

GERMINATION RESPONSE OF COMMON BEANS (*Phaseolus vulgaris*) USING GROWTH REGULATORS SODIUM NITROPRUSSIDE (SNP), INODLE-3-ACETIC ACID (IAA) AND VITAMIN C

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ABSTRACT: Common beans (*Phaseolus vulgaris* L.) are a vital food crop in Nigeria, valued for their rich protein content and contribution to food security. However, challenges in seed germination and early seedling establishment often limit productivity. This study examined the effects of three growth regulators Indole-3-Acetic Acid (IAA), Sodium Nitroprusside (SNP), and Vitamin C (Vit C) on the germination, early growth, and field performance of brown and white bean varieties. Seeds were primed with 100, 500, and 1000 ppm concentrations of each regulator, germinated on cotton wool,

and later transplanted to nursery and field conditions. Parameters such as germination rate, shoot and root length, root number, biomass, and moisture content were evaluated. Results showed that SNP treatments produced the best overall growth, significantly enhancing germination rate, shoot elongation, and field performance. Vitamin C improved vegetative growth and seedling vigor, while high concentrations of IAA negatively affected germination and early development. The study concludes that moderate SNP concentrations can effectively promote seedling establishment and growth, and recommends further research on long-term yield impacts and varietal responses. These findings provide insight into optimizing bean production through the targeted use of plant growth regulators.

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is one of the most important legumes in global agriculture and nutrition. It provides a rich, affordable source of plant-based protein, fiber, and essential nutrients, particularly in developing regions such as Latin America, sub-Saharan Africa, and parts of Asia (FAO, 2024; Blair et al., 2010). In Nigeria, it is widely consumed in traditional dishes such as *akara*, *moi moi*, and *ewa riro*, serving as a key contributor to food security and a major livelihood source for smallholder farmers (Ugwu and Okoro, 2021). Despite its nutritional importance and adaptability to diverse environments, bean productivity remains limited by poor and uneven seed germination, which affects crop establishment, yield potential, and nutrient quality.

The nutritional quality of beans is typically evaluated through proximate analysis, which assesses key parameters such as moisture, crude protein, crude fat, fiber, ash, and carbohydrate content. These components reflect both the food's energy value and its contribution to dietary health. However, recent research has shifted from basic nutrient profiling to exploring how agricultural practices—particularly seed priming and plant growth regulator (PGR) application—can influence the nutritional value of harvested seeds. Factors such as seed variety, coat color, and environmental conditions all contribute to differences in proximate

composition (Broughton et al., 2003; Hayashi, 2004).

Plant growth regulators are chemical compounds that influence physiological processes in plants, modifying responses to internal and external stimuli. Natural and synthetic regulators such as Indole-3-acetic acid (IAA), Vitamin C (ascorbic acid), and Sodium Nitroprusside (SNP) play critical roles in plant development, germination, and stress adaptation (Davies, 2010; Smirnoff, 2000). IAA, a naturally occurring auxin, regulates cell elongation, root formation, and tissue differentiation, thereby supporting early seedling growth (Teale et al., 2006). Vitamin C functions as a potent antioxidant that protects plant tissues from oxidative stress and enhances enzyme activity linked to carbohydrate metabolism (Smirnoff and Wheeler, 2000). SNP, a nitric oxide donor, promotes seed dormancy release, enzyme activation, and tolerance to environmental stress (Mur et al., 2013; Fan et al., 2022). Collectively, these regulators influence germination success, vigor, and nutrient assimilation, making them useful tools in seed treatment research.

Seed priming controlled pre-hydration of seeds before planting has emerged as a practical method to improve germination and seedling uniformity. By partially activating metabolic processes before sowing, priming enhances enzyme activity, stress tolerance, and overall plant vigor (Farooq et al., 2019; Paparella et al., 2023). Primed seeds tend to germinate faster and more uniformly, leading to stronger early growth and better field performance, especially in stress-prone environments. Combining priming with PGR treatments may further enhance seed quality, yet the specific impact of these treatments on bean nutrition has received limited attention.

In Nigeria, both brown and white bean varieties are cultivated, with each having distinct physical and nutritional traits. Brown beans typically have higher phenolic content, contributing to their antioxidant potential and longer shelf life, while white beans are lower in tannins, making their minerals more bioavailable and their texture softer after cooking (Akond et al., 2011; Oluseyi et al., 2023). Despite these known differences, limited

comparative data exist on how seed color influences response to growth regulators during germination and subsequent nutritional outcomes.

Past studies have demonstrated that PGRs can enhance germination rates, root elongation, and early growth performance (Audi and Muhktar, 2009; Singh et al., 2014; Ali and El-Karkouri, 2018). However, few have examined how such treatments may affect the proximate composition of mature seeds. This gap is particularly relevant in Nigeria, where nutrient-rich food crops are vital for addressing protein-energy malnutrition and improving dietary diversity. Examining how PGRs influence both early growth and nutritional outcomes can therefore provide critical insights for agricultural improvement and food policy development.

Understanding the proximate composition of beans grown under the influence of IAA, SNP, and Vitamin C treatments can help identify the most effective approaches for optimizing both germination performance and nutritional value. By comparing brown and white beans, this study aims to clarify varietal differences in response to PGRs and provide empirical data to guide better seed management practices. Such findings will be valuable to farmers, food processors, and policymakers seeking sustainable methods to improve crop productivity and nutritional quality.



Plate 1 shows the white and brown *Phaseolus vulgaris* L. seeds used in this study, representing the two major varieties examined.

In summary, the literature underscores that while plant growth regulators and seed priming have been widely studied for their effects on germination, there remains a significant gap regarding their influence on seed nutrient composition, particularly between white and brown beans. This research therefore aims to fill this gap by investigating how IAA, Vitamin C, and SNP affect the proximate composition of common bean seeds, contributing to efforts that enhance both food quality and agricultural productivity in Nigeria.

Materials/Methods

Study Area

The samples were obtained in a market within Benin metropolitan

Equipment

Analytical weighing balance.

Apparatus

Petri dish, Beaker ,Plastic Bottles,Filter paper ,Distilled Water ,Cotton wool, Measuring cylinder

Reagents:

Sodium Nitroprusside ,Indole-3-Acetic Acid ,Vitamin C

METHODS

Sample Collection

The bean samples used for this study were obtained from Ring Road Market, Benin City, Edo State, on the 6th of July. The reagents Sodium Nitroprusside (SNP), Indole-3-Acetic Acid (IAA), and Vitamin C (ascorbic acid) were provided by the Space-Earth Environment Research Laboratory, University of Benin, Benin City, Edo State, Nigeria. All materials were handled under clean laboratory conditions to prevent contamination and maintain experimental accuracy.

Sample Preparation

Three concentrations (100 ppm, 500 ppm, and 1000 ppm) of each reagent were prepared and properly labelled. The reagents used to treat a total of 200 viable bean seeds, comprising both brown and white varieties. Twenty (20) seeds ten (10) of each variety were placed in each of nine (10) clean beakers corresponding to the different concentrations of the reagents. Each set of seeds was primed with 20 mL of its respective reagent concentration and allowed to soak for 30 minutes before further processing. This process ensured uniform exposure of the seeds to the growth regulators and established a standardized condition for subsequent germination and growth assessment.

METHODOLOGY

Preparation Of Reagent

A total of Ten (10) plastic bottles were thoroughly cleaned and labelled with each filled with 250 ml of distilled water.

- Growth regulator solutions of 100 ppm, 500 ppm, and 1000 ppm were prepared as follows:
 1. 100 ppm solution: 0.025 g of the solute was weighed and dissolved in 250 ml of distilled water.
 2. 500 ppm solution: 0.125 g of the solute was weighed and dissolved in 250 ml of
 3. distilled water.
 4. 1000 ppm solution: 0.25 g of the solute was weighed and dissolved in 250 ml of distilled water.

SEED PRIMING

A total of ten (10) clean beakers were prepared and appropriately labeled according to the type of growth regulator and concentration used: Vitamin C (100 ppm, 500

ppm, and 1000 ppm), Sodium Nitroprusside (100 ppm, 500 ppm, and 1000 ppm), Indole-3-Acetic Acid (100 ppm, 500 ppm, and 1000 ppm), and a control (distilled water).

Two hundred (200) viable bean seeds were selected comprising 100 brown and 100 white seeds and evenly distributed among the ten (10) beakers, with twenty (20) seeds (ten of each variety) per beaker. Each beaker received 20 mL of its corresponding reagent concentration, ensuring uniform coverage of the seeds. The seeds were allowed to soak for 30 minutes to complete the priming process, enabling optimal absorption of the growth regulators.

Simultaneously, ten (10) sterile Petri dishes were prepared and labeled to match the beakers. A uniform layer of cotton wool was spread across the base of each Petri dish to provide moisture and serve as a carbon source during germination. After 30 minutes of priming, the treated seeds were carefully transferred from the beakers into the corresponding Petri dishes. The two bean varieties were arranged separately within each dish to maintain experimental consistency.

Seed germination was monitored over a period of 120 hours, during which changes in root and shoot development were observed and recorded.



Plate 2: Plate showing germinating bean seeds in Petri dishes lined with cotton wool after immediately after planting



Plate 3: Plate showing germinating bean seeds in Petri dishes lined with cotton wool after 48hours



Plate 4: Plate showing germinating bean seeds in Petri dishes lined with cotton wool after 72 hours



Plate 5: Plate showing germinating bean seeds in Petri dishes lined with cotton wool after 120 hours

CALCULATIONS:

TO PREPARE 100ppm SOLUTION:

100mg (0.1g) of solute is dissolved in 1000ml of Distilled Water For 250ml: 0.1g = 1000ml

$$X = 250\text{ml}$$

Cross multiply the equation $X=25/1000$ this would equal 0.25g TO PREPARE 500ppm SOLUTION:

500mg (0.5g) of solute is dissolved in 1000ml of Distilled Water For 250ml: 0.5g = 1000ml

$$X = 250\text{ml}$$

Cross multiply the equation $X=125/1000$ this would equal 0.125g

TO PREPARE 500ppm SOLUTION:

1000mg (1g) of solute is dissolved in 1000ml of Distilled Water For 250ml: 1g = 1000ml

$$X = 250\text{ml}$$

Cross multiply the equation $X=250/1000$ this would equal 0.25g TO GET MOISTURE CONTENT;

Wet weight – Dry weight= Moisture conten

TRANSPLANTING INTO NURSERY

Raising the bean seedlings in a nursery was an important step in this study because it provided a more controlled and gentle environment for the young plants to develop. At this stage, the seedlings were protected from harsh weather, pests, and other stress factors, giving them the best chance to grow strong and healthy. The nursery setup also helped ensure that all seedlings grew at a relatively uniform rate, which made it easier to observe the effects of the different growth regulators.

For the nursery, ten (10) plastic bottles were cut into halves, cleaned, labeled, and filled with sand to serve as small growing containers. The sand was moistened with

water to prevent dryness and help the roots establish properly. Two (2) seedlings from each treatment concentration were then transplanted into these containers and kept under close observation.

The seedlings were allowed to grow for four (4) days in the nursery to give them enough time to stabilize before being moved to the main field. This short nursery phase helped the plants adjust gradually, making the transition to the field smoother.



Plate 5: Bean seedlings after transplanting into nursery soil after 120 hours.

FIELD PREPARATION AND TRANSPLANTING

Transplanting seedlings from the nursery to the main field is crucial because it allows plants to grow in wider spaces with adequate access to soil nutrients, water, and sunlight. This step ensures proper plant population, reduces competition among crops, and encourages stronger root establishment. By transplanting only healthy and well- developed seedlings, farmers increase the chances of better crop survival, higher yields, and improved overall productivity in the field. For this project, transplanting to the field was necessary to observe how the bean seedlings responded to natural conditions after initial nursery growth, and to evaluate the overall effect of the applied growth regulators on their survival, establishment, and performance under field conditions.

The field was first prepared by clearing and tilling the soil,

Each of the nursery bottle were watered before uprooting to soften the soil and reduce root damage.

10 holes were digged and prepared in the field, and the seedlings were placed into the holes and soil was added to cover the roots and make ridges to prevent water logging. 4. Regular aftercare practices such as irrigation, weeding, and pest control were carried out to ensure proper growth and development.



Plate 6: Image of bean seedlings transplanted into the field after nursery growth.



Plate 7: image of the grown Beans after 2 months of observation



Plate 8: An image showing the plant growth after 3 months of observation



Plate 9: An image showing the plant growth after 4 months of observation

GERMINATION RATE RESULTS

Table 1.0 table showing Germination rate results.

Samples	No of germinated seeds	Shoot length(cm)	Root length(cm)	No of roots	Wet weight	Dry weight	Moisture Content
Water (control) bb	10	4.3	2.2	11	2.93	0.53	2.4
Water (control) wb	5	6	2	8	2.15	0.52	1.63

SNP100ppm bb	4	10	3	6	1.68	0.46	1.22
SNP100ppm wb	5	10	0.8	2	1.16	0.15	1.01
IAA100ppm bb	4	16	2	5	1.21	0.36	0.85
IAA100ppm wb	3	8.4	4	5	1.15	0.26	0.89
VITc 100ppm bb	10	23.5	1	15	0.81	0.23	0.58
VITc 100ppm wb	10	8.4	1	10	1.14	0.44	0.7
SNP500ppm bb	5	7	0.5	12	0.51	0.17	0.34
SNP500ppm wb	7	5	1.5	3	0.3	0.03	0.27
IAA500ppm bb	8	0	4.5	6	1.12	0.23	0.89
IAA500ppm wb	7	11	4	7	1.4	0.52	0.88
VITc 500ppm bb	8	8.9	4	15	1.64	0.63	1.01
VITc 500ppm wb	10	9.5	5.8	6	0.72	0.55	0.17
SNP 1000ppm bb	4	2	1	4	0.72	0.27	0.45
SNP1000ppm wb	3	7	0.8	0	0.65	0.06	0.59
IAA1000ppm bb	0	0	0	0	0	0	0
IAA1000ppm wb	2	4	1	0	0	0	0
VITc 1000ppm bb	5	3.4	2	4	0.83	0.29	0.54
VITc 1000ppm wb	10	13.5	1.6	2	0.94	0.3	0.64

Key: The table shows the germination and growth responses of brown and white beans under different treatments compared with the water control. Vitamin C at 100 ppm recorded the highest shoot length and number of roots in brown beans, indicating better vegetative growth. In contrast, higher concentrations of SNP and IAA generally reduced germination and seedling growth, with IAA at 1000 ppm showing no germination in brown beans. Overall, Vitamin C treatments showed better early growth performance compared to other treatments.

KEY WORDS:

SNP = Sodium Nitropusside

IAA = Indole-3-Acetic acid

VITc = Vitamin C

bb = Brown beans

wb =White beans

FIELD OBSERVATION:

Table 1.1: Table showing the parameters gotten from field observation

Sample	Lenght Of Spread (cm)	No. Of Branches	No. Of Leaves	Dry Weight of Spread
CTR	247	3	88	9.3
Vit C 100ppm	196	4	131	9.59
IAA 100ppm	200	2	75	9
SNP 500ppm	239	7	198	22.96

The table shows the spread, number of branches, number of leaves, and dry weight of plants treated with different growth regulators compared with the control. SNP at 500 ppm recorded the highest number of branches, leaves, and dry weight, indicating better vegetative growth. Vitamin C at 100 ppm also showed relatively high leaf production compared with the control, while IAA at 100 ppm recorded the lowest number of branches and leaves. This suggests that plant growth varied depending on the type of treatment applied.

KEY WORDS:

CTR: WATER

Vit C: Vitamin C

IAA: indole-3- Acetic Acid

SNP: Sodium Nitro Prusside

Table 1.2: Number of pods produced from commonbeans treated with different growth regulator concentration

Sample	NO. Of pods
CTR	1
SNP 100 ppm	2
IAA100ppm	1
VitC 100ppm	1
SNP 500ppm	3
IAA 500 PPM	0
VitC 500ppm	2
SNP1000ppm	3
IAA 1000ppm	0
Vit C 1000ppm	2

The table shows the number of pods produced by plants treated with different concentrations of SNP, IAA, and Vitamin C compared with the control. SNP at 500 ppm and 1000 ppm recorded the highest number of pods, indicating better reproductive performance. Vitamin C treatments produced moderate pod numbers, while IAA at 500 ppm and 1000 ppm produced no pods. This suggests that pod production varied depending on the treatment applied



Plate 10: An image showing the spread of the plant grown with SNP concentration after 3months



Plate 11: an image of the the spread of the plant grown with IAA growth regulator after 3 months



Plate 12: an image showing the spread of the plant grown with Vit C growth regulator after 3 months

Plate 10: An image showing the spread of the Control (Water)



Plate 13: A picture showing the bean pod produced under 100 ppm VitC treatment after 4 months of observation



Plate 14: A picture showing the bean pod produced under 100 ppm IAA treatment after 4 months of observation



Plate 15: An image showing the bean pod produced under 100 ppm SNP treatment after 4 months of observation



Plate 16: An image showing the bean pod produced under 500 ppm SNP treatment after 4 months of observation



Plate 17: An image showing the bean pod produced under 100 ppm SNP treatment after 4 months of observation.



TABLE OF OBSERVATION:

Table 1:3 Summary of Field Observations and Laboratory Analysis

Observation Time	Treatment / Concentration	Observation
24 hours	Sodium Nitroprusside (SNP); Vitamin C treatments	Discoloration was observed in SNP-treated seeds, while Vitamin C–treated seeds showed good early germination and growth compared to other treatments.
30 hours	Sodium Nitroprusside (SNP)	It was observed that the seeds treated with sodium nitroprusside showed discoloration, with a blackish appearance. This discoloration persisted throughout the germination period.
48 hours	Vitamin C treatments; Sodium Nitroprusside (SNP)	Vitamin C–treated seeds showed improved germination and vegetative response, whereas SNP-treated seeds continued to exhibit discoloration and reduced growth response.
72 hours	IAA (100 ,1000 ppm); SNP (500 ppm); SNP (1000 ppm); Vitamin C treatments	Maggots were observed in seeds treated with IAA (100 ppm and 1000 ppm) and SNP (500 ppm and 1000 ppm). SNP and IAA (1000 ppm) treatments showed the least growth performance, while Vitamin C treatments exhibited the highest growth response.
120 hours	IAA (100 ppm) and all SNP treatments	It was observed that the presence of maggots occurred in seeds treated with 100 ppm IAA and in all SNP-treated samples.
120 hours	Vitamin C treatments	It was observed that Vitamin C–treated seeds exhibited the most pronounced

		vegetative growth among all treatments.
120 hours	All treatments	It was observed that leaf emergence occurred in most treatments; however, no leaf formation was observed in SNP-treated samples and seeds treated with 100 ppm IAA.
Field growth stage	SNP (all concentrations)	It was observed that SNP-treated plants showed vigorous vegetative growth and a wider spread compared to other treatments.
Field growth stage	IAA (1000 ppm)	It was observed that plants treated with 1000 ppm IAA displayed the least growth performance under field conditions.
First month	All treatments	It was observed that pest attack occurred across all treatments, with SNP-treated samples being the most affected.
Four months	All treatments	It was observed that vigorous vegetative growth, flowering, and pod formation occurred, indicating the onset of the reproductive stage.
Proximate Analysis		
Laboratory analysis	All treatments	It was observed that moisture content varied across treatments, with higher values recorded in some Vitamin C and SNP-treated samples compared to the control.
Laboratory analysis	IAA (100 ppm)	It was observed that seeds treated with IAA at 100 ppm recorded the lowest moisture content among all treatments.

Laboratory analysis	IAA (500 ppm)	It was observed that ash content was highest in seeds treated with IAA at 500 ppm, indicating higher mineral composition.
Laboratory analysis	IAA and SNP treatments	It was observed that crude fibre content was generally higher in treated seeds compared to the control.
Laboratory analysis	All treatments	It was observed that crude fat content showed minimal variation across all treatments and remained close to the control value.
Laboratory analysis	Vitamin C (100 ppm)	It was observed that seeds treated with Vitamin C at 100 ppm recorded the highest crude protein content.
Laboratory analysis	Vitamin C and IAA treatments	It was observed that carbohydrate content was higher at lower concentrations of Vitamin C and IAA and reduced at higher concentrations.

The table summarizes the observations recorded during germination, field growth, and laboratory analysis of seeds treated with SNP, IAA, and Vitamin C. During early germination (24–72 hours), SNP-treated seeds showed discoloration and reduced growth, while Vitamin C treatments exhibited better germination and vegetative response. Maggot infestation was observed in some IAA and SNP treatments, particularly at higher concentrations, which corresponded with poor growth performance. Under field conditions, SNP treatments showed wider vegetative spread, whereas IAA at 1000 ppm showed the least growth performance. Proximate analysis indicated variations in moisture, ash, fibre, protein, and carbohydrate contents, showing that the treatments influenced the nutritional composition of the harvested seeds.

PROXIMATE ANALYSIS RESULT

Table 1.4: Results of the Proximate Analysis Test

Cool	CONC.	Moisture Cont%	Ash Cont. %	Crude Fire Cont. %	Crude Fat %	Crude Protein%	Carbohydrate%
IF 01	Vit C 100	20.2	4.2	0.4	1.19	13.33	61.68
IF 02	Vit C 500	26.4	10.2	0.8	1.2	12.14	49.26
IF 03	Vit C 1000	33.4	9.6	0.8	1.2	12.34	42.66
IF 04	IAA 100	16.1	6.2	0.8	1.22	12.12	63.56
IF 05	IAA 500	21.4	10.8	1.2	1.16	12.43	53.01
IF 06	SNP 100	34	6.8	1.2	1.17	11.96	44.87
IF 07	SNP 500	20.4	4.8	1	1.23	12.41	60.16
IF 08	SNP 1000	34	4.2	1.2	1.17	11.97	47.46
CTR		34	8	0.8	1.16	12.93	43.11
Sowing Seed		13.6	4.6	0.4	1.25	12.69	67.46

The table shows the proximate composition of seeds treated with different concentrations of Vitamin C, IAA, and SNP compared with the control and the sowing seed. The results indicate variations in moisture, ash, crude fibre, fat, protein, and carbohydrate contents across the treatments. Vitamin C and SNP treatments generally recorded higher moisture contents, while IAA 100 ppm and the sowing seed showed higher carbohydrate values. These results suggest that the different treatments influenced the nutritional composition of the seeds.

KEY WORDS:

CTR: WATER

Vit C: Vitamin C

IAA: indole-3- Acetic Acid

SNP: Sodium Nitro Pusside

DISCUSSION

The effects of Vitamin C, Sodium Nitroprusside (SNP), and Indole-3-acetic acid (IAA) on the germination, growth, and nutritional makeup of common beans (*Phaseolus vulgaris*) were examined in this study. The findings demonstrated that, depending on the type and concentration of the regulator, plant growth regulators had a significant impact on seed germination and subsequent plant performance.

SNP treatments generally produced better germination performance and field growth compared to other treatments and the control. Improved shoot development, plant spread, and pod formation observed under moderate SNP concentrations may be attributed to the role of nitric oxide in enhancing enzyme activation and metabolic processes during seed germination and early growth. However, seed discoloration and increased pest attack recorded in SNP-treated plants suggest that rapid vegetative growth may increase susceptibility to environmental stress factors.

Vitamin C treatment promoted vigorous vegetative growth and enhanced seedling establishment. Its antioxidant properties likely reduced oxidative stress during germination, leading to improved leaf development and overall plant health. In addition, seeds treated with lower concentrations of Vitamin C recorded relatively higher protein content, indicating improved metabolic activity and nutrient assimilation.

IAA, on the other hand, displayed effects that were dependent on concentration. Higher concentrations, especially 1000 ppm, inhibited germination and decreased plant performance, whereas lower concentrations promoted moderate growth. Overproduction of auxin can limit the establishment and productivity of seedlings by interfering with normal cellular differentiation and root development. The differences between brown and white bean varieties show that responsiveness to growth regulators is influenced by varietal characteristics. The variance in germination rate and growth performance between treatments may be explained by variations in seed coat characteristics and physiological reactions.

Growth regulators had an impact on the nutritional makeup of seeds, according to the proximate analysis. While crude fat stayed mostly constant, treatments had an impact

on the amounts of moisture, ash, fibre, protein, and carbohydrates. Improved levels of protein and carbohydrates were supported by lower concentrations of vitamin C and IAA, indicating that proper regulator dosage can improve both growth and nutritional quality. Overall, the results show that while high IAA concentrations have a detrimental effect on growth performance, moderate application of growth regulators, especially SNP and vitamin C, can enhance germination, plant development, and seed quality in common beans.

CONCLUSION

This study showed how different plant growth regulators can influence the way common beans (*Phaseolus vulgaris* L.) germinate and grow, especially during their early stages. Common beans are an important part of Nigeria's diet and economy, and understanding how to improve their growth can make a real difference for farmers and consumers alike. From the results, Sodium Nitroprusside (SNP) proved to be the most effective treatment overall, producing seedlings with stronger roots, longer shoots, and a wider field spread compared to other treatments. However, it also caused some discoloration in the seeds and made them more prone to pest attacks. Vitamin C also boosted growth, encouraging more leaves and healthy vegetation, while high concentrations of Indole-3-Acetic Acid (IAA), particularly at 1000 ppm, slowed down germination and reduced plant performance. These findings suggest that using SNP at moderate concentrations can greatly improve germination and early establishment in beans, while Vitamin C can serve as a helpful alternative, especially in stressful growing environments. IAA, on the other hand, should be used carefully and at lower concentrations. Moving forward, future studies should look into how these growth regulators affect yield, pest resistance, and soil conditions over time. It's also important to remember that white and brown bean varieties may respond differently to each treatment, so tailoring the approach to each variety could lead to even better results for farmers and researchers. The proximate analysis showed that the growth regulators also affected seed nutritional composition, with variations observed in moisture, ash, protein, fibre, and carbohydrate contents. Lower concentrations of Vitamin C and IAA supported improved protein and carbohydrate levels, while crude fat content remained relatively unchanged across treatments.

Overall, the results indicate that growth regulators can influence both early growth performance and seed nutritional quality.

RECOMMENDATION

Based on the findings of this research, it is recommended that Sodium Nitroprusside (SNP) should be applied at moderate concentrations as a seed priming agent to enhance germination rate and early growth in common beans, as its ability to promote strong root and shoot development makes it a valuable tool for improving field establishment. However, attention should be paid to its tendency to increase susceptibility to pest attack and seed discoloration.

Vitamin C should also be promoted as an alternative, especially in environments where plants are exposed to stress. In this research, it was observed that its antioxidant properties help improve seedling vigor and overall plant health. In addition, low concentrations of Vitamin C were found to support improved protein and carbohydrate content in the seeds. High concentrations of Indole-3-Acetic Acid (IAA) should be avoided, as they were found to suppress germination and reduce early growth performance. Lower concentrations may be considered where nutritional quality and controlled growth responses are desired.

Future research should focus on the long-term effects of these growth regulators on yield, pest resistance, soil interaction, and seed nutritional quality under various environmental conditions. Lastly, it is important that farmers and researchers take into account the differences between bean varieties, as brown and white beans may respond differently to each growth regulator.

Reference

1. Akond, A. S. M. G. M., Crawford, H., Berthold, J., Talukder, Z. I., & Hossain, K. (2011). Minerals (Zn, Fe, Ca and Mg) and antinutrient (phytic acid, tannin and phytate:Zn molar ratio) concentrations in common bean. *International Journal of Food Sciences and Nutrition*, 62(3), 299–307.
2. Amanpour-Balaneji, B., & Sedghi, M. (2012). Seed priming techniques to improve germination and early growth of common bean (*Phaseolus vulgaris* L.)

- under salinity stress. *International Journal of Agriculture and Crop Sciences*, 4(12), 787–792.
3. Aouani, M. E., Mhamdi, R., Mars, M., & Ghrir, R. (1998). Nodulation and growth of common bean under NaCl-stress. *Soil Biology and Biochemistry*, 30(10–11), 1473–1475.
 4. Aouani, M. E., Mhamdi, R., Mars, M., & Trabelsi, M. (1998). Effects of salt on growth and nitrogen fixation of common bean (*Phaseolus vulgaris* L.) inoculated with *Rhizobium tropici* CIAT899. *Agronomie*, 18(4), 281–287.
 5. Arc, E., Galland, M., Cueff, G., Godin, B., Lounifi, I., Job, D., & Rajjou, L. (2011). Re-establishment of desiccation tolerance in germinated *Arabidopsis thaliana* seeds by chemical genetic manipulation of the antioxidant machinery and ABA/GA balance. *The Plant Journal*, 67(5), 1037–1050.
 6. Audi, P. O., & Muhktar, A. A. (2009). Effect of growth regulators on seed germination and seedling growth of tomato (*Lycopersicon esculentum* Mill.). *Nigerian Journal of Basic and Applied Sciences*, 17(1), 17–20.
 7. Beaver, J. S., & Rosas, J. C. (1994). Heritability of seed coat permeability in common bean. *Crop Science*, 34(5), 1251–1255.
 8. Beebe, S., Gonzalez, A. V., & Rengifo, J. (2013). Research on trace minerals in the common bean. *Food and Nutrition Bulletin*, 21(4), 387–391.
 9. Bello, O. B., Olawuyi, O. J., Ige, S. A., Mahamood, J., Azeez, M. A., Abdulmalik, S. Y., & Oladoye, P. O. (2021). Genetic variability and character association for seed coat colour, weight and dormancy in cowpea (*Vigna unguiculata* (L.) Walp). *Journal of Agricultural Science*, 13(2), 45–59. <https://doi.org/10.5539/jas.v13n2p45>
 10. Blair, M. W., González, L. F., Kimani, P. M., & Butare, L. (2010). Genetic diversity, inter-gene pool introgression and nutritional quality of common bean (*Phaseolus vulgaris* L.) from Central Africa. *Theoretical and Applied Genetics*, 121(2), 237–248. (Note: Duplicate entry removed).

11. Bouis, H. E., & Welch, R. M. (2010). Biofortification: A sustainable agricultural strategy for reducing micronutrient malnutrition in the global South. *Crop Science*, 50(S1), S-20–S-32.
12. Broughton, W. J., Hernández, G., Blair, M., Beebe, S., Gepts, P., & Vanderleyden, J. (2003). Beans (*Phaseolus* spp.) – model food legumes. *Plant and Soil*, 252(1), 55–128. (Note: Duplicate entry removed).
13. Cohen, J. D. (1992). Identification and quantitation of indole-3-acetic acid and related compounds: Studies in vitro and in vivo. *Plant Growth Regulation*, 11(2), 193–201.
14. Cohen, J. D., & Addison, R. (1989). Indole-3-acetic acid in plants: Occurrence, biosynthesis, and metabolism. In W. G. Hopkins & D. Graham (Eds.), *The biochemistry of plants: A comprehensive treatise* (Vol. 15, pp. 387–439). Academic Press.
15. Davies, P. J. (2010). *Plant hormones: Biosynthesis, signal transduction, action!* (3rd ed.). Springer.
16. Fan, H., Li, T., Gong, J., & Zhao, J. (2022). Nitric oxide promotes seed germination and seedling growth under salt stress by modulating hormonal and antioxidant responses in plants. *Plant Physiology and Biochemistry*, 171, 27–35.
17. Fan, H., Liu, J., Nie, J., Wang, Y., Wang, G., & Liang, Y. (2022). Role of nitric oxide in plant responses to abiotic stresses. *Frontiers in Plant Science*, 13, Article 839675.
18. Food and Agriculture Organization. (2020). *FAOSTAT database*. Retrieved from [insert URL if applicable] (Note: Consolidated with the incomplete 2024a/2020 entries).
19. Graham, P. H., & Vance, C. P. (2003). Legumes: Importance and constraints to greater use. *Plant Physiology*, 131(3), 872–877.
20. Heydecker, W., Higgins, J., & Gulliver, R. L. (1975). Accelerated germination by osmotic seed treatment. *Nature*, 246(5426), 42–44.

21. Katungi, E., Farrow, A., Mutuoki, T., Gebeyehu, S., Karanja, D., Alemayehu, F., Sperling, L., Beebe, S., Rubyogo, J. C., & Buruchara, R. (2009). *Improving common bean productivity: An analysis of socioeconomic factors in Ethiopia and Eastern Kenya*. CIAT, Pan-African Bean Research Alliance (PABRA).
22. Khatri, K., Singh, N. B., & Prakash, R. (2017). Ascorbic acid mediated improvement in plant growth, physiology, and antioxidant responses under abiotic stresses: An overview. *Plant Physiology Reports*, 22(4), 409–424.
23. Kucera, B., Cohn, M. A., & Leubner-Metzger, G. (2005). Plant hormone interactions during seed dormancy release and germination. *Seed Science Research*, 15(4), 281–307.
24. Maingi, J. M., Gitonga, N. M., Shisanya, C. A., Hornetz, B., & Mwaura, F. (2001). Nitrogen fixation by common bean (*Phaseolus vulgaris* L.) in pure and mixed stands in semi-arid areas of Kenya. *European Journal of Agronomy*, 14(1), 1–12. [https://doi.org/10.1016/S1161-0301\(00\)00081-0](https://doi.org/10.1016/S1161-0301(00)00081-0)
25. Mekonnen, H., Desta, M., & Alemu, T. (2022). Seed priming for improving germination, seedling growth and yield of crops under stress conditions: A review. *Heliyon*, 8(1), Article e08741.
26. Mur, L. A. J., Mandon, J., Persijn, S., Cristescu, S. M., Moshkov, I. E., Novikova, G. V., Hall, M. A., Harren, F. J. M., & Hebelstrup, K. H. (2013). Nitric oxide in plants: An assessment of the current state of knowledge. *AoB Plants*, 5, Article plt052.
27. Muratović, A., Čolak, F., Sokolović, A., & Šarac, Z. (2017). Sodium nitroprusside influences on morphological and anatomical characteristics in *Allium cepa* L. *Herbologia*, 17(1), 37–48.
28. Nunes, R. C., Moraes, G. A. B. K., & Nogueira, F. T. S. (2020). Ascorbic acid in seed germination and seedling development. *Plant Signaling & Behavior*, 15(8), Article 1784019.
29. Nwokocha, C. C., Olaitan, N. I., & Adeyemo, S. O. (2019). Analysis of

- constraints to common bean production in Northern Nigeria. *African Journal of Agricultural Research*, 14(5), 278–284.
30. Oluseyi, O. A., Olatunji, O. M., & Akinyemi, S. O. S. (2023). Nutritional comparison of white and brown beans (*Phaseolus vulgaris* L.): Implications for food processing and human health. *Journal of Food Science and Technology*, 60(3), 812–821.
31. Ouma, J. O., Jeruto, P., & Arusei, R. (2021). Germination and early growth of common bean (*Phaseolus vulgaris* L.) under abiotic stress conditions. *African Journal of Agricultural Research*, 17(10), 1399–1409.
32. Paparella, S., Araújo, S. S., Rossi, G., Wijayasinghe, M., Carbonera, D., & Balestrazzi, A. (2023). Seed priming beyond stress adaptation: Broadening the agronomic reach. *Agronomy*, 15(8), Article 1829.
33. Petry, N., Boy, E., Wirth, J. P., & Hurrell, R. F. (2015). Review: The potential of the common bean (*Phaseolus vulgaris*) as a vehicle for iron biofortification. *Nutrients*, 7(2), 1144–1173.
34. Sano, N., Kim, J. S., Onda, Y., Nomura, T., Mochida, K., Okamoto, M., & Seo, M. (2016). RNA-Seq using bulked recombinant inbred line populations uncovers the importance of brassinosteroid for seed longevity after priming treatments. *Scientific Reports*, 6, Article 33988.
35. Singh, S. P., & Muñoz, C. G. (1999). Resistance to common bacterial blight among *Phaseolus* species and common bean improvement. *Crop Science*, 39(1), 80–89.
36. Singh, V. P., Kumar, J., Singh, S., Prasad, S. M., & Dwivedi, R. (2021). Emerging roles of nitric oxide in plant responses to abiotic stresses. *Acta Physiologiae Plantarum*, 43, Article 25.
37. Smirnoff, N., & Wheeler, G. L. (2000). Ascorbic acid in plants: Biosynthesis and function. *Critical Reviews in Biochemistry and Molecular Biology*, 35(4), 291–314.

38. Souri, M. K., & Hatamian, M. (2019). Aminochelates in plant nutrition: A review. *Journal of Plant Nutrition*, 42(1), 67–78.
39. St. Clair, D. A., Holbrook, C. C., & Kvien, C. K. (2005). Influence of irrigation on seedling emergence and vigor in peanut. *Crop Science*, 45(2), 363–370. <https://doi.org/10.2135/cropsci2005.0363>
40. Teale, W. D., Paponov, I. A., & Palme, K. (2006). Auxin in action: Signalling, transport and the control of plant growth and development. *Nature Reviews Molecular Cell Biology*, 7(11), 847–859.
41. Tully, R. E., Musgrave, M. E., & Leopold, A. C. (1981). The seed coat as a control of soybean seed quality. *Plant Physiology*, 67(5), 1050–1054.
42. Ugwu, D. S., & Okoro, C. (2021). Constraints to increased common bean (*Phaseolus vulgaris* L.) production in Nigeria. *Journal of Agricultural Extension*, 25(2), 87–97.
43. Wang, X., Liu, Y., Zhang, Q., & Li, H. (2025). Sodium nitroprusside seed-soaking enhances germination of *Phaseolus vulgaris* under saline–alkaline stress. *Journal of Plant Growth Regulation*, 44(1), 152–165.
44. Wortmann, C. S. (1993). Contribution of bean morphological traits to seed yield in semiarid environments. *African Crop Science Journal*, 1(1), 39–47.