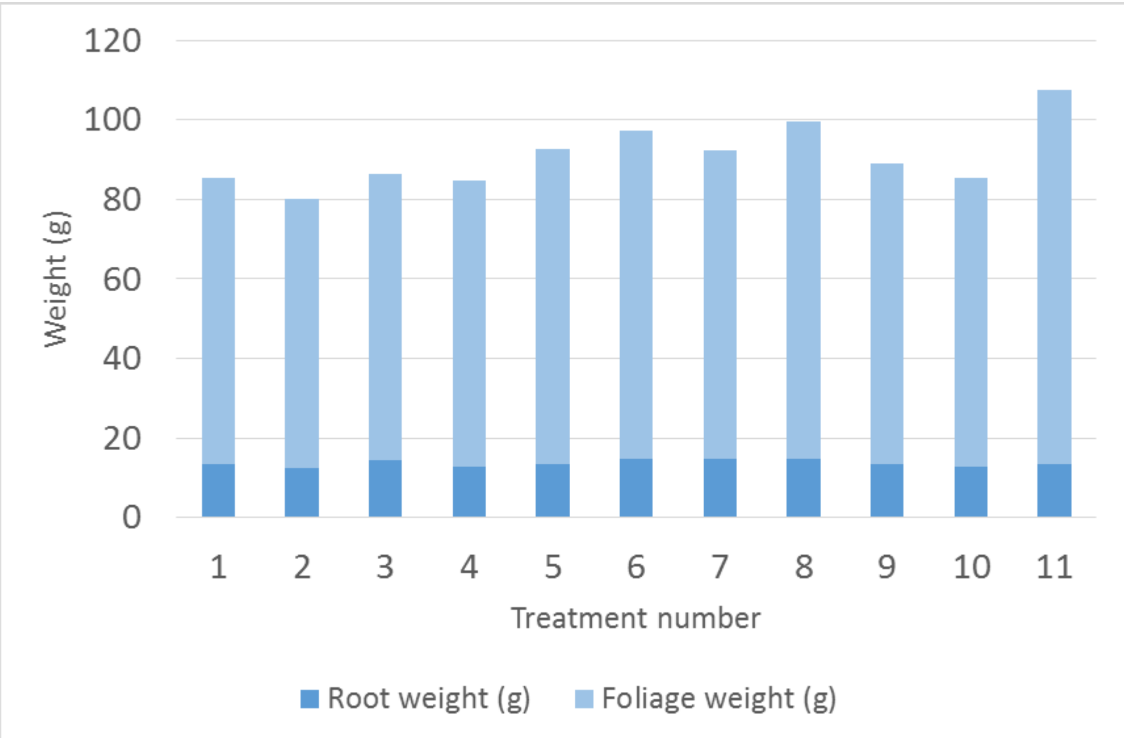

Figure 4. Results of first destructive harvest on 16 and 17 July, two weeks after the first biostimulant application showing total mean root and 'shoot' (foliage) weight by treatment number with root weight in dark blue and shoot weight in light blue. Balmullo, Scotland. F pr = 0.339 (NS), L.S.D = 20.95.

Second destructive harvest

There were no significant effects on biomass or head diameter of the broccoli produced by the biostimulant treatments at the second and final destructive harvest, when compared to the untreated control (Table 9). There are significant differences between blocks (root weight - F pr <0.001, LSD = 18.66 g; foliage weight - F pr = 0.014, LSD = 139.4 g), indicating a high degree of variation between the beds which has influenced differences in biomass greater than any effect from treatments (Appendix; Tables D, E and F). There was no consistent trend for those which increased biomass in the first destructive assessment, to continue to give the greatest weights in the final destructive assessment.

Although there was no significant effect of the treatments on the head diameter of the broccoli when compared to the untreated control, when Duncan's post-hoc test was applied there was a significant difference between the largest and smallest mean diameter head size as indicated by the letters in Table 9. Treatments with the same letters are not significantly different. Plots treated with the programme of AF Bioflex and AF Naturamin in a tank mix had the largest mean head diameter, while the plots treated with either Bridgeway or TTL Plus were the smallest.

Table 9. Results of second destructive harvest on 20 August, one week after the final biostimulant application. Table showing total mean root and foliage weights in grams, as well as mean diameter of the broccoli heads. Figures highlighted in bold are 5% greater in weight than the untreated control (Treatment 1) in its respective category.

Trt no	Treatment name	Full destructive assessment - 20 August				
		Mean root weight (g)	Mean foliage weight (g)	Mean whole plant weight (g)	Head diameter (mm)	
1	Untreated	96.5	1,573	1,669	109.9	ab
2	Bridgeway	**110.0**	1,594	1,704	95.9	a
3	Omex Bio 20	83.3	1,500	1,584	102.9	ab
4	TTL plus	77.0	1,432	1,509	95.7	a
5	Zenith	94.6	1,560	1,655	105.9	ab
6	SupaStandPhos then Fortifos	77.0	1,542	1,619	108.6	ab
7	Coded 1	86.9	1,601	1,688	114.9	ab
8	AF Turret + AF Nurture then AF Turret + AF Phosphorous	89.1	1,593	1,683	113.2	ab
9	AF Bioflex + Naturamin	87.3	**1,652**	1,739	117.2	b
10	NTS Tri- Kelp	87.1	**1,667**	**1,754**	113.5	ab
11	NTS Triacontinol	83.4	**1,637**	1,721	105.6	ab
	F pr value	0.653 (NS)	0.691 (NS)	0.683 (NS)	0.262 (NS)	
	d.f.	10	10	10	10	
	L.S.D	30.95	231.2	242.3	18.19	

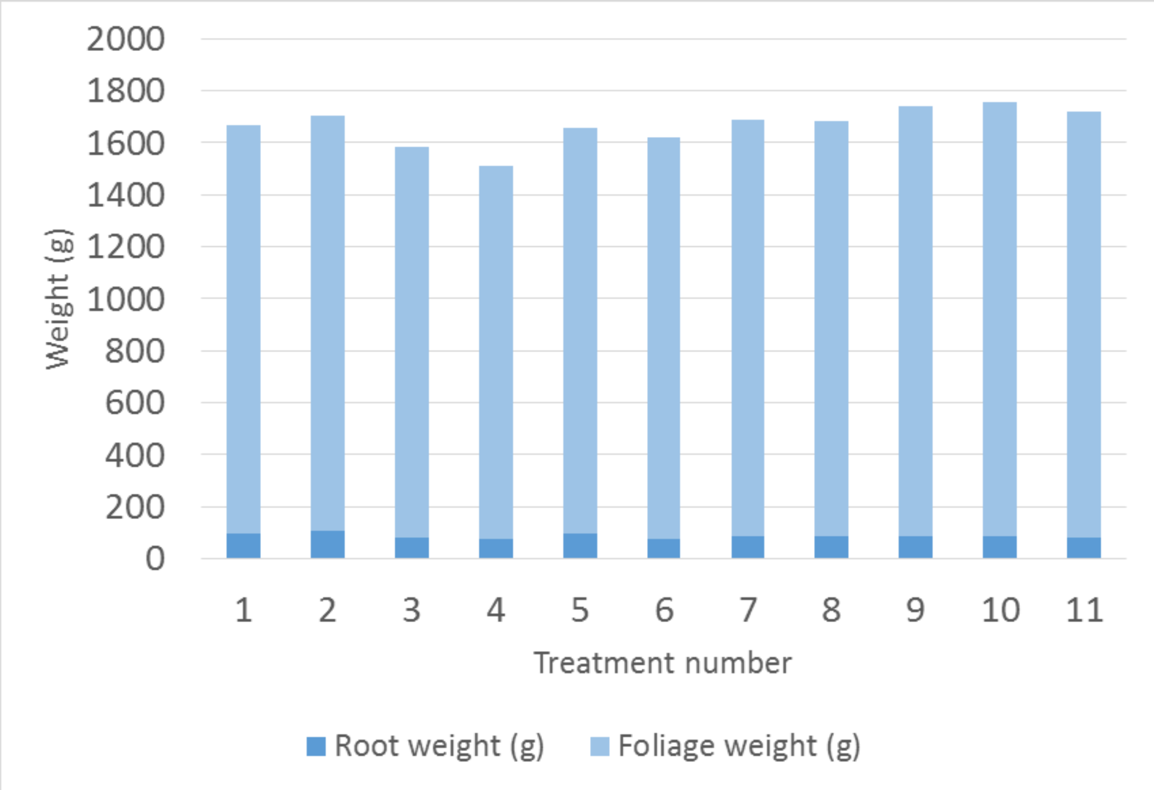

Figure 5. Results of final destructive harvest on 20 August, one week after the third and final biostimulant application showing total mean root and 'shoot' (foliage) weight by treatment number with root weight in dark blue and shoot weight in light blue. Balmullo, Scotland. F pr = 0.683 (NS), L.S.D = 242.3.

In addition to assessing plant biomass at each assessment timing, the change in weight between the two destructive assessments was calculated and analysed. This was to investigate differences in growth rate in mean total plant and root weights over the month between assessments (Figure 6 and 7). However, there was no significant difference between any of the weight increases in either root or plant weight when compared to the untreated plots (Table 10). As with the previous biomass measurements, the lack of significance is due to a high degree of variability in measurements between blocks, and any differences seen cannot be attributed confidently to treatment effects. Despite no significant differences when treatments are compared to the untreated, there was a significant difference between the treatments with the smallest increase in root weight (Supastand Phos then Fortifos) and the largest gain in root weight (Bridgeway) over the month, which is indicated in Table 9 by the Duncan's post-hoc test. Treatments with the same letters are not significantly different.

Table 10: Mean plant weight increase and root weight increase in grams between the July and August assessments.

Trt No	Treatment	Mean plant weight increase (g)	Duncan's range test	Mean root weight increase (g)	Duncan's range test
1	*Untreated*	1,584	a	82.6	ab
2	*Bridgeway*	1,621	a	97.3	b
3	*Omex Bio 20*	1,501	a	68.3	ab
4	*TTL plus*	1,424	a	63.8	ab
5	*Zenith*	1,567	a	81.5	ab
6	*SupaStandPhos then Fortifos*	1,520	a	62.4	a
7	*Coded 1*	1,595	a	71.9	ab
8	*AF Turret + AF Nurture then AF Turret + AF Phosphorous*	1,583	a	74.1	ab
9	*AF Bioflex + Naturamin*	1,645	a	73.7	ab
10	*NTS Tri- Kelp*	1,667	a	74.5	ab
11	*NTS Triacontinol*	1,619	a	70.5	ab
	F pr value	0.692 (NS)		0.521 (NS)	
	d.f.	30		30	
	L.S.D	238.0		29.35	

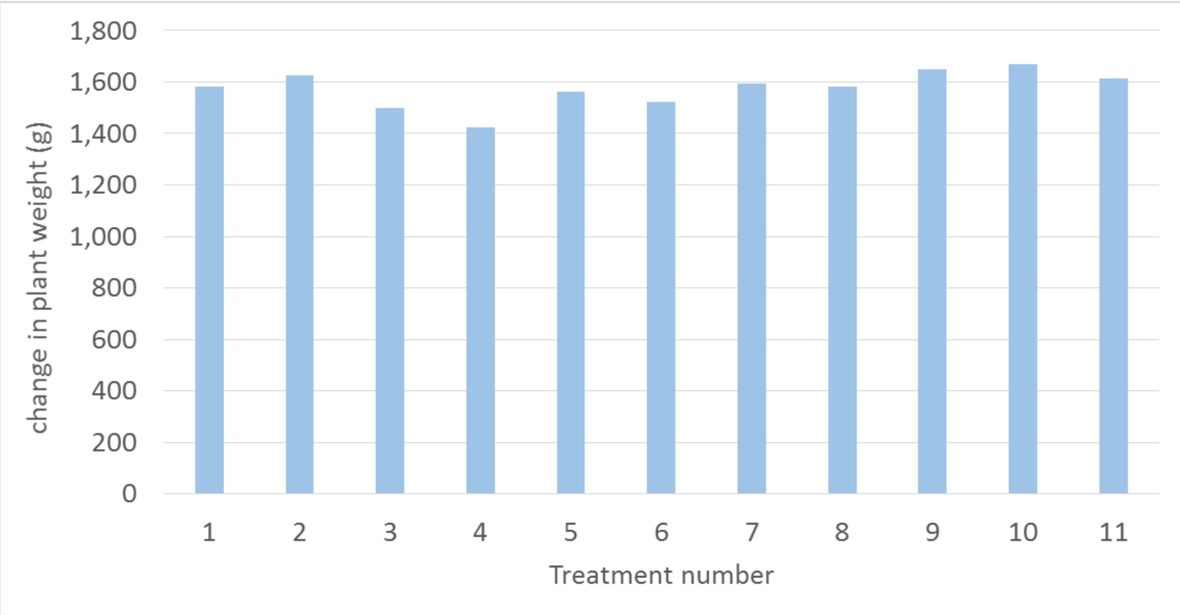

Figure 6. Mean change in total broccoli plant weight per treatment between the July and August destructive assessments. F pr = 0.692 (NS), L.S.D = 238.0.

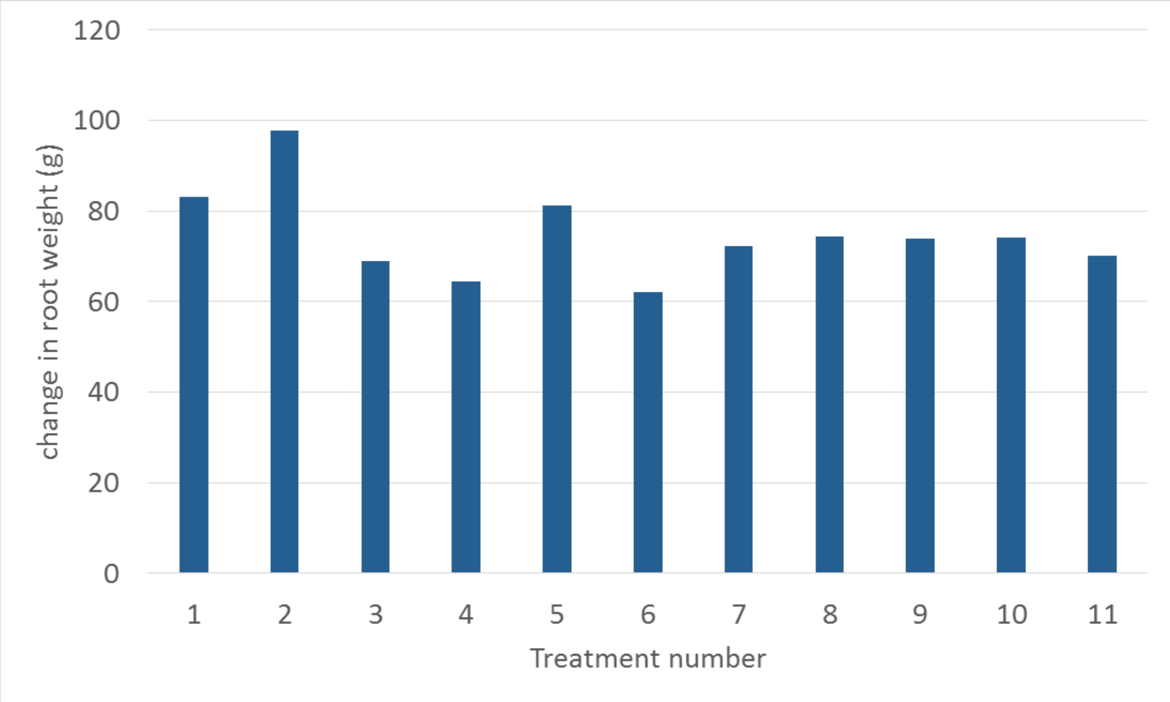

Figure 7. Mean change in broccoli root weight per treatment between the July and August destructive assessments. F pr = 0.521 (NS), L.S.D = 29.35

Nutrient levels at final harvest

There were no significant changes in leaf nutrient levels with the exception of Zinc (Table 11), where the programme AF Turret + AF Nurture followed by AF Turret + AF Phosphorous significantly increased levels of this element (P value = 0.019, L.S.D. = 2.521). All samples fell well within acceptable ranges for each nutrient for broccoli with no deficiencies when compared to the table in AHDB factsheet 21/05 – Interpretation of leaf nutrient analysis results.

Table 11. Mean nutrients levels and total nitrogen (%) at harvest, 20 August 2020

	Nutrient levels										
Trt. No.	**Total nitrogen (%)**	**P (mg_Kg)**	**K (mg_Kg)**	**Ca (mg_Kg)**	**Mg (mg_Kg)**	**S (mg_Kg)**	**Mn (mg_Kg)**	**Cu (mg_Kg)**	**Zn (mg_Kg)**	**Fe (mg_Kg)**	**B (mg_Kg)**
Untreated	5.14	7073	33364	26603	2351	6049	62.0	27.78	35.02	79.2	50.98
Bridgeway	5.38	7275	30961	24836	2296	5436	60/4	17.50	37.32	129.5	49.1
Omex Bio 20	5.33	7263	31865	26073	2283	6410	56.9	22.68	34.22	80.1	51.22
TTL plus	5.44	7156	31522	27393	2400	5227	68.1	25.86	36.12	84.1	51.8
Zenith	5.33	7243	32918	25676	2348	5864	68.2	21.32	34.26	79.1	49.48
SupaStandPhos then Fortifos	5.48	7417	32020	26373	2415	5734	70.4	24.14	37.34	81.3	50.82
Coded 1	5.39	7261	32533	26541	2330	6016	69.8	23.80	37.02	82.7	51.24
AF Turret + AF Nurture then AF Turret + AF Phosphorous	5.49	7279	31400	26984	2455	5527	64.4	25.92	38.82	86.1	51.14
AF Bioflex + Naturamin	5.46	7177	33513	25683	2379	5898	66.0	22.06	36.64	81.1	50.52
NTS Tri- Kelp	5.39	7076	31330	26936	2500	5242	59.9	19.96	36.06	81.1	50.08
NTS Triacontinol	5.37	7294	31661	24968	2299	5183	60.8	21.48	36.68	91.6	49.7
P value	0.933 (NS)	0.992 (NS)	0.393 (NS)	0.555 (NS)	0.436 (NS)	0.972 (NS)	0.798 (NS)	0.444 (NS)	0.019	0.471 (NS)	0.774 (NS)
d.f.	40	40	40	40	40	40	40	40	40	40	40
L.S.D	0.4312	610.8	2358.8	2510.1	194.1	2025.6	16.71	8.350	2.521	41.96	3.059
Significantly different from the untreated control											
Not significantly different from the untreated control											

Crop health indicators – visual assessment of head rot

There were no significant differences in the incidence of broccoli head rot (F pr = 0.376, LSD = 3.44), and the mean incidence of head rot was low in the untreated (mean = 5.2%, Table 12 and Figure 8). Head rot was assessed visually by East of Scotland Growers agronomists, and symptoms which appeared to be spear or head rot were recorded, however these were not subsequently confirmed with a lab analysis.

Despite no significant differences when treatments are compared to the untreated, there was a significant difference between the treatments using Duncan's post-hoc test. The programme - AF Turret and AF Nurture then AF Turret and AF Phosphorous applied twice had consistently less incidence head rot than the plots treated with Omex Bio20 with 1.94% head rot compared to 6.43%. But, it should be noted that data for this latter treatment was skewed by one plot with much higher incidence of head rot.

Table 12. Mean percentage head rot of broccoli per treatment, 25 August 2020, Balmullo.

		Head rot (no of infected heads per plot)							
Trt no	**Product**	**Block**					**Mean Counts per plot**	**Mean Head Rot (%)**	**Duncan's range test**
		1	**2**	**3**	**4**	**5**			
1	*Untreated*	3	7	6	4	1	4.2	5.24	ab
2	*Bridgeway*	5	4	1	2	5	3.4	4.18	ab
3	*Omex Bio 20*	3	6	11	1	5	5.2	6.43	b
4	*TTL plus*	3	6	1	2	5	3.4	4.18	ab
5	*Zenith*	5	3	1	2	3	2.8	3.46	ab
6	*SupaStandPhos then Fortifos*	2	3	1	5	3	2.8	3.46	ab
7	*Coded 1*	3	5	6	3	2	3.8	4.72	ab
8	*AF Turret + AF Nurture then AF Turret + AF Phosphorous*	0	1	1	2	4	1.6	1.94	a
9	*AF Bioflex + Naturamin*	1	2	4	7	0	2.8	3.50	ab
10	*NTS Tri- Kelp*	7	6	4	4	3	4.8	5.96	ab
11	*NTS Triacontinol*	5	6	2	4	2	3.8	4.73	ab
	F pr						0.387	0.376	
	d.f.						40	40	
	L.S.D.						2.774	3.44	

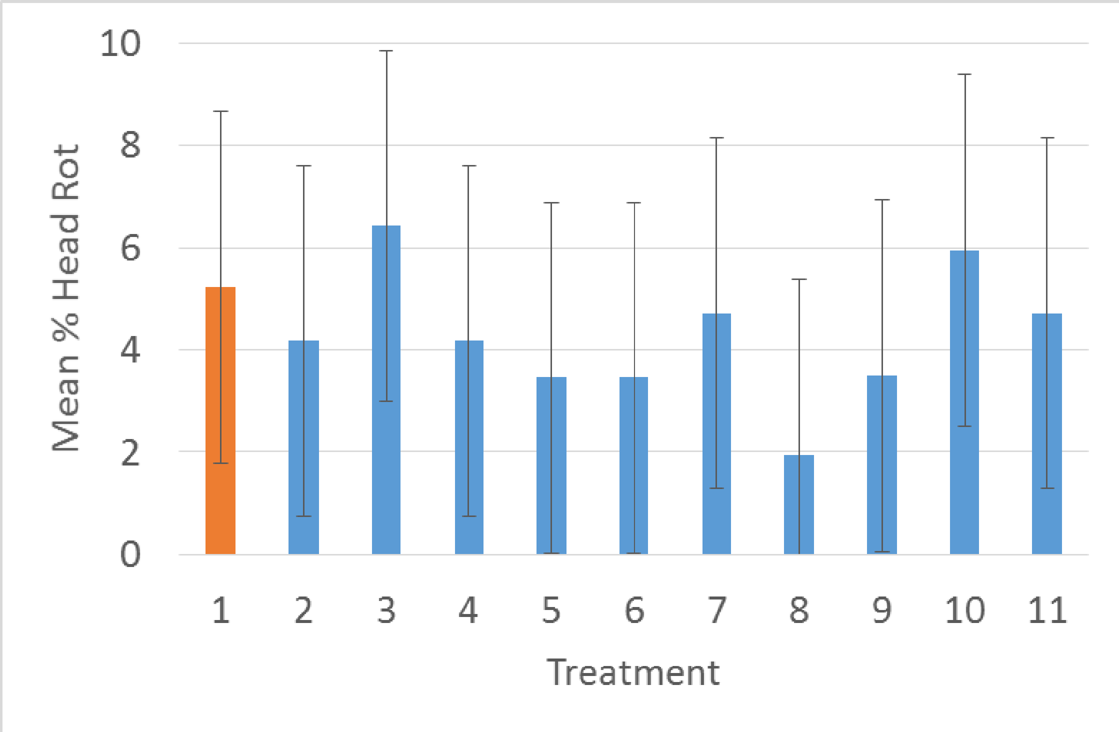

Figure 8. Mean percentage head rot per treatment (F pr = 0.376, LSD = 3.44), 25 August 2020. The orange bar indicates the untreated control.

Discussion

All treatment programmes in the experiment were safe to use over broccoli with no adverse effects observed on the crop. A significant increase in foliar Zinc of 3.8 mg/kg compared to the untreated was observed in the broccoli leaves in plots where the Aiva Fertilisers programme of AF Turret plus AF Nurture, then two applications of AF Turret plus AF Phosphorous were applied. This programme contained the highest concentration of Zinc when compared to the other treatments with AF Phosphorous containing 1.5% Zinc, and this was applied at 5.0 L/ha. Zinc is involved in plant processes such as photosynthesis, and the development and function of growth regulators (auxins), and is a structural and functional element of enzymes.

There were no other significant effects on any of the other elements which were analysed – which were; Total % Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Manganese (Mn), Copper (Cu), Iron (Fe), and Boron (B). It should be highlighted that all samples fell well within acceptable ranges for each nutrient for broccoli with no deficiencies when compared to the table in AHDB factsheet 21/05 – Interpretation of leaf nutrient analysis results.

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.

At each biomass assessment there were significant differences between blocks indicating that the differences between individual beds down which the treatments were arranged influenced differences in biomass greater than any effect from treatments. But, there were trends for selected products to increase biomass by greater than 5% in selected assessments, though it should be highlighted that due to the lack of significance these trends cannot be attributed to the effect of a particular biostimulant product or programme with confidence. Therefore it would be valuable to repeat the experiment in a further season to see if any consistent effects are detected. Such as the trend observed for an increase in early biomass by the three treatments which showed the overall highest mean total plant weight in the first assessment. These were Nutri-Tech Solutions Triacontinol, Aiva Fertilisers products, AF Turret plus AF Nurture and Pharm Fertilisers SupaStandPhos. The latter two products are based around starter fertilisers which contain a higher percentage of phosphorous which is an element associated with improved rooting as well as a vital role in energy transfer (ATP) and photosynthesis which could have led to the greater investment in root and foliar growth at this early broccoli growth stage (BBCH 16 or 6 true leaves).

Head rot occurred at harvest in the broccoli at low levels - 5.24% in the untreated control plots, and the incidence was assessed as an indicator for crop health. Head rot was assessed visually by East of Scotland Growers agronomists, and symptoms which appeared to be spear or head rot were recorded, however these were not subsequently confirmed with a lab analysis. There were no significant differences between any of the treatments and the untreated control in the incidence of broccoli head rot (F pr = 0.376, LSD = 3.44). But, despite the lack of significant differences when treatments are compared to the untreated, there was a significant difference between the treatments using Duncan's post-hoc test. The programme - AF Turret and AF Nurture then AF Turret and AF Phosphorous applied twice had consistently less incidence head rot than the plots treated with Omex Bio20 with 1.94% head rot compared to 6.43%.

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.
- There were no significant differences in nutrient levels between treatments and the untreated control with the exception of Zinc.
    - There was a significant increase in Zinc of 3.8 mg/kg in plots treated with the Aiva Fertilisers programme of AF Turret plus AF Nurture, then two applications of AF Turret plus AF Phosphorous.
- Plots treated with this programme also had the lowest headrot at the final assessment, and one of the greatest biomass increases at the first destructive assessment. Though these were not significant effects.

Knowledge and Technology Transfer

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

References

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

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

Table A. Mean total **whole plant biomass in g** per plot from five plants sampled per plot in first destructive harvest on 16 and 17/07/2020 by treatment and replicate to show variation.

Treatment	Block					Total mean
	1	2	3	4	5	
1	61.2	72.0	88.4	120.2	85.8	85.52
2	109.8	70.2	70.6	82.0	68.0	80.12
3	81.8	101.8	70.4	78.2	100.0	86.44
4	96.8	95.8	72.8	76.4	81.4	84.64
5	86.0	103.0	89.8	71.8	112.6	92.64
6	79.2	128.0	89.8	98.8	90.4	97.24
7	96.4	105.4	83.0	85.6	91.4	92.36
8	99.8	119.8	117.6	62.4	98.0	99.52
9	83.8	106.8	93.8	93.0	67.2	88.92
10	83.2	93.6	99.4	71.0	79.4	85.32
11	112.2	113.4	74.2	106.0	130.8	107.32

Table B. Mean total **root biomass in g** per plot from five plants sampled per plot in first destructive harvest on 16 and 17/07/2020 by treatment and replicate to show variation.

Treatment	Block					Total mean
	1	2	3	4	5	
1	12.0	14.2	13.4	15.8	11.8	13.44
2	17.2	9.4	11.6	12.4	10.8	12.28
3	13.2	21.2	13.6	12.0	11.2	14.24
4	12.0	15.6	11.8	13.2	10.6	12.64
5	14.4	14.0	12.0	11.8	14.2	13.28
6	13.2	17.2	13.4	14.6	15.6	14.8
7	12.4	20.4	16.4	10.6	13.0	14.56
8	14.8	19.2	15.4	10.4	13.2	14.6
9	15.0	13.4	12.4	13.6	12.8	13.44
10	14.4	11.4	15.2	9.6	14.2	12.96
11	12.2	16.0	11.2	12.0	14.8	13.24

Table C. Mean total **shoot/foliar biomass in g** per plot from five plants sampled per plot in first destructive harvest on 16 and 17/07/2020 by treatment and replicate to show variation.

Treatment	Block					Total mean
	1	2	3	4	5	
1	49.2	57.8	75.0	104.4	74.0	72.08
2	92.6	60.8	59.0	69.6	57.2	67.84
3	68.6	80.6	56.8	66.2	88.8	72.2
4	84.8	80.2	61.0	63.2	70.8	72
5	71.6	89.0	77.8	60.0	98.4	79.36
6	66.0	110.8	76.4	84.2	74.8	82.44
7	84.0	85.0	66.6	75.0	78.4	77.8
8	85.0	100.6	102.2	52.0	84.8	84.92
9	68.8	93.4	81.4	79.4	54.4	75.48
10	68.8	82.2	84.2	61.4	65.2	72.36
11	100.0	97.4	63.0	94.0	116.0	94.08

Table D. Mean total **plant weight** in kg per plot from five plants sampled per plot from final destructive harvest on 20/08/2020 by treatment and replicate to show variation.

Treatment	Block				Total mean
	1	2	3	4	
1	1.836	1.580	1.592	1.671	1.669
2	2.119	1.749	1.480	1.469	1.704
3	1.571	1.770	1.482	1.511	1.584
4	1.464	1.805	1.346	1.423	1.509
5	1.489	1.717	1.704	1.711	1.655
6	1.953	1.847	1.274	1.403	1.619
7	1.727	1.873	1.652	1.501	1.688
8	1.686	1.893	1.612	1.539	1.683
9	2.008	1.644	1.717	1.589	1.739
10	1.881	1.524	1.812	1.799	1.754
11	1.972	1.846	1.587	1.480	1.721

Table E. Mean total **root weight** in kg per plot from five plants sampled per plot from final destructive harvest on 20/08/2020 by treatment and replicate to show variation.

Treatment	Block				Total mean
	1	2	3	4	
1	0.128	0.122	0.069	0.067	0.096
2	0.229	0.087	0.065	0.058	0.110
3	0.108	0.093	0.066	0.066	0.083
4	0.086	0.094	0.062	0.065	0.077
5	0.137	0.084	0.079	0.077	0.095
6	0.106	0.081	0.064	0.057	0.077
7	0.103	0.093	0.085	0.066	0.087
8	0.119	0.105	0.063	0.068	0.089
9	0.134	0.072	0.070	0.073	0.087
10	0.115	0.083	0.077	0.073	0.087
11	0.099	0.095	0.063	0.076	0.084

Table F. Mean total **foliage weight** in kg per plot from five plants sampled per plot from final destructive harvest on 20/08/2020 by treatment and replicate to show variation.

Treatment	Block				Total
	1	2	3	4	
1	1.708	1.458	1.522	1.604	1.573
2	1.889	1.662	1.415	1.412	1.595
3	1.463	1.677	1.416	1.446	1.501
4	1.377	1.711	1.284	1.357	1.433
5	1.353	1.633	1.624	1.633	1.561
6	1.847	1.766	1.211	1.346	1.543
7	1.624	1.779	1.567	1.434	1.601
8	1.567	1.787	1.549	1.471	1.594
9	1.874	1.572	1.647	1.516	1.652
10	1.766	1.443	1.734	1.726	1.667
11	1.872	1.751	1.524	1.404	1.637

Weather data – provided by East of Scotland Growers

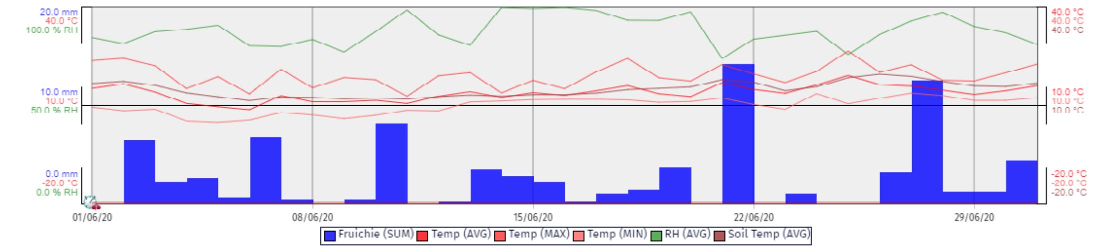
June

2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Y

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SUM (mm)	6.4	2.2	2.6	0.6	6.8	0.4	0.0	0.4	8.2	0.0	0.2	3.4	2.8	2.2	0.2
AVG (°C)	14.1	10.6	9.6	8.7	13.0	11.1	11.1	11.6	10.6	12.8	14.2	12.5	13.9	13.1	14.5
MIN (°C)	8.9	5.3	4.9	5.6	7.9	7.1	6.0	7.0	8.6	8.4	11.1	11.4	11.8	11.9	11.9
MAX (°C)	22.2	15.2	18.8	13.5	21.1	15.4	18.6	17.9	12.8	19.1	20.1	13.9	17.7	15.1	20.3
AVG (% RH)	87.7	89.0	90.9	80.5	80.2	83.8	77.3	87.7	98.8	86.0	80.8	100.0	99.4	100.0	98.5
MIN (% RH)	58.5	74.2	67.2	62.2	62.8	74.1	60.7	69.6	94.8	69.0	65.8	100.0	96.4	100.0	89.0
MAX (% RH)	100.0	100.0	99.6	99.5	99.0	94.8	88.8	98.8	100.0	100.0	99.9	100.0	100.0	100.0	100.0
AVG (°C)	16.2	13.9	12.7	11.5	12.6	12.4	12.0	12.2	11.9	12.7	13.2	12.8	13.3	13.3	13.8

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	June
SUM (mm)	1.0	1.4	3.6	0.0	14.2	0.0	1.0	0.0	0.0	3.2	12.6	1.2	1.2	4.4	80.2
AVG (°C)	16.1	13.6	12.7	17.0	14.9	13.7	16.3	19.2	16.4	15.9	14.7	13.4	14.5	16.1	13.8
MIN (°C)	11.7	11.0	11.2	12.3	10.3	8.9	13.6	10.5	12.2	13.8	13.0	11.5	11.5	12.3	4.9
MAX (°C)	24.4	18.5	17.5	22.5	19.7	17.0	20.4	26.7	20.2	22.5	17.8	17.5	20.0	22.7	26.7
AVG (% RH)	93.5	93.4	97.8	74.0	83.9	85.9	87.9	76.0	86.2	93.2	97.6	90.4	87.2	81.2	88.3
MIN (% RH)	72.5	75.0	82.9	46.3	65.2	73.2	74.0	53.0	72.5	68.5	87.0	78.3	66.0	53.7	46.3
MAX (% RH)	100.0	100.0	100.0	100.0	99.8	98.9	97.7	100.0	99.8	100.0	100.0	96.6	97.0	99.2	100.0
AVG (°C)	14.9	15.2	15.7	17.9	17.1	14.5	15.7	18.5	19.6	18.9	17.3	16.0	15.8	16.9	14.9



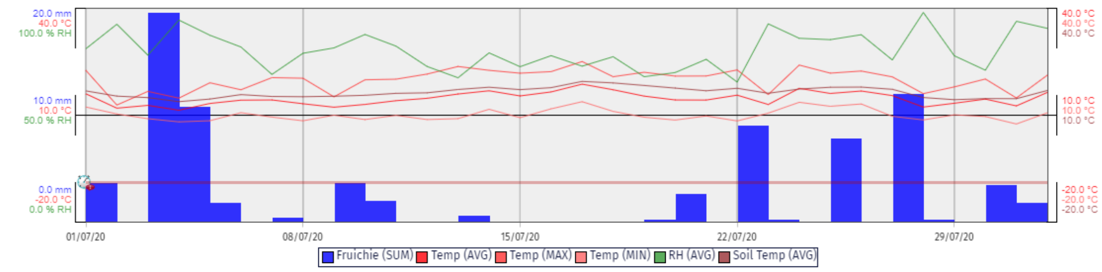
July

2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Y

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SUM (mm)	0.0	19.6	10.8	1.8	0.0	0.4	0.0	3.6	2.0	0.0	0.0	0.6	0.0	0.0	0.0
AVG (°C)	12.8	11.4	13.3	14.3	14.3	13.2	12.3	13.1	14.1	14.8	16.0	16.9	15.4	16.6	18.8
MIN (°C)	9.0	8.1	8.5	10.7	9.5	8.4	10.0	8.8	10.0	8.8	9.0	11.7	9.3	11.8	13.8
MAX (°C)	16.7	14.8	19.2	17.2	20.6	20.4	15.2	20.0	20.2	21.6	23.8	22.7	21.9	22.3	25.1
AVG (% RH)	78.2	94.7	87.6	82.1	69.2	79.1	81.6	88.0	82.5	72.9	67.6	79.3	72.8	78.0	73.1
MIN (% RH)	63.5	69.8	69.2	65.2	47.8	50.5	62.4	53.5	56.2	50.1	44.2	53.9	50.7	55.3	56.0
MAX (% RH)	96.3	100.0	100.0	100.0	89.9	93.6	96.1	100.0	100.0	95.8	88.5	96.4	95.9	97.0	87.7
AVG (°C)	15.0	13.8	14.6	15.8	15.3	15.2	15.4	15.6	16.2	16.3	17.3	17.9	17.2	17.8	19.5

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	July
SUM (mm)	0.0	0.0	0.2	2.6	0.0	9.0	0.2	0.0	7.8	0.0	12.0	0.2	0.0	3.4	1.8	79.6
AVG (°C)	17.2	15.4	14.3	14.3	15.7	13.0	17.6	16.1	16.8	15.5	12.3	13.4	14.6	12.6	16.	14.7
MIN (°C)	11.1	9.4	8.6	9.8	8.4	10.6	13.7	12.5	13.2	9.7	8.7	10.1	9.6	7.5	10.	7.5
MAX (°C)	20.9	22.1	21.0	21.1	22.8	15.8	24.2	21.9	22.5	20.8	16.1	18.0	20.2	14.9	21.	25.1
AVG (% RH)	77.5	68.1	70.1	76.3	65.6	92.9	86.2	85.5	87.8	76.0	98.3	77.9	71.2	94.1	90.	80.6
MIN (% RH)	57.1	44.6	48.0	51.1	42.9	75.9	57.4	63.2	67.7	47.9	93.2	61.3	49.6	79.3	75	42.9
MAX (% RH)	93.8	97.6	90.1	94.5	92.7	100.0	100.0	99.7	100.0	99.1	100.0	98.5	90.4	100.0	100	100.0
AVG (°C)	19.1	18.4	17.7	16.9	17.6	16.2	17.4	17.9	17.9	17.3	15.0	14.4	14.7	14.7	17.	16.5

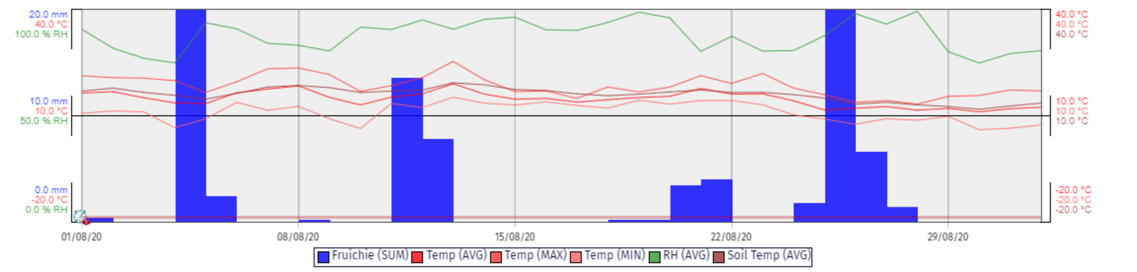


August

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Y

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SUM (mm)	0.0	26.4	2.4	0.0	0.0	0.2	0.0	0.0	13.6	7.8	0.0	0.0	0.0	0.0	0.0
AVG (°C)	13.7	13.5	16.5	17.6	18.5	15.2	13.1	15.3	16.2	19.1	16.1	14.7	14.9	13.9	14.6
MIN (°C)	6.6	9.2	13.8	11.6	12.6	9.2	6.4	13.5	12.3	15.3	13.6	13.0	14.0	12.9	12.2
MAX (°C)	19.9	16.6	19.7	23.3	23.5	21.7	16.9	18.5	20.8	25.4	20.2	16.9	17.0	14.9	18.1
AVG (% RH)	75.0	93.9	91.0	84.2	83.3	80.6	91.8	90.7	95.2	90.8	95.5	96.5	90.6	90.3	94.1
MIN (% RH)	51.4	79.6	78.6	63.4	65.9	54.2	79.7	78.1	82.5	73.9	85.2	90.4	81.1	84.7	81.4
MAX (% RH)	98.8	100.0	99.4	99.4	98.1	99.5	100.0	98.9	100.0	100.0	100.0	100.0	98.3	95.9	100.0
AVG (°C)	15.8	14.7	16.3	18.1	18.6	18.0	16.6	17.0	17.3	19.3	18.8	17.4	17.2	16.2	15.7

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	August
SUM (mm)	0.2	0.2	3.4	4.0	0.0	0.0	1.8	31.6	6.6	1.4	0.0	0.0	0.0	0.0	100.0
AVG (°C)	15.2	15.5	17.7	16.2	16.2	14.2	11.7	12.1	12.6	11.6	12.1	11.1	12.0	12.4	14.7
MIN (°C)	14.4	13.3	14.3	14.3	13.1	10.3	9.1	7.6	9.2	8.7	9.8	6.1	6.5	7.4	6.1
MAX (°C)	16.7	18.1	21.4	19.2	22.0	17.8	16.0	13.8	14.3	13.3	15.5	15.8	17.3	17.1	25.4
AVG (% RH)	98.9	96.2	80.4	87.5	80.5	80.8	87.8	98.2	93.3	99.3	80.3	74.9	79.4	80.7	87.8
MIN (% RH)	92.6	86.1	61.8	76.8	58.8	60.3	71.1	92.0	81.4	94.5	56.0	56.9	53.7	57.0	50.5
MAX (% RH)	100.0	100.0	100.0	98.3	94.6	98.5	100.0	100.0	100.0	100.0	100.0	94.1	94.9	98.8	100.0
AVG (°C)	16.1	16.8	17.3	16.6	16.6	16.0	15.0	13.3	13.8	13.1	12.6	11.8	12.8	13.6	16.0



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