INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY: APPLIED BUSINESS AND EDUCATION RESEARCH
2024, Vol. 5, No. 10, 4030 – 4045
http://dx.doi.org/10.11594/ijmaber.05.10.19

Research Article

Growth and Productivity of Carrots *(Daucus carota)* Applied with Bio-Stimulant Solution

Paulino A. Oñal, Jr.*, Eged B. Cabillan, Nathaniel Arly A. de la Paz, Christian Togle, Francis E. Andrade, Allan G. Gayat, Owen B. Buenafe

School of Agriculture, University of Negros Occidental-Recoletos,, 6100 Bacolod City, Philippines

Article history:
Submission 31 September 2024
Revised 07 October 2024
Accepted 23 October 2024

**Corresponding author:*
E-mail:
docpaulonal011260@gmail.com

ABSTRACT

Carrots (*Daucus carota*) is an essential vegetable because of its high beta-carotene (Vitamin A). This study seeks to determine the growth and yield performance of carrots applied with different concentrations of bio-stimulant (BSS). This study was conducted at the University of Negros Occidental – Recoletos, School of Agriculture last December 28, 2023 to March 27, 2024. Eighty (80) carrot seeds (Kaneko Bonfire Variety) were used as planting materials. The seedlings were transferred in polyethylene bags using the Complete Randomized Design (CRD) with four treatments replicated four times. The treatments were the Control (no BSS), 10%, 20%, and 30% BSS. The BSS was applied at the plant base 15 and 35 days after transplanting (DAT). The data gathered was analyzed utilizing the STAR 2.1.0 software. To determined the relationships among different characteristics, we used Pearson's Product Moment Correlation Analysis to assess the correlations and associations. The results indicate that plants applied with 30%BSS have an average stem length of 17.79cm, more foliage of 7.95, bigger taproots with 9.28cm, heavier taproots of 32.45gm, heavy stems and leaves at 16.35gm, biomass accumulation of 46.60gm, and average yield of 16,225kg/hectares. The control (0 BSS), on the other hand, has an average stem length of 14.75cm, fewer leaves at 7.10, smaller taproots with 7.59cm, lighter taproots of 16.90gm, the lighter weight of stems and leaves at 10.15gm, smaller biomass accumulation of 28.98gm, and lower yields at 8,450kg/hectare. This study recommends the application of 30% bio-stimulant concentration in enhancing the growth and yield performance of the carrot plants.

Keywords*: Beta-carotene, Biomass, Bio-stimulant, Genome, Foliage, Yield, Taproots*

How to cite:
Oñal, Jr., P. A., Cabillan, E. B., de la Paz, N. A. A., Togle, C., Andrade, F. E., Gayat, A. G., & Buenafe, O. B. (2024). Growth and Productivity of Carrots *(Daucus carota)* Applied with Bio-Stimulant Solution. *International Journal of Multidisciplinary: Applied Business and Education Research*. *5*(10), 4030 – 4045. doi: 10.11594/ijmaber.05.10.19

Introduction

The carrot (*Daucus carota*) is not just a common root vegetable but a nutritional powerhouse and a staple in global cuisines. Carrots, typically known for their vivid orange hue, come in various colors due to their diverse cultivars, each with a unique flavor profile and health benefits. (Ahmad et al, 2019).

Carrots are usually classified as a vegetable crop that thrives in cool seasons and is cultivated worldwide, with Europe's highest per capita production. However, there has been a considerable increase in production in warmer regions of Asia over the past 50 years (Bolton et al, 2020).

Historically, the carrot was first cultivated for its aromatic leaves and seeds, but over time, selective breeding has focused on enhancing the taproot for its flavor and nutritional content.

The domestic carrot has been shape into a more palatable form, with an agreeable and less fibrous texture, making the root an appealing ingredient in savory and sweet dishes (Amirkhani et al, 2016).

Furthermore, as a biennial plant in the Apiaceae family, the carrot is an agronomic subject of great interest. During its initial year, it undergoes a significant transformation, developing a rosette of leaves while accumulating resources in the taproot. From a botanical perspective, the carrot's germination is classify as epigeal, with cotyledonary leaves emerging above ground as the shoot grows upward.

Understanding the allocation of resources between the shoot and storage root is crucial, as it informs the cultivation techniques that can optimize growth and yield. In the agricultural sciences, studies have delved into how dry matter distribution and assimilation partitioning between these structures are guided by their competitive demands for nutrients and energy (Que et al, 2019).

Nutritionally, carrots are renowned for their abundance of beta-carotene, a precursor to vitamin A, and their rich ascorbic acid content. They also contribute essential macronutrients such as protein, carbohydrates, and dietary fiber, positioning them as a vitamin addition to diets worldwide.

Due to the convergence of terpenoids and polyacetylenes, the characteristic flavor of carrots has made them a sought-after ingredient for culinary experts and home cooks alike (Xie et al, 2022).

Moreover, the roots of carrots contain diverse bioactive compounds, including carotenoids, which are vital for human health (Haq et al, 2015). Carotenoids occur naturally as pigments in plants, algae and certain bacteria. In humans, carotenoids act as antioxidants, helping shield cells against harm resulting from free radicals. These compounds are converted into vitamin A and are known for their potential health benefits. The text reminds us to promote good eye health and enhance the immune system (Anthony, 2018).

In modern horticultural practices, the term 'bio-stimulant' has emerged as a cornerstone, especially in sustainable agriculture. A comprehensive definition highlights the role of bio-stimulants in stimulating natural plant processes to enhance growth, nutrient efficiency, and resilience against abiotic stressors (Bastiaanse et al, 2017).

Extensive research validates the promise of bio-stimulants, revealing their capacity to boost plant growth and quality, improve the efficiency of nutrient utilization, and fortify plants against various environmental stresses (Van Oosten et al, 2017). A particular interest in applying bio-stimulants in root vegetables such as carrots has developed.

It has been position that foliar application of bio-stimulants can mitigate the darkening of carrot roots and augment their content of bioactive compounds. It introduces the potential for increasing the nutritional value of carrots and extending their shelf life, which is of significant interest to the agri-food industry (Szczepanek et al, 2020).

A recent study has focused on the sustainability of agricultural techniques, particularly in light of climate change and environmental deterioration. Bio-stimulants represent a strategic response to these challenges, offering a means to enhance agricultural output while minimizing the reliance on synthetic inputs. These natural products, derived from plant extracts or microbial formulations, present an environmentally friendly approach to boosting crop yield and quality.

In the context of carrots, more scientific inquiries are being made into bio-stimulants' effects on their output and quality to ensure sustainable crop management. Bio-stimulants' efficacy in enhancing tomato fruits' yield and functional quality in various agricultural systems also underscores their potential applicability to carrots (Caruso et al, 2019).

Bio-stimulants have drawn considerable attention for their role as plant growth and health enhancers. Utilizing photosynthetic microorganisms is anticipates to be a solution for aiding plant growth, development, and resistance to stress in enclosed environments, such as those intended for space settlement (Renaud et al, 2023).

Their broad benefits include increased crop yields, improved plant vigor, enhanced fruit quality, heightened disease resistance, accelerated germination rates, and boosted photosynthetic efficiency. (Amirkhani et al, 2019).

Bio-stimulants improve the overall quality of seed germination by boosting the percentage of seeds that successfully germinate, increasing the speed at which germination occurs, and ensuring a more consistent and uniform germination process (Qiu et al, 2020).

Additionally, bio-stimulants contribute to plant resilience by fortifying their ability to withstand environmental stresses, an ongoing struggle due to the impacts of climate change. These properties of bio-stimulants hold the promise of not only improving crop performance but also reducing the environmental footprint of agricultural practices. (Jeba et al, 2022).

In particular, applying bio-stimulants presents an opportunity to improve the production and sustainable cultivation of indigenous leafy vegetables like carrots. They can significantly contribute to food security, dietary diversification, and regional and global health.

Bio-stimulants are heralded for their contribution to nutrition efficiency, stress tolerance, and enhancement of crop quality traits, offering a compelling case for their inclusion in modern agricultural protocols (Du, 2015).

A multitude of factor influence the efficacys of bio-stimulants. These include but are not limited to the dosage, timing, application method, the specific crop species or cultivar, growing conditions, and other environmental variables. When applied to the leaves, bio-stimulants can act as systemic agents, requiring effective cuticle penetration to reach the active sites within the plant tissues.

The time available for absorptions became restricted by the requirement for the bio-stimulant to stay as a liquid, which is easiest when the air humidity is near saturation. It becomes essential when plants have treated various elements in field settings. (Grabowska et al, 2021).

The versatility of bio-stimulant application methods, be it through foliar fertilization, fertigation, or direct soil incorporation, has opened new avenues for enhancing crop growth, quality, and resilience to stresses. Recent insights into plant bio-stimulants and microbiome engineering illuminate their pivotal role in crop improvement and stress mitigation. (Lau et al, 2022).

Considering these vast potentials, this study was initiate to explore the application of different concentrations of bio-stimulants to carrot crops. The research intends to determine if these treatments can improve carrot growth and productivity, providing farmers with cost-effective options (Roy, 2024).

The combination of plant microbial bio-stimulants, ProbioHumus and NaturGel, has significantly enhanced the quality of carrots grown in organic and non-organic farming environments. When combined, bio-stimulants have shown to boost the levels of monosaccharides, ascorbic acid, carotenoids, and phenols in carrots, thus increasing their antioxidant activity.

Recently, a growing focus has been on applying plant-beneficial microorganisms, known as probiotics, as a partial replacement for chemical fertilizers. The increasing need for sustainable agriculture and the European Green Deal initiative drove this shift. Probiotic microorganisms for plants can serve various functions, including protection, biocontrol, biofertilization, and bio-stimulation.

Plant bio-stimulants are broadly define as substances or microorganisms supplied to plants primarily to enhance their growth, improve yield, and boost the overall quality of the crops, particularly regarding their nutrient content.

Probiotics offer the potential to replace chemical fertilizers with bio-fertilizers and contribute to producing highly functional foods, which can have dual benefits for human health.

Furthermore, research has shown that probiotics can mitigate the adverse effects of chemical fertilization on vegetables, such as nitrate accumulation, in organic farming, which strictly prohibits synthetic fertilizers. Improved nutritional properties define the products obtained. Therefore, applying plant probiotics as bio-fertilizers could provide a viable solution to enhance crops and vegetables' food quality and nutritional value. Nevertheless, it is essential to note that organic farming is often associated with lower crop yields and higher production costs. (Gavelienė et al, 2021).

It is crucial to understand that while bio-stimulants can positively increase crop yield and quality, their effects are limited and must be combine with other techniques to ensure optimal results, especially given the current challenges of climate change. Effective crop management practices and the utilization of sustainable resources are essential alongside the use of bio-stimulants.

In recent years, there has been a growing interest in developing new bio-stimulants to enhance agricultural production. Over the past two decades, these products have been widely recognized as promising solutions for mitigating the adverse effects of global changes on agricultural productivity.

The European Bio-stimulant Industry Council (EBIC) has provided a comprehensive definition of bio-stimulants, stating that they contain substances and microorganisms that are apply to plants or the rhizosphere to stimulate natural processes, thereby enhancing nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and overall crop quality.

Bio-stimulants can classified in various ways, and these classifications may sometimes overlap, making it challenging to distinguish them from other types of chemicals. However, the primary goal of bio-stimulants is to improve crop production and quality by enhancing plants' nutrient use efficiency and increasing their stress tolerance, all without directly delivering additional nutrients (fertilizers) or eradicating pests and diseases (phytosanitary treatments).

In the European Union, a plant bio-stimulant is consider a fertilizing product designed solely to stimulate plant nutrition processes regardless of the product's nutrient content. The purpose of enhancing one or more of the following specific plant or plant rhizosphere's characteristics include nutrient utilization efficiency, ability to withstand abiotic stress, desirable traits, and the presence of limited nutrients in the soil or rhizosphere (Zulfiqar et al, 2024).

Thus this study is conducted to determine effect of application of different concentrations of bio-stimulant on the growth and yield of carrot plants and to contribute to the pool of knowledge in agriculture and technology.

Theoretical Background

In modern horticultural practices, the term 'bio-stimulant' has emerged as a cornerstone, especially in sustainable agriculture. A comprehensive definition highlights the role of bio-stimulants in stimulating natural plant processes to enhance growth, nutrient efficiency, and resilience against abiotic stressors (Bastiaanse et al., 2017).

Extensive research validates the promise of bio-stimulants, revealing their capacity to boost plant growth and quality, improve the efficiency of nutrient utilization, and fortify plants against various environmental stresses (Van Oosten et al., 2017).

A particular interest in applying bio-stimulants in root vegetables such as carrots has developed. It has been deposited that foliar application of bio-stimulants can mitigate the darkening of carrot roots and augment their content of bioactive compounds. It introduces the potential for increasing the nutritional value of carrots and extending their shelf life, which is of significant interest to the agri-food industry (Szczepanek et al., 2020).

A recent study has focused on the sustainability of agricultural techniques, particularly in light of climate change and environmental deterioration. Bio-stimulants represent a strategic response to these challenges, offering a means to enhance agricultural output while minimizing the reliance on synthetic inputs. These natural products, derived from plant extracts or microbial formulations, present an environmentally friendly approach to boosting crop yield and quality.

In the context of carrots, more scientific inquiries are being made into bio-stimulants' effects on their output and quality to ensure sustainable crop management. Bio-stimulants' efficacy in enhancing tomato fruits' yield and functional quality in various agricultural systems also underscores their potential applicability to carrots (Caruso et al., 2019).

Bio-stimulants have drawn considerable attention for their role as plant growth and health enhancers. Utilizing photosynthetic microorganisms is anticipate to be a solution for aiding plant growth, development, and resistance to stress in enclosed environments, such as those intended for space settlement (Renaud et al., 2023).

Their broad benefits include increased crop yields, improved plant vigor, enhanced fruit quality, heightened disease resistance, accelerated germination rates, and boosted photosynthetic efficiency. (Amirkhani et al., 2019). Bio-stimulants improve the overall quality of seed germination by boosting the percentage of seeds that successfully germinate, increasing the speed at which germination occurs, and ensuring a more consistent and uniform germination process (Qiu et al., 2020).

Additionally, bio-stimulants contribute to plant resilience by fortifying their ability to withstand environmental stresses, an ongoing struggle due to the impacts of climate change. These properties of bio-stimulants hold the promise of not only improving crop performance but also reducing the environmental footprint of agricultural practices. (Jeba et al., 2022).

In particular, applying bio-stimulants presents an opportunity to improve the production and sustainable cultivation of indigenous leafy vegetables like carrots. They can significantly contribute to food security, dietary diversification, and regional and global health.

Bio-stimulants are selected for their contribution to nutrition efficiency, stress tolerance, and enhancement of crop quality traits, offering a compelling case for their inclusion in modern agricultural protocols (Du Jardin, 2015).

A multitude of factor influence the efficacy of bio-stimulants. These include but are not limited to the dosage, timing, application method, the specific crop species or cultivar, growing conditions, and other environmental variables. When applied to the leaves, bio-stimulants can act as systemic agents, requiring effective cuticle penetration to reach the active sites within the plant tissues. The time available for absorptions was restricted by the requirement for the bio-stimulant to stay as a liquid, which is easiest when the air humidity is near saturation. It becomes essential when plants have treated various elements in field settings (Grabowska et al., 2012).

The versatility of bio-stimulant application methods, be it through foliar fertilization, fertigation, or direct soil incorporation, has opened new avenues for enhancing crop growth, quality, and resilience to stresses. Recent insights into plant bio-stimulants and microbiome engineering illuminate their pivotal role in crop improvement and stress mitigation. (Lau et al., 2022).

Considering these vast potentials, this study was initiated to explore the application of different concentrations of bio-stimulants to carrot crops. The research intends to determine if these treatments can improve carrot growth and productivity, providing farmers with cost-effective options (Roy, 2024).

The combination of plant microbial bio-stimulants, ProbioHumus and NaturGel, has significantly enhanced the quality of carrots grown in organic and non-organic farming environments. When combined, bio-stimulants have shown to boost the levels of monosaccharides, ascorbic acid, carotenoids, and phenols in carrots, thus increasing their antioxidant activity.

Recently, a growing focus has been on applying plant-beneficial microorganisms, known as probiotics, as a partial replacement for chemical fertilizers. The increasing need for sustainable agriculture and the European Green Deal initiative drove this shift. Probiotic microorganisms for plants can serve various functions, including protection, biocontrol, bio-fertilization, and bio-stimulation.

Plant bio-stimulants are broadly define as substances or microorganisms supplied to plants primarily to enhance their growth, improve yield, and boost the overall quality of the crops, particularly regarding their nutrient content. Probiotics offer the potential to replace chemical fertilizers with bio-fertilizers and contribute to producing highly functional foods, which can have dual benefits for human health.

Furthermore, research has shown that probiotics can mitigate the adverse effects of chemical fertilization on vegetables, such as nitrate accumulation, in organic farming, which strictly prohibits synthetic fertilizers. Improved nutritional properties define the products obtained. Therefore, applying plant probiotics as bio-fertilizers could provide a viable solution to enhance crops and vegetables' food quality and nutritional value. Nevertheless, it is essential to note that organic farming is often associated with lower crop yields and higher production costs. (Gavelienė et al., 2021).

It is crucial to understand that while bio-stimulants can positively impact crop yield and quality, their effects are limited and must be combined with other techniques to ensure optimal results, especially given the current challenges of climate change. Effective crop management practices and the utilization of sustainable resources are essential alongside the use of bio-stimulants.

In recent years, there has been a growing interest in developing new bio-stimulants to enhance agricultural production. Over the past two decades, these products have been widely recognized as promising solutions for mitigating the adverse effects of global changes on agricultural productivity.

The European Bio-stimulant Industry Council (EBIC) has provided a comprehensive definition of bio-stimulants, stating that they contain substances and microorganisms that are applied to plants or the rhizosphere to stimulate natural processes, thereby enhancing nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and overall crop quality.

Bio-stimulants can classified in various ways, and these classifications may sometimes overlap, making it challenging to distinguish them from other types of chemicals. However, the primary goal of bio-stimulants is to improve crop production and quality by enhancing plants' nutrient use efficiency and increasing their stress tolerance, all without directly delivering additional nutrients (fertilizers) or eradicating pests and diseases (phytosanitary treatments).

In the European Union, a plant bio-stimulant is consider a fertilizing product designed solely to stimulate plant nutrition processes regardless of the product's nutrient content. The purpose of enhancing one or more of the following specific plant or plant rhizosphere's characteristics include nutrient utilization efficiency, ability to withstand abiotic stress, desirable traits, and the presence of limited nutrients in the soil or rhizosphere (Zulfiqar et al., 2024).

Objective of the Study

This study aimed to determine the effect of applying the different levels of concentration of bio-stimulant solution on the growth and yield of carrot plant.

Specifically, it aims to:

1. Determine the effect of applying the different levels of concentration of bio-stimulant solution on the growth of the carrot plant.
2. Determine if there is a significant increase in the yield of carrot plants applied with different concentrations of bio-stimulant solution.
3. Determine other characteristics of the carrot plant that are directly correlated with the length of stems and tap root weight.

Research Design and Treatments

This study is laid out in Complete Randomize Design (CRD), the use of CRD is the standard design for agricultural experiments where similar experimental units are grouped into blocks.

This study applies the different levels of concentrations of bio-stimulant solution on carrot plants. It is conducted at the University of Negros Occidental-Recoletos, School of Agriculture, Bacolod City, Philippines for the period December 2023 to March 2024.

Treatments

T1- Control (no BSS)
T2- 10% BSS
T3- 20% BSS
T4- 30% BSS

Cultural Management

Area Preparation and Lay-outing

The area was cleared and the layout was done per research design. The type soil was sandy clay loam.

Seedling Preparation

Used egg trays were utilized as seedling container in sowing the carrot seeds. The plant were watered before and after sowing until it reaches 60% germination

Transplanting

Carrot seedlings were transferred in polyethylene bags 26 days after sowing, eighty (80) carrot seedlings utilized for our study.

Water Management

Soil moisture was maintained by watering as needed.

Weed Management

Cleanliness of the area was done by removing the weeds.

Pests and Diseases Control

Monitoring for the presence of pests and diseases was done during the entire duration of the study.

Harvesting

Harvesting of cucumber fruits was done by priming starting forty-five (45) days after sowing. Fruits were carefully cut from the vines using a pruning knife.

Preparation and Application of Bio-stimulant Solution

a. Preparation of solutions was done at the onset of every application.
b. The required concentrations per treatment were diluted in water.
c. Application of solutions was done 15 and 35 days after transplanting. A plastic measuring cup was used to measure the solution for even distribution.
d. The mixture was applied at the base of the plants.
e. Application was done early in the morning or late in the afternoon.

Data Gathered

1. Number of Leaves
2. Length of Stems
3. Length of Tap Roots
4. Diameter of Tap Roots
5. Weight of Tap Roots
6. Weight of Stems and Leaves
7. Biomass
8. Yield

Statistical Analysis

All data gathered were computed statistically. It was subjected to Analysis of Variance (ANOVA) in CRD using STAR 2.0.1.

The Least Significant Differences (LSDs) were utilized to determine the significant differences among treatments.

Pearson's Product Moment Correlation Coefficient was used to measure the strength of the linear correlation between two variables.

Results and Discussions

Number of Leaves

The data taken shows that the number of leaves at three critical growth stages: 20, 40, and 60 days after transplanting is transcribe in Table 1. The application of bio-stimulants significantly hasten the leaf production at 20DAT and 60DAT and has moderate significant effect at 40DAT.

It is worth noting that the highest leaf count at each stage is observe in treatment with 30%BSS concentration. On the other hand, the control (no BSS) consistently exhibited the lowest leaf count, indicating the stimulating effect of the bio-stimulant throughout the growth period.

In particular, at 20 DAT carrots applied with 30%BSS produce the highest number of leaves of 4.90 higher by 27.27% or 1.05 leaves than 0% BSS. Comparative results is shown by those applied with 20%BSS and 10%BSS with average of 4.40 and 4.25 leaves, respectively.

At 40DAT, the result indicates a moderate significant at 5% level. A comparative result is shown between the plants applied with 30%BSS and 20%BSS with average of 6.90 and 6.65 leaves, respectively. Same result is indicated between those applied with 20%BSS and 10%BSS with 6.65 and 6.40 leaves as well. Those with 0%BSS had produced the lowest number of leaves with an average of 6.25 only.

Furthermore, the application of different levels of concentration of bio-stimulant shows the same trend viz-a-viz the production of leaves of carrot plants at 60DAT.

Plants applied with 30%BSS produces the most number of leaves with 7.95 higher by 11.97% or an average of 0.85 leaves from plants with 0%BSS. Zero percent BSS has the lowest production of 7.10 leaves only. Relatively, comparable result is observe between the 10%BSS application and 0%BBS with 7.10 and 7.16 leaves, respectively.

Table 1. The average number of leaves of carrot plants applied with different levels of concentration of Bio-stimulant solution 20DAT, 40DAT and 60DAT.

Concentration of Bio-stimulant	Average Number of Carrot Plants		
	20DAT	40DAT	6oDAT
T1 – Control (no BSS)	3.85^{c}	6.25^{c}	7.10^{c}
T2 – 10% BSS	4.25^{b}	6.40^{bc}	7.16^{c}
T3 – 20% BSS	4.40^{b}	6.65^{ab}	7.47^{b}
T4 – 30% BSS	4.90^{a}	6.90^{a}	7.95^{a}
Mean	**4.35**	**6.55**	**7.42**
Pr (>F)	0.0000**	0.0101*	0.0000**
CV (%)	3.38	3.58	1.55

*Means followed by the same letter are not significantly different at its other, **=highly significant*

It can be deduce from the research conducted by Pobereżny et al. (2020), the results indicated a substantial increase in the growth of carrot leaves and an improvement in the nutrient composition when bio-stimulants were utilize. These positive changes resulted in enhancing the nutrient absorption and processing enabled by the bio-stimulants.

However, it is essential to note that bio-stimulants' had an impact on soil health that may vary depending on factors such as soil type, management practices, crop varieties, and environmental conditions (Saa et al, 2015). This variability could potentially hinder the widespread adoption of bio-stimulants in the agricultural sector.

After analyzing the data, it is apparent that there are substantial variations in the leaf count across different treatment groups, with 30% BSS yielding auspicious outcomes. These findings suggest a compelling association between bio-stimulant concentration in carrot plants and their leaf development.

These findings underscore the significance of conducting further research, highlighting the need to pinpoint the most effective bio-stimulant dosages for optimizing vegetative growth. This optimization could increase plant vitality and potentially higher yields (Nikmatullah et al, 2021).

Length of Stems

The stem length data in Table 2 show a highly significant result at 20DAT, 40DAT, and at 60DAT, respectively. These results highlight the impact of application of different levels of concentration of BSS on stem length and suggest differential effects on plant development at various stages.

Overall, carrot plants applied with 30%BSS concentration produced the longest stems as compared to those plants with no BSS application at different period of growth.

At 20DAT plants applied with 30%BSS produces the longest stem of 13.62cm longer by 74.84% or 5.83cm from those with 0%BSS with has the shortest length of 7.70cm only. Those applied with 20%BSS and 10%BSS the average length of 12.02cm and 8.67cm, respectively, which is comparable among the two concentration.

Relatively at 40DAT application of 30%BSS has still the greatest result with 17.11cm a difference of 17.76% or 2.92cm from those plants with 0%BSS which has a length of 14.19cm, the shortest among the different concentration. A comparative result is observe for plants applied with 20%BSS and 10%BSS with a stem length of 15.75cm and 15.13cm, respectively.

Same trend is observe with the data taken at 60DAT. Plants applied with 30%BSS has the longest leaf with 17.79cm a difference of 20.61% or 3.04cm from those plants with 0%BSS with 14.75cm only. Furthermore, a comparative result is observe between plants applied with 20%BSS and 10%BSS concentration with 16.66cm and 15.76cm, respectively.

The result indicates that the length of the stem of the carrot plant could be enhance significantly with high concentration of BSS.

Table 2. The average length of stems (cm) of carrot plants applied with different levels of concentration of Bio-stimulant solution 20DAT, 40DAT and 60DAT.

Concentration of Bio-stimulant	Average Length of Carrot Leaves		
	20DAT	40DAT	6oDAT
T1 – Control (no BSS)	7.79^{d}	14.19^{c}	14.75^{c}
T2 – 10% BSS	8.67^{c}	15.13^{b}	15.76^{b}
T3 – 20% BSS	12.02^{b}	15.75^{b}	16.66^{b}
T4 – 30% BSS	13.62^{a}	17.11^{a}	17.79^{a}
Mean	**10.52**	**15.54**	**16.24**
Pr (>F)	0.0000**	0.0000*	0.0001**
CV (%)	4.78	3.40	3.91

*Means followed by the same letter are not significantly different at its other, **=highly significant*

It can be deduce from the study of the group of Renaud in 2023 that Bio-stimulants have drawn considerable attention for their role as plant growth and health enhancers. Utilizing photosynthetic micro-organisms which is one of the component of bio-stimulant which could be a solution for aiding plant growth, development, and resistance to stress.

Length, Diameter, and Weight of Taproots

Table 3 discuss the three most important variables gathered in relation to the yield as well as the reaction of carrot plants on the application of the different concentration of bio-stimulant.

Length of Taproots

The table (table 3) shows the reaction of the length of the taproot of carrots as applied with the different levels of concentration of bio-stimulant solution taken at 60DAT. The result shows that taproot length does not influence by the application or non-application of bio-stimulant solution.

Diameter of Taproots

The size of the taproot of carrots is significantly influence by the application of bio-stimulant at higher concentration. Bigger taproot size is being produced with the application of 30%BSS with average diameter of 9.28cm.

A comparative result is observe between the application of 20%BSS and 10%BSS with an average diameter of 8.08cm and 7.85cm, respectively. Same observation is shown between the application of 10%BSS and 0%BSS with an average diameter of 7.85cm and 7.59cm, respectively.

Weight of Taproots

Weight of the taproots also significantly influence with the application of different concentrations of BSS. Relatively heavier taproots are produce at carrot plants applied with greater concentrations of BSS.

Foremost, plants applied with 30%BSS has produced the heaviest taproot of 32.45gm higher by 92.01% or an average difference of 15.55gm from those plants with 0%BSS which is the lightest among the treatments. Comparative result is shown between the plants applied with 20%BSS and 10%BSS with average weight of 21.80gm and 20.02gm, respectively.

Table 3. The average length (cm), diameter (cm) and weight of carrot taproots applied with different levels of concentration of Bio-stimulant 60DAT.

Concentration of Bio-stimulant	Length of Taproot (cm)	Diameter of Taproot (cm)	Weight of Taproot (gm)
T1 – Control (no BSS)	13.67	7.59^{c}	16.90^{c}
T2 – 10% BSS	14.09	7.85^{bc}	20.02^{b}
T3 – 20% BSS	14.20	8.08^{b}	21.80^{b}
T4 – 30% BSS	15.13	9.28^{a}	32.45^{a}
Mean	**14.27**	**8.20**	**22.79**
Pr (>F)	0.0631^{ns}	0.0000*	0.0000**
CV (%)	4.84	3.41	6.94

*Means followed by the same letter are not significantly different at its other, ns= not significant, **=highly significant*

Taproot length, diameter, and weight measurements indicate that applying microbial biostimulants, such as ProbioHumus and NaturGel, has increased the average weight of carrot roots (Nikmatullah, 2021). Moreover, these bio-stimulants have promoted the accumulation of monosaccharides, ascorbic acid, carotenoids, and phenols in the taproots.

The above-mentioned results further intricate dynamics between bio-stimulants and carrot plant development, which could provide valuable insights for optimizing agricultural practices and enhancing crop productivity.

Weight of Stems & Leaves and Biomass

Weight of Stems and Leaves

The average weight of stem and leaves of carrots at different levels of concentrations of Bio-stimulant is shown in Table 4. The results indicate that application of different levels of concentration of bio-stimulant can significantly affect the weight of stem and leaves of carrots plants.

The data was determined at 60DAT and the result shows that the heaviest weight of stem and leaves was observe on the carrot plants applied with 30%BSS and 20%BSS with 16.35gm and 15.20gm, respectively which are significantly comparable. Plants with 0%BSS has the lightest weight of 10.15gm only.

The Biomass

Biomass is the total volume of dry matter produced by any plant. The biomass of the carrot plants also determined at 60DAT. It also indicates that the accumulation of biomass of the carrot plants is greatly influence by the application of different levels of concentration of biostimulant

Plants applied with 30%BSS accumulated the highest volume of biomass with 46.60gm heavier by 28.20% or 10.25gm higher for those applied with 20%BSS with 36.35gm. A comparable result is observe between those plant applied with 10%BSS and no BSS application with 30.30gm and 28.98gm, respectively lower from the two other concentration mentioned above.

It indicates that heavier stems and greater volume of biomass can be realize by applying a higher concentration of bio-stimulant to carrot plants.

Table 4. The average weight of stems and leaves (gm) as well as the biomass (gm) of carrot plants applied with different levels of concentration of Bio-stimulant 60DAT.

Concentration of Bio-stimulant	Weight of Stems and Leaves (gm)	Biomass (gm)
T1 – Control (no BSS)	10.15[c]	28.98
T2 – 10% BSS	12.00[b]	30.30[cc]
T3 – 20% BSS	15.10[a]	36.35[b]
T4 – 30% BSS	16.35[a]	46.60[a]
Mean	**13.40**	**35.56**
Pr (>F)	0.0000**	0.0000**
CV (%)	6.25	5.02

Means followed by the same letter are not significantly different at its other, ns= not significant

The weight of the taproot, which is a vital component of yield, shows a robust positive correlation with the number of leaves and the weight of stems and leaves. It suggests that biomass accumulation above ground is intricately link with the growth of roots below ground.

Moreover, the diameter of the taproot, overall biomass, and yield all exhibit strong correlations with root weight, underlining the pivotal role of more extensive and healthier roots in enhancing overall plant vigor and productivity. This thorough assessment offers a detailed examination of the significance and impact of an array of natural plant bio-stimulants on the yield and quality of crops. (Drobek et al, 2019).

The Yield

The average yield of carrot plant is greatly influence by the application of different concentrations of bio-stimulant. A significant result is obtain on the carrot yield with highest concentration of the same.

Plants applied with 30%BSS has the highest yield of 16.225.00kg/ha which is higher by 92.20% or a difference of 7,775.00kg/ha from plants with no BSS application with 8,450.00kg/ha only which is the lowest among the treatments.

A comparative result is observe between carrot plants applied with 20%BSS and 10%BSS with average weight of 10,900.00kg/ha and 10,012.50kg/ha, respectively.

Table 5. The average yield (kg/ha) of carrot plants applied with different levels of concentration of Bio-stimulant 60DAT.

Concentration of Bio-stimulant	Yield (kg/ha)
T1 – Control (no BSS)	8,450.00[c]
T2 – 10% BSS	10,012.50[b]
T3 – 20% BSS	10,900.00[b]
T4 – 30% BSS	16,225.00[a]
Mean	**11,396.88**
Pr (>F)	0.0000**
CV (%)	6.94

Means followed by the same letter are not significantly different at its other, ns= not significant

The research highlighted above offers compelling evidence that plant microbial bio-stimulants significantly impacts the weight and quality of carrot roots and the accumulation of beneficial substances.

According to Gavelienė et al (2021), these bio-stimulants improved the weight and quality of carrot roots, reinforcing the idea that they play a crucial role in enhancing crop yields.

They similarly demonstrated that applying the soil bio-stimulant Agriful resulted in a noteworthy 4.47% increase in the average weight of carrot taproots, effectively contributing to a higher overall yield. (Fabianová et al, 2021).

Moreover, using plant microbial bio-stimulants was associated with a significant 10g increase in root weight. It is worth emphasizing the dynamic and complex nature of the microbial communities within the rhizosphere microbiome.

These communities often called the plant's second genome, form intricate and essential relationships with the host plant. As highlighted, the plant microbiome plays a crucial role in influencing plant fitness and growth while protecting against diseases and aiding the plant's resistance to environmental stresses (Afridi et al., 2022).

Characteristics Correlated with the Length of Stems of Carrot Plants

Table 6 shows the characteristics that are correlates with the length of stems of the carrot plants. Among the characteristics tested for correlation with the length stem of carrot plants, five characteristics are positively correlate.

Among the positive correlations are, the number of leaves, weight of stems and leaves, diameter of taproots, biomass, and yield are strongly correlated with the length of stems, with coefficient *r-values* of 0.84, 0.90, 0.81, 0.88, and 0.87, respectively.

Table 6. Characteristics of carrot plants that significantly correlated with the length of stems applied with different levels of concentration of bio-stimulant solution

Characteristics Correlated with Length of Stems	Correlation Coefficient *(r)*	P-value	Interpretation
Number of leaves	0.8468	0.0000**	Strong (+) linear correlation
Weight of stems and leaves	0.9063	0.0000**	Strong (+) linear correlation
Diameter of taproot	0.8143	0.0001**	Strong (+) linear correlation
Biomass	0.8853	0.0000**	Strong (+) linear correlation
Yield	0.8759	0.0000**	Strong (+) linear correlation

***=highly significant at a 1% level of probability,*

Characteristics Correlated with the Taproot Weight of Carrot Plants

Table 7 indicates the characteristics that correlates with the taproot weight of carrot plants. Among the characteristics tested for correlation with the taproot weight of carrot plants, five characteristics are positively correlate.

Among the positive correlations are, the number of leaves, weight of stems and leaves, diameter of taproot, and biomass are all strongly correlated with the weight of taproots, with a coefficient *r-values* of 0.91, 0.84, 0.90, and 0.96, respectively. The yield has a perfect correlation with *r-value* of 1.00.

Table 7. Characteristics of carrot plants that significantly correlated with the weight of taproots applied with different levels of concentration of bio-stimulant solution.

Characteristics Correlated with the Weight of Taproot	Correlation Coefficient *(r)*	P-value	Interpretation
Number of leaves	0.9139	0.0000**	Strong (+) linear correlation
Weight of stem and leaves	0.8411	0.0000**	Strong (+) linear correlation
Diameter of taproot	0.9017	0.0003**	Strong (+) linear correlation
Biomass	0.9628	0.0000**	Strong (+) linear correlation
Yield	1.000	0.0000**	Perfect (+) linear correlation

***=highly significant at a 1% level of probability,*

Conclusion and Recommendations

The application of bio-stimulants at varying concentrations has a significant effect on carrot vegetative growth's and productivity parameters. Notably, application of 30%BSS concentration demonstrated the most substantial influence on the number of leaves, stem length, weight of the stem and leaves, the weight and diameter of the taproot, the accumulated biomass, and yield of the carrot crop. Interestingly, the taproot length remained unaffected by the bio-stimulant application, suggesting a selective impact on specific growth characteristics.

Based on these findings, applying a concentration of 30% of bio-stimulant effectively enhances the growth and yield of carrot plants. Additionally, a strong correlation has been identify between several growth characteristics and the productive capacity of the plants, indicating the intricate link between vegetative growth and yield outcomes.

These results suggest the potential for targeted bio-stimulant application to optimize carrot crop production. This study aims to determine the most effective treatment to improve the development and production of carrots by evaluating the impact of various concentrations of bio-stimulant application (De Vasconcelos and Chaves, 2020).

The researchers highly recommend using 30% levels of concentration of bio-stimulant in carrots' growth and yield performance. In addition, based on our study's results and the significant correlations observed, the following recommendations are propose to optimize the growth and yield of carrots.

It is recommend that application of 30% concentrations of bio-stimulant be incorporate as a standard practice to enhance the overall carrots and yield. This specific concentration has proven to be highly effective across various growth parameters, including the number of leaves, weight of stems and leaves, diameter of the taproot, the accumulated biomass and yield of the carrot crops.

When cultivating carrots, it is essential to employ correct cultivation techniques to enhance the overall growth and yield of the crop. Additionally, selecting superior seed varieties is crucial in influencing carrot production. When making cultivation decisions, it is essential to consider bio-stimulants impact on specific traits such as leaf number, stem length, and taproot diameter. These considerations are vital in ensuring successful carrot cultivation.

Regarding cultivation and crop production, the monitoring and evaluation process is essential for ensuring the health and success of our crops. It is vital to consistently evaluate the state of our carrot crops and take immediate action to address any issues hindering their growth. By closely monitoring our crops, we can intervene proactively to prevent any problems from escalating.

In addition, optimizing the yield of our carrot crops is a key priority. Research indicates that adjusting the dosage of bio-stimulants can significantly impact the overall yield. By carefully fine-tuning the concentration of bio-stimulants, we can aim to achieve our desired yield targets.

It is essential to recognize a correlation between the dosage of bio-stimulants and the resulting yield. In general, higher dosages of bio-stimulants lead to improved growth and higher yields for our carrot crops.

The researchers plan to conduct additional in-depth studies focusing on the effects of varying bio-stimulant concentrations on carrot plants' growth parameters. These extended studies will thoroughly examine various carrot varieties to evaluate their impact on the ultimate yield.

In future research, it would be beneficial to include a diverse range of carrot varieties to evaluate their specific responses to bio-stimulant application. This approach will allow for a more customized and targeted use of bio-stimulants, considering each variety's unique characteristics.

Investigate the long-term effects of consistent bio-stimulant use on soil health and carrot crop sustainability to ensure that increased yields do not compromise future production capabilities.

Conflict of Interest

No other group is involved in this study

Acknowledgment

Our deepest gratitude to our fellow faculty, the school administrators, and the students who are involved in this study.

References

Afridi, M. S., Ali, S., Salam, A., Terra, W. C., Hafeez, A., Sumaira, N., Ali, B., AlTami, M. S., Ameen, F., Ercisli, S., Marc, R. A., Medeiros, F. H. V., & Karunakaran, R. (2022). Plant Microbiome Engineering: Hopes or hypes. *Biology*, *11*(12), 1782. https://doi.org/10.3390/biology11121782

Ahmad, N., Cawood, N., Iqbal, N., Ariño, N., Batool, N., Tariq, N., Azam, N., & Akhtar, N. (2019). Phytochemicals in Daucus carota and Their Health Benefits—Review Article. *Foods*, *8*(9), 424. https://doi.org/10.3390/foods8090424.

Amirkhani, M., Mayton, H. S., Netravali, A. N., & Taylor, A. G. (2019). A seed coating delivery system for Bio-Based biostimulants to enhance plant growth. *Sustainability*, *11*(19), 5304. https://doi.org/10.3390/su11195304.

Amirkhani, M., Netravali, A. N., Huang, W., & Taylor, A. G. (2016). Investigation of soy protein–based biostimulant seed coating for broccoli seedling and plant growth enhancement. *HortScience*, *51*(9), 1121–1126. https://doi.org/10.21273/hortsci10913-16

Anthony, K. (2018, September 18). *Carotenoids: Everything you need to know*. Healthline. https://www.healthline.com/health/carotenoids

Bastiaanse, H., Théroux-Rancourt, G., & Tixier, A. (2017). Abiotic stress. In A. Groover & Q. Cronk (Eds.), *Plant genetics and genomics: crops and models* (pp. 275–302). Springer, Cham. https://doi.org/10.1007/7397_2016_13

Bolton, A., Klimek-Chodacka, M., Martin-Millar, E., Grzebelus, D., & Simon, P. W. (2020). Genome-assisted improvement strategies for climate-resilient carrots. In C. Kole (Ed.), *Genomic designing of climate-smart vegetable crops* (pp. 309–343). Springer, Cham. https://doi.org/10.1007/978-3-319-97415-6_6

Caruso, G., De Pascale, S., Cozzolino, E., Cuciniello, A., Cenvinzo, V., Bonini, P., Colla, G., & Rouphael, Y. (2019). Yield and nutritional quality of Vesuvian Piennolo Tomato PDO as affected by farming system and biostimulant application. *Agronomy*, *9*(9), 505. https://doi.org/10.3390/agronomy9090505.

De Vasconcelos, A. C. F., & Chaves, L. H. G. (2020b). Biostimulants and their role in improving plant growth under abiotic stresses. In S. Mahyar (Ed.), *Biostimulants in Plant Science*. https://doi.org/10.5772/intechopen.88829

Drobek, M., Frąc, M., & Cybulska, J. (2019). Plant Biostimulants: Importance of the quality and yield of horticultural crops and the improvement of plant tolerance to abiotic Stress—A review. *Agronomy*, *9*(6), 335. https://doi.org/10.3390/agronomy9060335

Du Jardin, P. (2015). Plant biostimulants: Definition, concept, main categories and Regulation. *Scientia Horticulturae*, *196*, 3–14. https://doi.org/10.1016/j.scienta.2015.09.021

Fabianová, J., Andrejiová, A., Šlosár, M., Hegedűsová, A., & Benzová, L. (2021). The effect of soil biostimulant AgriFul on the selected quantitative and qualitative parameters of carrot (Daucus carota subsp. sativus (Hoffm.) Arcang.). *Slovak Journal of Food Sciences*, *15*, 1120–1127. https://doi.org/10.5219/1696

Gavelienė, V., Šocik, B., Jankovska-Bortkevič, E., & Jurkonienė, S. (2021). Plant Microbial Biostimulants as a Promising Tool to Enhance the Productivity and Quality of Carrot Root Crops. *Microorganisms*, *9*(9), 1850. https://doi.org/10.3390/microorganisms9091850

Grabowska, A., Kunicki, E., Sękara, A., Kalisz, A., & Wojciechowska, R. (2012). The effect of cultivar and biostimulant treatment on the carrot yield and its quality. *Journal of Fruit and Ornamental Plant Research*, *77*(1), 37–48.

https://doi.org/10.2478/v10032-012-0014-1

Haq, R., & Prasad, K. (2015). Nutritional and Processing aspects of carrot (Daucus carota)-A review. *South Asian Journal of Food Technology and Environment*, *1*(1), 1–14. https://doi.org/10.46370/sajfte.2015.v01i01.01

Jeba, F. R., Farzana, M., Tabassum, T., Rahaman, T. I., Ullah, A., Araf, Y., Ansary, M. W. R., Gupta, D. R., Chakraborty, M., & Islam, T. (2022b). Biostimulants for promoting eco-friendly sustainable agriculture. In M. Hasanuzzaman (Ed.), *Biostimulants for Crop Production and Sustainable Agriculture* (pp. 36–54). https://doi.org/10.1079/9781789248098.0003

Lau, S. E, W. F., A. Teoh, E. Y., Tan, B. C. (2022). Microbiome engineering and plant biostimulants for sustainable crop improvement and mitigation of biotic and abiotic stresses. *Discover Food* *2*, 9. Doi:10:1007/s44187-022-00009-5.

Nikmatullah, A., Khairunnisa, N., Amalia, R., Zawani, K., & Sarjan, M. (2021). Effect of biofertilizer on growth and yield of carrot (Daucus carota l.) plants in different latitudes of Lombok Island. *IOP Conference Series. Materials Science and Engineering*, *1098*, 042107. https://doi.org/10.1088/1757-899x/1098/4/042107

Pobereżny, J., Szczepanek, M., Wszelaczyńska, E., & Prus, P. (2020). The Quality of Carrot after Field Biostimulant Application and after Storage. *Sustainability*, *12*(4), 1386. https://doi.org/10.3390/su12041386.

Qiu, Y., Amirkhani, M., Mayton, H., Chen, Z., & Taylor, A. G. (2020). Biostimulant seed coating treatments to improve cover crop germination and seedling growth. *Agronomy*, *10*(2), 154. https://doi.org/10.3390/agronomy10020154

Que, F., Hou, X., Wang, G., Xu, Z., Tan, G., Li, T., Wang, Y., Khadr, A., & Xiong, A. (2019). Advances in research on the carrot, an important root vegetable in the Apiaceae family. *Horticulture Research*, *6*, 69. https://doi.org/10.1038/s41438-019-0150-6

Renaud, C., Leys, N., & Wattiez, R. (2023). Photosynthetic microorganisms, an overview of their biostimulant effects on plants and perspectives for space agriculture. *Journal of Plant Interactions*, *18*(1). https://doi.org/10.1080/17429145.2023.2242697

Roy, D. (2024). Role of Biostimulants towards Sustainable agriculture: A review. *Food and Scientific Reports*, *5*, 9. https://foodandscientificreports.com/details/role-of-biostimulants-towards-sustainable-agriculture-a-review.html

Saa, S., Rio, A. O., Castro, S., & Brown, P. H. (2015). Foliar application of microbial and plant based biostimulants increases growth and potassium uptake in almond (Prunus dulcis [Mill.] D. A. Webb). *Frontiers in Plant Science*, 6. https://doi.org/10.3389/fpls.2015.00087

Szczepanek, M., Pobereżny, J., Wszelaczyńska, E., & Gościnna, K. (2020). Effect of biostimulants and storage on discoloration potential of carrot. *Agronomy*, *10*(12), 1894. https://doi.org/10.3390/agronomy10121894

Tariq, U., Younis, A., Ahsan, M., & Nadeem, M. (2022c). Biostimulant-induced improvement of soil health and water-use efficiency in plants. In M. Hasanuzzaman (Ed.), *Biostimulants for Crop Production and Sustainable Agriculture* (pp. 72–84). https://doi.org/10.1079/9781789248098.0005

Van Oosten, M. J., Pepe, O., De Pascale, S., Silletti, S., & Maggio, A. (2017). The role of biostimulants and bioeffectors as alleviators of abiotic stress in crop plants. *Chemical and Biological Technologies in Agriculture*, *4*. https://doi.org/10.1186/s40538-017-0089-5

Xie, Q., & Wang, C. (2022). Polyacetylenes in herbal medicine: A comprehensive review of its occurrence, pharmacology, toxicology, and pharmacokinetics (2014-2021). *Phytochemistry*, *201*, 113288.

https://doi.org/10.1016/j.phytochem.2022.113288.

Yousfi, S., Marín, J., Parra, L., Lloret, J., & Mauri, P. V. (2021). A rhizogenic biostimulant effect on soil fertility and roots growth of turfgrass. *Agronomy*, *11*(3), 573. https://doi.org/10.3390/agronomy11030573

Zamana, S. P., Kondratieva, T. D., Savich, V. I., Fedorovsky, T. G., & Sokolov, S. A. (2022). The influence of biostimulants on the qualitative composition of carrots. *IOP Conference Series. Earth and Environmental Science*, *1045*, 012087. https://doi.org/10.1088/1755-1315/1045/1/012087

Zulfiqar, F., Moosa, A., Ali, H. M., Bermejo, N. F., & Munné-Bosch, S. (2024). Biostimulants: a sufficiently effective tool for sustainable agriculture in the era of climate change? *Plant Physiology and Biochemistry*, *211*, 108699. https://doi.org/10.1016/j.plaphy.2024.108699