EFFECTIVENESS OF BIO-STIMULANT SOLUTIONS IN INDUCING THE GERMINATION OF GINGER RHIZOMES

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Annotation. Many countries in the world are using ginger as a spice. Ginger is one of the root crops that is well-known for its numerous health advantages, e.g., its anti-inflammatory and anti-nausea benefits. However, ginger is one crop that takes a long time to harvest and is very hard to raise because untreated planting materials can easily rot due to pathogens. This study evaluated the effectiveness of bio-stimulant solutions' in inducing the germination of ginger rhizomes'. Around 4 kilograms of ginger and 4 liters of bio-stimulant solutions were used in this study. Relatively, the study was done using sixteen plastic crates as planting containers. Ten pieces of ginger rhizomes were placed in each create as planting material. The study was laid out in a Complete Randomized Design (CRD) with four (4) treatments replicated four (4) times. The treatments were as follows: Treatment 1 – Control (no-Bss, water only); Treatment 2– 5% Bss diluted in water; Treatment 3 – 10% Bss diluted in water; and, Treatment 4 – 15% Bss diluted in water. All data gathered were computed and subjected to the Analysis of Variance (ANOVA) in CRD using STAR 2.0.1. The Least Significant Difference (LSD) was used to determine significant differences among treatments. Results show that ginger rhizomes developed rapidly for all treatments applied with Bss solutions. Ginger under Treatment 1 (the control, applied with water only) developed its rhizomes in a longer period (around 17-18 days) as compared to ginger applied with Bss solutions. Furthermore, it was found that Treatment 4, or the treatment with 15% of Bss obtained the shortest period of germination of 13 to 15 days only. On the other hand, ginger under Treatment 2 (5% Bss solutions), and Treatment 3 (10% Bss solutions) induced the development of rhizomes between 14-16 days.

Key word: anti-inflammatory, anti-nausea, bio-stimulant, germination, root crop, rhizomes.

Introduction

Many countries in the world use ginger as a spice. Ginger is well-known for its numerous health advantages because of its anti-inflammatory and anti-nausea effects. Originally from Southeast Asia, ginger is a tropical booming plant now readily accessible to farmers worldwide. The root, or rhizome, is the component of ginger utilized as a spice or health aid. The inside of the root might be yellow, red, or white, depending on the variety. (Goldman, 2022).

Due to the actions of several of its ingredients, the rhizome of the ginger plant has significant medicinal potential in treating several ailments. The 6-gingerol, phenolic chemicals and carotenoids influence macrophage modulation, antiplatelet aggregation, and immunosuppressive activity. The findings showed that samples from organic farming included more 6-gingerol, fiber, and total protein. Since it contains considerable 6-gingerol, fiber, and protein, one should still consume

organic ginger. The paper spray ionization mass spectrometry was used to identify several chemical classes in both organic and traditional ginger, including sugars, fatty acids, phenylpropanoids, and flavonoids. (Oliveira et al., 2020).

A crucial ingredient in both traditional and contemporary medicine is ginger. It boosts resistance and is a rich source of minerals and medically valuable substances. Because it may be cultivated in a wide range of conditions, the output of this spice increased in some parts of the world. As a nutrient-exhaustive crop, it requires a sufficient supply of nutrients at crucial points in its growth, whether in chemical fertilizers, organic manures, or a combination of both. Effective nutrient management can help to reduce the overuse of chemical fertilizers while still obtaining high quality and quantity of ginger rhizomes and safeguarding the soil's health and environmental quality. (Divyashree et al., 2022).

Ginger is a widely used spice in the world and an active component in several pharmaceuticals and dietary supplements. Because of the presence of active compounds (secondary metabolites) in the matrix, this plant has a wide range of applications due to its health benefits. Even though numerous studies indicate that fresh ginger rhizomes have a more decisive pharmacological action, the unprocessed plant is only occasionally employed. (According to Zagórska et. al, 2022).

However, ginger is one of the crops known to have an extended period needed before one can harvest it. It takes two months before the roots start to develop and 8-10 months to harvest. (Kurtz, 2023).

The most critical conditions for growing ginger are warm, humid climates with rich soil and shaded areas. Ginger is a tropical plant. Ginger is cultivated in Sikkim using indigenous varieties. The ideal time to harvest ginger is between November and January, following 8 to 9 months of seeding, but this depends on Sikkim's market demand dynamics. Farmers often receive 90–100 q/ha under organic conditions, depending on the methods used for ginger growing. Using enhanced ginger farming techniques, forward-thinking farmers receive, on average, Rs. 150,000 per hectare (benefit-cost ratio ranged from 3.50 to 3.80). (Vijayan et al., 2020).

According to Chitra R. & Vinothini L. (2020). The high production of ginger results from timely and sufficient nutrition input to the plant. Nutrition has been discovered to significantly impact ginger growth and yield among the numerous agronomic approaches affecting ginger production. An uneven, insufficient, or nonexistent fertilizer application is a significant factor in a low yield. Organic and inorganic fertilizers are frequently used to grow ginger to improve rhizome quality and yield. It is possible to promote organic farming given the increased demand for organic food, the improvement of soil health and productivity, and the availability of local resources.

Recently, the agricultural industry has been confronted with the combined difficulties of boosting production to feed the world's growing population and increasing resource use efficiency, all while lowering the environmental impact on ecosystems and human health. In truth, fertilizers and pesticides play an essential role in agriculture, providing growers with a potent weapon for increasing yield and ensuring sustained productivity throughout the seasons under both optimal and substandard conditions. Several technical advancements have been proposed in the last three decades to improve the sustainability of agricultural production systems by significantly reducing synthetic agrochemicals such as pesticides and fertilizers. Natural plant bio-stimulants (PBs), improve flowering, plant growth, fruit set, crop yield, and nutrient usage efficiency, and are a promising and environmentally beneficial breakthrough. (Rouphael, Y., & Colla, G. (2020).

Finding environmentally friendly strategies to encourage plant development and improve agricultural output is a top goal in modern agriculture. Bio-stimulants are organic substances that

can boost plant growth and nutrient uptake while reducing the demand for chemical fertilizers. A path to waste recycling and reduction is paved by creating bio-stimulants from by-products, which benefits growers, the food sector, registration and distribution businesses, and consumers. (Xu, L., & Geelen, D. (2018). Biostimulants are a viable and efficient replacement for or addition to their synthetic equivalents, benefiting the environment, biodiversity, human health, and economy. (Rouphael, Y., & Colla, G. (2020).

Plant bio-stimulants are used to enhance crop output and the nutrient content of agrifood products. They are frequently included in agricultural management techniques intended to lower the use of chemical inputs, boost production, and restore the agroecosystem's natural equilibrium. (Woo et al., 2018).

More scientific study on the impact of biostimulants on vegetable output and quality is being conducted to manage crops sustainably. Biostimulants have been shown to increase tomato fruit yield and functional quality when used in both conventional and organic vegetable systems. (Caruso et al (2019).

In-depth research is being done on plant bio-stimulants as a practical way to boost the productivity of horticultural crops in a long-term, sustainable way. They are one of the organic treatments applied to plants to promote growth and development while guarding against disease. (Muhie, 2022).

Bio-stimulants are substances or micro-organisms that, when applied to plants or the rhizosphere (the area of soil immediately surrounding the roots), stimulate natural processes that improve crop quality, tolerance to abiotic stress, nutrient uptake, and nutrient use efficiency. Inoculants, bio-chemicals, humic and fulvic acids, and seaweed extracts are available for bacteria and other micro-organisms. (Joshi et al, 2019) These substances could improve plant hormonal processes to withstand abiotic stresses like salinity, drought, and high temperatures. (Piotrowska, A., & Boruszko, D. (2022). Other bio-stimulants may benefit the plant, such as enhanced root development, increased root hairs, increased water retention, or increased microbial activity, which increases nutrient availability. (Nycholat, 2021).

The researchers wanted to see if the different levels of treatment of bio-stimulant solutions help in inducing the germination of ginger rhizomes. In this way, it will help farmers worldwide to hasten the development or germination of ginger rhizomes so that they can also harvest it in a shorter time than in the usual harvest time of ginger crops.

The study's major purpose was to assess the effects of different levels of bio-stimulant solutions on the development of ginger rhizomes.

This study aimed to determine the adequate level of treatment for developing ginger rhizomes as planting material. Specifically, it aimed to:

Determine the significant effects of different treatment levels of bio-stimulant solutions, and determine the most effective level of treatment used in the study. The study will also determine the weight loss of germinated and un-germinated ginger rhizomes applied with different treatment levels of bio-stimulant solutions.

Based on the prior problem statement, the following null hypothesis was formulated, contradictory to the problem mentioned above: the different bio-stimulant treatments did not affect the rhizome development of ginger. There is no significant effect on the rhizome of ginger treated with different levels of bio-stimulant as planting material. There is no significant weight loss of germinated and un-germinated ginger rhizomes applied with different treatment levels of bio-stimulant.

The use of common plant bio-stimulants (PBs), which increase blooming, crop development, fruit formation, crop yield, effective nutrient mobilization, and ability to withstand a variety of abiotic stressors, should be considered a positive and environmentally sustainable modernization. (Nephali et al., 2020) PBs were primarily understood by excluding other functions akin to fertilizers or by-products of plant protection. They use a variety of substances and bacteria to promote plant development. (Bhupenchandra et al., 2020).

In order to ascertain the impact of various horticultural substrates on the mineral nutrient concentrations in the ginger (Zingiber officinale Rosc.) rhizomes cultivated in a greenhouse. Ginger, a perennial herbaceous plant in the Zingiberaceae family, is well-known for its therapeutic benefits. Ginger is becoming increasingly important economically in various parts of world health. However, due to its high-temperature requirements, ginger cannot grow in frigid areas with unfavorable environmental conditions. The species requires a nutrient-rich substrate soaked with water for optimum growth. (According to Zhang et al., 2021).

According to Zahid et al., 2021, Both as a spice and herbal medicine, ginger rhizomes are prized worldwide. The following factors, which have been noted in numerous reports and contribute to ginger's severe constraints, can be summed up as follows: (1) Ginger typically reproduces by rhizome with a low proliferation rate. The reproducing part (the rhizome) of the plant is also the economically valuable part. It limits the supply of ginger seeds required for cultivation. (2) Ginger is easily infected by soil-borne pathogens like bacterial wilt (Pseudomonas solanacearum), soft rot (Pythium aphanidermatum), and nematodes (Meloidogyne spp.), which cause heavy losses in yield. (3) Ginger rhizomes show variations and degeneration under long-term vegetative propagation and (4) regular breeding of ginger is a real problem due to poor flowering and seed set.

Bio-stimulants' numerous advantages as stimulators of plant growth and health have attracted study interest. Bio-stimulants' many advantageous characteristics are increased yields, improved plant development, better fruit quality, and defense against diseases, increased antioxidants, quick germination, and improved photosynthetic capacity.

Additionally, bio-stimulants can help plants cope better with environmental stress by increasing their resistance to it, which plants constantly struggle with due to climate change. Importantly, bio-stimulants can offer alternatives for more environmentally friendly agriculture methods. (Jeba et. al, 2022).

The main objectives of contemporary agriculture are to reduce environmental impact while maintaining steady and high-quality high yields. Reduce the usual dose of fertilizer without compromising production by using seaweed extract and humic compounds. The primary factors regulated by plant bio-stimulants in terms of qualitative characteristics are tuber size, protein, vitamin C, starch, and phenol content. Weaknesses in the usage of plant bio-stimulants were demonstrated, and these weaknesses were related to variations in the efficacy of the products due to their origin, manufacturing method, and microbial species. (Ahmad et al., 2021). There have also been interactions between the product, strain, and genotype. Both microbial and non-microbial plant bio-stimulants can have their effectiveness affected by environmental factors, farming practices, and the timing of the treatment. (Caradonia et al. (2021).

In order to maintain sustainable agriculture and long-term high crop output, organic farming has emerged as a viable alternative to the alarming rise in synthetic fertilizers and pesticides. However, crop demand and nutrient bio-availability are significant yield-limiting elements in many organic farming systems (N and P). Bio-effectors, often called bio-stimulants, are applied organic materials and microorganisms that boost nutrient uptake, accelerate growth, and improve crop quality while

enhancing plant resistance. (Piotrowska, A., & Boruszko, D. (2023). They may include humic acids, protein hydrolysates, seaweed extracts, microorganisms, and other materials. In order to manage plant diseases biologically, bacteria, fungi, and yeasts create chemicals that resemble hormones. (Joshi et al. (2021).

The European Bio-stimulant Industry Council (EBIC) defines bio-stimulants as "products containing substances, and when applied to plants or the rhizosphere, microorganisms encourage natural processes that improve/benefit nutrient uptake, nutrient efficiency, abiotic stress tolerance, and crop quality. (Iriti et al., 2019). Every year, the market for bio-stimulants expands. According to studies, the market for bio-stimulants with active ingredients is predicted to grow to $5 billion by 2025. Thousands of published scientific studies have demonstrated the advantages of utilizing bio-stimulants in agriculture. Under ideal and unfavorable conditions, plant biostimulants like Plant Growth Promoter Rhizobacteria (PGPR) are thought to be highly effective and long-lasting for agricultural output. (Kenekar, (2023).

Fertilizer residue is always left in the soil after intensive use. It frequently enters the environment by runoff from agricultural land, polluting the water and the air. Enhancing the bioavailable soil nutrient content with biostimulants is the most effective way of lowering pesticide use while improving output. Bio-stimulants are defined as compounds or organisms that have the potential to alter the physiological processes of plants when administered to seeds, plants, the rhizosphere, or growth substrates in particular formulations. In this process, bio-stimulants help plants grow faster, contain more nutrients, and adapt well to stress. (Kenekar, (2021).

Several studies have shown that using bio-stimulants in agriculture increases the size and growth of fruits and vegetables. It results in a rise in plant size, weight, density, and root length. It has an impact on how fruits and vegetables look and feel. For instance, the stiffness, shelf life, mechanical strength, and growth conditions under stress have all been significantly enhanced. Chemical characteristics are also affected, including acidity, dry mass, and vitamin content. According to several studies, using bio-stimulants positively impacts antioxidant qualities. ((Kenekar, (2021).

As a result, the researchers were curious about how they could help farmers hasten ginger rhizomes germination as planting material. The bio-stimulant solution was used to help induce the germination of ginger rhizomes. With the following goals in mind: Are the different bio-stimulant treatments effective in ginger's rhizome development? Is there a significant effect on the rhizome of ginger treated with different levels of bio-stimulant as planting material? Is there a significant weight loss of germinated and un-germinated ginger rhizomes applied with different treatment levels of bio-stimulant?

Methodology

This project assessed the different levels of treatments of bio-stimulants in inducing the germination of ginger rhizomes, which are substances or microorganisms that, when applied to plants or the rhizosphere (the area of soil immediately surrounding the roots), serve to stimulate natural processes to improve crop quality, tolerance to abiotic stress, nutrient uptake, and nutrient use efficiency. These substances could improve plant hormonal processes to withstand abiotic stresses like salinity, drought, and high temperatures. Other bio-stimulants may benefit the plant, such as enhanced root development, increased root hairs, increased water retention, or increased microbial activity, which increases nutrient availability. (Nycholat, 2021).

Plant bio-stimulants enable modern agriculture to become more robust and sustainable. Plant bio-stimulants stimulate natural processes to improve plant nutrient uptake, nutrient usage efficiency,

and tolerance to abiotic stress, biocontrol, and crop quality when applied to plants or the rhizosphere. (Hamid et al., 2021).

Research Design

This study concentrated on bio-stimulant solutions and was done following a Complete Randomize Design. Each treatment is replicated four times with ten (10) ginger rhizomes sample each replicate. All data collected in this experiment were statistically analyzed using Analysis of Variance (ANOVA).

Treatment	Description
T1	Control (water only)
T2	5% bio-stimulant solution
T3	10% bio-stimulant solution
T4	15% bio-stimulant solution

Materials and Equipment

Materials	Quantity	Purpose
Ginger	4 kilos	Used as an experimental plants
Plastic crate	16 boxes	Used as the planting area
Hand spray	4 pcs	Used for spraying the plants
Bio-stimulant Solutions	3 liters	Used as a concentration in Ginger
Sand	5 kilos	Used as soil medium
Banana leaves	16 pcs	Used as cover in every boxes
Plastic bottles	4 pcs	Used as water measurement

Preparation and Application of Ginger

1. Four kilos of native ginger were washed thoroughly, removing the dirt and rotten parts.
2. After washing, they were air-dried to remove the extra water for 2hrs.
3. Weight at least 250 grams of ginger per replication was done.
4. Each treatment had four (4) replication and at least ten (10) pcs (thumb size) of ginger as sample material.
5. The ginger was soaked in different concentrations of bio-stimulant solution for at least 8 hours.
6. After soaking the materials for the required hours, all materials were placed over a layer of sand in an air-cooled plastic crate.

Preparation and Application of Bio-stimulant

1. A bio-stimulant solutions were mixed in a liter of water depending on the percentage of every treatment needed.
2. A control or water was also prepared.
3. Soak the ginger rhizomes in every treatment for at least 24 hrs.
4. Place the ginger in the plastic craters with sand after soaking.
5. Daily spraying was done to maintain the moisture needed by ginger rhizomes.

6. Data for initial germination were gathered after 35% of ginger rhizomes germinated, and the data for the final germination were gathered when 70% of ginger rhizomes germinated.

The bio-stimulant formulation must be physically homogeneous and chemically stable under all expected storage conditions for the lowest effective dosage to be precisely given to target regions. Maximizing bio-stimulant efficacy while guaranteeing safety during handling and delivery are the goals. (Hazra, D. K., & Purkait, A. (2020).

Data gathering

1. Initial germination period – this was taken after 24 hours of soaking the ginger rhizomes.
2. Final germination period was taken after 70% of ginger rhizomes germinated.
3. Initial ginger weight was taken before soaking the rhizomes with bio-stimulant.
4. Final weight of ginger- this was taken after 70% of the ginger rhizomes were germinated.
5. Weight differences of ginger rhizomes were taken before the ginger was treated with bio-stimulant and after 70% of ginger rhizomes germinate.

Analysis of Variance, Design, and Regression: Linear Modeling for Unbalanced Data discusses linear modeling frameworks with an emphasis on including specific ideas (hypotheses) about the nature of the data. The book performs in-depth analyses of small data sets using tools easily extendable to big data. The techniques can also be utilized with small relevant data sets extracted from massive data. (Christensen, 2020).

The data gathered were computed and subjected to Analysis of Variance (ANOVA) in CRD using STAR 2.0.1, and Least Significant Difference (LSD) was used to determine significant differences among treatments. According to Dafaallah, (2019), Many studies believe that LSD is the finest way to compare various methods for simple holding and then for accurate access to the correct answers.

Results and Discussions

Table 1. The initial and final period (days) of germination of ginger rhizomes applied with different Levels of bio-stimulant solutions.

Table 1 shows the initial and final day of germination of ginger rhizomes applied with different bio-stimulant solutions. The initial germination was taken when any one of the planting materials shows the growth of the rhizomes. Among all treatments. Treatment 4 had shown the shortest period of germination with only 3.3 days only. Treatment 3 rhizomes had initially germinated for 4.3 days while Treatment 2 and Treatment 1 had a long day to germinate at 5.5 and 6.3, respectively.

According to Chitra R. & Vinothini L. (2021). In a field experiment, the effects of organic manures and bio-stimulants on ginger's physiological and biochemical properties were examined. It was also shown that different applications of organic manures and bio-stimulants made at different times during crop growth significantly impacted crop growth rates, relative growth, and net assimilation.

The table implied further the final period of germination (taken when 70% of the ginger rhizomes had germinated). Among the treatments, it's Treatments 4 and 3 had which has the shortest final day of germination which are 13.75 and 14.75 days, respectively. Treatment 1 on the other hand, had the longest day with 17.5 days.

According to De Vasconcelos et al (2019). When applied to seeds or young plants, bio-stimulants encourage root creation and development, especially in soils with low nutrients and low water supply, acting on the seedlings' hastened recovery in unfavorable situations, such as water shortage.

Because they operate as a hormonal and nutritional supplement, these products, primarily organically grown ones, boost the productivity of plants and increase their tolerance to water and climate stress.

According to Maigari, 2018). Ginger farming is practiced in Kaduna State's Jaba region, where most of the country's ginger is produced. Field observation, FGD, and in-depth interviews are some methodologies used. The findings indicate that ginger farming in the Jaba region occurs throughout a calendar year, with tasks and activities being dispersed following operational and timing needs. Three fundamental qualities are needed for farming: effective time management, qualified labor, and adequate fertilizer inputs. The study makes the following recommendations: ginger farmers should be educated on the advantages of value-adding strategies; new ginger slicing techniques should be investigated; and government should regulate intermediaries' activities, establish ginger marketing outlets, and provide investors with enticing policies and opportunities.

Table 1. The initial and final period (days) of germination of ginger rhizomes applied with different levels of bio-stimulant solutions.

Treatment	Concentration	Period of Germination (days)	
		Initial	Final
1	Control – no Bss	6.3a	17.5a
2	5% Bss	5.5a	15.7b
3	10% Bss	4.3b	14.8bc
4	15% Bss	3.3c	13.8d
Mean		**4.8***	**15.4****
CV (%)		10.81	5.04
Remarks		Significant	Highly significant

Means with the same letters are not significantly different at 5% level

Table 2. The number of germinated ginger rhizomes taken at 7 and 14 days after soaking with different levels of bio-stimulant solutions.

Table 2. indicate the number of germinated rhizomes applied with different levels of bio-stimulant at 7 and 14 days after soaking. Seven days of reading implied significant results with Treatment 4 having produced an average of 2.2 rhizomes with Treatment 1 that produces an average of almost rhizomes only.

The table also implied that Treatment 4 had produced an average of 2.5 rhizomes after 14 days with Treatment getting the lowest with an average of 1.1 rhizomes only. Treatments 2 and 3 on the other hand had almost the same number of germinated rhizomes that ranges from 1.5 to 1.7 at 7 days after soaking and 1.5 to 1.8 at 14 days after soaking, respectively.

According to Liu et al., 2021. Researchers looked at the compositional changes in ginger (Zingiber officinale Rosc.) rhizome preserved at 22° or 12.5°C. In 4 weeks, the rhizome surface Hunter "b" score increased from 9.2 to 18. After 12 weeks of storage at 22°, water loss became noticeable. Rhizomes kept at 12.5° experienced a negligible increase in dry matter. The amount of protein, total phenols, crude fiber, and oil in the rhizome did not alter appreciably. With a 5-fold rise in pungency as determined by gingerol concentration, rhizome total sugar considerably increased during storage at 12.5° for 32 weeks. Rhizome variation was more significant than the storage effect, and no discernible changes in volatile taste were noticed. No discernible quality loss resulted from the variations in rhizome surface color. It is possible to find the increase in pungency as a positive

development for the fresh ginger market. Rhizomes held at 22° have a considerable decline in overall look and quality due to water loss and an increase in dry matter percentage

Table 2. The number of germinated ginger rhizomes taken at 7 and 14 days after soaking with different levels of bio-stimulant solutions.

Treatment	Concentration	Number of Germinated Rhizomes	
		7 days after soaking	14 days after soaking
1	Control – no Bss	1.1a	1.1a
2	5% Bss	1.5a	1.5a
3	10% Bss	1.7b	1.8b
4	15% Bss	2.2c	2.5d
Mean		**1.6***	**1.7****
CV (%)		6.22	5.04
Remarks		Significant	Significant

Means with the same letters are not significantly different at 5% level

Table 3. The initial and final weight of ginger rhizomes (in grams) applied with different levels of bio-stimulant solutions..

Table 3. shows the initial and final weight of ginger rhizomes (in grams) applied with different levels of bio-stimulant. The weight differences among treatments show a highly significant result. Treatment 4 shows the lowest loss in the final weight with 16.20 grams only as compared to Treatments 1 and 2 with 20.00 and 18.70 grams. Treatment 3 on the other has a weight loss of 17.16 grams.

Several studies have shown that using bio-stimulants in agriculture increases the size and growth of fruits and vegetables. It results in a rise in plant size, weight, density, and root length. It has an impact on how fruits and vegetables look and feel. For instance, the stiffness, shelf life, mechanical strength, and growth condition under stress have all been significantly enhanced. Chemical characteristics are also affected, including acidity, dry mass, and vitamin content. According to several studies, using bio-stimulants positively impacts antioxidant qualities. ((Kenekar, (2021).

Table 3. The initial and final weight of ginger rhizomes (in grams) applied with different levels of bio-stimulant solutions.

Treatment	Concentration	Weight of Rhizomes (grams)		
		Initial weight	Final weight	**Mean Difference**
1	Control – no Bss	261.30	241.30a	20.00a
2	5% Bss	263.80	245.10a	18.70a
3	10% Bss	248.80	231.20b	17.16b
4	15% Bss	250.00	233.80b	16.20c
Mean		**255.90**	**237.85****	**18.50****
CV (%)		6.19	4.59	6.39
Remarks		ns	Significant	Highly significant

Means with the same letters are not significantly different at 5% level

Conclusion and Recommendation

The researchers did analyze the data presented and, thus, came up with the following conclusions:

1. The results of the study showed that the initial and final germination of ginger rhizomes is significantly affected when applied with different levels of bio-stimulant solutions. Furthermore, the results indicate that the higher the concentration of the solutions the faster the germination.
2. The final weight of the un-germinated and germinated rhizomes shows very significant differences among treatments
3. Further study should be undertaken to explore the efficacy and effectiveness of bio-stimulant as plant growth enhancers.

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Conflict of Interest

The authors declare no conflict of interest. This is an original study conducted by the authors.

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REFERENCES

1. Ahmad, M., Wang, P., Li, J., Wang, R., Duan, L., Luo, X., Irfan, M., Peng, Z., Yin, L., & Li, W. (2021). Impacts of bio-stimulants on pyrene degradation, prokaryotic community compositions, and functions. Environmental Pollution, 289, 117863. https://doi.org/10.1016/j.envpol.2021.117863
2. Bhupenchandra, I., Devi, S. H., Basumatary, A., Dutta, S., Singh, L. R., Kalita, P., Bora, S. S., Devi, S., Saikia, A., Sharma, P., Bhagowati, S., Tamuli, B., Dutta, N., & Borah, K. (2020). Biostimulants: Potential and Prospects in Agriculture. International Research Journal of Pure and Applied Chemistry, 20–35. https://doi.org/10.9734/irjpac/2020/v21i1430244
3. Caradonia, F., Ronga, D., Tava, A., & Francia, E. (2021). Plant Biostimulants in Sustainable Potato Production: an Overview. Potato Research, 65(1), 83–104. https://doi.org/10.1007/s11540-021-09510-3
4. 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
5. Chitra R & Vinothini L. (2020). Effect of Organic Amendments on Growth, Nutrient Uptake Pattern and Yield of ginger (Zingiber officinale Rosc.). Madras Agricultural Journal, 107, 1–4. https://doi.org/10.29321/maj.10.000471
6. Chitra, R., & Vinothini, L. (2021). Effect of organic manures and bio-stimulant on physiological and biochemical characters of ginger (Zingiber officinale Rosc.). International Journal of Innovative Horticulture, 10(2), 191–195. https://doi.org/10.5958/2582-2527.2021.00022.1
7. Christensen, R. (2020). Analysis of Variance, Design, and Regression: Linear Modeling for Unbalanced Data, Second Edition. Routledge & CRC Press. https://www.routledge.com/Analysis-of-Variance-Design-and-Regression-Linear-Modeling-for-Unbalanced/Christensen/p/book/9780367737405

8. Dafaallah, A. B. (2019). 11 Least Significant Difference. ResearchGate. https://doi.org/10.13140/RG.2.2.19618.38082
9. De Vasconcelos, A. T. R., & Chaves, L. H. G. (2019). Biostimulants and Their Role in Improving Plant Growth under Abiotic Stresses. In IntechOpen eBooks. https://doi.org/10.5772/intechopen.88829
10. Divyashree, N., Poojashree, S., Venukumar, S., & Vishwanath, Y. (2022). Sustainable Ginger Production through Integrated Nutrient Management. In IntechOpen eBooks. https://doi.org/10.5772/intechopen.107179
11. Goldman, R. (2022). What Is Ginger? Nutrition Facts, Health Benefits, Uses, and More. EverydayHealth.com. https://www.everydayhealth.com/diet-nutrition/diet/ginger-nutrition-facts-health-benefits-alternative-uses-more/
12. Hamid, B., Zaman, M., Farooq, S., Fatima, S., Sayyed, R. Z., Baba, Z. A., Sheikh, T. A., Reddy, M. S., Enshasy, H. a. E., Gafur, A., & Suriani, N. L. (2021). Bacterial Plant Biostimulants: A Sustainable Way towards Improving Growth, Productivity, and Health of Crops. Sustainability, 13(5), 2856. https://doi.org/10.3390/su13052856.
13. Hazra, D. K., & Purkait, A. (2020). Role of biostimulant formulations in crop production: Anoverview. ResearchGate. https://www.researchgate.net/publication/342095340_Role_of_biostimulant_formulations_in_crop_production_An_overview
14. Ikechukwu, G. A., Mallik, S., Ebem Njoku, J. E., & Depiver, J. (2020). Experimental Analysis of Thin Layer Drying of Ginger Rhizome in Convective Environment. Advances in Science, Technology and Engineering Systems Journal, l Vol. 5, No. 6,(1132–1142), 2415–6698. https://pdfs.semanticscholar.org/1fe4/76f42880648462d9f47ab05c1de484a5b976.pdf
15. Iriti, M., Scarafoni, A., Pierce, S., Castorina, G., & Vitalini, S. (2019). Soil Application of Effective Microorganisms (EM) Maintains Leaf Photosynthetic Efficiency, Increases Seed Yield and Quality Traits of Bean (Phaseolus vulgaris L.) Plants Grown on Different Substrates. International Journal of Molecular Sciences, 20(9), 2327. https://doi.org/10.3390/ijms20092327
16. 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. (2022). Biostimulants for Promoting Eco-friendly Sustainable Agriculture. In CABI eBooks (pp. 36–54). https://doi.org/10.1079/9781789248098.0003
17. Joshi, H., Duttand, S., Choudhary, P., & Mundra, S. (2019). Role of Effective Microorganisms (EM) in Sustainable Agriculture. International Journal of Current Microbiology and Applied Sciences, 8(03), 172–181. https://doi.org/10.20546/ijcmas.2019.803.024
18. Joshi, N., Parewa, H. P., Joshi, S., Sharma, J., Shukla, U. K., Paliwal, A., & Gupta, V. (2021). Use of microbial biostimulants in organic farming. In Elsevier eBooks (pp. 59–73). https://doi.org/10.1016/b978-0-12-822358-1.00011-0
19. Kenekar, A. (2023). Biostimulants in Agriculture: Challenges, Function and Efficacy. Organica Biotech. https://organicabiotech.com/biostimulants-in-agriculture-challenges-function-and-efficacy/
20. Kenekar, A. (2021). The Use of Biostimulants for Enhancing Soil Nutrient Content. Agricultural Technology and Precision Farming.

https://www.agritechtomorrow.com/article/2021/05/the-use-of-biostimulants-for-enhancing-soil-nutrient-content-/12861

21. Kurtz, L. (2023). How to Harvest Ginger: 12 Steps (with Pictures) https://www.wikihow.com/Harvest-Ginger
22. Liu, H., Yang, H., Zhao, T., Lin, C., Li, Y., Zhang, X., Ye, Y., & Liao, J. (2021). Combined Metabolome and Transcriptome Analyses of Young, Mature, and Old Rhizome Tissues of Zingiber officinale Roscoe. Frontiers in Genetics, 12. https://doi.org/10.3389/fgene.2021.795201
23. Maigari, A. (2018). Ginger Farming Practice in Jaba Region, Kaduna State, Nigeria. www.academia.edu. https://www.academia.edu/94314638/Ginger_Farming_Practice_in_Jaba_Region_Kaduna_State_Nigeria
24. Muhie, S. H. (2022). Plant Biostimulants in Organic Horticulture: A Review. Journal of Plant Growth Regulation, 42(5), 2698–2710. https://doi.org/10.1007/s00344-022-10738-7
25. Nycholat, E. (2021). What Are Biostimulants. Nutrien Ag Solutions. https://www.nutrienagsolutions.ca/about/news/what-are-biostimulants
26. Nephali, L., Piater, L. A., Dubery, I. A., Patterson, V., Huyser, J., Burgess, K., & Tugizimana, F. (2020). Biostimulants for Plant Growth and Mitigation of Abiotic Stresses: A Metabolomics Perspective. Metabolites, 10(12), 505. https://doi.org/10.3390/metabo10120505
27. Oliveira, C. T., Ramos, A. L. C. C., De Oliveira Prata Mendonça, H., Cosenza, G. P., Silva, M. R., Fernandes, C., Augusti, R., Melo, J. O. F., Ferreira, A. V. M., & De Araújo, R. L. B. (2020). Quantification of 6-gingerol, metabolomic analysis by paper spray mass spectrometry and determination of antioxidant activity of ginger rhizomes
28. (Zingiber officinale). Research, Society and Development, 9(8), e366984822. https://doi.org/10.33448/rsd-v9i8.4822
29. Piotrowska, A., & Boruszko, D. (2022). The Effect of Using Effective Microorganisms on the Changes in the Chemical Composition of Spring Wheat. Journal of Ecological Engineering, 23(6), 50–57. https://doi.org/10.12911/22998993/147874
30. Piotrowska, A., & Boruszko, D. (2023). Analysis of the potential of effective microorganisms in plant production. Ekonomia I Środowisko, 83(4), 180–195. https://doi.org/10.34659/eis.2022.83.4.485
31. Rouphael, Y., & Colla, G. (2020). Toward a Sustainable Agriculture Through Plant Biostimulants: From Experimental Data to Practical Applications. Agronomy, 10(10), 1461. https://doi.org/10.3390/agronomy10101461
32. Shahrajabian, M. H., Sun, W., & Cheng, Q. (2019). Clinical aspects and health benefits of ginger (Zingiber officinale) in both traditional Chinese medicine and modern industry. Acta Agriculturae Scandinavica Section B-soil and Plant Science, 69(6), 546–556. https://doi.org/10.1080/09064710.2019.1606930
33. Vivekanandhan, P., Swathy, K., & Chordia, M. A. (2022). Pseudomonas Species-Derived Chitinase Mass Multiplication, Production Cost Analysis, and Marketing: As a Biocontrol Agent for Crop Protection. In Plant Biostimulants in Organic Horticulture: A Review (pp. 179–192). https://doi.org/10.1007/978-981-19-6664-4_12

34. Vijayan, A. K., Gudade, B. A., Gautam, A., Deka, T. N., Bora, S. S., Dhanapal, K., & Remashree, A. B. (2020). Cultivation of Ginger in Sikkim under an Organic System. In Cultivation of Ginger in Sikkim under an Organic System. https://doi.org/10.5772/intechopen.87049

35. Woo, S. L., & Pepe, O. (2018). Microbial Consortia: Promising Probiotics as Plant Biostimulants for Sustainable Agriculture. Frontiers in Plant Science, 9. https://doi.org/10.3389/fpls.2018.01801

36. Xu, L., & Geelen, D. (2018). Developing Biostimulants From Agro-Food and Industrial By-Products. Frontiers in Plant Science, 9. https://doi.org/10.3389/fpls.2018.01567

37. Zagórska, J., Czernicka-Boś, L., Kukula-Koch, W., Szalak, R., & Koch, W. (2022). Impact of Thermal Processing on the Composition of Secondary Metabolite of Ginger Rhizome—A Review. Foods, 11(21), 3484. https://doi.org/10.3390/foods11213484

38. Zahid, N. A., Jaafar, H. Z. E., & Hakiman, M. (2021). Micropropagation of Ginger (Zingiber officinale Roscoe) 'Bentong' and Evaluation of Its Secondary Metabolites and Antioxidant Activities Compared with the Conventionally Propagated Plant. Plants, 10(4), 630. https://doi.org/10.3390/plants10040630

39. Zhang, M., Zhao, R., Wang, D., Wang, L., Zhang, Q., Shujun, W., Lu, F., & Peng, W. (2021). Ginger (Zingiber officinale Rosc.) and its bioactive components are potential resources for health beneficial agents. Phytotherapy Research, 35(2), 711–742. https://doi.org/10.1002/ptr.6858