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Growth, nodulation and yield response of green bean (*Phaseolus vulgaris* L.) to plant population and blended NPS fertilizer rates at Alage, Central Rift Valley of Ethiopia

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Recently Green bean production and demand is increasing in Ethiopia due to its fast maturity and nutritional value. However, various constraints are reported for its low productivity, including inappropriate uses of plant population and fertilizer rates. The objective of this study was to determine the optimum plant population and NPS rate for quality and economically feasible yield of Green bean. The experiment was conducted in field conditions at Alage, Central Rift Valley of Ethiopia, under supplemental irrigation in 2019. A factorial combinations of three plant populations (222222, 250000 and 333333 plants ha^{-1}) and five levels of blended NPS (0, 132, 142, 152 and 162 kg NPS ha^{-1}) were used in a randomized complete block design (RCBD) with three replications. Number of nodules per plant, number of effective nodule per plant, number of leaf per plant, plant height, and number of branches per plant, number of pod per plant, total above ground fresh biomass, pod diameter, pod length, harvest index and yield per plant and per hectare were recorded. All parameters were subjected to analysis of variance. The least significant differences (LSD) at the level of 5% significance were used to compare the treatments mean. The results showed that plant population and NPS rates had significant effects on number of nodules, number of leaf, number of branch, plant height, number of pod, pod length, harvest index, yield per plant and per hectare. The highest Green bean yield of 13.75 tons ha^{-1} and 16.06 tons ha^{-1} was obtained at the highest plant population (333333 plants ha^{-1}) and the highest NPS rate (162 kg NPS ha^{-1}), respectively. The highest acceptable marginal rates of return (57349%) and (6997.2%) were obtained from 333333 plants ha^{-1} and 162kg NPS ha^{-1}, respectively. Thus, it can be concluded that 333333 plants ha^{-1} and application of 162kg NPS ha^{-1} were gained the superiority for both agronomic and economic growth and productivity for plati variety of Green bean under supplementary irrigation at Alage area.

Key words: Green bean, plant population, NPS fertilizer rate, growth, yield.

INTRODUCTION

Green bean (*Phaseolus vulgaris* L.) is the strain of common bean which is grown for its unripe freshly eaten fibreless succulent pods (Abate, 2006; CIAT, 2006). It is widely cultivated in the world due to its contribution to soil fertility through nitrogen fixation (Demelash, 2018); and having high market value and protein (Damián et al.,

2013; Celmeli et al., 2018). In Ethiopia, it is one of fresh legume vegetables grown for export market (Alemu et al., 2017), and domestic consumption in a variety of dishes (Dessalegn et al., 2006). Globally, green bean is cultivated over an area of 1.5 million hectare with a production and productivity of 22.83 million tons and 15.22 tons ha^{-1}, respectively. China is the leading producer of green bean, with 40% of area (0.57million ha) and 18.69 million tons (81.9%) of production followed by India and Indonesia (FAO, 2016). In Ethiopia, its production in the past five years (2013-2017) increased from 6200 to 7384 tons (FAO, 2017).

Green bean productivity could be raised through the use of improved varieties and agronomic practices including type, rate of fertilizers, spacing and crop protection (Mulugeta, 2011). On the other side, poor agronomic practices like low soil fertility, untimely and inappropriate field operations, erratic rain fall, drought, diseases, weed and insect could be a cause for low productivity (Chekanai et al., 2018). Limited production and productivity of common bean in Ethiopia is attributed to several production constraints, which include lack of improved varieties for the different agro-ecological zones, poor agronomic practices such as low soil fertility, untimely and inappropriate field operations (Mulugeta, 2011).

According to Wortmann (2006), the deficiency in N and P is the major constraint of common bean production, and responsible for the loss of grain yield up to 1.2 million tons in Africa. Production of crops using sulfur containing fertilizer enhances concentration of sulfur-rich proteins, cysteine and methionine (Pandurangan et al., 2015). Total number of nodules and active nodules increased with the increase in application of S up to 20 kg ha^{-1} (Ganeshamurthy and Reddy, 2000). In addition sulfur assimilation and nitrogen fixation is interdependent (Kalloniati et al., 2015). Pod fresh weights of green bean could increase from the application of sulfur containing fertilizer (Kovács et al., 2013). Girma (2016) also found that low soil nitrogen and phosphorus levels, and acidic soil conditions are important constraints for bean production in most cropping areas of Ethiopia.

Moreover, keeping appropriate plant population under prevailing resource and suitable agro-ecological condition can also increase green bean yield. In order to produce high dry matter as a result of intercepted solar radiation, crop has to cover the soil as early as possible (Abu et al., 2016), and the net light absorbed to be converted to dry matter of well-spaced plant is usually high (Snowden and Bruce, 2015). According to Chakravorty et al. (2009), closely spaced green bean attains maximum height, minimum number of branches and leaves per plant but the total pod yield obtained per hectare increases as a result of increased plant population per a given area. However, irrespective of the growing conditions and locations, 142 kg NPS ha^{-1} and 250000 plants ha^{-1} (40cm x 10cm) has been recommended for the crop (MoANR, 2016). The variation in plant population and NPS fertilizer rates with environment and variety calls for area-specific recommendation. The Central Rift Valley area of Ethiopia, including Alage is a suitable belt for the production of green bean for export and domestic markets. Research based recommendations on plant population and NPS fertilizer rate could increase productivity of the crop and increase the benefits of the growers in the area. Therefore, the present study was undertaken to determine the optimum plant population and NPS rate to obtain the highest yield of green bean for Alage area, representing the Central Rift Valley area of Ethiopia.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Alage ATVET College during 2019 cropping season. The site is located 217 km south of Addis Ababa and 32 km west of Bulbula town at the coordinates of 7° 65'N and 38° 56'E at 1600 m above sea level, in the agro-ecology of dry plateau of the central rift valley of Ethiopian. The area has bimodal rainfall pattern where the short rain occurs during March and April and the main rain from June to September. The highest amount of rainfall is obtained in July and August with the annual rainfall of 800 mm. The mean annual minimum and maximum temperatures of Alage area are 11 and 29°C, respectively. The land is having sandy loam to sandy clay loam with some clay loam and few clay soils (Eylachew, 2004).

Description of treatments and design

The factorial combination of three plant populations (222222 plants ha^{-1} from 30 cm x 15 cm spacing, 333333 plants ha^{-1} from 30 cm x 10 cm spacing and 250000 plants ha^{-1} from 40 cm x 10 cm spacing) and five blended NPS fertilizer rates (0, 132, 142, 152 and 162 kg ha^{-1}) were considered as treatments in the experiment. The amount of nitrogen, phosphorus and sulfur, corresponding to each rate of NPS fertilizer is shown in Table 1. Fifteen treatment combinations were laid in randomized complete block design (RCBD) with three replications. The gross plot size was 3.6 m x 2.4 m (8.64 m^2); with 12 and 9 rows in 30 and 40 cm inter-row spacing, respectively. There were 24 and 16 plants in each row with intra-row spacing of 10 and 15 cm, respectively. The outermost one row from one side and two rows from the other side for 40 cm inter-row and two rows from both sides for 30 cm inter-row spacing were considered as the border rows. The blocks were separated by 1.5 m width whereas the space between each plot within a block was 1.2 m. In accordance with specifications of the design, each treatment was assigned randomly to experimental units within a block. Plati variety of green bean seed having high yielding potential than the variety under production before (BC 4.4) was used as test crop in this

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Table 1. NPS fertilizer rate (kg ha-1) and corresponding nutrient content (kg ha^{-1}).

NPS (19% N, 38% P and 7% S) rates (kg/ha)	Nutrient contents of NPS (kg/ha^{-1})		
	Nitrogen	**Phosphorus**	**Sulfur**
132	25.08	50.16	9.24
142	26.98	53.96	9.94
152	28.88	57.76	10.64
162	30.78	61.56	11.34

experiment. This variety was released in 2016 by Melkassa Agricultural Research Center (MoANR, 2016).

Experimental procedures and crop management

The seeds of green bean plati variety were generously provided by the Melkassa Agricultural Research Center. The experimental site was ploughed and leveled by tractor on January 30, 2019. After laying out the site by spacing of 1.5 m and 1.2 m between blocks and plots, respectively, ridges were prepared manually on February 12, 2019 and then the seed was sown on February 21, 2019 at 5 cm depth based on the treatment decided for population density study. The calculated amount of NPS fertilizer for each experimental unit was applied in band method of application at the time of sowing. The research work took three months to complete till final harvesting on May 5, 2019. Beside all of these practices of treatments, uniform field management such as disease, weed and insect control, watering and other cultivation practices were done for all plots as per recommended for the crop (EARO, 2016).

Data collection

The effect of plant population and blended NPS rate on green bean was investigated by measuring growth, yield and yield component parameters data. Growth data include (plant height, leaf number and number of branch per plant) were taken in each plot from ten randomly selected plants at physiological maturity stages. Number of nodules and number of effective nodules were collected from the bulk of roots of 5 randomly selected plants by distractive sampling from each plot at 50% flowering. Effectiveness of the nodules was determined after cutting the nodules by the inside color they exhibit (determined pink as effective and cream white as ineffective). Nodules for each category were counted and presented as the percentage of the total. Yield component parameters (number of pods per plant, pod diameter, pod length, yield per plant and hectare) were recorded from the central rows of each plot and converted into yield per plant (kg plant^{-1}) and yield per hectare (tons ha^{-1}). Above ground total fresh biomass (kg plant^{-1}) was obtained by summing up the weighed crop residues and yields. Harvest index was determined as the ratio of horticultural matured yield to total above ground fresh biomass yield from the rows of net plot area and converted into percentage.

Soil sampling and analysis

Pre-planting soil samples were taken randomly using a zigzag model from the experimental plots at the depth of 0 to 30 cm before planting. Fifteen soil core samples were taken by an auger from the whole experimental field and combined to form a composited sample in a bucket. Then, the collected samples were air-dried at room temperature under shade and ground to pass through a 2 mm

sieve for laboratory analysis of soil pH, and available phosphorus. Small quantity of 2 mm sieved soil material was received through 0.2 mm sieve for soil organic carbon (OC) and total nitrogen. The composite soil samples were analyzed for selected physicochemical properties mainly textural analysis (sand silt and clay), soil pH, total nitrogen (N), available sulphur (S), organic carbon (OC), available phosphorus (P), cation exchange capacity (CEC) (c mol kg-1), exchangeable potassium, magnesium and calcium using the appropriate laboratory procedures at the Soil and Water Analysis Laboratory of Horticoop Ethiopia (Horticultural PLC). Soil textural class was determined by Bouycos Hydrometer Method. Electrical conductivity of the soil was measured in water suspension with soil to water ratio 1:5 (W/V) by electro-conductivity meter method (Slavich and Petterson, 1993). Organic carbon was estimated by wet digestion method and organic matter was calculated by multiplying the organic carbon % by a factor of 1.72 (Walkley and Black, 1954). The soil pH was measured potentio-metrically in 1:2.5 soil-water suspensions with standard glass electrode pH meter (Van Reeuwijk, 1992). Cation Exchange Capacity was determined by leaching the soil with neutral 1 M ammonium acetate. Total nitrogen was determined by treating the sample with a mixture of concentrated sulfuric acid and digestion catalysis following the modified Kjeldhal method (Okalebo et al., 2002). Available phosphorus was determined by Olsen's method (Olsen and Sommers, 1982). Available sulfur was measured using turbidimetric method (Okalebo et al., 2002). Available potassium was measured by 1 M ammonium acetate method (Mehlich, 1984). The Physico-chemical properties of the experimental site soil before planting are shown in Table 2.

Data analysis

The results were analyzed using analysis of variance techniques (SAS, 2002) and mean separation was based on LSD at 5% level of significance. Simple partial budget analysis was made for economic analysis of optimum pod size with appropriate intra-row spacing. The economic analysis was calculated following the formula developed by CIMMYT (1988).

Partial budget analysis

Partial budget analysis was employed for economic analysis of fertilizer application and seed rate. The potential response of crop towards the added fertilizer and seed sown corresponding to fertilizer and seed price ultimately determine the economic feasibility.

According to CIMMYT (1988), the marginal rate of return (MRR), which refers to net income is obtained by incurring a unit cost of fertilizer, seed rate and labor. The net benefit (NB) was calculated as: NB = (AY × P) – TVC, when, APY×P= Gross Field Benefit, AY= Adjusted yield and P= green bean price

The actual yield was adjusted downward by 10% to reflect the

Table 2. Physico-chemical property of experimental site soil before planting

Soil property	Value	Rating
Soil textural properties		
Sand (%)	37.81	-
Silt (%)	42.41	-
Clay (%)	19.78	-
Textural class of soil	-	Loam
Soil chemical properties		
Electrical conductivity (ECe) (dS/m)	2.214	-
Cat-ion exchange capacity (cmol (+)/kg soil)	28.02	High
Organic carbon (%)	1.49	Medium
PH (H_2O) (W/V)	8.26	moderately alkaline
Total nitrogen (%)	0.13	Low
Available phosphorus (mg/kg (ppm))	14.53	Medium
Available sulfur (mg/kg (ppm))	29.43	Sufficient
Available potassium (mg/kg (ppm))	479.03	-

dS/m = decisiemens/meter, ppm = parts per millennium, mg/kg = milli gram/kilogram, W/V = weight of soil/volume of water, cmol = centimole/kilogram.

difference between the experimental yield and the yield farmers could expect from the same treatment. The dominance analysis was used to select potentially profitable treatments. The discarded and selected treatments were called dominated and un-dominated treatments, respectively. For each pair of ranked treatments, % MRR was calculated using the following formula:

$$MRR\ (\%) = \frac{change\ in\ NB\ (NBb-NBa)}{change\ in\ TVC\ (TVCb-TVCa)} \times 100$$

NBa = NB with the immediate lower TVC, NBb = NB with the next higher TVC, TVCa = the immediate lower TVC and TVCb = the next highest TVC. The % MRR between any pair of un-dominated treatments was the return per unit of investment in fertilizer and seed rate. Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input.

RESULTS AND DISCUSSION

Effect of plant population and blended NPS fertilizer rates on growth parameters of green bean

Number of leaves per plant

Number of leaves per plant of green bean was significantly (P≤0.001) influenced by plant population. The highest (83.92) number of leaves per plant was achieved using 222222 plants per hectare which, however, was statistically similar with 250000 plants population; the lowest (71.24) number of leaves per plant of green bean was recorded using 333333 plant population per hectare (Table 3). Blended NPS fertilizer rates had highly significant (P ≤ 0.001) effect on number of leaves per plant of green bean. The highest number of leaf per plant (87.63) was recorded from the highest (162

kg/ha) NPS rate and it was statistically similar with 142 and 152 kg/ha NPS rates. The lowest number of leaf per plant (67.04) was recorded from the control (0) treatment and it was statistically similar with 132 kg/ha NPS rate (Table 3). Interaction effect of plant population and blended NPS rate on number of leaves per plant was not significantly different.

From the above presented data, there was a progressive decrease in number of leaf per plant with increases in plant population from 222222 to 333333 plants population per hectare (Table 3). This result is in agreement with the finding of Gebremedhin (2015) who reported that as plant population increased and number of leaves per plant of haricot bean decreased. Increasing rates of blended NPS fertilizer from 0 to 162 kg ha⁻¹ also showed progressive increase in number of leaves per plant of green bean (Table 3). This result is in agreement with the finding of Jaisankar and Manivannan (2018) who reported that number of leaves per plant increased with the increase of N and P ha⁻¹. This result could be attributed to the promotion of chlorophyll formation by nitrogen (Negash et al., 2018) and functional growth of new leaves and tissue by phosphorus and sulfur (Faegheh and Hashem, 2015).

Number of branches per plant

The data pertaining to number of branch per plant are given in Table 3 from which it is evident that number of branch per plant was highly significantly (P ≤ 0.001) influenced by plant population. Number of branch per plant of green bean in the present study ranged from 5.73 to 9.64 (Table 3). The highest (9.64) number of branch

Table 3. Effects of plant population and blended NPS fertilizer application rate on growth of green bean.

Treatment	Number of leaves per plant	Number of branch per plant	Plant height (cm)	Number of nodule per plant	Number of effective nodule per plant
Plant population (plants ha^{-1})					
222222	83.92[a]	9.64[a]	50.74[c]	43.81	27.01
250000	83.28[a]	8.64[a]	58.11[b]	36.62	26.32
333333	71.24[b]	5.73[b]	63.09[a]	38.38	29.53
LSD (5%)	**5.49**	**1.15**	**3.3**	**NS**	**3.42**
NPS rate (kg ha^{-1})					
0	67.04[b]	6.76[c]	54.62	29.48[c]	25.38
132	73.03[b]	6.86[bc]	54.07	35.49[bc]	26.29
142	84.09[a]	8.29[ab]	58.03	43.45[ab]	30.51
152	85.6[a]	8.69[a]	55.64	44.78[a]	26.51
162	87.63[a]	9.43[a]	55.31	44.79[a]	29.42
LSD (5%)	**7.08**	**1.49**	**NS**	**8.42**	**NS**
CV	**9.23**	**19.2**	**7.69**	**22.02**	**16.56**

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance.

per plant was obtained with the lowest plant population (333333) which, however, were statistically similar with 250000 plant populations. The lowest (5.73) number of branch per plant was obtained from the highest (333333) plant population (Table 3). Blended NPS fertilizer rates had significant (P ≤ 0.05) effect on number of branch per plant. The lowest (6.76) number of branch per plant was achieved at control treatment which, however, was statistically at par with 132 kg/ha of NPs rates and the highest (9.43) number of branch per plant were recorded on 162 kg/ha of NPs rates and it was also statistically similar with 152 kg/ha of NPs rates (Table 3). Interaction effect of plant population and blended NPS rate on number of branches per plant was not significantly different.

The number of branches per plant was also influenced by plant population and blended NPS fertilizer rates. This might be due to the presence of limited competition among plants for soil nutrients. Moreover, at the smallest plant population plants could intercept more photo synthetically active radiation owing to better geometric situation that might have resulted in vigorous plant growth and more number of branches. The result was in conformity with the findings of Almaz (2019) who reported that the highest number of branches per plant was obtained at the smallest plant population. In addition, Alemayehu et al. (2015) also reported that the higher number of branches with the smallest number of plant population per hectare. In this study, a progressive increase in the number of branches plant^{-1} was observed from increasing application rates of blended NPS fertilizer from 0 to 162 kg ha^{-1} (Table 3). The finding is in line with Shumi et al. (2018b) who reported that increasing rates of blended NPS fertilizer from 0 to 250 kg ha^{-1} showed progressive increase in the number of primary branches

plant^{-1} of common bean.

Plant height

Plant population had a highly significant (P ≤ 0.001) effect on plant height. Increasing plant population from 222222 to 333333 significantly increased plant height. Plant populations with 333333 produced 24.34% higher plant height than the smallest (222222) plant population (Table 3). However, blended NPS fertilizer rates and its interaction with plant population had no significant effect (P> 0.05). Plant height was the lowest at small number of plant population, and increased with increasing plant population reaching maximum at the highest plant population (Table 3). Such effect was probably due to competition of plants in higher densities for light, resulting in taller plants. Similar findings were reported by Khalil et al. (2015), who indicated that the denser plant population increased the plant height of faba bean due to competition among plants. Moreover, Moniruzzaman et al. (2009) also reported that plant height increased from 43 to 44.5 cm (maximum plant height) with increase in plant density from 250,000 to 500, 000 plants ha^{-1}.

Number of nodules per plant

Blended NPS fertilizer rates had a significant (P ≤ 0.01) effect on the number of nodules per plant of green bean. As NPS fertilizer rates increased from 0 to 142, number of nodules also increased (Table 3); however, with further increase in NPS rates the change in nodule number was not significant. This might be due to better root development as a result of starter nitrogen supplement in

NPS form, while formation of number of nodules might be due to the role of P and S. This result is similar with finding of Shumi et al. (2018b) who reported an increase in number of nodules with the increase in blended NPS rates until it reaches 200 kg/ha. Plant population and its interaction with blended NPS rates were not significantly different on number of nodules per plant.

Number of effective nodules per plant

The number of effective nodules per plant of green bean was not significantly (P > 0.05) affected by plant population and blended NPS fertilizer rate (Table 3). The result is in agreement with the finding of Xuan et al. (2017) who reported that effectiveness of nodules was reduced with an increasing concentration of nitrogen fertilizer application.

Effect of plant population and blended NPS fertilizer rates on yield and yield components of green bean

Number of pods per plant

The analysis of variance showed significant (P≤0.05) effect of plant population and NPS application rate on number of pod per plant, while their interaction had no significant effect. With increasing plant population from 222222 to 333333 plants ha^{-1} there were progressive decrease in number of pods per plant. Thus, the highest number of pods per plant (85.76) was recorded at the lowest plant population (222222 plants ha^{-1}) and it was statistically similar with 250000 plants ha^{-1} (83.44), while the lowest (69.48) was recorded at the highest plant population (333333 plants ha^{-1}) (Table 4). Blended NPS fertilizer rate has significant (P≤0.05) effect on number of pods per plant. The highest number of pods per plant (96.44) was obtained at the highest rate of application (162 kg NPS ha^{-1}) and it was statistically similar with the number of pod per plant obtained at application of 152 kg NPS ha^{-1} but statistically at par with that recorded for 142, 132 and 0 kg NPS ha^{-1}, while the lowest number of pod per plant (60.29) was recorded for the unfertilized plot (Table 4).

Wide space between the plants resulted in decreased inter plant competition that in turn lead to increased plant capacity for utilizing the environmental inputs in building great amount of metabolites to be used in developing new growth components and increasing its yield components. The result is in agreement with the findings of Almaz (2019) who reported that the number of pods per plant increased from 24.2 to 32.1 with increasing inter row spacing from 30 to 50 cm (from higher to lower plant population ha^{-1}) and from 25.2 to 30.2 with increasing intra row spacing from 8 cm to 12 cm (higher to lower plant population ha^{-1}). Since the lowest number of pod per plant was recorded at the highest plant population per

hectare, this difference might be attributed to higher competitions between plants for growth requirements which are capable to increase number of pod bearing branches that triggers high yield per plant.

Increasing application rates of blended NPS fertilizer from 0 to 162 kg ha^{-1} resulted in progressive increase of the number of pods per plant. The highest number of pods at the highest rates of NPS (162 kg ha^{-1}) might be attributed to the fact that NPS enhances establishment of beans, promote the formation of nodes, canopy development and pod setting and also the increase in number of pods with these levels might be due to various enzymatic activities which controlled flowering and pod formation. This result is in conformity with the findings of Shumi et al. (2018b) who recorded that, increasing application of blended NPS fertilizer from 0 to 250 kg ha^{-1} increased the number of pod plant^{-1} of common bean from 8.7 to 18.52. Moreover, Shumi et al. (2018a) noted that the highest (8.64) and lowest (6.45) number of pod per plant were obtained at 150 and 0 kg of P ha^{-1} in blended NPS fertilizer, respectively.

Pod diameter

Main and interaction effects of plant population and blended NPS fertilizer rates had no-significant (P > 0.05) effect on pod diameter of green bean (Table 4). This result is contrary to that of Munirazzaman et al. (2009) who noted that wider pod diameter was recorded at the smallest plant population. This might be because of using available growth inputs to produce dry matter which was equally partitioned to the reproductive part of green bean.

Pod length

Pod length of green bean was significantly (P ≤ 0.05) influenced by blended NPS fertilizer rates. The longest (14.72 cm) pod length was recorded at 162 kg/ha NPS fertilizer rate which, however, was statistically similar with 152 kg/ha NPS rates while the shortest pod length (13.27cm) was recorded from the control treatment; blended NPS fertilizes with other rates performed in between the two (Table 4). Plant population and its interaction with blended NPS fertilizer rate had no significant (P > 0.05) effect on pod length of green bean. The finding is in contrary to Munirazzaman et al. (2009) who obtained highest pod length at lower plant density.

Pod length was thus influenced by blended NPS fertilizer rates. Pod length was lowest at the control (0) treatment while it was highest at the highest NPS rates (Table 4). This could be due to the availability of sufficient N, P and S which ultimately increased the rate of photosynthesis by chlorophyll formation, and thus more photo-assimilate partitioned to its pod length. This finding is similar with Moniruzzaman et al. (2008) who reported

Table 4. Effect of plant population and blended NPS fertilizer rate pod characters of green bean

Treatment	Number of pod per plant	Pod diameter	Pod length
Plant population (plants ha^{-1})			
222222	85.76[a]	8.39	14.04
250000	83.44[a]	8.31	14.08
333333	69.48[b]	8.29	13.83
LSD (5%)	**11.86**	**0.36**	**0.51**
NPS rate (kg ha^{-1})			
0	60.29[c]	8.19	13.27[c]
132	70.02[bc]	8.19	13.79[bc]
142	84[ab]	8.39	13.87[bc]
152	87.04[a]	8.63	14.26[ab]
162	96.44[a]	8.25	14.72[a]
LSD (5%)	**15.3**	**0.46**	**0.66**
CV	**19.92**	**5.7**	**4.9**

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance

that pod length was increased with the increase in N up to 120 kg/ha, S up to 20 kg/ha and 50 kg/ha of P_2O_5 (Jaisankar and Manivannan, 2018).

Green pod yield per plant

Pod yield per plant of green bean was significantly (P≤0.05) affected by plant population and it was in the range of 0.21 to 0.26 kg. Plant population with 250000 plant/ha produced 19.23% higher green pod yield per plant than the highest (333333) plant population (Table 5). Similarly, blended NPS fertilizer rates had a highly significant (P ≤ 0.001) effect on green pod yield per plant. The lowest (1.04) green pod yield per plant was achieved at the control (0) treatment and it was highest at 162 kg/ha of NPS rates which, however, was statistically similar with 142 and 152 kg/ha of NPS rates (Table 5). Interaction effect of plant population and blended NPS rate on green pod yield per plant was not significantly different. Thus, green pod yield per plant was significantly influenced by plant population blended NPS fertilizer rates. This result is in line with the findings of Moniruzzaman et al. (2009) and Ayoub and Abdella (2014) who reported that green pod yield per plant was decreased from 87.3 to 58.8 g plant[-1] with increasing plant density from 250 x 10^{3} to 500 x 10^{3} plants ha^{-1}. This green pod yield per plant difference might be due to reduced competition between plants for growth requirements like nutrient and light. Increasing NPS fertile rates from 0 to 142 kg/ha significantly increased green pod yield per plant but further increase had no significant effect. This result is in conformity with that of Moniruzzaman et al. (2008) who noted that green pod weight per plant increased significantly with the increase

in N up to 120 kg ha^{-1}, increase in P up to 120 kg ha^{-1} and increase in S up to 20 kg S ha^{-1}.

Green pod yield per hectare

Both plant population and blended NPS fertilizer rates showed a highly significant (P≤0.001) effect on green pod yield per hectare. The highest pod yield (13.75 ton ha^{-1}) was recorded from the highest (333333) plant population and it was statistically at par with 250000 plant population, whereas it was lowest at the smallest (222222) plant population (Table 5). The highest yield per hectare (16.06 ton ha^{-1}) was recorded at the highest rate of application of NPS fertilizer (162 kg NPS ha^{-1}) and it was statistically similar with 152 and 142 kg ha^{-1} NPS fertilizer rate, while the lowest (4.16 ton ha^{-1}) was recorded at the control (0 kg ha^{-1} NPS) (Table 5). Interaction effects of plant population and blended NPS rate on green pod yield per hectare was not significantly different.

The result is in line with the findings of Moniruzzaman et al. (2009) who reported that green pod weight ha^{-1} was increased from 20.0 to 24.5 ton ha^{-1} with the increase of plant density from 250, 000 to 500,000 plants ha^{-1}. Moreover, Essubalew et al. (2014) reported that green bean yield ha^{-1} was increased by 49.43% as plant spacing decreased from 40 cm x 10 cm to 40 cm x 7cm (250000 to 357143 plants ha^{-1}) and the total marketable yield ha^{-1} decreased from 3,473 kg ha^{-1} to 2,531 kg ha^{-1} as plant spacing decreased from 50 cm x 7 cm to 40 cmx7 cm (285714 to 357143 plants ha^{-1}). With regard to NPS rates it was similar to the findings of Moniruzzaman et al. (2008) who found that green pod yield was significantly increased with the increase in nitrogen rate

Table 5. Effect of plant population and blended NPS fertilizer rate on pod yield of green bean

Treatment	Green pod yield per plant (kg)	Green pod yield/ha (tone/ha)	Harvest index
Plant population (plants ha^{-1})			
222222	0.23[ab]	10.14[b]	71.01
250000	0.26[a]	12.76[a]	70.59
333333	0.21[b]	13.75[a]	70.53
LSD (5%)	**0.04**	**1.54**	**4.09**
NPS rate (kg ha^{-1})			
0	0.1[c]	4.16[c]	41.25[c]
132	0.18[b]	10.56[b]	52.38[b]
142	0.29[a]	15.05[a]	63.05[a]
152	0.29[a]	15.23[a]	60.59[ab]
162	0.30[a]	16.06[a]	62.77[a]
LSD (5%)	**0.05**	**1.98**	**5.28**
CV	**22**	**16.8**	**7.73**

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance.

of 120 kg N ha^{-1}, 120 kg P_2O_5 ha^{-1} (by 23.14% over control), and sulfur 20 kg ha^{-1} (by 25.83% over control). Such response of the crop may be due to the availability of sufficient amount of nitrogen, phosphorus and sulfur for the formation of more number of leaves per plant which could be capable of producing high dry matter and bearing long and high weighing pods which in turn produce maximum yield of green pod per hectare.

Harvest index

The data pertaining to harvest index are given in Table 5 from which it is evident that harvest index was significantly ($P \leq 0.001$) influenced by blended NPS fertilizer rates. Harvest index of green bean in the present study ranged from 41.25 to 63.05 (Table 5). The highest harvest index (63.05) at 142 kg/ha NPS rate which was statistically similar with that of 152 and 162 kg/ha NPS rates was observed (Table 5). This might be due to uptake of available N, P and S to produce high dry matter that is highly partitioned to reproductive part than vegetative part of green bean which contributed to raise harvest index. Plant population and its interaction effect with blended NPS fertilizer rates had no significant ($P > 0.05$) influences on harvest index of green bean.

Above ground total fresh biomass

The data pertaining to above ground total fresh biomass are given in Table 6 from which it is evident that above ground total fresh biomass was significantly ($P \leq 0.01$) influenced by the interaction effects of plant population and blended NPS fertilizer rates. Above ground, fresh biomass per plant increased with the increase in plant

population and NPS fertilizer rates; but, the extent of its increment in relation to both plant population and blended NPS fertilizer rates was distinct (Table 6). In the present study, above ground total fresh biomass ranged (Table 6). At 0 kg/ha blended NPS fertilizer rate, increasing plant population per hectare from 222222 to 250000 increased above ground total fresh biomass by 13.33%, whereas further increase in plant population resulted in a 36.36% decrease. At 162 kg/ha NPS fertilizer rate, increasing plant population from 222222 to 333333 reduced the above ground total fresh biomass by 18.18 and 16.67% (Table 6). Similarly, using plant population with 222222 plants/ha, increasing blended NPS fertilizer rates from 132 to 162 enhanced the above ground total fresh biomass by 13.33, 25 and 9.09%. Similar results are evident at the other plant population and blended NPS fertilizer combinations (Table 6).

This result is in accordance with Cakmak (2008), Tarekegn and Serawit (2017), Lake and Jemaludin (2018) who reported that shoot dry mass of common bean and dry matter production of French bean was increased significantly with the application of different levels of nitrogen and phosphorus fertilizers.

Partial budget analysis

The partial budget analysis of the 15 treatments is shown in Table 7. Based on this result, the highest net benefit of 173, 450.55 Birr ha^{-1} was obtained with MRR of 5,734.9% from 333333 plant populations and at 162 kg/ha of NPS fertilizer rates. The highest (214216.32 Birr ha^{-1}) net field benefit was obtained with MRR of 6997.20. According to CIMMYT (1988), the minimum acceptable marginal rate of return (MRR%) should be between 50 and 100%. In agreement with this study, Shumi et al. (2018) reported

Table 6. Interaction effects of plant population and blended NPS fertilizer rate on above ground total fresh biomass of green bean.

Treatment	NPS rate (kg/ha)				
Plant population (plant/ha)	0	132	142	152	162
222222	0.13[de]	0.13[de]	0.15[de]	0.2[ab]	0.22[a]
250000	0.15[de]	0.17[cd]	0.19[ab]	0.21[a]	0.18[bc]
333333	0.11[e]	0.18[bc]	0.16[cd]	0.14[de]	0.15[de]
LSD (5%)	**0.04**				
CV (%)	**16.07**				

Means followed by different letters in the same column are significantly different from each other at 5% level of significance.

Table 7. Partial budget analysis of effect of plant population and blended NPS fertilizer rate on green bean.

PP (Plants/ha)	APY (ton/ha)	GB (birr/ha)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
222222	9.13	136950	8066.85	128883.15	0
250000	11.48	172200	9075	163125	3396.5
333333	12.37	185550	12099.45	173450.55	5734.9
NPS rate (kg/ha)					
0	3.75	56250	0	56250	0
132	9.5	142500	2214.48	140285.52	3794.8
142	13.55	203250	2370.88	200879.12	38742.7
152	13.72	205800	2527.28	203272.72	1530.4
162	14.46	216900	2683.68	214216.32	6997.2

GB = Gross benefit, NB= Net benefit, MRR (%) = Margin rate of return in percent, NPS cost= 15.64 birr/kg, NPS application cost = 150 birr/ha, TVC= Total variable cost APY= Adjusted pod yield down wards by 10%, Price of green pod/kg = 15 birr/kg, Cost of seed = 48.89, 55 and 73.33 kg/ha for 222222, 250000 and 333333 plants/ha, respectively.

the highest net benefit with the application of 150 kg ha^{-1} NPS compared with the control (0) treatment on common bean. Therefore, the most attractive plant population and NPS fertilizer application rate for producers or farmers with higher net return was 333333 plant population per hectare and 162 kg/ha NPS fertilizers application rate.

Conclusion

The major production variables that a producer can manipulate to influence the potential yield of a given crop are soil fertility, plant population, spacing, variety selection and crop management activities. Among those fertilizer rate and plant populations per a given area require special focus to maximize the yield obtained from improved varieties of crops. Results from the present study showed that the plant population and application of blended NPS fertilizer rate stimulated the growth and yield of green bean and to obtain maximum growth and yield, the economical plant population and application rate have been optimized. From the current results, it can be concluded that, growth and yield of green bean economically improved with 333333 plants ha^{-1} and 162 kg NPS ha^{-1}. Therefore, this treatment can be

suggested for better growth, yield and yield attributing characteristics of green bean for Alage and areas having similar agro-ecologies and soil types.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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