COMPARING THE PERFORMANCE OF PLANT-BASED FERTILIZERS AND BIOSTIMULANTS WITH SYNTHETIC ALTERNATIVES

Ensuring that plants have all the nutrients and minerals necessary for optimal growth is a common goal and crucial with respect to meeting global food requirements. Fertilizer use is essential, with estimates suggesting that global food crops would be around half their current levels without the addition of synthetic nitrogen[1].

However, nitrogen fertilizer manufacture is currently dependent on fossil fuels and responsible for around 1-2 % of global greenhouse gas emissions[2]. Efforts towards greater sustainability increase demand for plant care solutions that support optimal plant growth with less environmental impact.

Roquette, a global leader in the development and manufacture of plant-based ingredients, offers a range of solutions for plant nutrition and protection.

Developed in collaboration with external partners and experts, these products have been refined for specific applications, conditions, and crops. They allow customers to substitute mineral and chemical fertilizers and biostimulants for natural alternatives that offer balanced, optimized NPK (nitrogen, phosphorus, potassium) in combination with organic acids, vitamins and other trace minerals.

Here we focus on comparative studies of the performance of fertilizers in the cultivation of tomato plantlets, presenting case study data from trials at Iowa State University (ISU in Ames, Iowa, US) and from in-house studies at Roquette. The results demonstrate the ability of Roquette plant-based products to deliver comparable performance to that of synthetic fertilizers and at the same time offer complementary benefits due to their potential as biostimulants.

A DIFFERENT ROUTE TO PLANT HEALTH

Developed in the early 1900s, the Haber-Bosch process for ammonia production remains the cornerstone of modern fertilizer production, supplying the nitrogen which so often limits yield. In this highly energetic nitrogen-fixing process, ammonia forms from the reaction between nitrogen in the air and hydrogen from natural gas. The reaction of ammonia with by-product carbon dioxide produces urea, the world's most used nitrogen fertilizer.

Global moves towards greater sustainability make the dependence of synthetic fertilizer production on fossil fuels increasingly problematic, stimulating interest in alternative solutions. One option is to switch to "green" hydrogen, produced via the electrolysis of water, depending on the availability of renewable energy.[2] Another is to reduce use. Going forward, it is predicted that farmers will progressively "apply more knowledge per hectare" using technology to monitor and understand nutrient use efficiency and drive precision farming.[3]

There is scope to more effectively target fertilizer use, adding only as and where required, to reduce environmental impacts while sustaining yields.[1,3]

However, these are mid- to long-term strategies. New solutions are needed now. In the US, synthetic fertilizers are already banned in some municipalities. For example, South Portland City Council (Maine) approved a citywide ban of synthetic fertilizers in November 2020.[4]

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Consumers are notably eager for change in the way that food is grown. It is important to establish alternative, non-synthetic sources of nitrogen for use now and into the future.

Plant proteins hold nitrogen in their constituent amino acids. Plants can therefore be processed to create fertilizers/biostimulants and other plant care solutions, using some or all of the following processing steps:

- Solubles extraction, via steeping (extended contact with water)
- Fermentation
- Enzymatic hydrolysis
- Separation, including filtration and centrifugation
- Concentration, notably low-temperature drying.

Such processing calls for relatively benign operating conditions and uses no solvents. The carbon footprint associated with making plant-based products is therefore low.

The resulting fractions are complex mixtures rather than the single chemicals manufactured via chemical synthesis but, as a result, offer multiple benefits for plant health and protection. For example, products that act as a valuable source of nitrogen may also exhibit biostimulant properties, improving plant tolerance to environmental stress, quality traits, or nutrient-use efficiency.

Progressive refining enables the isolation and formulation of products tailored to specific plant cultivation applications.

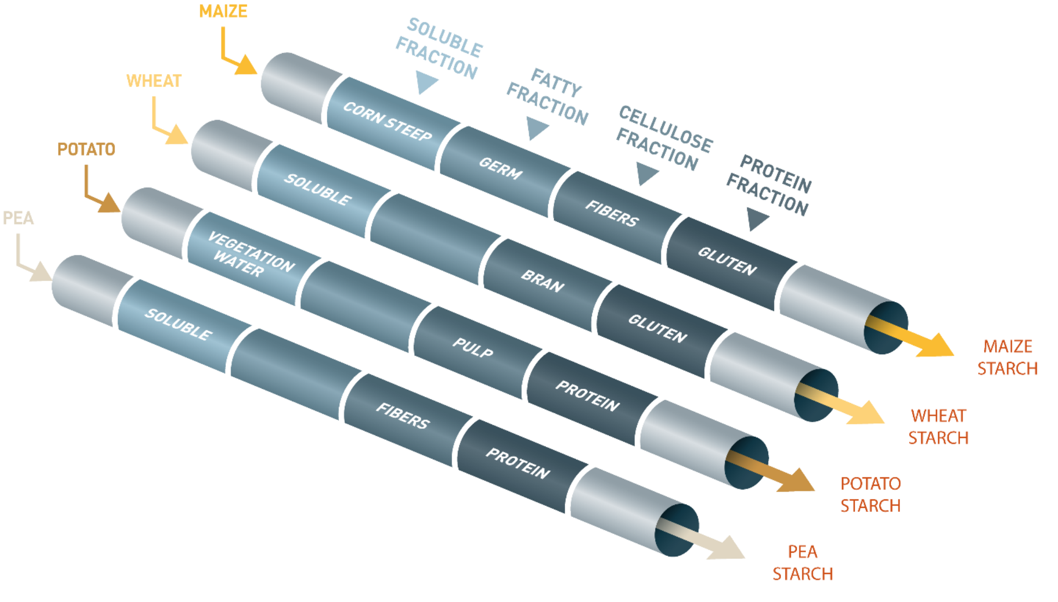

Figure 1. **Roquette produces fertilizers/biostimulants and other plant care solutions from plants such as maize, wheat, potato, or pea via a process of progressive refining that extracts starch, proteins, and other valuable ingredients.**

Roquette solubles, organic fertilizers and other plant care solutions are all made from plants using specific (often patented) and well-controlled processes that eliminate the inherent variability of plant-based feedstocks. The result is uniform, consistent products with good stability that meet grower requirements for dependable performance. Furthermore, the known provenance of Roquette feedstocks enables the production of a number of fertilizers that are OMRI (Organic Materials Review Institute) compliant, making them suitable for use in organic production and processing.

The following case studies demonstrate the performance of Roquette plant-based products, showing how it compares with conventional synthetic fertilizers.

CASE STUDY ONE

COMPARING THE PERFORMANCE OF PLANT-BASED FERTILIZERS/BIOSTIMULANTS WITH SYNTHETIC NPK FOR TOMATO TRANSPLANT GROWTH

Table 1 shows summary data from a trial to evaluate the performance of a series of Roquette products relative to synthetic NPK fertilizer (the industry standard), with respect to the growth, health, and quality of tomato transplants.

The trials were carried out by researchers at ISU using a randomized complete block design (RCBD) with four replications.

Twenty-five tomato seedlings ("German Johnson"; organic pelleted) were subject to each treatment making 100 seedlings per treatment in total. Seeding was into a peat-based organic growing medium with seeded flats subsequently subject to temperature control (70°F day/ 60°F night) and a constant photosynthetically active radiation level of 250 $\mu mol.m^{-2}.s^{-1}$.

Treatments were applied during week 3, 4, 5, and 6 after seeding, on the basis of nitrogen equivalence, with an additional basal dose of NPK (20-20-20 balanced fertilizer) applied to all treatments except the control at week 3.

Irrigation was provided as required; beneficial insects were used to manage thrips and aphids. All data were subject to Analysis of Variance (ANOVA) to confirm statistical significance.

Table 1: *Data for tomato transplants illustrate the ability of plant-derived products to deliver comparable performance to synthetic NPK fertilizer.*

	Transplant Height (cm)	Transplant Height Statistical Group	Stem Diameter (mm)	Stem Diameter Statistical Group	SPAD	SPAD Statistical Group
Roquette Product A	21.3	*B*	4.5	*BC*	32.1	*CD*
Roquette Product B	22.8	*AB*	4.6	*B*	33.3	*C*
Roquette Product C	21.8	*B*	4.1	*CD*	32.5	*CD*
Roquette Product D	21.0	*B*	4.1	*D*	34.2	*BC*
Roquette Product E	21.2	*B*	4.1	*D*	43.6	*A*
Roquette Product F	21.8	*B*	4.2	*CD*	41.8	*A*
Untreated	9.9	*D*	2.8	*F*	23.5	*E*
NPK Fertilizer (Ind. Std)	23.8	*A*	5.0	*A*	37.3	*BC*
Basal NPK	12.6	*C*	3.5	*E*	28.9	*D*

	Total Dry Weight (g)	Total Dry Weight Statistical Group	Shoot Dry Weight (g)	Shoot Dry Weight Statistical Group	Root Dry Weight (g)	Root Dry Weight Statistical Group
Roquette Product A	3.3	*D*	2.5	*C*	0.8	*C*
Roquette Product B	3.7	*BCD*	2.7	*BC*	1.0	*BC*
Roquette Product C	3.3	*D*	2.3	*C*	1.0	*BC*
Roquette Product D	3.4	*CD*	2.5	*C*	0.9	*BC*
Roquette Product E	4.0	*BCD*	3.2	*BC*	0.9	*BC*
Roquette Product F	3.9	*BCD*	3.1	*BC*	0.9	*BC*
Untreated	1.0	*F*	0.7	*D*	0.3	*E*
NPK Fertilizer (Ind. Std)	5.6	*A*	4.6	*A*	1.3	*A*
Basal NPK	1.7	*E*	1.1	*D*	0.6	*D*

	Longest Root (cm)	Longest Root Statistical Group	Total Root Length (cm)	Total Root Length Statistical Group	Root Surface Area (cm²)	Root Surface Area Statistical Group	Root Volume (cm³)	Root Volume Statistical Group
Roquette Product A	22.4	*A*	1360.6	*B*	157.7	*BC*	1.5	*B*
Roquette Product B	21.9	*AB*	1376.3	*B*	165.3	*BC*	1.6	*B*
Roquette Product C	22.7	*A*	1453.8	*AB*	159.5	*BC*	1.4	*B*
Roquette Product D	21.9	*AB*	1645.0	*A*	175.2	*B*	1.5	*B*
Roquette Product E	22.5	*A*	1219.2	*BC*	150.4	*C*	1.5	*B*
Roquette Product F	22.7	*A*	1036.2	*C*	123.6	*D*	1.2	*C*
Untreated	19.0	*C*	744.8	*D*	74.1	*E*	0.6	*E*
NPK Fertilizer (Ind. Std)	21.9	*AB*	1683.6	*AB*	204.8	*A*	2.0	*A*
Basal NPK	20.2	*BC*	1001.9	*C*	104.4	*D*	0.9	*D*

Results are shown for six Roquette products, representative of different raw material extracts. Overall, the more complex, plant-based products perform extremely well compared with the synthetic fertilizer. Notably, Products A and B give rise to transplants with good stem diameter and height.

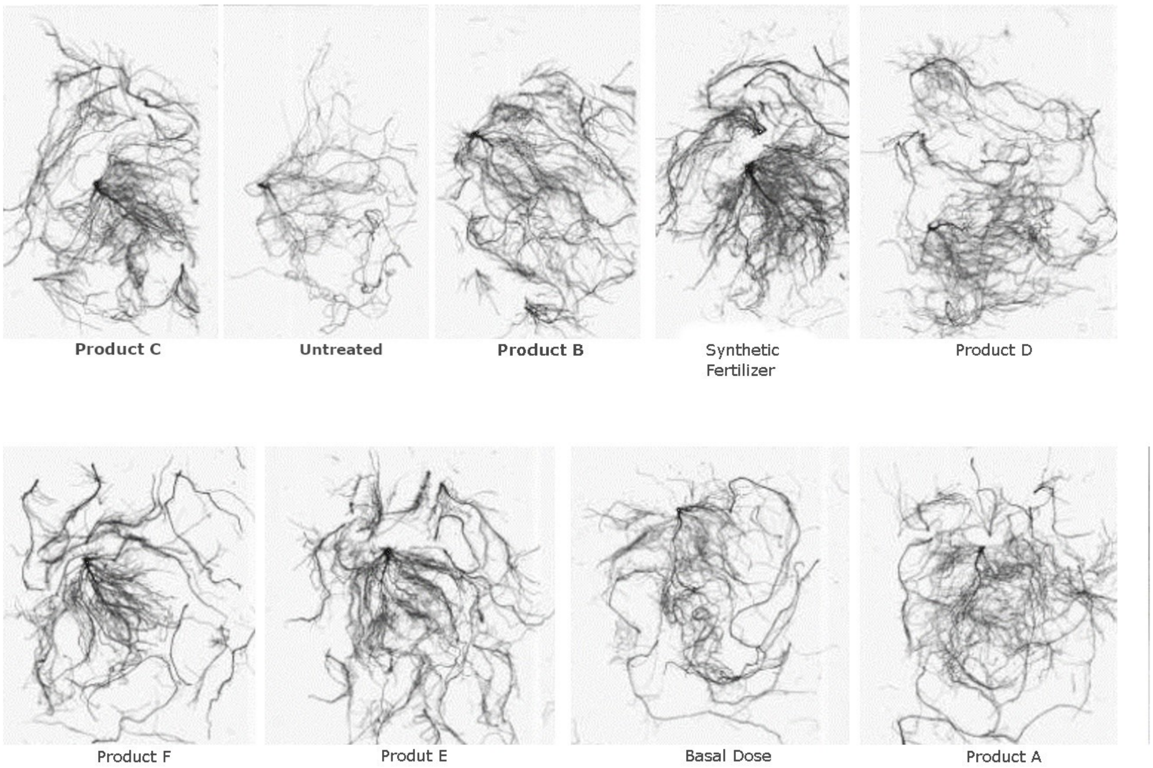

Figure 2: Root images show that plant-derived products promote root growth, relative to no treatment, to a comparable level to synthetic fertilizers.

Product B performs best of all of the plant-based solutions with respect to plant height. Products C and D are especially beneficial with respect to root growth, while Product E and F promote the growth of transplants that combine high total dry weight and SPAD (Soil Plant Analysis Development) values. Dry weight is a valuable indicator of total plant biomass; SPAD values quantify chlorophyll and are a commonly used diagnostic tool for monitoring the nitrogen status of crops.

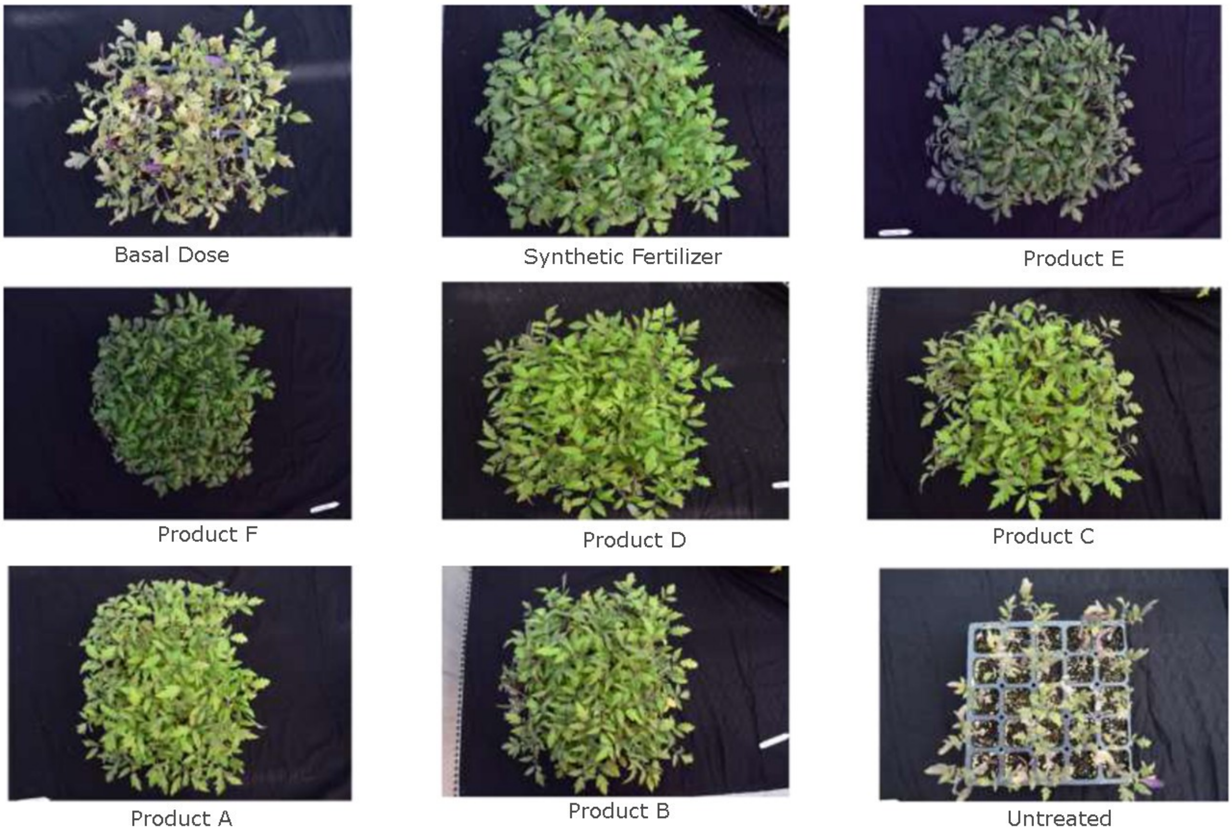

Figure 3: **Transplant images demonstrate the ability of plant-derived products to successfully promote growth.**

"Overall, the results are very promising. The Roquette products in their relatively complex forms did exceptionally well when compared to synthetic salt-based fertilizers, clearly demonstrating the potential to significantly influence transplant growth and development" said **Dr. Ajay Nair, Associate Professor and Extension Vegetable Specialist, ISU**

In summary, these initial results are **highly encouraging** for the use of plant-based products in this application, especially given the considerable scope for dose optimization. Further trials are already underway at ISU to determine the dose required to establish equivalency with the synthetic fertilizer with the expectation of delivering performance on par with established industry standards.

More specific assessment of the biostimulant properties of the Roquette products is also a potentially beneficial avenue of research.

CASE STUDY TWO

COMPARING THE PERFORMANCE OF PLANT-BASED FERTILIZERS/BIOSTIMULANTS WITH SYNTHETIC NPK FOR THE GROWTH OF TOMATO TRANSPLANT OF DIFFERENT VARIETIES, IN DIFFERENT MEDIA.

◢ ROQUETTE TRIAL ONE: GROWING IN POTTING COMPOST UNDER MARGINAL NUTRITIVE STRESS

Table 2 shows summary data from a trial to evaluate the performance of Roquette Product A relative to a commercial synthetic 20/20/20 NPK fertilizer (the industry standard). The trial was carried out by researchers at Roquette using 36 tomato seedlings per test modality ("German Johnson," as in the ISU trial).

Seeding was into a two-thirds to one-third potting soil/perlite mix; perlite is used routinely in seed propagation to aerate potting compost and enhance water retention/drainage. Treatment was subsequently applied in four equal applications to the roots of the plantlets at regular intervals over the seven-week growing period, on the basis of nitrogen equivalence.

No treatments were added to the negative control (NC) and application levels were set so as to subject the plantlets to marginal nutritive stress to accentuate any biostimulant activity associated with the Roquette product.

Irrigation was provided as required with plants grown under minimally controlled conditions typical of those found in a standard greenhouse. All data were subject to Analysis of Variance (ANOVA) to confirm statistical significance; results are presented in terms of % increase or decrease relative to the negative control.

Table 1: Data for tomato plantlets illustrate the ability of plant-derived products to deliver comparable performance to the standard NPK fertilizer, and substantially superior growth characteristics relative to the negative control.

	Aerial part						Roots						Chlorophyll	
Name of pots	Stem diameter (in mm)	Stem diameter statistical group	Fresh matter (leaves) in mg	Fresh matter (leaves) Statistical group	Dry matter (leaves) in mg	Dry matter (leaves) Statistical group	Root length Max (in cm)	Root length max Statistical group	Fresh matter (roots) in mg	Fresh matter (roots) Statistical group	Dry matter (roots) in mg	Dry matter (roots) Statistical group	Mmol of chlorophyll/m²	Statistical group
NC 2,7.10^{1}gN/plant	0.00	A	0.00	A	0.00	A	0.00	A	0.00	A	0.00	A	0.00	A
Commercial fertilizer 3,60.10^{2}gN/plant + 2,7.10^{1}gN/plant	53.08	B	376.73	B	165.87	B	-14.18	B	49.11	B	66.40	B	41.25	B
Product A 3.60.10^{-2}gN/plant + 2,7.10^{1}gN/plant	41.86	C	291.10	C	116.20	C	-25.65	C	105.78	C	103.39	C	23.82	C

The results show that overall Product A performs extremely well relative to the negative control, delivering comparable growth characteristics to the commercial NPK fertilizer.

With respect to aerial characteristics – stem diameter and leaf mass – and also chlorophyll level, the results with the plant-based product are marginally lower than with the synthetic fertilizer.

However, in terms of root development, this is markedly better with Product A. The plant-based treatment encourages the growth of a dense root system, with the shorter maximum root length attributable to an ability to thrive in the environment local to the root origin.

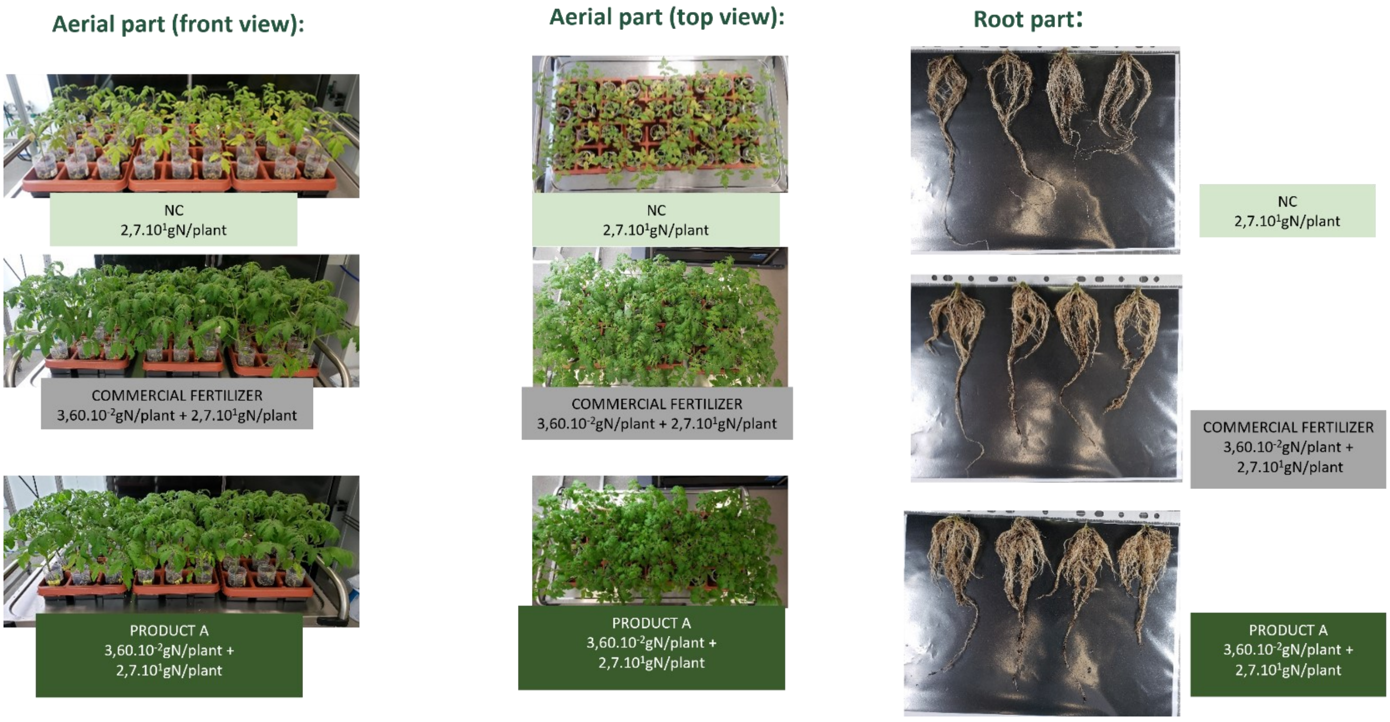

Figure 4: Aerial and root images show the ability of the plant-based product to promote growth notably with respect to root development.

Deconvoluting fertilizer and biostimulant effects is complex but these data are consistent with Product A having a beneficial effect on the soil and/or the microbial population within the rhizosphere. It is also worth noting that the high solubility of the synthetic fertilizer though beneficial for rapid assimilation, means that much of the application is easily washed away and lost.

In contrast, the organic, plant-based product is more likely to be retained in the growing medium, increasing the chance of beneficial impact on root development. For commercial growers, plantlets are routinely transferred to their final growing position at about this age.

The ability of plant-based Product A to deliver plantlets with comparable leaf development and an enhanced root system, relative to synthetic fertilizer, is therefore an extremely encouraging endpoint for this relatively short trial that echoes the success observed at ISU.

◢ ROQUETTE TRIAL TWO: GROWING IN AN INERT MEDIA

Table 3 shows summary data from a trial closely similar to Roquette trial 1 but using an inert growing media with vermiculite in place of potting compost; perlite was incorporated in exactly the same way. As before, 36 tomato seedlings were used per test modality (‘German Johnson’); the treatment application regime and growing conditions were strictly comparable. While no treatments were added to the NC, a positive control (PC) was established by dosing with a minimal level of NPK fertilizer to form a basal medium. Treatment levels for the synthetic fertilizer and Product A were set so as to be comparable to levels in the first trial taking this into account. In addition, in this trial a mixed NPK synthetic fertilizer was made up using mono salts to ensure not only nitrogen equivalence but also equivalence with respect to P and K to eliminate any confounding influence of NPK ratio; Product A has a NPK ratio of 17/20/20. All data were subject to Analysis of Variance (ANOVA) to confirm statistical significance; results are presented in terms of % increase or decrease relative to the negative control.

Table 3: ***Data illustrate the ability of plant-derived products to deliver comparable performance to the standard NPK fertilizer, and substantially superior growth characteristics relative to both the NC and PC.***

	Aerial part						Roots						chlorophyll	
Name of pots	**Stem diameter (mm)**	**Stem diameter Statistic group**	**Fresh matter (leaves) in mg**	**Fresh matter (leaves) Statistic group**	**Dry matter (leaves) in mg**	**Dry matter (leaves) Statistic group**	**Root length (cm)**	**Root length Statistical group**	**Fresh matter (roots) in mg**	**Fresh matter Statistical group**	**Dry matter (roots) in mg**	**Dry matter (roots) Statistical group**	**mmol of chlorophyll per m²**	**Statistical group**
NC "Vermiculite + perlite"	0.00	A	0.00	A	0.00	A	0.00	A	0.00	A	0.00	A	0.00	A
Basal Medium + "Vermiculite+perlite" 3,00.10^{-3}gN/plant	167.22	B	1081.89	B	1520.16	B	50.53	B	514.87	B	592.96	B	791.45	B
Mix N-P-K+ “Vermiculite+perlite” 3,90.10^{-2}gN/plant	229.55	C	3393.02	C	2735.96	C	-10.09	A	1281.59	B	890.03	B	915.67	C
Product A "Vermiculite+perlite" 3,90.10-^{2}gN/plant	238.49	C	3101.83	C	2972.97	C	-17.02	C	1982.30	C	1434.83	C	940.01	C

Under these trial conditions, Product A performs even more strongly relative to synthetic alternatives. There is no statistically significant difference with respect to the aerial characteristics of the treated plantlets, including chlorophyll levels, but the superior root development associated with Product A is again evident (see figure 5).

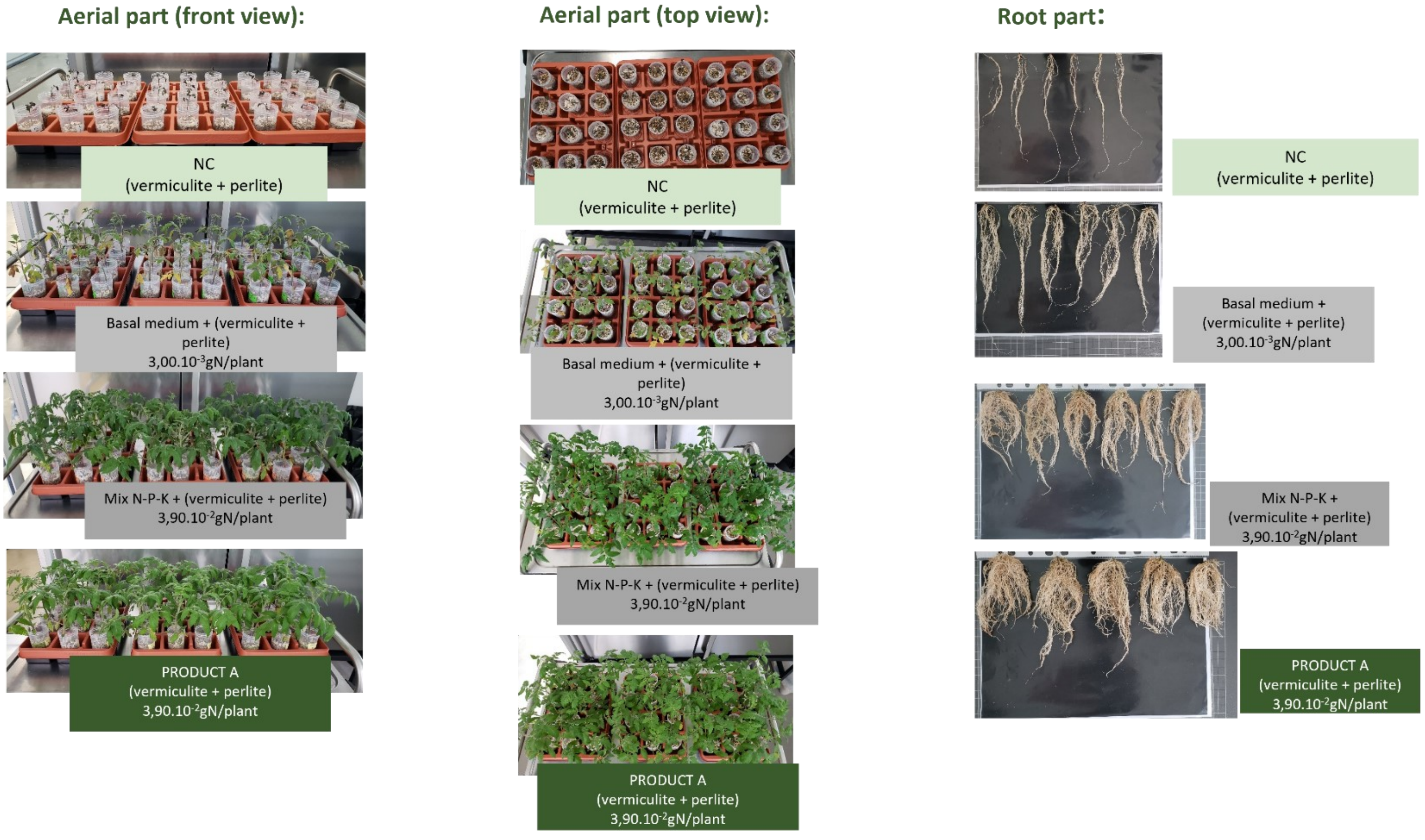

Figure 5: Aerial and root images show the ability of the plant-based product to promote growth notably with respect to root development.

◢ ROQUETTE TRIAL THREE: GROWING A DWARF TOMATO SPECIES

Table 4 shows summary data from a final Roquette trial, this time with a dwarf tomato variety. The growth media, treatment application regime, synthetic fertilizer, and growing conditions were all identical to Roquette trial 1, but just 12 tomato seedlings were used per test modality due to the statistical robustness of preceding trials. As before, the treatment regime applied resulted in the plants being subject to marginal nutritive stress. All data were subject to Analysis of Variance (ANOVA) to confirm statistical significance; results are presented in terms of % increase or decrease relative to the negative control.

Table 4: *Data illustrate the ability of plant-derived products to deliver comparable performance to a standard NPK fertilizer in the cultivation of dwarf tomato plantlets; growth characteristics are superior to the NC.*

	Aerial part			Roots			Chlorophyll
Name of pots	Stem diameter (in mm)	Fresh matter (leaves) in mg	Dry matter (leaves) in mg	Root length (in cm)	Fresh matter (roots) in mg	Dry matter (roots) in mg	mmol of chlorophyll/m²
NC $2,7.10^{1}$gN/plant	3.31	1473.33	333.58	25.50	890.00	115.08	148.95
Commercial fertilizer $3,60.10^{-2}$gN/plant + $2,7.10^{1}$gN/plant	4.94	10660.83	1443.58	21.71	3716.67	286.83	411.93
Product A $3.60.10^{-2}$gN/plant + $2,7.10^{1}$gN/plant	4.80	8097.50	996.17	13.79	3072.50	302.92	380.33

Once again Product A delivers marked improvement in both aerial and root characteristics compared with the NC and comparable performance with the synthetic fertilizer. However, the marked improvement in root development is not observed with this species. In fact, the synthetic fertilizer produces more fresh root matter than Product A though this situation is reversed with respect to dry matter. Here, ANOVA analysis indicates no statistically significant difference between the two products with respect to root development. The pattern with respect to aerial characteristics is more consistent across all three trials.

While this trial with a dwarf species reinforces those with standard varieties, there are clearly some differences in the pattern of enhancement which may relate to the specific nutritional requirements of the species or to the length of the trial relative to the cycle time of the plant; dwarf species have a shorter cycle, and the plantlets are therefore relatively advanced in terms of their development. However, the potential for the plant-based product to compete effectively with synthetic analogs across different tomato species is clear.

"*Following on from the results generated by ISU, we wanted to explore the robustness of beneficial effects with respect to growing media and plant variety. The results of this set of trials are very positive in that regard. We see strong performance across different media and with dwarf as well as standard tomato varieties. This suggests that the potential gains of switching to plant-based fertilizers/biostimulants are accessible to growers working in a range of environments***"** said **Matthieu Ramette, Research Engineer in Microbiology, Roquette**

CONCLUSION

Plant-based plant care solutions have considerable potential to meet societal requirements for more sustainable, low-environmental impact alternatives to synthetic fertilizers. The results presented here demonstrate this potential, providing evidence of the ability of Roquette fertilizers/biostimulants to match and even outperform synthetic NPK fertilizer in the cultivation of tomato plantlets.

Inherently more complex than synthetic products, plant-based products simultaneously support growth via multiple mechanisms, for example, acting both as a nitrogen source and biostimulant. Those leading the way in plant-based chemistry are working to develop an increasingly sophisticated range of highly consistent products that capitalize on this inherent complexity to produce solutions tailored to specific crops, environments, and cultivation requirements.

Going forward, these solutions have an important role to play in helping growers maintain healthy plants and land productivity while minimizing the harms associated with synthetic chemical use.

A COMPREHENSIVE PLANT-DERIVED PORTFOLIO FOR PLANT CARE

Roquette has a comprehensive, established portfolio of plant-derived products for plant nutrition and protection. These help customers to provide key nutrients and growth factors, increase nutrient absorption, enhance stress tolerance, improve germination, and stimulate growth while reducing the use of synthetic chemicals. Specific products for the formulation of plant nutrition solutions, solid- or liquid-based include the following:

SOLULYS® soluble corn protein, **GLUTALYS™** insoluble corn protein, **NUTRALYS®** pea protein, and **TUBERMINE®** potato protein: Derived from corn (SOLULYS® and GLUTALYS™), peas, and potatoes respectively, these fertilizers are all sources of nitrogen with various additional features. For example, SOLULYS® is OMRI compliant and available as a liquid product, for formulation as a water-based spray or drip.

NEOSORB® sorbitol and **PEARLITOL®** mannitol: These cereal-derived polyols offer humectant, stress reducer, and biostimulant properties and are used as formulation excipients to help plants resist abiotic stress.

Dextrose: Supplied in liquid or powder form, in a range of free-flowing grades, this nutrient and carrier is particularly valuable as an energy/carbon source for microbial solutions.

Gluconic acid, Sodium Gluconate, **BIOSUCCINIUM®** biobased succinic acid: These organic acids and salts are used as progressive acidifiers and complexing agents to increase the uptake of minerals and metal ions, particularly in neutral and alkaline soils.

To find out more about these products and how they can help you formulate an optimized plant care solution for your needs, check our website and contact us.

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