



Impacts of gibberellic acid (GA₃) on growth and yield of green beans (*Phaseolus vulgaris* L.) in Northern Tanzania

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Abstract

Green bean production in Tanzania ranges from 6 to 8 t/ha which is far below the potential yield of 15 to 20 t/ha, which is largely caused by poor soil fertility of most of Tanzania's land. Gibberellic acids (GAs) are naturally occurring growth-stimulating substances used to promote the growth and development of many plant species. Therefore, the study was carried out to determine the effects of Gibberellic acid growth hormone on the growth and yield of green beans at field conditions. The experiment was conducted using Randomized Complete Block Design with four replications and five treatments at TARI - Tengeru research farm from May to August 2023. Treatments were negative control, with three rates of Gibberellic acid (6.25 g/ha, 12.5 g/ha, and 18.75 g/ha) and Snow Paushak (500 ml/ha) as positive control. Data on growth and yield variables were collected at 33, 40, 47, 54, and 62 days after planting (DAP). The results showed that the application of GA₃ significantly ($p < 0.05$) increased the leaf area index of green beans at 33 DAP. Also, the application of GA₃ at 40, 47, and 54 DAP significantly ($p < 0.05$) affected the plant height of green beans whereby GA₃ (18.75 g/ha) showed the highest. The highest plant fresh weight was recorded at GA₃ at 12.5 g/ha (13.39 t/ha) with the equivalent of 11.86% yield increase, followed by GA₃ at 18.75 g/ha (12.72 t/ha) with the equivalent of 6.27% yield increase. This study concluded that the use of 12.5 g/ha up to 18.75 g/ha GA₃ can be used as an alternative foliar fertilizer since it has shown a significant improvement in the yield of green beans. This will contribute to economic development and livelihood by engaging communities in the production of green beans. Further study particularly on economic aspects is recommended before upscaling of this practice.

Key words: Foliar fertilizer; Gibberellic acid; Green beans; Growth parameters; Yield attributes

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Introduction

Green Beans (*Phaseolus vulgaris* L.) are one of the most important and commonly consumed horticultural vegetable crops in the world (Sachan and Krishna, 2021). The *P. vulgaris* has a high nutritional index at which fresh pods of green beans contain 1.7% protein content while dried ones have 21.1% protein content. Green beans are good sources of dietary fiber, and antioxidants, low in calories, vitamins A, B, and C, and essential minerals like iron, calcium, potassium, and selenium which have health benefits to the human body. Green beans are mostly preferred to be consumed as whole fresh pods rather than dry seeds (Blair *et al.*, 2010; Kamble *et al.*, 2016).

The crop is widely cultivated in tropical, subtropical to temperate regions all over the world (Thapa *et al.*, 2022). The total world production is over 17 million tons per year, with China, Indonesia, Turkey, India, and Egypt being the largest producers and consumers of the crop (Ngelenzi *et al.*, 2017). In Tanzania, the crop is widely cultivated in Arusha, Kilimanjaro and Manyara regions, but elsewhere in the country, the crop is almost unfamiliar (Hillocks *et al.*, 2006; Uwiringiyimana *et al.*, 2020). Moreover, green beans productivity in East Africa is low ranging from 6 to 8 tons per hectare while the potential yield ranges from 15 to 20 tons per hectare (Wahome *et al.*, 2013; Ngelenzi *et al.*, 2017). This low yield has been observed and was mainly attributed to biotic and abiotic conditions, such as high temperatures and low rainfall, poor seed quality, poor soil fertility, and use of local landraces which are susceptibility to insect pests, and diseases and poor crop management (Gogo *et al.*, 2014; Chauhan and Bagyaraj, 2015; Alharbi and Adhikari, 2020).

Gibberellic acids (GA₃), belonging to the gibberellins group are among the five growth-promoting hormones which are naturally occurring and plants produce them in low amounts (Mahmoody and Noori, 2014). Gibberellic acid is one of the most important growths stimulating substances used for promoting cell elongation, and cell division and thus to promote the growth and development of many plant species from seed germination to senescence (Buchanan *et al.*, 2015; Naik *et al.*, 2019).

Although green beans have been produced in the northern part of Tanzania the crop has been more frequently exposed to low air temperatures about 16-19°C during cold seasons and 29 - 31°C in hot seasons and unpredictable rainfall, which affects leaves and shoot development, flower and pod fading and dropping (Labuda and Brodaczewska, 2007). Studies have shown that Green beans require an air temperature of 20-25°C for optimum growing while beyond that temperature, the crop becomes poor in development and low productivity (Labuda *et al.*, 2006). The use of phytohormones such as Gibberellic acids has shown a positive effect on increasing crop production in other horticultural crops (Jaques *et al.*, 2019). Fahad *et al.* (2016), reported that, the application of phytohormones, enhanced plant growth, development, and crop yield. Phytohormones modify growth and development in various ways under normal and stressful environmental conditions. But also, Ammanullah *et al.* (2010), mentioned that plant growth substances are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates to sink thereby helping in effective flower formation, fruit and seed development and ultimately enhancing the productivity of the crops.

Even though PGRs are known to influence plant growth and development at very low concentrations they can inhibit plant growth and development at high concentrations (Giannakoula *et al.*, 2012; Hikosaka and Sugiyama, 2015). Moreover, the response of plants to PGRs may vary with species, varieties, environmental conditions, physiological and nutritional status, stage of development, and endogenous hormonal balance (Sabagh *et al.*, 2021). Thus, the foliar liquid fertilizer product contains the active ingredient of Gibberellic acid is the plant growth regulator (PGR) whose application may directly influence plant growth, as well as its morphological and reserve attributes. Therefore, this study was undertaken to assess the effects of Gibberellic acids as an alternative foliar fertilizer on green bean growth development to maximize green bean production in Tanzania.

Materials and methods

Description of the study sites

The experiment was conducted at TARI Tengeru

Madiira Research farm, Arumeru District, Arusha region which is located at latitude 3° 22' S, longitude 36° 41' E, and 1,260 m.a.s.l. The average monthly temperature at the studied site ranges from 13°C to 34°C with the coldest months starting from May to July. The annual average rainfall is 800 mm. The site experiences a bi-modal rainfall pattern where long rains start in March ending in June and short rains start in November ending in January (Ojiewo *et al.*, 2013).

Experimental materials

The green bean variety used in this study was Vanilla which is characterized by a medium-erect bush, with a maturity period of 55 days, and pod length ranging from 14 to 16 cm. The variety used is tolerance to diseases such as rust, bean common mosaic virus, and anthracnose.

Experiment method

The experiment was laid out in a Randomized Complete Block Design (RCBD) with five treatments replicated four times. The experiment comprises total of 20 treatments at which the treatments were as follow; Untreated negative control; 6.25 g/Ha, 12.5 g/Ha, 18.75 g/Ha of Gibberellic acid application rate; and positive control Snow Paushak (having Gibberellic acid + 6 benzylladenniane active ingredient) application rate 500 ml/Ha. The green beans 'Vanilla variety' was planted at the spacing of 50cm x 5cm making a plant population of 160 000 plants per acre. Each treatment plot hosted 360 plants with the area of 9 m².

Treatment formulation and application

Gibberellic acid rates were formulated according to the protocol. The amount of respective rate was measured by sensitive electrical balance and ground by mortar and pestle. The Gibberellic acid fine powder was dissolved in 200 liters of water/hectare.

The method and time of application of Gibberellic acid were applied according to the manufacturers' recommendations. Gibberellic acid and Snow Paushak were applied at the vegetative stage, three weeks after planting. The first foliar treatment application was carried out four weeks after planting and continued every seven days until the crop reached the flowering stage. Sampling involved five (5) Green bean

plants from each plot randomly selected within the rows.

Data collection

Data were collected on the vegetative parameters; data on crop height, plant canopy, number of leaves, leaf area, and leaf area index were collected after seven days (7) of each treatment application; yield data, data were collected after crop maturity which included data on; pod diameter, length of green pod, number of pods per plant, weight of pod per plant and green pod yield per hectare were estimated. The weather data were collected from a weather station located within 10 km of the study areas.

Data analysis

The data collected were subjected to one-way ANOVA at a significance level $\alpha=5\%$ by using GenStat 16th edition. Means were separated and compared by using Tukey's Honestly Significant Difference (HSD) test.

Results

The effect of Gibberellic acid on the leaf area index of green beans

The results on the effect of Gibberellic acid growth hormone on the leaf area index of green beans are shown in Table 1. The application of Gibberellic acid at 33 days after planting (DAP) significantly ($P\leq 0.05$) increased the leaf area index of green beans, while at 62 days after planting, the application of Gibberellic acid did not significantly ($P>0.05$) increase the leaf area index of green beans. During this period (33 and 62 DAPs), the application of Gibberellic acid (18.75 g/Ha) and Positive Control Snow Paushak (500 ml/Ha) showed the highest leaf area indices of 0.004517 and 0.002666 respectively while negative control showed the lowest of 0.002246 of the leaf area indexes.

Also, the application of Gibberellic acid at 40, 47, and 54 days after planting did not significantly ($p>0.05$) affect the leaf area index of green beans. At 40 days after planting, the application of Snow Paushak (500 ml/Ha) showed the highest leaf area index while Gibberellic acid (6.25 g/Ha) showed the lowest leaf area index. At 47 and 54 days after planting, the application of Gibberellic acid (12.5 g/Ha) and Snow Paushak (500 ml/Ha) showed the highest leaf area index while negative control showed the lowest leaf area index. At 62 days after

planting, the application of Gibberellic acid (6.25 g/Ha) and Snow Paushak (500 ml/Ha) showed the highest leaf area index, and Gibberellic acid

(12.5 g/Ha) and Control showed the lowest leaf area index.

Table 1

The effect of Gibberellic acid on the leaf area index of the green beans at different day intervals after planting

TREATMENT	33 DAP	40 DAP	47 DAP	54 DAP	62 DAP
Control	0.002152ab	0.003269a	0.003722a	0.003664a	0.002246a
Gibberellic acid (6.25 g/Ha)	0.000773a	0.00301a	0.004215a	0.004405a	0.002382a
Gibberellic acid (12.5 g/Ha)	0.000882a	0.003804a	0.00526a	0.004844a	0.00195a
Gibberellic acid (18.75 g/Ha)	0.004517b	0.003336a	0.004431a	0.00406a	0.002036a
Snow Paushak (2 mls/1 lt H ₂ O)	0.002666ab	0.004311a	0.004812a	0.004252a	0.002266a
Grand Mean	0.0022	0.00355	0.00449	0.00425	0.00218
LSD at p = 0.05	0.002249	0.001544	0.001713	0.001117	0.001
CV (%)	28.7	13.2	15.7	19.2	33.3
<i>p - value</i>	0.027	0.419	0.339	0.281	0.873

Values in the same column, followed by the same letter(s) do not differ significantly ($P \leq 0.05$) according to Tukey's honestly significance test, DAP = Days after planting

The effect of Gibberellic acid on the plant height of green beans

The results on the effect of Gibberellic acid growth hormone on plant height of green beans are shown in Table 2. The application of Gibberellic acid at 33 and 62 days after planting did not significantly ($p > 0.05$) increase the plant height of green beans. During this period (33 and 62 DAPs), the application of Gibberellic acid (18.75 g/Ha) and Snow Paushak (500 ml/Ha) showed

the highest plant height while Negative control showed the lowest plant height, respectively. The application of Gibberellic acid at 40, 47, and 54 days after planting significantly ($p < 0.05$) affected the plant height of green beans. During this period (40, 47, and 54 DAPs), the application of Gibberellic acid (18.75 g/Ha) showed the highest plant height while Negative control showed the lowest plant height.

Table 2

The effect of Gibberellic acid on the plant height of the green beans at different day intervals after planting

TREATMENT	33 DAP	40 DAP	47 DAP	54 DAP	62 DAP
Negative Control	41.25a	45.8a	48.96a	55.16a	59.84a
Gibberellic acid (6.25 g/Ha)	43.32a	56ab	53.46ab	58.88ab	66.37a
Gibberellic acid (12.5 g/Ha)	43.55a	62.6bc	54.35ab	59.19ab	66.34a
Gibberellic acid (18.75 g/Ha)	47.25a	68.15c	59.39b	64.47b	64.75a
Snow Paushak (500 ml/Ha)	46.28a	67.25c	59.4b	61.28ab	67.67a
Grand Mean	44.33	60	55.11	59.79	65
LSD at p = 0.05	4.904	7.12	6.141	5.615	7.34
CV (%)	7	6.5	3.9	3.1	3.4
<i>p-value</i>	0.117	<.001	0.014	0.053	0.226

Values in the same column, followed by the same letter(s) do not differ significantly ($P \leq 0.05$) according to Tukey's honestly significance test, DAP = Days after planting

The effect of Gibberellic acid on the leaf number of green beans

Results from the study revealed that the application of Gibberellic acid had no significant

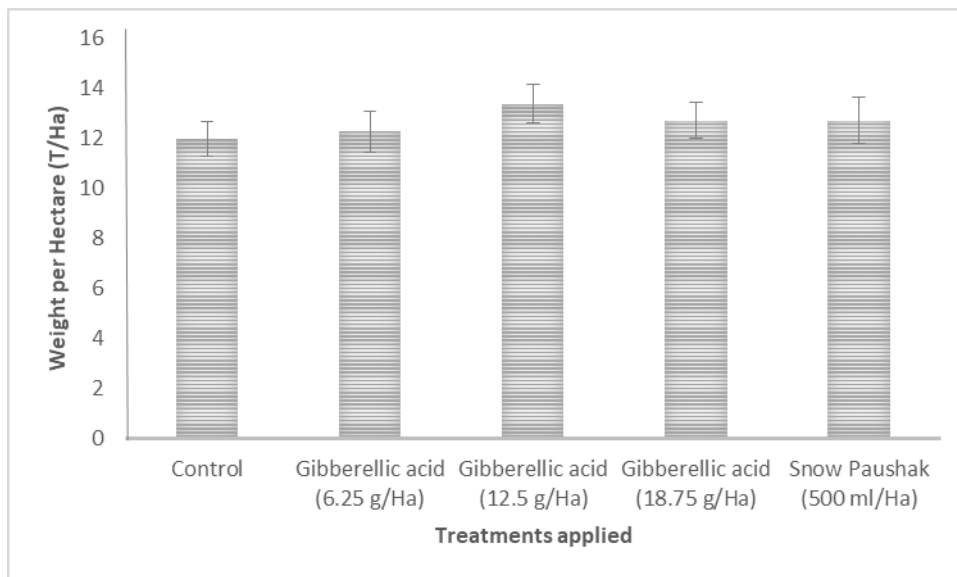
($p>0.05$) effect on the leaf number of green beans.

The effect of Gibberellic acid on the yield and yield parameters of green beans

The results on the effect of Gibberellic acid growth hormone on yield and yield parameters of green beans are shown in Figure 1 and 2. The application of Gibberellic acid did not significantly ($p>0.05$) affect the yield and yield parameters of green beans under study.

Figure 1

The effect of Gibberellic acid on the yield of green beans (harvested 67 days after planting)



ii) Pod length (cm) and Pods diameter (cm)

From the graph, the results show, pod length on Gibberellic acid at 6.25 g/Ha (14.13 cm), Gibberellic acid at 12.5 g/Ha (15 cm), Gibberellic acid at 18.75 g/Ha (14.61 cm), Positive Control Snow Paushak at 500 ml/Ha (14.47 cm). The

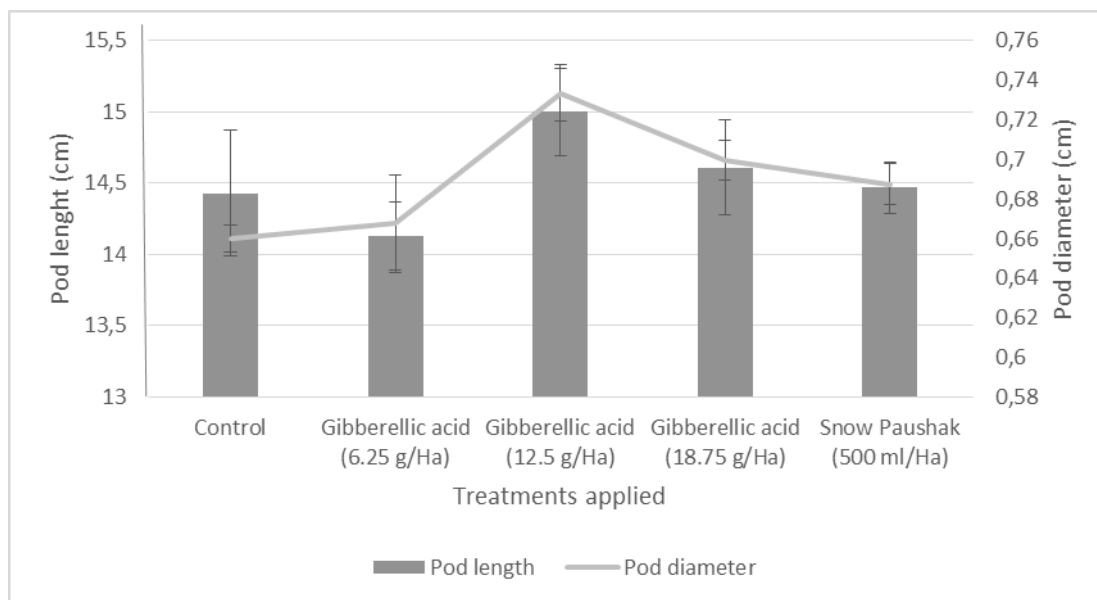
i) The plant fresh weight

From the graph, the results show that the highest plant fresh weight was observed at Gibberellic acid at 12.5g/Ha (13.39 tons/hectare), Gibberellic acid at 18.75g/Ha (12.72 tons/hectare), Positive Control Snow Paushak 500 ml/ Ha (12.72 tons/hectare). The negative control plot presented the lowest plant fresh weight (11.97 tons/hectare) as indicated in the graph below.

control plot presented pod length of 14.43 cm. Also, the results show, there was no significant difference ($p>0.05$) on pods diameter at all rates of Gibberellic acid at 6.25 g/Ha, 12.5 g/H, 18.75 g/Ha, Snow Paushak 500 ml/Ha.

Figure 2

The effect of Gibberellic acid on the yield parameters (pod diameter and pod length) on green beans (harvested 67 days after planting)



Percentage yield increase of green bean

The results on the effect of Gibberellic acid rates applied in the increase in yield as compared to the control are shown in Table 3. Gibberellic acid applied at a rate of 12.5 g/Ha showed the highest

percentage increase in yield as compared to all other treatments applied, while the Gibberellic acid applied at a rate of 6.25 g/Ha showed the lowest percentage increase.

Table 3

The percentage yield of the green beans applied with treatments as compared to the control

Treatments	Yield (T/Ha)	% yield increase
Control	11.97	
Gibberellic acid (6.25 g/Ha)	12.28	2.59
Gibberellic acid (12.5 g/Ha)	13.39	11.86
Gibberellic acid (18.75 g/Ha)	12.72	6.27
Snow Paushak (500 ml/Ha)	12.72	6.27

Discussion

The leaf area index per plant increased significantly due to application of Gibberellic acid as it was observed at 33 days after planting. The hormone treatments largely had significant effect on the leaf area index than untreated crops as this might be caused by the application of Gibberellic acid is known to influence plant growth and development in low concentrations but inhibit

plant growth in high concentrations. The enhanced growth after application of Gibberellic acid created more leaves there by improved photosynthesis and subsequent higher leaf area index. This agrees with findings of Miceli *et al.* (2019), reported that the application of gibberellic acid below the concentration of 10⁻⁴ M which is equivalent to 12.5 g/Ha has shown a significant effect in stimulating plant growth and enhancing leaf expansion at the vegetative stage thus

providing greater area for photosynthesis.

The application of Gibberellic acid had an effect on plant height as shown above. This is evidenced by the observation that hormone-treated plants resulted in higher plant height measurements than the control plants. This observation agrees with Noor *et al.* (2017) who reported that gibberellic acid applied at a rate of 50 ppm to 75 ppm is one of the most important growths stimulating substances used for cell division and elongation thus promoting growth and development in Green beans. Similarly, Fahad *et al.* (2016) found that foliar application of PGR with different concentrations led to significant increases in plant height but only under favorable temperature conditions which proves the non-significant difference in plant height in this study. at which the area had low temperatures (the lowest recorded was 17°C) during the later days after green bean planting.

Also, from the results above, the application of Gibberellic acid had no significant ($p>0.05$) effect on the leaf number of green beans. This might be caused by higher concentration of Gibberellic acid which inhibit excess increase in the number of leaves in green beans. Similar results were stated by Giannakoula *et al.* (2012) that plant growth regulators inhibit plant growth when applied at high concentrations. However, these results are contrary to that of Noor *et al.* (2017), who reported that GA₃ at a rate of 100 ppm concentration can influence the production of a higher number of leaves at 60 and 80 days after planting.

Thus, from the results of this study, the increase in plant fresh weight was associated with increase in the cell division, enlargement and growth. There was consistent increase in plant fresh weight with increase of Gibberellic acid application. This was attributed to efficiency in the assimilation of photosynthetic products thus promoting plant growth hence increasing in plant biomass. Gibberellic acid has been shown to enhance water retention in plant cells, hence increasing plant fresh weight (Miceli *et al.*, 2019). This observation agrees with Noori (2014), who found out that gibberellic acid is the most important growth-stimulating plant growth regulator that is used for cell elongation and thus promotes plant growth and development in legumes.

For the yield parameters observed, the results show, that there was no significant difference in pods diameter, pod length, and diameter at all rates and this was attributed to efficiency in the assimilation of photosynthetic products thus promoting plant growth hence increasing in pod length. It was well observed that gibberellic acid promotes cell elongation, the cambium activity and stimulates protein synthesis thus the observed results in this study are contrary to those of Noor *et al.* (2017) and Rajani *et al.* (2016), who found that gibberellic acid is the most important growth stimulating plant growth regulator that is used for the cell elongation and thus promotes plant growth and development and increased number of pods, pod length and pod diameter.

Conclusion

The results show that Gibberellic acid application at different rates produces yield ranging from 4.5 tons per hectare to 6 tons per hectare. The highest green bean yield was observed at Gibberellic acid applied at a rate of 12.5 g/Ha. Also, the highest green bean plant height was observed on Gibberellic acid rate of 18.75 g/Ha followed by Gibberellic acid applied at 12.5 g/Ha. Moreover, GA (12.5 g/Ha) contributed to high yield increase percentage of 11.86% compared to GA (18.75 g/Ha) which managed to contribute yield increase percentage of 6.27%.

Recommendation

From the study above, it is recommended that Gibberellic acid applied at a rate of 12.5 g/Ha and 18.75 g/Ha are highly recommended to be used a foliar fertilizer in green bean production due to their potentiality of maximizing growth and yield green beans.

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Conflict of interest

We declare no potential conflict of interest.

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