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Growth, Yield and Quality of Green Bean (*Phaseolus vulgaris* L.), Varieties Affected by NPS Fertilizer at Gambella, South West Ethiopia

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Abstract

In Ethiopia, the green bean (*Phaseolus vulgaris* L.) is a significant vegetable and a top priority crop. The countrywide productivity of the green bean is low, primarily due to poor soil fertility. According to the governmental soil database, the majority of the southwest Ethiopian soils are sulfur, phosphorus and nitrogen deficient. However, a study on using two different types of green beans and NPS fertilizer rates. In order to ascertain the optimal rate of NPS fertilizer and varieties for Gambella in 2020, a field experiment was conducted. Treatments included four NPS fertilizer rates (0 kg ha^{-1}, 50 kg ha^{-1}, 100 kg ha^{-1} and 150 kg ha^{-1}) and green bean varieties ($BC_{4.4}$ and Platia). The factorial design was used in a randomized complete block arrangement three times to set up the experiment. SAS software was used to collect and statistically analyze data on plant height, number of primary branches, number of pods per plant, total pod yield per hectare, marketable pod yield per hectare, above ground dry biomass, harvesting index and pod protein content. The combined application of NPS and varieties substantially impacted plant height, the number of pods produced per plant, total pod yield, marketable pod yield and above ground dry biomass, according to the results. The predominant effect of NPS fertilizer rates, however, was on the number of primary branches, harvesting index and protein concentration of the pods. When the plots received the combined treatment of 150 kg ha^{-1} of NPS fertilizer with $BC_{4.4}$ variety, the highest pod yield (3.43 ha^{-1}) and marketable pod yield (2.72 t ha^{-1}) of green beans were attained. Therefore, based on the findings of the current study, farmers can gain extra advantages by applying 100 kg of NPS fertilizer along with the $BC_{4.4}$ green bean variety, which produces the highest yield of marketable green beans.

Keywords: Pod yield; NPS fertilizer; Varieties; Green bean; Pod quality

Introduction

Green bean (*Phaseolus vulgaris* L.), belongs to the Fabaceae family and the Papilionaceae subfamily. French beans, string beans, wax beans and snap beans are just a few of its numerous common names. Morphologically, it is separated into definite, semi-determinate, and indeterminate forms. The dwarf, erect definite forms range from 10 cm to 20 cm in spread to 25 cm to 38 cm in height. Green beans first emerged in central and South America. Africa is regarded as the secondary center of variety, according to Bose, et al. There are rumors that the Portuguese brought the green bean to Ethiopia in the sixteenth century [1].

Green bean is the most important food legume and one of the most widely grown vegetables in the world. It is valued for its rich in many vitamins and minerals, as well as its higher concentrations of vitamin A and C, calcium, starch and protein. It is a warm season crop that grows best in environments without frost, with warm days and strong sunlight. The majority of cultivars can survive temperatures between 19°C and 40°C in warmer climates [2]. They can also grow in a variety of soil types, from light sand to heavy clay and many cultivars can withstand a wide range of pH values between 5.5 and 6.5. The average rainfall in areas where green beans grow successfully ranges from 400 mm to 1200 mm. Green beans are one of the key vegetable crops grown in Ethiopia for both export and domestic markets. Because of the engagement of state horticultural businesses, local and international private investors, and farmers, its output has been continuously rising, occupying the biggest percentage (94%) of all vegetables' export potential. Ethiopian agriculture is known for its low production per unit area based on deteriorating soil fertility, variable rainfall, pest pressure, inadequate agronomic techniques, and limited access to high quality seed [3].

One of the problems with maintaining crop production and productivity in Ethiopia is low soil fertility. Based on the national soil database, most Southwestern Ethiopian soils are deficient in macronutrients (nitrogen, phosphorus and sulfur). Secondly, the yield potential and quality of green beans are not sufficiently maintained in Gambella because there are insufficient improved varieties for specific or wider production locations. However, Ethiopia has few green bean varieties with variable yielding potential.

One of the most well-known mitigating techniques for optimizing the output of crops is to choose the type and rate of fertilizer. To ensure a balanced fertilizer use by the crop grown, new mineral fertilizers with primary and secondary nutrients are important. Applying these nutrients might increase crop profitability. Numerous researchers found that increasing fertilizer application to the optimum amounts enhanced plant growth and production [4].

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To enhance output and quality, commercial green bean agriculture significantly relies on fertilizer application. Therefore, fertilizer application is essential to enhancing crop development, yield and quality. As a result, nitrogen fertilizer, which was crucial in increasing snap bean production, had a significant impact on the vegetative growth, yield and quality of green beans. The other key plant nutrient is phosphorus, which has been found to affect plant height, pod yield, pod number per plant, and phosphorus concentration. Similar to the above, Ganie, et al., showed that sulfur fertilizer significantly affected the number of nodules, dry biomass weight, pod yield, number of pods per plant, and pod protein content of green beans [5].

On the other side, the most crucial element and a prerequisite to determining the production level are choosing a high yielding variety. Variety development is a time consuming and expensive process. However, evaluating the present and available green bean varieties for their capacity to adapt to and perform well in specific agro climatic conditions or locations is a speedier method to boost green bean production and productivity. Moreover, smallholder farmers in the Gambella condition do not fully understand the choice of high yielding varieties and fertilizer types depending on nutrient shortages. Therefore, the goal of this study was to determine the optimum NPS fertilizer rate for different varieties of green beans in Gambella, Southwest Ethiopia [6].

Specific objectives: To examine the possible interactions between different green bean varieties with NPS fertilizer with regards to growth, yield and quality in Gambella, Southwest Ethiopia.

Materials and Methods

Description of the study area

The experiment is performed in the Gambella district using rain fed conduction during the 2020 growing season. The area is suitable in Ethiopia's Gambella region, which is located at an elevation of 840 m.a.s.l., at latitudes 80 23'N and 340 44'E,' and at those coordinates. The district's average minimum and maximum temperatures typically range between 25°C and 42°C, respectively. During the months of February and March, the temperature in this region is extremely hot, reaching 42°C-45°C. The annual rainfall average is between 900 mm-920 mm (Figure 1).

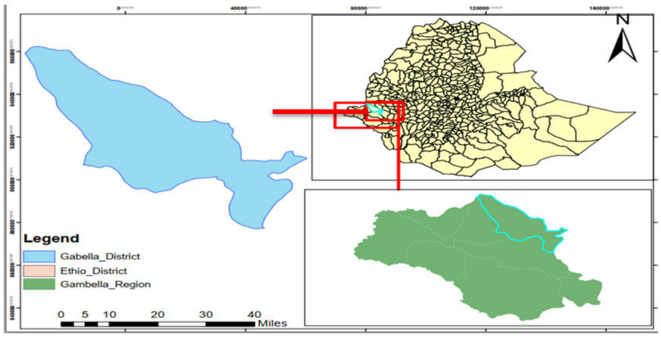

Figure 1: Study area map.

Materials for experiments

Green bean varieties (Platia and $B.C_{4.4}$) obtained from the Melkasa Agricultural Research Center (MARC) was utilized as experimental subjects. It is perfectly suited to the research area and formally is of the MARC released variety. NPS fertilizer supplied as the study's source of nitrogen, phosphorous and sulphur [7].

Treatments and experimental design

Two factors were used in the experiment: Two green bean varieties, $B.C_{4.4}$ and Platia and four levels of NPS fertilizer rates (0 kg ha^{-1}, 50 kg ha^{-1}, 100 kg ha^{-1} and 150 kg ha^{-1}) based on the agricultural transformation agency's tentative fertilizer recommendation rate for the study area (Table 1). The experiment was duplicated three times and arranged as a factorial Randomized Complete Block Design (RCBD). Eight different treatment combinations were randomly distributed to each plot (Table 2).

Treatments	Description
T_1	Control (0+$BC_{4.4}$)
T_2	50 kg ha^{-1} NPS fertilizer+$BC_{4.4}$
T_3	100 kg ha^{-1} NPS fertilizer+$BC_{4.4}$
T_4	150 kg ha^{-1} NPS fertilizer+$BC_{4.4}$
T_5	Control (0+Platia)
T_6	50 kg ha^{-1} NPS fertilizer+Platia
T_7	100 kg ha^{-1} NPS fertilizer+Platia
T_8	150 kg ha^{-1} NPS fertilizer+Platia

Table 1: Treatment combinations.

No.	NPS fertilizer rate (kg ha^{-1})	N	P_2O_5	S
1	0	0	0	0

2	50	9.45	18.85	3.475
3	100	18.9	37.7	6.95
4	150	28.35	56.55	10.425

Table 2: Rate of fertilizer and their nutrient content (kg ha^{-1}) treatments for the experiment.

Experimental procedure

Oxen were used to plow and harrow the experimental field and plots were leveled by hand. Each plot has a size of 1.5 meters × 2 meters (3 m^2). Each plot included five rows, with a distance of 40 cm between rows and 10 cm between plants. The middle three rows were used to gather data and produce measurements, while the two outer rows served as a border. A 1.5 m wide open area separated the blocks, while a 0.5 m wide open area divided the plots within a block. Sowing took place at the experimental research location on July 7, 2020. As a source of mineral nutrients, NPS fertilizer was utilized and full doses which varied depending on treatments were applied as side bands at the time of planting. Other agronomic procedures were maintained consistently across all treatments, as recommended [8]. By sowing two seeds per hill and reducing the number of plants to one when trifoliate leaves started to develop, the plant population was kept stable.

Soil sampling and analysis

Soil sampling and analyses were done before sowing the crop. Soil samples were taken at random in a w-shaped pattern from the entire experimental field of the study site. Using an auger, ten samples were obtained from each arm of the w-shaped lines of the field to a depth of 20 cm. A 1 kg composite sample was taken from this mixture. The sample soil was air dried as well as sieved through a 2 mm sieve mesh prior to analysis. Textural analysis (sand, silt and clay), soil pH, total nitrogen, available phosphorus, cation exchange capacity and organic carbon were among the physicochemical parameters analyzed in the composite soil samples [9].

The soil's texture was assessed using the Bouyoucous hydrometer method. The total nitrogen was calculated using the Kjeldhal method. After saturating the soil with 1 N H_4OAC and measuring the pH using a potentiometric pH meter with a glass electrode at a soil to water ratio of 1:2.5, the cation exchange capacity was calculated using the ammonium acetate method. The amount of phosphorus that was readily available was determined using the Olsen method.

Results from the soil testing revealed that the experimental site's soil textural class was clay loam, with a particle size distribution of 45% sand, 34.5% clay and 30.5% silt. The capacity of this physical soil to hold water and nutrients for plants is improved. The experimental soil has a pH of 6.8, according to the pre-sowing soil study (neutral). According to Roy, et al., pH values between 5-7.2 are suitable for most grain crops. As a result, the pH of the experimental soil is within the range of soil that is productive and suited for growing green beans [10]. The soils at the experimental site had 0.04 % total nitrogen. The nitrogen content of the soils is quite low, according to Bruce and Rayment. The soils' available phosphorus content was 5.3 ppm and according to Hazelton and Murphy, the experimental soil is reported to be low and deficient in phosphorus as the area experiences frequent heavy rain (Table 3).

No.	Parameter	Values	Rating for soil	References
		Soil		
1	pH	6.8	Neutral	Landon
2	OM %	2.67	Low	Hazelton and Murphy
3	TN %	0.04	Very low	Bruce and Rayment
4	Avp (ppm)	5.3	Low	Hazelton and Murphy
5	Soil texture			
	Sand %	45		
	Clay %	34.5		
	Silt %	30.5		
	Textural class	Clay loam		
Note: pH=Hydrogen power; % OM=percent of Organic Matter; %TN=Percent of Total Nitrogen; Avp ppm=Available phosphorus in parts per million.				

Table 3: Initial physicochemical properties of soil.

Data collection and measurements

To examine the effects of NPS fertilizer rates and green bean types, data on phonology, growth, yield and quality factors were collected. The phonological parameters were measured as the number of days from sowing when 50% of the plants reached flowering and 75% of them reached physiological maturity. In order to gather information on the parameters affecting growth and yield, ten randomly chosen plants from each plot were picked at physiological maturity and harvest time.

At the time of physiological maturity, the mean height of ten plants randomly selected from the net plot of each plot was measured [11]. Numbers of branches per plant was obtained from ten randomly sampled primary branches of the net plot. The mean of ten randomly selected plants from the net plot was used to calculate the total number of pods per plant and the overall pod yield. Marketable pod yield, however, was categorized based on visual observations. Pods that were uninjured by insect and disease damage, slightly curved and straight were considered to have marketable pod yield, while undersized, curved and curved pods that were infected with insect and disease were considered to have unmarketable pod yield, which was then converted to ton per hectare. The harvesting index was determined as the ratio of the total above ground dry biomass output per plant to the number of dry pods per plant. Total nitrogen was determined using the micro Kjeldahl technique to determine the crude protein level.

Statistical data analysis

All of the measured parameters were treated to an Analysis of Variance (ANOVA) appropriate to a factorial experiment in RCBD using SAS software version 9.3's General Linear Model (GLM) and the results were interpreted according to Gomez and Gomez's procedure. When the ANOVA revealed significant differences, the LSD test was employed to compare means at a 5% probability level [12].

Results and Discussion

Phenological and growth parameters of green bean

Days to 50% flowering: The number of days needed for 50% flowering was significantly influenced by the main effect of NPS fertilizer (P<0.04). The main effect of varieties and the interactions between NPS fertilizer and varieties, however, were not statistically significant. The application of NPS fertilizer at a rate of 150 kg ha^{-1} resulted in the earliest day of 50% flowering (33.17) that was similar to the control treatment. According to statistical data, plots that received 100 kg of fertilizer per hectare flower late. The possible reason of earliest day of 50% flowering due to, phosphorus, a crucial nutrient involved in promoting and improving bud growth and set, seed formation and crop blooming, may be the cause of the earliest day of 50% flowering due to heavy application of NPS fertilizer. It might hasten a plant's maturation. Similar to how inadequate sulfur causes the fruits and flows to be delayed [13].

Days to 75% physiological maturity: The main effect of NPS fertilizer had a highly significant (P<0.001) influence on the number of days required for green beans to reach physiological maturity, but not for varieties or interaction effects. The application of NPS fertilizer at 150 kg ha^{-1} resulted in the observation of the earliest day of physiological maturity (56). Plots fertilized with 100 kg ha^{-1} of NPS fertilizer matured late, which was statistically in par with plots that received 50 kg ha^{-1} NPS fertilizer. The probable reason for the earliest day of physiological maturity at 75% is phosphorus, a crucial nutrient involved in promoting and stimulating crop seed production and flowering and frequently hastening maturity. It could accelerate the maturity of a plant. Similar to the above, when there is not enough sulfur, the fruits and flowering is delayed [14].

Number of primary branches: The main effects of NPS fertilizer were highly significant differences in the number of primary branches (P<0.001), while the variety and interaction effects were not. The application of 150 kg ha^{-1} NPS fertilizer resulted in the highest number of primary branches per plant (5.78), while the lowest number of primary branches per plant (3.25) was recorded from the control treatment, which was statistically similar to the number of primary branches per plant (3.6) obtained from 50 kg ha^{-1} NPS fertilizer (Table 4). As NPS fertilizer application rates are increased until the optimum level is reached, more primary branches per plant will grow. The increases may be attributable to the availability of nitrogen, phosphorus, and sulfur for cell division, which promoted increased plant height and lateral plant growth.

Treatment			
NPS fertilizer kg ha^{-1}	Days to 50% flowering	Days to 75% physiological maturity	Number of primary branch
0	33.33^{ab}	57.1^{b}	3.25^{c}
50	37.17^{a}	59.17^{a}	3.63^{c}
100	37.17^{a}	59.17^{a}	4.8^{b}
150	36.17^{b}	56^{c}	5.78^{a}
LSD (0.05)	0.8675	0.48	0.48
CV (%)	2.94	3.22	8.8

Note: Means in the column followed by the same letter (s) are not significantly different at 5% level of significance. LSD (0.05)=Least Significant Difference at 5% level and CV (%)=Coefficient of Variation in percent.

Table 4: The main effects of NPS fertilizer on days to 50% flowering, 75% physiological maturity and number of primary branch.

Plant height: Green bean plant height was significantly affected by the main effects of NPS fertilizer, varieties, as well as their interaction effect (P<0.002). The application of 150 kg ha^{-1} with $BC_{4.4}$ resulted in the highest plant height (58.40 cm), which was similar to the combined applications of 150 kg ha^{-1} NPS fertilizer with Platia and 100 kg ha^{-1} NPS with Platia, whereas the control treatment produced the lowest plant height (44.87 cm) (Table 5). This result may be because a sufficient nitrogen supply encourages chlorophyll production, which in turn leads to active vegetative growth and taller plants.

In shoot and root tips, where metabolism is high and cell division is quick, phosphorus is also advantageous [15]. Similarly, sulfur encourages the production of chlorophyll, taller plants and plants with robust vegetative growth.

Factors NPS fertilizer (kg ha^{-1})	Varieties	Plant height (cm)
0	$BC_{4.4}$	44.8^{e}
	Platia	49.87^{d}
50	$BC_{4.4}$	51.23^{cd}
	Platia	51.50^{c}
100	$BC_{4.4}$	56.00^{b}
	Platia	57.90^{a}
150	$BC_{4.4}$	58.40^{a}
	Platia	58.13^{a}
LSD (5%)		1.54
CV (%)		9.6

Note: Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.05)=Least Significant Difference at 5% level and CV (%)=Coefficient of Variation in percent.

Table 5: Interaction effects of NPS fertilizer and varieties on plant height (cm).

Yield and quality parameters of green bean

Number of pod per plant: NPS fertilizer rates, variety and their interactions had a significant effect on the number of pods produced per plant (P<0.029). When 150 kg ha^{-1} NPS fertilizer was applied with $BC_{4.4}$ produced the most pods per plant (33.98), but variety Platia produced the fewest pods per plant (24.50) when 0 kg ha^{-1} NPS fertilizer was used. The maximum total number of pods per plant that was seen from the higher application of NPS fertilizer may have occurred from the presence of sufficient nitrogen, phosphorus and sulfur nutrients, which improved vegetative development and increased light assimilation for the formation of more pods. Phosphorus fertilizer application increased the amount of pods per plant, promote that it encourages flower production and enhances fruit setting. Similarly, sulfur also encourages the activation of enzymes, which increases chlorophyll synthesis in plants and improves carbohydrate metabolism [16].

Total pod yield: The result of the statistical study showed that the interaction effect of NPS fertilizer and varieties had a significant (P<0.05) impact on the total pod yield per hectare. When the $BC_{4.4}$ variety of green beans was planted with the application of 100 kg ha^{-1} NPS fertilizer, the highest grain yield of green beans was recorded (3.43 t ha^{-1}); the lowest grain yield of green beans (1.57 t ha^{-1}) was recorded when the Platia variety of green beans was planted with the application of 0 kg NPS fertilizer. This result might be attributed to thegenetic make-up of the varieties and the soil's availability of nitrogen, phosphate and sulfur, which led to improved vegetative growth. The production of a greater number of pods as a result of proper photo assimilation partitioning of photosynthesis from source to sink increased green bean productivity [17].

Marketable pod yield: The marketable pod yield of green beans is significantly different (P<0.05) as a result of the interaction effect. The highest marketable pod yield (2.7 t ha^{-1}) was observed at an NPS fertilizer rate of 150 kg ha^{-1}+$BC_{4.4}$. The control treatment produced the lowest marketable pod yield (1.1 t ha^{-1}). The possible reasons for the highest marketable pod yield observed from the application of NPS fertilizer were related to the increase in the nutrients in the soil that resulted in better vegetative growth, which in turn enabled the crops to produce greater amounts of photo assimilated in the pods.

Above ground dry biomass per plant: The interaction effect of NPS fertilizer and varieties had a significant (P<0.04) effect on above ground dry biomass. The mean comparison revealed that an NPS fertilizers rate of 150 kg ha^{-1} with $BC_{4.4}$ produced the maximum aboveground dry biomass per plant (82.22 g) (Table 6). On the other side, the control treatment had the lowest aboveground dry biomass per plant (37.39 g). In this study, the amount of above ground dry biomass produced by each plant grew as NPS fertilizer application was increased [18]. This outcome might be the result of enhanced food availability and reduced plant competition, which ultimately led to a better accumulation of photosynthetic material in the plants' sinks (pods) as compared to the control.

Factors		Number of pod per plant	Total pod yield	Marketable pod yield	Aboveground dry biomass
NPS fertilizer (kg ha^{-1})	Varieties				

0	$BC_{4.4}$	26.70^{d}	1.95^{c}	1.33^{c}	50.10^{ef}
	Platia	24.50^{e}	1.57^{d}	1.11^{d}	37.39^{g}
50	$BC_{4.4}$	30.47^{b}	2.98^{b}	2.31^{b}	60.08^{cd}
	Platia	28.00^{c}	2.16^{c}	1.44^{c}	47.69^{f}
100	$BC_{4.4}$	33.06^{a}	3.23^{a}	2.66^{a}	73.25^{b}
	Platia	31.01^{b}	3.07^{b}	2.46^{b}	57.53^{c}
150	$BC_{4.4}$	33.98^{a}	3.43^{a}	2.72^{a}	82.22^{a}
	Platia	31.80^{b}	3.11^{b}	2.48^{b}	58.33^{cd}
LSD (5%)		1.9	0.31	0.19	6.52
CV (%)		3.2	5.3	5	6.33

Note: Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.05)=Least Significant Difference at 5% level and CV (%)=Coefficient of Variation in percent.

Table 6: Interaction effects of NPS fertilizer and varieties on total number of pod plant^{-1}, total pod yield, marketable pod yield (t ha^{-1}) and aboveground dry biomass (g).

Harvesting index

The main effects of NPS fertilizer (P<0.043) caused a significant difference in harvest index, but not the varieties and their interaction. A maximum harvesting index of 44.94% was recorded at a 150 kg ha^{-1} NPS fertilizer rate. The lowest harvesting index (28.91%) was recorded from the control treatment (Figure 2). This result may be the result of increased photo assimilation partitioning of photosynthesis from source to sink (pods) as compared to the control, which was ultimately caused by an increase in the availability of nutrients in soil solution [19].

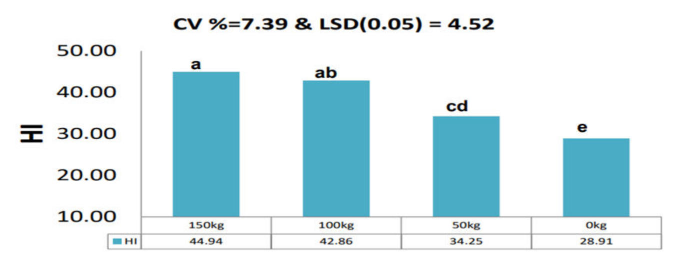

Figure 2: The main effect of NPS fertilizer on the green bean harvesting index means followed by the same letter within a treatment is not significant ly different at 5% significant.

Pod protein concentration: The main effects of NPS fertilizer showed significant (P 0.012) variations in the analysis of variance, but not the interaction and green bean varieties. The maximum protein content (12.95%) was obtained with the application of 150 kg ha^{-1} NPS fertilizer, which was not systematically different from the application of 100 kg ha^{-1} NPS fertilizer. The lowest protein level was found in the control treatment (10.28%), (Figure 3). The fact that nitrogen is used to synthesize amino acids, which in turn make proteins, may account for the increase in protein content as nitrogen application increases [20]. The importance of sulfur fertilizer can be attributed to the fact that it is a component of cysteine, methionine and clusters with iron that are necessary for key plant cell functions such as protein production, assembly and activity control.

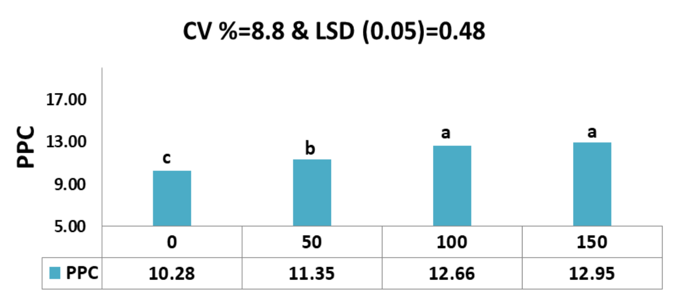

Figure 3: The main effect of NPS fertilizer on the green bean pod's protein content means followed by the same letter within a treatment is not significant ly different at 5% significant.

Conclusion

The findings of this study demonstrated that NPS fertilizer application rates and variety selections increased along with the growth, yield and quality parameters of green beans, such as days to 50% flowering, days to 75% physiological maturity, plant height, number of primary branches, number of pods per plant, total yield, marketable yield, aboveground dry biomass and pod protein concentration. As a result, the main effects of NPS fertilizer on days to 50% flowering, days to 75% physiological maturity, the number of primary branches, harvesting index and pod protein content were significant. The maximum number of primary branches (5.78) and pod protein concentration were obtained with the use of 150 kg ha^{-1} NPS fertilizer (12.95%). The interaction effect of NPS fertilizer and varieties had a significant impact on plant height, number of pods per plant, total pod yield, marketable pod yield and aboveground dry biomass. The maximum mean number of pods per plant (33.06 plant^{-1}), pod production (3.32 t ha^{-1}) and marketable pod yield (2.66 t ha^{-1}) were observed with a combined application rate of 100 kg ha^{-1} NPS fertilizer with the $BC_{4.4}$ variety.

In summary, the current study demonstrated that the $BC_{4.4}$ variety of green beans grew and yielded considerably better when NPS fertilizer was used and that the $BC_{4.4}$ variety generated more marketable pods and related yield parameters than the control treatment produced. For instance, the $BC_{4.4}$ variety and 100 kg NPS application together produced the maximum marketable pod production per hectare under the Gambella conditions. Therefore, it is clear that green beans may survive in the studied area and that farmers can gain more by applying 100 kg of NPS fertilizer along with the $BC_{4.4}$ variety, producing the highest yield of marketable green beans. However, to make meaningful conclusions and recommendations, it would be preferable to repeat the experiment in the field in other seasons and locations as the data only come from one season.

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