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Research Article

Effect of Bio-Stimulant Concentrations on Growth and Yield of Peanut *(Arachis hypogaea)* in the Philippines

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ABSTRACT

The study sought to determine the effects of different levels of concentrations of bio-stimulant solution (BSS) in improving the growth and yield performance of peanut plant. The study was conducted at UNO-R, Inc, Philippines last February to June 2024. Biyaya variety was used as planting material. The study was layout in RCBD (Randomized Complete Block Design) with 4 treatments, and replicated 4 times. BSS was diluted in water and applied 6 inches from the base of each plant. Statistical analysis revealed highly significant differences among treatments in growth parameters such as germination period and flower initiation, plant height, weight of stems and leaves, and biomass. For the period of germination, highest plant height, weight of stems and leaves, biomass, and period of flowering they were obtained from plants applied with 15%, followed by 10%, and 5% BSS (α =0.01), respectively. On the other hand, untreated plants have the longest days of germination, shortest height, lightest weight of stem and leaves, as well as the biomass, and late in flower initiation. Furthermore, results showed highly significant differences among treatments in the number of pods per plant, pod weight per plant, number of seeds per pod, total weight of seeds, and yield of peanut (α =0.01). Peanut pods per plant were great in number, heavier in weight from plants treated with 15% BSS among the other treatments, the most number of seeds per pod, and the heaviest seed weight as well as the highest seed yield per hectare (α =0.01). This study recommends the application of 15% BSS for optimal peanut growth and yield.

Keywords: *Bio-stimulant, Legumes, Peanuts, Organic farming, Soil microorganisms, Food sustainability, Yield performance*

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Introduction

Ensuring quality food and crop productivity to provide food security to the growing population is one of the major restraining factors worldwide. By the year 2050, a challenge was given to Agriculture to feed the 2.3 billion people, producing 70% of food crops (Albdaiwi et al, 2019). Securing limited access to sufficient, nutritious, safe but sustainably produced food for the entire population is one of the complex challenges that required collective actions. Sustainable agriculture aimed to grow food in a way that meets the needs of the present without compromising future generations' ability to meet their needs. Society needed to re-focus its goals towards food security while practicing healthy and sustainable cultivation.

Peanut or Arachis hypogaea is one of the many crops that received significant recognition due to its capability to transform local economies and provide food security. Peanut locally known as 'Mani' is an annual crop belonging to the family of Leguminosae, which originated in South America (Basuchaudhuri, 2022). The plant possesses procumbent stems and reaches a maximum height or length of approximately 0.5 meters (20 inches). Its leaves are alternate and compound, bearing 4 ovate to oblong leaflets, each measuring up to 6 centimeters (2.25 inches) in length. The 5-parted flowers are tubular, yellow in coloration, and capable of self-fertilization.

Hypogaea means "under the earth". Peanut grew its legumes and the mature fruit developed into a pod deep in the soil. They are pack with prebiotics and polyphenol substances that promoted a healthy gut environment. Their high energy, protein, and carbohydrate content make them valuable in tackling protein-energy malnutrition and hunger. Numerous studies have linked regular nut consumption to a lowered risk of serious illnesses and better overall health (Jimenez-Lopez, 2021). Additionally, a decent amount of Coenzyme Q10 is boast by the consumption of Peanut. These bioactive compounds are renowned for their disease-preventative properties and are even believe to promote longevity (Moharana et al, 2020).

Known for their sustainability functions, nutritional benefits, and resiliency, Peanut is a valuable crop in Philippine Agriculture. Peanut as a crop not only produced legumes for protein, carbohydrates, and high-valued oils but also medicinal properties like flavonoid and phenolic compounds that benefit humans. The peanuts contains all of the 20 amino acids in variable proportions and is the biggest source of the protein called *"arginine"* (Moharana et al, 2020). According to Syed et al (2020), these compounds present in the crop are composed of disease preventive effects and are consider to promote healthy living for individuals. Peanut as a seemingly ordinary legume holds immense potential as a viable economic crop, holding the key to improving livelihoods and fostering economic growth in resource-challenged communities.

In the Philippines, peanuts are one of the food legumes with economic importance that contributed to the domestic income and livelihood of the local farmers. However, low-yielding varieties are commonly plant in the Philippines. Peanuts serve many uses as it can be eaten raw, cooked in food, made into solvents and oils, textiles, medicine, input materials, and peanut butter, as well as many other uses. Seeds can be pressed for oil production that contains well-balanced fatty acids or a popular snack of roasted or boiled peanuts, and dried leaves can be use to produce a kind of tea.

Peanut crops can grow in warm and temperate regions throughout the world. Production of the crop is influence by a variety of environmental and physical factors, husbandry practice, propagation methods, pests and diseases, a variety of peanuts, soil, and weather conditions. With the appropriate management and practices, peanuts could be of great value to the people and the economy. Peanuts, like other leguminous crops, form a symbiotic relationship with one of the most beneficial bacteria called *rhizobia.*

Dos Santos et al (2020) reported that Rhizobia bacteria are a great alternative for farmers in reducing the reliance on chemical fertilization and pesticide input without promoting the negative environmental impact and yield-reducing production of crops thereby stimulating an improvement in growth and harvest. These improvements include the supply of growth regulators and essential minerals such as potassium, phosphorus, and Nitrogen (Yao et al, 2021).

The Philippines produced roughly 31,520 metric tons of peanuts in 2022, marking a slight uptick from the previous year. This popular crop, prized for its culinary versatility, has seen its production levels fluctuate over time (Statistica, 2023). Region I is the top peanut-producing region in the country with 11,914.50 metric tons of peanut produced in 2020 (Department of Agriculture, 2020). This signify that peanuts are an essential crop in the Filipino diet. Therefore, Peanuts offered significant nutritional, cultural, and economic benefits to the country.

Adopting this promising peanut lines hold the potential to significantly enhanced peanut production. This will result in increased profits for farmers and ultimately drive the growth and sustainability of the entire peanut industry (Bernabe and Sugui, 2019). A thriving peanut production, fueled by increased yield and profitability, can continue to contribute to the economic growth and development in peanut-growing regions. Supplying to the needs and demands of the Filipino Market can translate to greater income for farmers, incentivizing continued investment and innovation in the industry. By providing solutions to the challenges and implementing sustainable management practices, the peanut industry will constantly thrive and contribute to the nation's food security and economic productivity.

Despite its significance, peanut production in the Philippines faced several challenges. Fluctuating weather patterns, diseases, and pests will threaten yields and impact farmers' incomes. Propelled by the increasing threats of environmental and abiotic stressors, soil degradation, and the dire need for sustainable agriculture, researchers were delving into alternative and healthy approaches to foster peanut growth and yield. One promising method is the utilization of bio-stimulants, naturally derived substances that promote plant growth, enhanced nutrient absorption, and strengthen plant resilience against environmental stressors.

Recently, Chemical Agriculture has proven to harm human health and the environment (Elbana et al, 2018). The reliance on such methods could lead to the decline of the natural microorganisms present in the soil. Continuous cropping practices caused a severe decline in peanut yield and thus the use of organic and beneficial active organisms was vital in combating the challenges in peanut production compared to other chemical methods (Yang et al, 2020). This raise concerns about potential health risks associated with consuming crops grown using these chemicals that we thought were helping us. This reliance on unconventional methods will cause a greater problem than there is.

Organic fertilization at appropriate times was essential to stabilize and ensure peanut production with high quality and yield. Bio-stimulants were versatile and could affect all aspects of a plant's life: e.g. nutrition and growth, plant processes and development, to the response to biotic and abiotic stresses encountered, relationship with other organisms in the ecosystem, increased soil fertility and productivity, and overall crop production.

Bio-fertilizers have gained recognition in today's agricultural production as they not only promoted healthy fertilization but also promoted the preservation of the land. Bio-stimulants affect the metabolic and enzymatic processes in plants, thus improving their yield and quality. They are microbial solutions consisting mainly of lactic acid bacteria, photosynthetic bacteria, and yeasts, and organic as they do not contain genetically modified microorganisms.

Bio-stimulants are mainly create by combining natural or organic materials that are hormones or plant hormone drivers. It is also be classified or identified based on the active ingredients used, which was significant because it highlight the idea that biological function will be positively influence to produce optimum production. Proven by many scientific studies, bio-stimulant impact on the vegetable's output and quality while practicing sustainable agriculture. In the study of Caruso et al (2019), Bio-stimulants had seen to increase the yield and production of tomato plants in a conventional and organic vegetable system. Bio-stimulants, comprising organic compounds, active microorganisms, or extracts from other plants, had shown promising results in various crop productions.

Hellequin et al (2020) reported that these beneficial microorganisms present in the substance, function greatly in the plant and the root zone area in the soil. It encouraged effective biological processes for plants to better absorbed the needed nutrients, the consistent utilization of nutrients, and the adaptation of plants to environmental or external stresses. The most vital advantage that were mention are important in the growth and development of the crop to get the most benefit from it.

The ability of bio-stimulants to alleviate abiotic stress and promote sustainable agriculture had received significant interest, as they offer an eco-friendly solution to the over-reliance on synthetic fertilizers and chemicals. Bio-stimulants act as growth enhancers to crops, ensuring appropriate nutrients are absorbed and processes are done to secure quality growth and yield.

This study aim to investigate the growth and yield performance of peanut plants subjected to various concentrations of bio-stimulants. Systematically examining the effects of different concentrations on plant growth parameters, such as; height, leaf area index, flower initiation, number of pods, number of pods per plant, weight of the pods per plant, number of seeds per pod, and ultimately bean yield in tons/ha. This research aims to provide valuable insights into optimizing the application of bio-stimulants for effective peanut production.

The outcomes of this study could have significant implications for farmers, teachers, researchers, and fellow agriculture students by offering guidance on the appropriate concentrations of bio-stimulants that can effectively enhance peanut crop performance, contribute to sustainable agricultural practices, and potentially mitigate the increasing challenges associated with the aggravated environmental conditions in peanut cultivation, maximizing productivity with sustainable practices.

Relatively this study can contribute to a pool of knowledge in food sustainability, organic agriculture, studies on eco-friendly technologies.

Objectives of the Study

This study aimed to evaluate the effectiveness of the different levels of concentration of bio-stimulant solutions on the growth and yield of peanut plants.

Specifically, it aims to:

1. determine the growth performance of peanuts applied with different levels of concentrations of bio-stimulant solution.
2. determine the effective level of Bio-stimulant solutions in increasing the yield of the peanut plant.
3. identify variables that are correlated to growth and yield of peanut plants when applied with different concentrations of bio-stimulant solutions.

Theoretical Framework and Related Literature

Theoretical Framework

This study is anchor to the theory of *SEED GERMINATION AND EMERGENCE*. The theory states that five main influences affect seeds' germination and plants' early development. These include seed and seedling characteristics, seedbed physical components, seedbed chemical components, seedbed biological components, and cropping systems. Each factor creates favorable conditions for germinating seeds and young plants to establish themselves (Lamichane et al, 2018).

Use of bio-stimulant in agriculture. Modern and industrialized Agriculture is propose as a threat to the fertility and sustainability of the soil. According to Ali et al (2023), plant Bio-Stimulant does not only improve the quality and yield of crops but also the restoration of the fertility of the land. It assists the efficient use of limited resources, with the least negative impact on the ecosystem. The same study was conducted by Naqve et al (2023), which emphasize the vital role of bio-stimulants in promoting sustainability in agriculture. It delves into how these natural substances contribute to reducing the environmental footprint by promoting healthier plant growth, improved soil health, reduced chemical dependency, and enhanced crop resilience to abiotic and biotic stresses.

Bio-stimulants, is considered as nutrient-supplying substances that contain microorganisms, can enhance plant growth and well-being. They offer promising opportunities to revolutionize agricultural methods, potentially leading to sustainable and cost-effective solutions for boosting crop productivity. Many studies and phenotypic observations have proposed the functions of Bio-Stimulant in improving plant processes. It aids in decreasing abiotic stresses, promotes plant growth and development, and improves the quality and the yield of the crops (Yuniati et al, 2023).

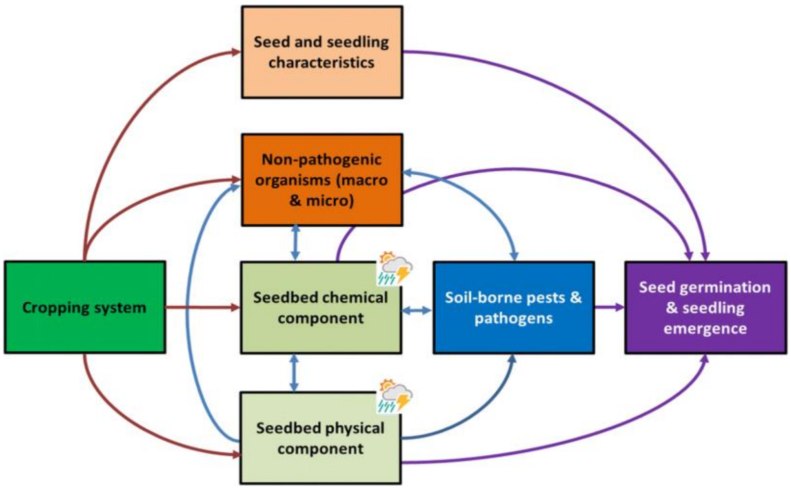

Fig 1. Abiotic and Biotic Factors Affecting Crop Seed Germination and Emergence. (Lamichane, et al, 2018)

Bio-stimulant effects on peanut plants. Peanut is a widespread, vital legume that has significant importance in the Agriculture sector and the economy. Today, improving the quality and yield of oil seed crops like peanuts is at its peak. Furlan et al (2021) reported that the addition of bio-stimulants on peanut plants affects the translocation to leaves, improves the growth of the plant, and nodulation in the drought stress conditions of the production. Therefore producing quality crops for the consumption of the economy.

Several studies have investigated the impact of Bio-stimulants on peanut growth. Research by Zheng et al (2023) proved that the application of plant bio-Stimulants derived from Several Plant extracts has influenced root development, leading to increased nutrient uptake and improved plant productivity in peanut cultivation. The same research findings by Abourayya et al (2020) suggested that humic substances, a type of bio-stimulant, stimulated plant growth by enhancing root architecture and nutrient assimilation in peanuts.

Li et al (2020) and Muhie (2023) have demonstrated the efficacy of different bio-stimulants for peanut cultivation. Humic acid application has shown to increase peanut pod yield by up to 15%. Seaweed extract application has enhanced peanut growth parameters such as leaf chlorophyll content, main stem height, lateral branch length and dry matter accumulation (Meng et al, 2022). Amino acid application has also increased peanut yield products (Sadak et al, 2021).

The study of Sivakumar et a,. (2024) investigated a natural bio-stimulant derived from the green seaweed Chaetomorpha aerea. The bio-stimulant significantly improved peanut growth and yield in pot and field experiments. Analysis of the bio-stimulant revealed the presence of compounds that promote plant growth, and suppress bacterial diseases and oxidative stress. This highlights the potential of bio-stimulants as a sustainable and effective tool for enhancing peanut production.

Extensive research has been conducted to investigate the effects of bio-stimulants on peanut growth and yield. Muhie (2022) explores the intricate mechanisms through which plant bio-stimulants exert their impacts on plant physiology and development. Discussions encompass signal transduction pathways, hormonal modulation, activation of the enzymes, and their influence on gene expression in the plant, elucidating the multifaceted ways bio-stimulants interact with plant cells.

The use of Titan FH bio-stimulant displayed a tangible influence on enhancing the productivity of peanut plants. This outcome underscores the importance and efficacy of bio-stimulant application, especially in augmenting the final yield of the crop (Ribeiro et al, 2023).

Effect of bio-stimulant on other crops. Bio-stimulants, which consist of various organic substances or microorganisms, have garnered attention as potential enhancers of plant growth and productivity. When implementing bio-stimulants to enhance nutrient use efficiency, it is crucial to consider the diverse geo-economic conditions prevailing in various regions around the globe (Xu and Geelen, 2018). The statistical analysis of the study reported by Oñal et al (2024) highlighted the pivotal role of BSS in influencing key aspects of mung bean development. The bio-stimulants facilitated nutrient uptake and hormonal balance in the legumes mentioned which resulted in a well-developed crop.

Oñal et al (2023) have investigated the effects of various bio-stimulant solutions on ginger rhizome germination. The Study has examined the application of natural extracts, organic compounds, and microbial formulations contained as potential bio-stimulants that enhance the germination efficiency of the crop. These solutions often contain active microorganism-promoting substances that initiate metabolic pathways and increase the availability of essential nutrients for the crop to absorb.

According to *Katu et al, (2022)*, the specificity of the bio-stimulant like Stimulate in promoting mean root length suggests a targeted action on root development, which could be crucial for later-stage plant growth and health. This indicates that the choice of bio-stimulant might be context-specific, and its efficacy could vary based on the specific requirements or conditions of the seeds or plants being treat.

Components of bio-stimulant. Microorganism components of the bio-stimulant such as bacteria, fungi, and yeasts can be utilize as bio-control agents to fight harmful plant pathogens in crops. These active microbes also create hormone-like substances that vitalize plant growth and enhance their resilience against environmental or abiotic stresses arising from soil conditions or other factors in their environment (Joshi et al, 2021). According to Yuniati et al, (2022), the application of moringa leaf extract as a plant Bio-stimulant has demonstrated effects on improving physical attributes such as increased plant metabolism, enhanced yield parameters, including size, color, and uniformity of produce, as well as prolonged shelf life and reduced post-harvest losses that is relevant in the production of leaf crops. It is valuable information not only in the considerations of different parameters but also in the benefit of the farmers economically.

Benefits of beneficial microorganisms on legumes and other crops. Organic waste is a valuable resource that can be transformed into bio-products through bio-conversion processes. Bio-conversion can recover nutrients from organic matter to create nutrient-rich supplements and generate useful energy *(Huang et al, 2021).* Dos Santos et al, (2020) highlighted the importance of diverse microorganisms residing in the rhizosphere, emphasizing their ability to thrive alongside plant roots, stimulate plant growth, and mitigate diseases.

A study by *Xie et al, (2020)* shows that peanut pods remove a significant amount of nutrients from the plant. Understanding these nutrient removal rates is essential for optimizing proper bio-fertilization. One of the prominent bacteria in action is the rhizobia, rhizobium inoculation stimulates the proliferation of potentially beneficial microbes, strengthens connections within rhizobacterial networks, and improve the composition of hub microbes that produce a great amount of nitrogen for the plant (Zhong et al, 2019). This beneficial transplantation of microbes promote the nutrient acquisition and biomass accumulation of host plants that aid in carrying out tested beneficial functions (Wang et al, 2021).

Del Canto et al, (2023) identified three highly effective indigenous rhizobium strains that not only improved cell wall elasticity, enhanced water use efficiency, and prevention of phenological delay but also paved the way for developing effective common bean inoculations and offered a sustainable alternative to chemical fertilization. The characteristics of the crop in physiology and biochemical, yield, and the development of antioxidant enzymes have significantly increased with the application of high-protein rhizobium in an organic Bio-stimulant (Ajaykumar et al, 2023).

Combining Dual *Rhizobium sp*., the inoculation of mung bean in protein content, yield attributes, and grain yield under saline stress has increased. The dual bio-inoculant resulted in an 8.92% increase in grain yield and a superior benefit-cost ratio of 1.87 (Kumawat et al, 2021).

A review by *Francesca et al,* (2022) proved that the plant-derived protein hydrolysate tested in this study demonstrated bio-stimulant activity by enhancing hormone production, improved photosynthesis, and increased antioxidant activity. The effect varied from plant variety and highlighted its potential for enhancing the crop's resistance to abiotic stresses.

Contribution to research. Theoretical background and related literature suggest that bio-stimulants has a notable effect on the peanut growth, root development, and increasing the yield. Optimal concentrations of bio-stimulants, such as seaweed extracts and humic substances, had shown positive effects on nutrient absorption, flowering, and overall yield parameters in peanuts. Further research was a requisite to determine the optimal concentrations and formulations of plant bio-stimulants for maximizing peanut productivity while ensuring sustainable agricultural management practices.

Limitation of the Study

The study was limited only to the growth and yield performance of peanut plants applied with the different levels of concentrations of bio-stimulant. This research was conduct in a 100-square-meter area. It was lay out at the compound of the University of Negros Occidental-Recoletos, Inc. (UNO-R, Inc.), Philippines from February 20, 2024, to June 11, 2024. There were four treatments and replicated four times using the randomized Complete Block Design (RCBD)

Methodology

This research aims to assess the growth and yield performance of peanut plants subjected to different concentration of bio-stimulants. Bio-stimulants, comprising organic compounds, active microorganisms, or extracts from other plants, had shown promising results in various crop production (Caruso et al, 2019). Bio-stimulants will enhance crop productivity, improve soil health, and protect plants from diseases and pests, all while reducing the reliance on chemical fertilizers.

Studies focusing on the yield response of peanuts to bio-stimulant applications had shown promising outcomes. In a study conducted by Eswaran et al, (2023), it was observed that the application of specific microbial-based bio-stimulants significantly increased peanut pod yield by promoting flowering, photosynthetic pigments, pod development, and ultimately, enhancing yield parameters.

Four (4) treatments with four (4) replications of every treatment is design for this experiment. This study evaluated the growth and yield performance of peanuts using bio-stimulant solutions following a Randomized Complete Block Design (RCBD).

Research Design and Treatments

Treatment	Description
T1	0% BSS)
T2	5% BSS
T3	10% BSS
T4	15% BSS

Cultural Management and Procedures

Seed Selection and Sowing

a. Two kilos of selected fresh peanuts with plump, firm shells and no signs of mold or insect damage was utilizes.
b. Biyaya 12 variety of peanuts was used.
c. The outer shell of the peanut was remove first.
d. Shriveled, discolored, or damaged seeds were discard.
e. Around 50 grams of peanut seeds were utilize for each replication.
f. The seeds were soaked in water 24 hours before planting.

g. After soaking the materials were rinsed for 30 minutes to remove excess water.
h. After air-drying, peanut seeds were sown in the polyethylene bags at approximately 1 inch deep, five (5) seeds per replication per treatment.

Preparation of Soil and Polyethylene Bags

a. We utilized loam and sandy soil as the medium for planting.
b. The soil was pulverized to provide better aeration and root development for the plant.
c. The polyethylene bag was filled 3/4 (three-fourths) of the way with a combination of loam and sandy soil.
d. The soil inside the bags was also leveled before sowing the seeds.
e. For the soil to be used, one (1) kilogram of soil in combination was gathered from all of the sample bags. This was a sample for soil testing and analysis as the representative of the soil medium for this study.

Thinning and Replanting

a. Thinning was perform two (2) weeks after the germination of the peanut seeds.
b. Plants with robust growth and well-developed root systems were selected as representative and the weaker or less vigorous plants were thinned out using a trowel.
c. After thinning, the remaining plants were watered and to help them recover from any stress caused during the thinning process.

Watering and Management

a. Ensuring that adequate watering and without over-saturation was monitored daily.
b. Regularly prevented water-logging and adjust watering by the moisture.
c. As the peanut plant grew, support was given for the stems if needed.
d. Inspection for pests or diseases or any signs was done daily.

Cultivation and Weeding

a. Peanuts thrived in well-draining, sandy loam soils. Hence, they are cultivated regularly for soil aeration and weed removal.
b. Manual weeding was done, especially during the early stages of crop growth, to prevent weed competition.

Pests and Diseases Control

a. Regularly inspected plants for signs of pests or diseases. Early detection allows for timely intervention.
b. Infected or damaged plant parts was remove to prevent the spread of diseases.

Harvesting

a. Peanut plants were harvested at 100-110 days after sowing.
b. The gradual wilting and yellowing of the majority of plant leaves were some of the indicators for harvesting, noticeable during dry season planting.
c. The peanut plant gently pulled out and allowed the peanut to be dry before further activity.

Preparation and Application of Bio-Stimulant

a. Bio-stimulant solutions were mixed on-site, in water depending on the requirement of every treatment.
b. The control treatment were watered as well.
c. The bio-stimulant solution were applied at 10 DAS, 25 DAS, and 40DAS, respectively.

Data Gathering

1. Germination Period (in number of days).
2. Flower Initiation (in number of days).
3. Plant Height (in cm) - was gathered at 15 days after sowing (DAS), 30 DAS, 45 DAS, and 75 DAS.
4. Data to be gathered after harvest:
   a. Pod number
   b. Pod weight per plant
   c. Number of seeds per pod
   d. Total weight of seeds
   e. Weight of leaves and stems
5. Bean yield (kg/hectare)
6. Biomass (kg/hectare) - It was done by adding the total dry weight of the roots and the upper portion of the plants including the weight of beans, pods, leaves, and stems.

   Formula: $Bs=Wr+Wb+Wp+Wl+Ws$

Statistical Tool and Analysis

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

The Least Significant Differences (LSDs) was utilize to determine significant differences among treatments.

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

Results and Discussions

Period of Germination of Peanut Seeds

Figure 2 indicate the days of germination of peanut seeds as treated with different levels of concentration of bio-stimulant solution.

The result revealed a positive relationship between the bio-stimulant concentration and the period of germination (α =0.01) with a CV of 6.96%. Treatment containing the highest concentration (15% BSS), exhibited the fastest germination period of 3.15 days only. Seeds treated with 10% BSS germinated a little longer at 3.58 days, statistically comparable to those treated with 5% BSS at 3.85 days. The untreated seeds indicates a slower germination time of 4.03 days but is statistically comparable with those treated with 5% BSS, respectively.

The result is supported, by the research of *Oñal et al, (2023)*, who demonstrated that a bio-stimulant solution had significantly accelerate the germination of the crops. This research explored the use of bio-stimulants to improve crop germination efficiency on ginger rhizomes.

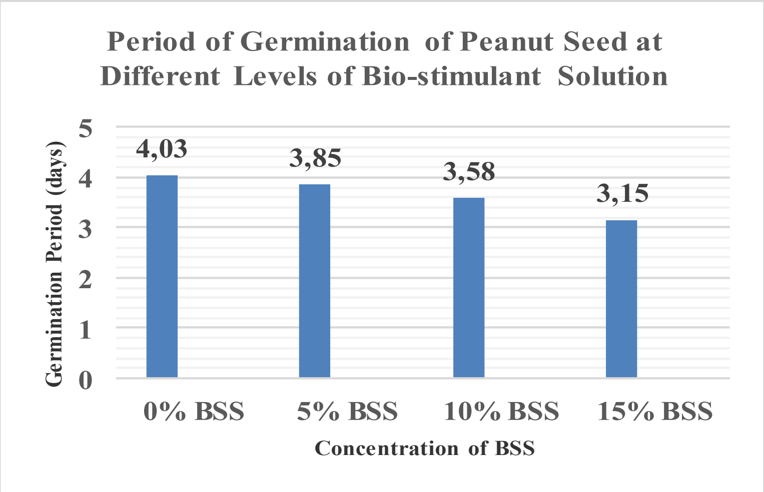

Fig 2. Period of germination of peanut seeds

Plant Height

Table 1 indicates the plant height of peanuts at 15DAS, 30DAS, 45DAS, and 75 DAS as influence by the application of different levels of concentration of bio-stimulant solution (α =0.01). The results implied that plant height of peanuts is significantly influence by the level of concentrations of bio-stimulant solution from 15DAS to 75DAS. The higher the concentrations of bio-stimulant solution applied the greater is the elongation of height of the plants.

15 Days after sowing

Initially Table 1 indicates the average height of peanut plants 15 days after sowing. The results is very transparent that plants treated with varying bio-stimulant doses exhibited significant differences in height compared to the control group. Plants applied with the highest bio-stimulant concentration of 15%, exhibited the greatest average plant height at 15 days, reaching 10.55 centimeters statistically comparable with plants applied with 10% BSS which averaged 9.85 centimeters, respectively. Those plants with no BSS displayed the least growth, with an average height of only 7.90 centimeters at 15 DAS.

These results suggest the potential utility of bio-stimulant application as a tool for promoting and enhancing the plant growth which is aligned with the research conducted by Dos Santos et al (2020), emphasizing the significance of the diverse microbial communities in the rhizosphere (zone surrounding plant roots). These microbes not only coexist with plant roots but also play a crucial role in promoting plant growth, potentially including increased in plant height.

30 Days after sowing

Plant height analysis at 30 DAS, revealed a significant differences among treatments (Table 1). Plants applied with 15% BSS exhibited the greatest average plant height, reaching 24.90 centimeters. Consistently, those with 0% BSS displayed the least growth, averaging only 15.40 centimeters at 30 DAS. These findings suggest a positive correlation between bio-stimulant application and peanut plant height at 30 DAS.

This is align with the research of Oñal et al (2024) on mung beans, where the analysis of the experiment's results showed clear differences in plant growth between the treated groups and the control at 35 DAS as shown, plant height was a key parameter exhibiting significant variation across the different treatments.

45 Days after sowing

Plant heights measured at 45 DAS, further solidify the positive impact of bio-stimulant application. Plants receiving the highest dose of 15% BSS, stood out with the tallest plants, averaging 34.00 centimeter. A clear dose-dependent trend continued to emerge, with progressively shorter average heights observed for lower bio-stimulant concentrations.

These findings strongly suggest that bio-stimulants can be a valuable material for enhancing peanut plant height. This evidence also aligns with the study of Hoque et al (2020), where the use of bio-stimulant has the great potential to increase the rate of growth of crops.

75 Days after sowing

Even at 75 DAS, plant height data continues to demonstrate the clear benefits of bio-stimulant application (α =0.01). Plants applied with 15% BSS, remained dominant with the tallest plants, averaging a remarkable 63.90 centimeters. The trend of decreasing height with lower bio-stimulant concentration persisted. Those with 0% BSS exhibited the least growth, reaching only 52.25 centimeters at 75 DAS. These findings strongly support the potential of bio-stimulants as a valuable growth enhancer for promoting significant increases in peanut plant height.

Similar with the research of the group of Furlan (2021), which demonstrated improved plant growth under drought stress, our study also observed a positive impact on peanut plant height with the application of bio-stimulants. This suggests that bio-stimulants can promote growth not only by enhancing nutrient translocation to leaves and nodulation but also by potentially increasing plant height, ultimately contributing to higher-quality crop yields.

Table 1. Average plant height of peanuts (cm) applied with different levels of concentration of bio-stimulant solution 15DAS, 30DAS, 45DAS, and 75DAS.

Treatment	Height of Peanuts (cm)			
	15DAS	**30DAS**	**45DAS**	**75DAS**
T1 – 0% BSS	7.90[c]	15.40[d]	23.10[d]	52.25[d]
T2 – 5% BSS	9.05[b]	18.00[c]	24.70[c]	56.32[c]
T3 – 10% BSS	9.85[a]	21.90[b]	31.25[b]	60.62[b]
T4 – 15% BSS	10.55[a]	24.90[a]	34.00[a]	63.90[a]
Mean	**9.34**	**20.05**	**28.26**	**58.27**
Pr (>F)	0.0000**	0.0000**	0.0000**	0.0000**
CV (%)	5.07	3.84	3.12	2.33

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

Days of Flower Initiation

Figure 3 presents the data on the flowering period of peanut plants treated with various bio-stimulant concentrations (α =0.01). Plants applied with 15% BSS exhibited the earliest flowering initiation, averaging 23.68 days after sowing. A progressive increase in flowering time was observe with decreasing bio-stimulant concentrations. Plants with 0% BSS demonstrated a flowering time comparable to those applied with 5% BSS, averaging 25.32 days. These results suggest a potential influence of bio-stimulant application on accelerating flowering time in peanut plants, with higher doses potentially leading to earlier flower initiation.

According to the study of Shukla et al (2024), the supplementation of bio-stimulant has the potential to induce earlier flowering in crops. This effect in particular is even observe in crops under stressful growing conditions. This is the result of the healthy soil environment that, the bio-stimulant creates proven by the research of Muhie (2022). It emphasizes the intricate mechanisms through which plant bio-stimulants exert their impacts on plant physiology and development.

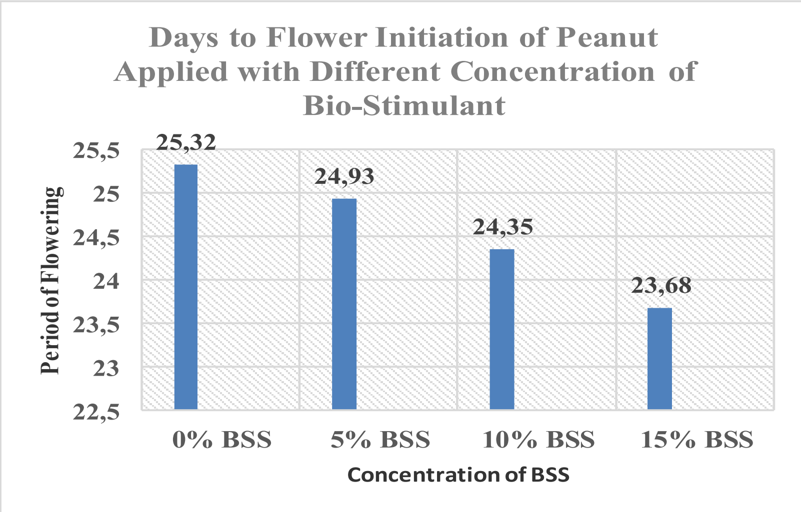

Fig 3. Days to flower initiation of peanut

Weight of Stems & Leaves and Biomass

Weight of Stems and Leaves

Table 2 presents the results for the weight of stems and leaves of the applied with varying levels of concentration of bio-stimulants solution on peanuts.

The application of the varying amounts of bio-stimulants solution also exhibited a parallel relationship with the weight of leaves and stems (α =0.01). Plants applied with 15% BSS, exhibited the heaviest weight, averaging 275.25 grams. The decreasing trend is observe with lower bio-stimulant concentrations. Plants with 0% BSS displayed the lowest weight at 172.75 grams. These findings suggest that bio-stimulant application has the potential to increase the total weight of leaves and stems in peanut plants.

These results is observe in the study of Hayat et al (2018) showing a statistical analysis that the application of bio-stimulant has a significant influence in increasing the number of leaves of crops. Similarly, the results revealed a positive correlation between bio-stimulant concentration and the combined weight of leaves and stems in peanut plants. This suggests that bio-stimulants may not only enhance the number of leaves but also potentially increased the leaf and stem weight.

Biomass

The data presented in Table 2 demonstrates a statistically significant effect of bio-stimulant application on total peanut biomass accumulated at 110 DAS (α =0.01). The figure illustrates the total biomass in grams for each treatment, highlighting the influence of different bio-stimulant concentrations on this crucial yield component.

The study revealed a positive result between bio-stimulant application and total crop biomass at harvest (110 DAS). Plants that received the highest bio-stimulant dose of 15% had accumulated the heaviest biomass of 494.42 grams. Plants with 0% BSS had the lowest biomass at 349.45 grams, respectively.

Building on the findings of Toscano et al (2023), the study suggests a positive correlation between bio-stimulant application and total crop biomass accumulation. This signifies a potentially positive economic benefit for peanut producers. Higher biomass within a given area equates to a greater yield of peanuts per hectare, (Oñal et al, 2024).

Table 2. Average weight of stems and leaves (gm) and biomass (gm) of peanut applied with different levels of concentration of bio-stimulant solution during harvest.

Treatments	Weight of Stem and Leaves (gm)	Biomass (gm)
T1 – 0% BSS	172.75^{d}	349.45^{c}
T2 – 5% BSS	203.00^{c}	396.50^{b}
T3 – 10% BSS	235.25^{b}	437.50^{b}
T4 – 15% BSS	275.25^{a}	494.25^{a}
Mean	**221.56**	**419.42**
Pr (>F)	0.0000**	0.0001**
CV (%)	5.07	6.46

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

Yield Parameters

Number of Pods per Plant

Presented in Table 3 are the yield parameters of peanut, applied with different levels of concentrations of bio-stimulant solution. The data reveals statistically significant differences in number of pods per plant among the treatment groups.

The number of pods per peanut plant exhibited a clear dose-dependent response to bio-stimulant application as shown on Table 3 (α =0.01). Plants applied with 15% BSS, emerged as top in pod production, averaging 93.45 pods per plant. Those plant with 0% BSS displayed the lowest pod production, averaging 64.35 pods per plant only. These results strongly suggest that applying bio-stimulants into peanut cultivation can be a promising strategy for significantly increasing pod yield.

Results are align with the study of Li et al (2020) and Muhie (2023) where they have demonstrated the efficacy of different bio-stimulants for peanut cultivation. Humic acid application has been shown to increase peanut pod yield by up to 15%. Thus, plants treated with higher bio-stimulant doses exhibited statistically significant increases in number of pods per plant compared to the control group.

Weight of Pods per Plant

The weight of peanut pods per plant (Table 3) showed a clear response to bio-stimulant application, with higher concentrations leading to heavier pods (α =0.01). Plants applied with 15% BSS, produced the heaviest pods, averaging 190.60 grams. The average pod weight progressively decreased with lower bio-stimulant concentrations. The total weight of 107.50 grams for those with 0% BSS.

These findings relate to the research conducted by Howeity et al (2019), which suggests that bio-stimulants can be a valuable enhancer for peanut growers to increase pod weight and potentially improve overall yield. Enhancing plant growth and development with bio-stimulants may result in more pods being produce by a single plant. The overall weight of the pod can increase.

Number of Seeds per Pod

Table 3 also presents the number of seeds per pod of peanuts that indicated a positive response to bio-stimulant application, with higher concentrations leading to a higher number of seeds per pod (α =0.01). Those plant applied with 15% BSS, yielded the highest number of seeds per pod, averaging 4.50 seeds. The average pod weight progressively decreased with lower bio-stimulant concentrations. Only 2.09 seeds per pod was produce by plants with 0% BSS.

Hence, the application of bio-stimulants is significant in enhancing the seed production of peanuts. These substances can demonstrably influence plant physiology, promoting more successful flower development and facilitating improved nutrient uptake. The net effect can be a significant increase in the number of seeds produced per plant, potentially leading to greater crop yields (Oñal et al, 2023).

Total Weight of Seeds

The data in Table 3 further indicates a positive correlation between bio-stimulant application and weight of seeds per peanut plant (α =0.01). Higher bio-stimulant concentrations at 15% resulted in the higher weight of seeds per pod and the heaviest weight of 114.60 grams among the three other treatments.

Sivakumar et al (2024) explored a green seaweed-based bio-stimulant derived from Chaetomorpha aerea. This natural product significantly enhanced peanut growth and yield, both controlled pot experiments and field trials. Analysis of the bio-stimulant revealed the presence of compounds that promote plant growth and potentially offer protection against bacterial diseases and oxidative stress.

Total Bean Yield

Table 3 illustrates the significant effect of bio-stimulant application on total peanut bean yield in kg/hectare (α =0.01). The data shows a dose-dependent response, with higher bio-stimulant concentrations leading to greater bean yields.

Plants applied with 15% BSS achieved the highest yield at 1,906.00 kg/hectare. As the concentration of the bio-stimulant decreases, the yield also decreases as well. Plants treated with 10% BSS, had a production of 1,075.00 kg/hectare only. These findings strongly suggest that bio-stimulant application can be a valuable enhancer for peanut growers seeking to increase their bean yield.

These results align with the research of Ribeiro et al (2023) who highlighted the importance of bio-stimulants. Similar to their findings, the results demonstrate a significant increase in total peanut yield (bean weight) following bio-stimulant application. These findings strongly support the potential of bio-stimulants as a valuable input for peanut growers seeking to enhance their final crop production.

Table 3. Yield parameters of peanuts applied with different levels of concentration of bio-stimulant solution

Treatment	Yield Parameters of Mung beans				
	Number of pods/plant	**Weight of pod/ plant (gm)**	**Number of seeds/pod**	**Total Weight of seeds (gm)**	**Bean Yield (kg/ha)**
T1 – 0% BSS	64.35[d]	107.50[d]	2.09[d]	65.15[d]	1,075.00[d]
T2 – 5% BSS	74.15[c]	126.40[c]	2.73[c]	85.30[c]	1,264.00[c]
T3 – 10% BSS	86.30[b]	169.55[b]	3.18[b]	104.55[b]	1,695.50[b]
T4 – 150% BSS	93.45[a]	190.60[a]	4.50[a]	114.60[a]	1,906.00[a]
Mean	**79.56**	**148.51**	**3.12**	**92.40**	**1,485.12**
Pr (>F)	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**
CV (%)	3.30	4.76	2.72	2.72	4.76

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

Correlation of Selected Characteristics

The competency of associating between characteristics provides the strength of a linear relationship between two parameters and helps identify the most important characteristic(s) to be consider in determining possible phenomena of the effect of bio-stimulant solution. In this novel study, it is important to obtain information on the relationship between yield and growth performance of peanut plants as subjected to different levels of concentration of bio-stimulant solution.

Growth Characteristics of Peanut Correlated with Plant Height

Table 4 shows the characteristics that correlates with the height of the peanut plant (α =0.01). Among the characteristics tested for correlation with the height of peanut plants, two characteristics were positively correlates. Among the positive correlations are, the weight of stems and leaves, and biomass are strongly correlated with the plant height, with coefficient r-values of 0.93, and 0.85, respectively.

On the other hand, the germination and days to flower have a negative (moderate) and a (strong) correlation with r-values of (-) 0.72 and (-) 0.86, respectively.

Table 4. Growth characteristics of peanut plants that significantly correlated with the plant height when applied with different levels of concentration of bio-stimulant solution.

Growth Characteristics of Peanut Correlated with Plant Height	Correlation Coefficients *(r)*	P-value	Interpretation
Germination	-0.7296	0.0000**	Moderate (-) linear correlation
Days to flower initiation	-0.8620	0.0000**	Strong (-) linear correlation
Weight of stems & leaves	0.9354	0.0000**	Strong (+) linear correlation
Biomass	0.8528	0.0000**	Strong (+) linear correlation

***= highly significant at 1% probability,*

Growth Characteristics Correlated with the Bean Yield of Peanuts

Table 8 indicates the characteristics that correlates with the bean yield of peanut (α =0.01). Among the characteristics tested for correlation with the bean yield of peanut plants, three characteristics are positively correlate. Among the positive correlations are, the number of pods per plant, number of seeds per pod, and the total weight of pods are all strongly correlated with the bean yield, with a coefficient r-values of 0.98, 0.90, and a perfect correlation of 0.99, respectively.

Table 5. Growth characteristics of peanut plants that significantly correlated with the bean yield when applied with different concentrations of bio-stimulant solution

Growth Characteristics of Peanuts Correlated with Bean Yield	Correlation Coefficients *(r)*	P-value	Interpretation
Number of pods/plant	0.9850	0.0000**	Strong (+) linear correlation
Number of seeds/pod	0.9097	0.0000**	Strong (+) linear correlation
Total weight of pods	0.9999	0.0000**	Perfect (+) linear correlation

***=highly significant at 1% probability*

Conclusion and Recommendation

The different levels of concentrations of bio-stimulant solutions resulted in a significant change in the growth and yield of peanut plants. The use of 15% BSS concentration significantly influences the germination period, plant height, and promotes the early flowering of peanut plants, respectively. Similarly, yield parameters such as the number of pods per plant were significantly increase by 29.10, heavier by 83.10 gm pod weight per plant, increased by 2.41 seeds per pod, heavier than 49.45g seed weight, and increased by 831 kg/ha seed (bean) yield.

Based on the findings, this study recommends the application of 15% BSS for optimal peanut growth and yield.

Conflict of Interest

No other group is involved in this study

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Ethical Consideration and Data Privacy

The researchers take responsibility for the securing the sanctity and confidentiality of all the results generated on this study.

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