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Effect of NPS Fertilizer Rate and Intra Row Spacing on Growth and Yield of Common Bean (*Phaseolus vulgaris* L.) at Metu, South western Ethiopia

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Abstract **– The production of common bean has been increasing in Ethiopia because of its high importance as a source of protein, and foreign exchange earnings. Low available phosphorus, total nitrogen and sulphur are the major yield limiting factors for common bean production in the study area. The use of optimum intra row spacing is also one of the agronomic practices to increase its productivity. Thus, an experiment was conducted at Metu in 2019 (July-October), to evaluate the effect of NPS fertilizer rates and intra row spacing on growth and yield of common bean and to identify economically feasible combination of the two factors. The experiment was laid down in randomized complete block design in factorial arrangement with three replications. Hence, factorial combinations of four NPS fertilizer rates (0, 50, 100 and 150 kg ha-^{1}) and three levels of intra row spacing (5cm, 10cm and 15cm) were tested. Result showed that NPS rates had highly significant effect on number of days to 50% flowering, which showed the highest value (48.00) for application of 150 kg NPS ha-^{1}, Similarly, NPS rates and intra row spacing had highly significant effect on the number of days to 90% physiological maturity, plant height, pod length, number of pods per plant, hundred seed weight, total above ground dry biomass yield, and harvest index. The highest number of days required to physiological maturity (101.56 and 97.17), number of pods per plant (24.53) and (17.52), pod length (11.43cm) and (10.83cm), hundred seed weight (55.24g and 49.19g), harvest index (0.314 and 0.287) were recorded for 150kg NPS and 15cm intra row spacing respectively. The highest leaf area (2751.39cm^{2}) was recorded for the interaction of 150kg NPS ha-^{1} and 15cm plant spacing. Maximum plant height with the respective values of 77.83cm 59.35cm was recorded for 150kg NPS ha-^{1} and 5cm intra row spacing. The highest above ground dry biomass yield (11449.1 and 11052.1 kg ha-^{1}) was recorded for 150kg NPS ha-1 and 15cm intra-row spacing, respectively, while maximum grain yield (4041.67) was recorded for the interaction of 150 kg NPS ha-1 and 5cm intra row spacing. The Longest plant (77.83cm) and (59.35cm) was obtained at 150kg NPS ha-^{1} and 5cm intra row spacing respectively, the highest above ground dry biomass yield (11449.1 kg ha-^{1}) and (11052.1) was recorded at 150kg NPS ha-^{1} and 5cm plant spacing respectively, number of branches, number of nodules, and number of seeds per pod were high significantly and significantly affected by NPS rates and intra row spacing respectively. The highest number of branches (3.11) and (2.35) was recorded at 150kg NPS ha-^{1} and the next result recorded for 10cm and 15cm plant spacing respectively. The highest number of seeds per pod (7.88 and 7.63) was recorded for 150 kg NPS ha-^{1} and 15cm intra row spacing respectively, the highest number of nodules (77.44 and 63.89) was recorded at 150kg NPS ha-^{1} and 5cm intra row spacing respectively. The highest agronomic efficiency (56.1) was recorded for 50kg NPS ha-^{1}. The economic analysis also indicated that the highest net return (46, 148 ETB ha-^{1}) was obtained from 5cm intra row spacing with application of NPS at the rate of 150 kg ha-^{1} with marginal rate of return of 861.2%. Based on the results of this study, it can be tentatively concluded that application of 150 kg NPS rate of 150 kg ha-^{1} combined with 5cm intra row spacing would be appropriate for common bean production in the study area.**

Keywords **– Determinate, Indeterminate, Economic Analysis, Intra-Row Spacing.**

I. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is herbaceous annual plant grown worldwide for its edible dry seeds or unripe fruit. It is domesticated in ancient Mesoamerica and in the Andes, and now is grown worldwide for both dry seeds and as a green bean. There are about thousands of legume species but common bean is the most cosumed by human beings compared to any other legumes [1]. It is termed as green bean or snap bean when it is used for its unripe fruit. Its protein content of 20-25% and carbohydrate of 50-56% makes it 2 to 3 times more nutritious compared to cereals. It is also considered as a short-season crop, as it requires 65 to 110 days from emergence to physiological maturity [2].

It is estimated to be one of the most important nutrient source for more than 300 million people in some parts of Eastern Africa and Latin America, and it covers 65% of total protein consumed and 32% of energy value [3]. The global bean production is approximately 12 million metric tons, with 5.5 and 2.5 million metric tons annually in Latin America Caribbean (LAC) and Africa, respectively [4]. Reported that, in Ethiopia common bean ranks third as an export commodity, contributing about 9.5% of the total export value from agriculture [5]. The total amount of export earnings per year from common bean is about $70.187million [6]. Its annual per capita consumption in the country is higher among low income people who cannot afford to buy nutritious food stuff such as meet [7].

It is adapted to areas with altitudes ranging from 700 to nearly 3000 meter above sea level [8]. Very high temperatures cause flowers to abscise, and very low temperatures delay pod production and results in empty pods [9]. In Ethiopia suitable production areas of common bean is altitude between 1200-2200 m.a.s.l., mean maximum and minimum temperature of less than 32°C and greater than 10°C, respectively, and with a rainfall ranging from 350 to 700 mm well distributed over 70-90 days [10].

Ethiopian farmers highly preferred common bean due to its fast maturing characteristics [11]. However, the average yield obtained nationally is very low (1.59 tone ha^{-1}) [12] and lowest than the attainable yield (2.5 to 3 tone ha-^{1}) under good management conditions for most improved varieties. The result low yield of common bean in Ethiopia is attributed to several production constraints, such as lack of improved varieties for the different agro-ecologies, poor agronomic practices such as low soil fertility management and untimely and inappropriate field works [13].

Hence, mineral fertilizers containing macro and micronutrients are required to ensure balanced fertilizer use by the crop grown as application of these nutrients can dramatically improve fertilizer-use efficiency and crop profitability [14]. Soil fertility mapping in Ethiopia showed that the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and it needs application of customized and balanced fertilizers [14]. The majority of Ethiopian farmers primarily depend on only two fertilizer types, DAP and Urea, to supplement the nutrient (N and P) content in their soil.

On the other hand, plant population and arrangement of plants in a unit area greatly determines resource utilization such as light, nutrients and water, the rate and extent of vegetative growth and development of crops, development of important diseases and pests, and also the seed cost ([15]. Plant population affects early ground cover, competitive ability of crops, soil surface evaporation, light interception, lodging and etc. It also affects canopy development, plant architecture and distribution of pods [16].

Optimum plant density is the minimum population that gives maximum yield and suitable plant arrangement per unit area, allowing crops to exploit resource optimally and produce high yields [17]. However, optimum plant density varies depending on crop varieties, height and branching, time of sowing, and the nature of the season [18].

Common bean varieties have difference in growth habit and seed size. But only one plant density (40 cm×10 cm or 250,000 plants ha^{-1}) has been adopted in Ethiopia; without considering rainfall amount and distribution, nature of varieties and climatic conditions [19]. In addition to this, the traditional spacing of common bean in most areas including Metu is not uniform because farmers simply broad cast the seed randomly to the prepared field.

While there is evidence that Metu woreda has suitable land for common bean production. The low bean yield obtained by local farmers of the area reflects lack of improved production technologies, mainly optimum spacing and recommended fertilizer rate. To this end, since optimum spacing and fertilizer requirement of a crop at one location may not similar with other locations because of variations in soil type, rainfall distribution, nutrient availability, etc., there is a need to develop site specific recommendation for the area. Therefore, this experiment was carried out in Metu area with the following objectives:

General Objective

- To determine the effect of NPS rate and intra-row spacing on growth and yield of common bean in Metu district.

Specific Objectives

- To determine the optimum plant density for optimum growth and yield of common bean.
- To determine the effect of NPS fertilizer rates on growth and yield of common bean.
- To determine the interaction of NPS fertilizer rates and intra row spacing on growth and yield of common bean.

II. Materials and Methods

2.1. *Description of the Study Area*

The experiment was conducted at Bishahar, Ilubabor zone, Oromia regional state, south western Ethiopia under rain-fed condition during the 2019 cropping season (July-October). The site is located at 600km away from Addis Ababa, capital city of the country. It is situated at an elevation of 1580 meters above sea level. The experimental site receives an average total annual rainfall of 1829 mm extending from April to October. The mean annual maximum and minimum temperatures are 28.90C and 12.70C, respectively. The soil of the experimental site is reddish brown classified as Nitisol [20]. The soil is clay in texture and moderately acidic with pH of around 5.96 (Table 2).

2.2. *Experimental Material*

Common bean variety SER-119, was obtained from Jimma Agricultural Research Center (JARC), and used as an experimental material because it’s the only improved variety dominantly used in the study area.

The variety was released by Melkassa agricultural research center (MARC) and it is well adapted in the areas with altitude of 1450-2000 m.a.s.l. Its growth habit is bush type with white flower. Its yield potential on research and farmer's fields was estimated to be 3300 and 2500 kg/ha respectively.

2.3. *Experimental Design and Treatments*

The experiment was carried out in 4x3 factorial arrangements in a Randomized Complete Block Design (RCBD) with three replications.

The treatments consisted of factorial combinations of four rates of NPS fertilizer (0, 50, 100 and 150 kg/ha) and three levels of intra row spacing (5, 10 and 15 cm) with 40cm inter row spacing, making up 12 treatments per replication and a total of 36 observations.

Table 1. Rates of fertilizer used and their nutrient content (kg ha^{-1}).

No.	NPS Fertilizer Rate (kg ha^{-1})	N	P2O5	S
1	0 kg NPS	0	0	0
2	50 kg NPS	9.5	19	3.5
3	100 kg NPS	19	38	7
4	150 kg NPS	28.5	57	10.5

2.4. *Data Collected*

Days to flowering was collected as the number of days from planting to when fifty percent of the plants produced flower. Days to 90% physiological maturity was recorded as the number of days from planting to when ninety percent of the leaves and pods changed to yellow.

Total leaf area (cm^2) per plant was recorded by taking a sample of ten plants from a net plot. It was measured just at the flowering stage using ruler, length and width of the leaves per plant was measured and average was taken and multiplied by the crop correction factor and mean number of leaves. Total leaf area per plant = Mean length of leaves x Mean width of leaves x Common bean correction factor x Mean number of leaves per plant. Plant height was measured for ten randomly taken plants from the net plot. It was measured from ground level to the tip of the main stem at physiological maturity and average was taken. Total number of nodules per plant was determined using ten randomly taken plants from border rows at flowering stage. Roots were carefully uprooted with the bulk of root mass and nodules. The nodules were separated from the soil washed and the total number of nodules was determined by counting. Number of primary branches per plant was obtained by counting branches on the main stem of ten randomly selected plants from the net plot area at flowering stage. Average pod length was measured as the mean of twenty randomly selected pods per net plot using a ruler [21].

Number of pods per plant was determined by counting the total number of pods on each of ten randomly selected plants per net plot at physiological maturity and average value was taken. Number of seeds per pod was counted from the average number of seeds of ten randomly selected pods at physiological maturity. Hundred seed weight (g) was measured by taking weight of hundred randomly sampled seeds from the total harvest each net plot area and adjusting to 12.5% moisture level.

Total above ground dry biomass yield (kg ha^{-1}) was determined by taking the total weight of the harvest including the seeds from each net plot area after sun drying the biomass to constant weight. Seed yield (kg ha^{-1}) was determined after threshing the seeds harvested from each net plot. The seed yield was adjusted to 12.5%

moisture level and converted to kg ha^{-1}. Harvest index (HI) was computed as the ratio of seed yield (kg ha^{-1}) to total above ground dry biomass yield. HI = Seed yield/Total above ground dry biomass yield or to express it by percentage HI = Seed yield/Total AGDBY*100. Agronomic efficiency was calculated in units of yield increase per unit of nutrient applied. The formula for agronomic efficiency for fertilizer application rate 1, 2, 3 are $Yield_1$-Y_o/$Fertilizer_1$*100, $Yield_2$-Y_o/$Fertilizer_2$*100, $Yield_3$-Y_o/$Fertilizer_3$*100 respectively, whereas $Fertlizer_1$ = 50kg NPS/ha, $Fertlizer_2$ = 100kg NPS/ha, $Fertlizer_3$ = 150kg NPS/ha and Y_o = Yield obtained from control plot, Y_1 = Yield obtained from 50kg NPS/ha application, Y_2 = Yield obtained from 100kg NPS/ha application, Y_3 = Yield obtained from 150kg NPS/ha application.

2.5. *Partial Budget Analysis*

Partial budget analysis was done using partial budget procedure described by [22]. Marginal rate of return was calculated by dividing change in net increase in yield of common bean due to the application of each NPS rate and intra row spacing to the cost of NPS rate and seed rate sown. Labor cost involved for sowing of common bean seeds and application of NPS fertilizer was recorded and used also for the analysis. The price of common bean grain was valued at an average open market price (ETB kg^{-1}) which was 14ETB kg^{-1}. The net benefits and other partial budget analysis were calculated based on the formula developed by CIMMYT (1988) and given as follows: Gross average grain yield (kg ha^{-1}) is an average yield of each treatment. Adjusted yield (AjY) is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. GFB = AjY*field/farm gate price for the crop (14 ETB kg^{-1}). Total variable cost (TVC) (ETB ha^{-1}) was calculated by summing up the costs that vary including the cost of NPS fertilizer, the cost of seed and labor for application of NPS and seed sowing. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding and harvesting were considered the same. Net benefit (NB) was calculated by subtracting the total costs from gross field benefits (GFB) for each treatment. NB = GFB – total cost. Marginal rate of return (MRR %) was calculated by dividing change in net benefit by change in cost. MRR = ΔNB ΔTVC*100.

2.6. *Statistical Analysis*

After the data were checked for normality, all the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD using SAS version 9.3 (SAS 2012) and the interpretations were made following the procedure described by Gomez and Gomez (1984). Least Significance Difference (LSD) test at 5% probability level was used for treatment mean comparison when the ANOVA showed significant differences.

III. Result and Discussion

3.1. *Physico-Chemical Properties of the Soil before Planting*

Soil texture is one of the inherent soil properties less affected by management and determines nutrient status and organic matter content. According to the soil textural class determination triangle, soil of the experimental site was found to be clay (Table 2). High clay content might indicate the better water and nutrient holding capacity. Soil pH of the experimental site was 5.96 (Table 2). Thus, according to [23] rating, it is moderately acidic. Total nitrogen content of the soil (0.36%) was low as per the rating of [24]. Available P of the soil was 6.775 ppm (Table 2) and according to EthioSIS (2014), it is very low and deficient. This means it is needed to apply additional P in the form that was readily available for the plant. As the area receives heavy rainfall, P is probably fixed by high concentrations of iron and aluminum because of leaching of the basic cations. Cation exchange capacity is the capacity of the soil to hold and exchange cations. It provides buffering effect to changes in pH, available nutrients, calcium levels and soil structural changes. The result showed the CEC of the experimental soil to be 13.4meq/100g (Table 2) and thus, rated as medium [23]. The total organic carbon in the soil was 3.575% and rated as medium. On the other hand, the available sulphur content in the soil has values of 14.8 mg kg-^{1} (Table 2) and it was rated as low as per the classification of [24].

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

Parameter	Value	Rating	Reference
Sand (%)	29	-	-
Silt (%)	13	-	-
Clay (%)	59	-	-
Texture class	Clay	-	-
pH	5.96	Moderately acid	Landon (1991)
OC (%)	3.575	Medium	Hazelton and Murphy (2007)
Total N (%)	0.36	Medium	EthioSIS (2014)
Available P (mg/kg soil)	6.775	Low readily available P	EthioSIS (2014)
Available S (mg kg-^{1})	14.8	Low	Hazelton and Murphy (2007)
CEC (meq/100g soil)	13.4	Low	Landon (1991)
Exchangeable Ca (meq/100g soil)	9.112	-	-
Exchangeable Mg (meq/100g soil)	13.668	-	-
Exchangeable Na (cmol(+)/kg soil)	0.163	-	-
Exchangeable K (cmol(+)/kg soil)	0.329	-	-

3.2. *Crop Phenology*

3.2.1. *Days to 50% Flowering*

Days to 50% flowering was high significantly ($P<0.01$) influenced by NPS rate while there was no significant difference among intra row spacing and their interaction. The highest number of days (48.0 days) to reach 50% flowering was recorded due to application of 150 kg NPS ha-^{1}, while the shortest duration to flowering (39.89 days) was recorded for application of 50 kg ha-^{1} of NPS (Table 3).

The result obtained from the current study revealed that the days to flowering were delayed with increment of application rate of NPS fertilizer which could be due to the prolonged vegetative growth as a result of nitrogen obtained from NPS fertilizer. This result was in line with the findings of [25] who reported that increasing NPS rate from 50 to 200 kg ha-^{1} significantly prolonged the period to 50% flowering of common bean (*phaseolus* *vulgaris* L). This might be due to the fact that excessive supply of N promotes luxuriant and succulent vegetative growth, dominating the reproductive phase. Similarly, reported that increasing NPS rate from 0 kg ha^{-1} to 100 kg ha^{-1} increased the number of days required to reach 50% flowering from 39.61 to 44.11 days in common bean [26]. The result was also in agreement with that of [27] who reported that when the nitrogen supply increased from 0 to 46 kg N ha^{-1}, the taken to reach 50% flowering was significantly prolonged in common bean. Similarly, reported that common bean crop supplied with nitrogen (160 kg N ha^{-1}) required significantly more number of days to reach the growth stage of 50% flowering [28].

3.2.2. *Days to 90% Physiological Maturity*

Both NPS rates and intra row spacing had highly significant (P<0.01) effect on days to 90% physiological maturity (Table 3), but their interaction was not significant (Appendix table 1). The highest number of days required to 90% physiological maturity (101.56) was recorded for the highest rate of NPS (150 kg ha^{-1}), while the shortest duration (90.56days) was recorded for the unfertilized plot (Table 3). The results indicated that days to maturity in most cases were prolonged in response to the increased levels of NPS which might be due to the role of nitrogen in the NPS that promoted vegetative growth. This was in conformity with the result reported by [29] which showed that an increase in nitrogen application rate from 0 to 46 kg N ha^{-1} led to a significant increase in the number of days required to reach physiological maturity of common bean (from 87.9 to 89.9 days). This indicates that the nutrients taken up by plant roots from the soil were used for increased cell division and synthesis of carbohydrate, which will predominantly be partitioned to the vegetative sink of the plants, resulting in plants with a luxurious foliage growth [32]. In agreement with the present finding, have also reported delayed physiological maturity days due to nitrogen fertilization of up to 80kg ha^{-1} [31].

In contrary [30] have reported that application of phosphorus speed up crop physiological maturity. Similarly, has reported that phosphorus could reduce the number of days to physiological maturity by controlling some key enzyme reactions that involve in hastening crop maturity [32].

In contrast also, indicated that application of sulphur (0 to 60 kg ha^{-1}) had no significant effect on number of days required for physiological maturity of common bean plants [32].

With respect to plant spacing, the highest number of days required to physiological maturity (97.166) was recorded for five centimeter, while the shortest days to physiological maturity (93.33) was recorded at fifteen centimeter intra row spacing (Table 3). The prolonged period to maturity with high population density or narrower intra row spacing might be due to high competition for the available resource, mainly light, moisture and nutrients. This result was in agreement with that of [33] who reported that closer row and plant spacing increased maturity days of safflower, On the other hand, have observed no significant effect of row spacing on maturity of soybean [34].

Table 3. Mean number of days to flowering and physiological maturity of common bean as influenced by main effect of NPS rate and intra row spacing.

Treatments	DF	DPHM
NPS rate (kg ha^{-1})		
0	42.78c	90.556c
50	39.89d	91.667c

Treatments	DF	DPHM
100	45.78b	97.00b
150	48.00a	101.556a
LSD (0.05)	1.7348	2.2492
CV (%)	4.022885	2.4
Intra row spacing (cm)		
5	43.5	97.1667a
10	43.83	95.0833b
15	45.00	93.3333b
LSD (0.05)	NS	1.9478
CV (%)	NS	2.4

DF: Days to 50% flowering; DPHM: Days to 90% physiological maturity; CV: coefficient of variation; LSD (0.05): least significant difference at 5% probability level; Means followed by same letter with in a column for a given treatment are not significantly different at 5% probability level.

3.3. *Growth Parameters*

3.3.1. *Leaf Area*

Total leaf area per plant was high significantly ($P < 0.01$) influenced by interaction of NPS fertilizer rate and plant spacing. The highest leaf area (2751.39cm2) was recorded for the highest rate of application of NPS (150 kg ha-1) combined with intra row spacing of 15cm, while the lowest (746.92cm2) was recorded for five centimeter plant spacing with no NPS application (Table 4). Total leaf area per plant increased with increasing rate of NPS from 0 kg to 150kg ha-1 and with spacing from 5cm to 15cm. The significant increase in leaf area in response to application of higher rates of NPS and wider intra row spacing might be due to maximum vegetative growth of the plants as a result of increased availability of N, P and S, less competition for light, moisture and nutrients and, thus, increased number and surface area or size of individual leaves. In line with this, it has been reported that nitrogen helps in chlorophyll formation; phosphorus establishes strong root system and sulphur enhances the formation of chlorophyll and encourages vegetative growth [35]. Furthermore, Beruktawit (2012) reported that total leaf area per plant of common bean increased with decreasing plant population.

In general, total leaf area per plant is an important character to increase yield per plant as vigorous and ample amount of leaves at the early stage of development are crucial to improve the photosynthetic capacity of the crop.

Table 4. Mean total leaf area per plant of common bean as influenced by interaction of NPS rate and intra row spacing.

NPS Rate (kg ha-^{1})	LA (cm^{2})		
	Intra Row Spacing (cm)		
	5	10	15
0	746.92j	847.766i	1048.31h

NPS Rate (kg ha-1)	LA (cm^2)		
	Intra Row Spacing (cm)		
	5	10	15
50	1045.40h	1320.64g	1441.82f
100	1703.84e	2156.87d	2376.30c
150	2350.60c	2456.97b	2751.39a
LSD (0.05)		69.848	
CV (%)		4.9	

LA: Leaf area; CV: coefficient of variation; LSD (0.05): least significant difference at 5% level; Means followed by same letter with in columns and rows are not significantly different at 5% P level.

3.3.2. *Plant Height*

Results of analysis of variance showed that main effects of NPS rate and intra row spacing highly significant (P<0.01), while their interaction was not significant for plant height (Appendix table 1). The maximum plant height (77.83cm) was observed for 150kg NPS ha-1, while the lowest value (38.02cm) was for the control treatment (Table 5). The increase in plant height in response to increased application rate of NPS might be due to maximum vegetative growth of the plants under higher N availability and better root development due to sufficient availability of P which support plant to better nutrient absorption. In line with this, it has been reported that nitrogen helps in chlorophyll formation, phosphorus establishes strong root system which helps plants in appropriate nutrient absorption and anchorage, and sulphur improved the formation of chlorophyll and encouraged vegetative growth [36].

Have also reported that the significant effect of high phosphorus level on plant height of maize may be due to better development of the root system and nutrient absorption [37]. Similarly, reported that, increasing nitrogen level from 0 kg ha-1 to 23 kg ha-1 enhanced plant height of common bean [32]. In contrast, reported that phosphorus rate had no significant effect on plant height in common bean (Phaseolus vulgaris L.) [36].

On the other hand, an increase in plant height with decreasing intra-row spacing or increasing plant population could be attributed to increased internode length as a result of enhanced competition for light. Tallest plant (59.35cm) was observed at 5cm plant spacing, while the shortest plant (53.533cm) was observed at 15cm intra row spacing (Table 5). The increment in plant height with increased plant density could be justified on the bases of increase in the number of plants per unit area coupled with very high plant to plant competition. This result was in line with the findings of [34] who reported that, competition for light in narrow spacing resulted in taller plants of mung bean, while at wider spacing light distribution was normal.

Similarly, have observed that increasing the density of soybean plants led to significant increases in plant height [38]. This was primarily because of lower amount of light intercepted by individual plants at high plant density resulting in increased inter node length. However, reported that plant height was not affected by increasing plant density of faba bean [39].

3.3.3. *Total Number of Branches Per Plant*

This parameter was observed that NPS fertilizer high significantly (P<0.01) influenced total number of branches per plant, which was also significantly (P < 0.05) affected by intra row spacing, while their interaction was not significant (Table 5). Increasing rates of NPS fertilizer from 0 to 150 kg ha-1 resulted progressive increase in the number of branches per plant (Table 5). Thus, the highest number of branches per plant (3.11) was recorded for the highest rate of NPS application (150 kg ha-1), while the lowest (1.489) was for the control plot.

The increase in total number of branches per plant in response to increased rate of NPS might be due to the importance of P in NPS fertilizer for cell division activity, leading to the increase of plant height and number of branches and importance of S in NPS for growth and physiological functioning of plants. Also sulphur plays a vital role in promoting nodule formation in legumes, chlorophyll formation, helps in nitrogenous activity, controls certain soil borne diseases and tolerance to heavy metal toxicity in plants. In agreement with this finding, showed that higher number of branches per plant of common bean was significantly affected with application of 75 kg P2O5 ha-1 over the control [40]. The number of branches increased with increased rate of phosphorus might also be due to the importance of phosphorus for cell division, resulting to an increase in plant height [41]. In line with this result, have also reported that the number of branches per plant of common bean significantly increased with increase in nitrogen rate up to 120 kg ha-1 [42].

Similarly, total number of branches per plant was significantly (P<0.05) affected by plant density and increased with increasing intra-row spacing. The highest number of branches (2.35) was obtained equally at plant spacing of 5cm and 10 cm, while the lowest number of branches (2.1) recorded at 5cm intra row spacing (Table 5). This is due to the fact that, as intra row spacing increased population density decreases and thus, resources become more available for individual plants that enhance lateral vegetative growth of the crop. The increased number of branches at the wider intra row spacing could also be attributed to more interception of sunlight for photosynthesis In agreement with this result, have observed increased number of branches at the wider plant spacing for soybean [43], have also reported reduced number of branches with increased plant population of faba bean [44].

3.3.4. *Number of Nodules Per Plant*

The main effect of NPS rate was highly significant (P<0.01) for total number of nodules per plant, Intra row spacing had also significant (P<0.05) effect on number of nodules (Table 5). However, the interaction of intra row spacing with NPS rate was not significant (Appendix table 1). The highest number of nodules per plant (77.44) was obtained from application of 150 kg NPS ha-1, while the lowest value (48.16) was recorded for the unfertilized plot.

The increase in total number of nodules per plant at higher rates of NPS could be due to better root development with increasing rates of these nutrients. It might also be due to increases in availability of phosphorus, which is required in relatively larger amounts for enhancing plant growth and yield parameters in different legumes [43]. In agreement with the present result, reported that nodule number in common bean significantly increased with increasing levels of phosphorus with the lowest (12.89) and highest (31.85) numbers obtained from the control treatment and application of 20 kg P2O5 ha-1, respectively [44].

Total number of nodules per plant significantly decreased with increasing plant density or decreasing intra-row spacing. The highest total number of nodules (63.89) was recorded for intra row spacing of five centimeter, while the lowest (60.12) was recorded for intra row spacing of fifteen centimeter (Table 5). The increase in number of total nodules in response to narrower plant spacing might be attributed to the competition among densely populated plants for soil nutrient. Thus, the requirement for uptake of more nutrients might have prompted the plants to grow more number of total nodules [45]. This result was in line with the findings of Beruktawit (2012) who reported statistically significant increase in common bean nodulation with increased plant density.

Table 5. Mean plant height, number of branches and nodules per plant of common bean as influenced by NPS rate and intra row spacing.

Treatments	PH	NBPP	NNPP
NPS rate (kg ha-^{1})			
0	38.022d	1.489d	48.16d
50	49.378c	2.067c	58.11c
100	58.167b	2.43b	64.52b
150	77.833a	3.11a	77.44a
LSD (0.05)	2.4157	0.2072	2.8365
CV (%)	4.42	9.31	4.675
Intra row spacing (cm)			
5	59.350a	2.10b	63.892a
10	54.667b	2.35a	62.167ab
15	53.533b	2.35a	60.125b
LSD (0.05)	2.0921	0.1795	2.4565
CV (%)	4.42	9.31	4.675

PH: Plant height, NBPP: Number of branches per plant; NNPP: Number of nodules per plant; CV: coefficient of variation; LSD (0.05): least significant difference at 5% level; Means followed by same letters with in a column for a given treatment level are not significantly different at 5% probability level.

3.3.5. *Pod Length*

Both NPS fertilizer rate and intra row spacing had high significantly (P<0.01) influenced pod length, while their interaction was not significant (Appendix table 2).

The longest pod (11.43 cm) was produced with application of 150 kg NPS ha-1, while the shortest pod (9.7 cm) was obtained from the control plot (Table 6). Longer pod formation at higher rates of NPS might be due to more availability of P, which plays an important role in cell division and, thus, in improvement of growth attributes [46]. In line with this, reported significant effect of P application on pod length of common bean cultivars [47].

On the other hand, the longest pod (10.83cm) was recorded for the widest intra-row spacing (15 cm), while the shortest pod (10.26cm) was recorded for intra row spacing of five centimeter (Table 6). The variation in pod length might be due to the fact that at wider intra row spacing; there is better photo assimilate production and translocation to other plant parts contributing to increments in pod length [48].

Table 6. Mean pod length of common bean as influenced by NPS rate and intra row spacing.

Treatments	**PL**
NPS rate (kg ha-^{1})	
0	9.7d
50	10.26c
100	10.87b
150	11.43a
LSD (0.05)	0.1799
CV (%)	1.74
Intra row spacing (cm)	
5	10.26c
10	10.61b
15	10.83a
LSD (0.05)	0.1558
CV (%)	1.74

PL: Pod length; CV: coefficient of variation; LSD (0.05): least significant difference at 5% level; Means followed by same letter with in a column for a given treatment are not significantly different at 5% probability level.

3.4. *Yield and Yield Components*

3.4.1. *Number of Pods Per Plant*

Highly significant (P<0.01) effects of NPS fertilizer application rate and intra-row spacing were observed for total number of pods per plant (Table 7), while their interaction was not significant (Appendix table 2). The highest number of pods per plant (24.53) was recorded for application of 150 kg NPS ha-1, whereas the lowest value (9.98) was obtained from the unfertilized plot (Table 7).

The increase in number of pods per plant with increased NPS rates might be due to enough supply of N, P and S amount which might have increased the formation of primary branches and height of the plant with a concomitant production of higher number of pods. In line with this, have reported significant effect of nitrogen fertilizers on pod formation of French bean with the maximum number of pods per plant (25.49) recorded for 120-120-60-20-4-1 kg of N-P2O5-K2O-S-Zn-B respectively [36].

The increment of number of pods per plant due to application of P fertilizer confirms the fact that P fertilizer promotes the formation of nodes and pods in legumes [49]. In agreement with the present result, have also observed higher number of pods per plant (48.16) of common bean with application of phosphorus at a rate of 20 kg P ha-1 [36]. Also reported that [44], application of phosphorus at a rate of 40 kg P2O5 ha-1 produced the maximum number of pods per plant. Furthermore, have also found that the number of pods per plant of common bean significantly increased in response to increasing rate of phosphorus up-to the highest rate (92 kg P2O5 ha-1) [14].

Number of pods per plant increased with decreasing plant density or increasing intra-row spacing. The highest total number of pods per plant (17.52) was recorded for 15 cm intra row spacing, whereas the lowest value (15.34) was obtained from intra row spacing of five centimeter (Table 7). The decrease in the number of pods per plant with an increase in plant density could be due to increased competition between plants (intra specific competition) which eventually might have caused lowering in the number of pods per plant.

Furthermore, increased plant density induced competition between the former and later emerged flowers could lead to flower abortion and, thus, lower pod set. In wider intra-row spacing, however, the growth factors (nutrient, moisture and light) for individual plants might be easily accessible to retain more flowers and support the development of lateral branches and more number of pods [50]. In line with this, have reported that the common bean crop displays considerable plasticity in response to variations in plant density [51], mainly with regard to number of pods per plant.

Similarly, have reported that the development of more and vigorous leaves in low plant density helped to improve the photosynthetic efficiency of faba bean crop and supported large number of pods [52].

3.4.2. *Number of Seeds Per Pod*

The number of seeds per pod was high significantly ($P<0.01$) and significantly ($P<0.05$) affected by NPS rate and intra row spacing respectively (Table 7). However, interaction of the two factors was not significant for number of seeds per pod (Appendix Table 2). The highest number of seeds per pod (7.88) was recorded for 150 kg NPS ha-1, while the lowest value (6.96) was for the un-fertilized plot (Table 7).

The increment in number of seeds per pod with increasing NPS fertilizer application rate might be due to adequate supply of nutrients for nodule formation, protein synthesis, fruiting and seed formation [50]. In agreement with the present result, reported relatively highest number of seeds per pod with the application of 46 kg ha-1 of P2O5 and 41 kg ha-1of N [51]. Similarly, also reported the highest number of seeds per pod (5.85) for application of P at a rate of 20 kg ha-1 [36]. On the other hand [49] showed that application of 40 kg Sulfur ha-1 resulted in the highest count of seeds per pod of blackgram. This might be due to the role of sulphur in enhancing crop photosynthetic activity.

On the other hand, decreases in plant density increased number of seeds per pod. Thus the highest number of seeds per pod (7.63) was recorded for 15 cm, while the lowest value (7.34) was recorded for five centimeter intra row spacing (Table 7). This variation might be due to the fact that widely spaced plants encounter less intra plant competition than closely spaced plants and thus exhibit better growth and access to available resources that contributed to more number of seeds per pod [52]. This result was in agreement with the findings of [45] who reported that number of seeds per pod increased with decreased plant density of faba bean.

Table 7. Mean number of pods per plant and seeds per pod of common bean as influenced by NPS rate and intra row spacing.

Treatments	NPPP	NSPP
NPS rate (kg ha-^{1})		
0	9.978d	6.956c000
50	14.300c	7.378b
100	17.990b	7.730a
150	24.530a	7.880a
LSD (0.05)	1.21	0.2512
CV (%)	7.44	3.43
Intra row spacing (cm)		
5	15.34b	7.34b
10	17.23a	7.48ab
15	17.52a	7.63a
LSD (0.05)	1.0525	0.218
CV (%)	7.44	3.43

NPPP: Number of pods per plant; NSPP: Number of seeds per pod; CV: coefficient of variation; LSD (0.05): least significant difference at 5% P level; Means followed by same letter with in a column for a given treatment are not significantly different at 5% P level.

3.4.3. *Hundred Seed Weight*

Hundred seed weight was high significantly ($p<0.01$) influenced by NPS fertilizer rate and intra row spacing (Table 8). However, the interaction of both factors was not significant (Appendix Table 2). The highest hundred seed weight (55.24g) was recorded for application of 150 kg NPS ha-1, while the lowest value (41.078g) was for the un-fertilized plot (Table 8). The increase in hundred seed weight with increased rate of NPS application might be because of enhanced nutrient use efficiency by the crop at optimum levels of N, P and S since grain weight indicates the amount of resource utilized during critical growth periods. The increase in hundred seed weight with fertilizer application rate was in agreement with the findings of [53] who related the increment in hundred seed weight to the influence of cell division and phosphorus content in the seed and also to the formation of fat and albumin. It might also be attributed to the major roles that phosphorus plays in regenerative growth of the crop [54], leading to increased seed size [55], may also improve hundred seed weight. Similarly, observed thousand seed weight of common bean significantly increased as a result of phosphorus application up to 40 kg ha-1 [56].

In addition, reported that phosphorous fertilized crop when compared with the control produced more pods per plant which were better filled with heavier seeds leading to higher grain yield [57]. Has also reported that increasing sulphur rate from 0 kg ha-1 to 20 kg ha-1 increased hundred seed weight of common bean from 35.7 g to 36.8 g [58]. Similarly, reported that increasing N rate from 0 kg ha-1 to 50 kg ha-1 increased thousand seed weight of common bean from 301.19 g to 311.63 g [59]. In contrast, the experiment done by [60] showed that the different rates of phosphorus (46, 69 and 92 kg P2O5 ha-1) fertilizer had not resulted significant difference in hundred seed weight of common bean. The other possible reason for increment of hundred seed weight with NPS application might be that nitrogen improves grain or seed weights in crop plants and reduces grain sterility [61].

On the other hand, hundred seed weight decreased with increasing plant density. The highest hundred seed weight (49.19g) was recorded for plant spacing of fifteen centimeter, while the lowest value (45.65g) was obtained from five centimeter intra row spacing (Table 8). The increase in hundred seed weight with an increase in intra row spacing might be wider spaced plants, that improved the supply of assimilates to be stored in the seed, hence, the weight of hundred seeds increased. In line with this result [49], reported that hundred seed weight of haricot bean decreased with an increase in plant density. Moreover, have reported that hundred seed weight of faba bean was negatively related with plant density [62]. In contrast to this, observed non-significant effect of plant density on hundred seed weight of soybean [62].

3.4.4. *Above Ground Dry Biomass Yield*

Results of the analysis of variance revealed that, NPS fertilizer application and intra row spacing had highly significant ($P < 0.01$) effect on above ground dry biomass of common bean (Table 8), while their interaction was not significant (Appendix Table 2). The highest above ground dry biomass yield (11449.1kg ha-1) was recorded for150 kg NPS ha-1; while the lowest value (7131.9kg ha-1) recorded for the control plot (Table 8). The increase in total aboveground dry biomass at the highest rate of NPS could be due to more availability of N, which may significantly increase height of the plant, pods number and overall vegetative growth of the plants. In agreement with this result [63] has revealed that total dry matter production per plant of French bean increased significantly from 12.0 to 16.03 g due application increased nitrogen rate from 40 to 120 kg N ha-1. The increment in above ground dry biomass yield with application of NPS fertilizer might also be due to adequate supply of phosphorus from the NPS that contributed to an increase in number of branches per plant, which enhanced photosynthetic area and pods number per plant.

Aboveground dry biomass yield increased in response to increasing rate of NPS application may indicate that the soil of the study area is deficient in available P, N, S and requires external fertilizer application for improving the yield of the crop. In line with this [64] have reported a significant linear response of above-ground dry biomass yield faba bean to phosphorus application on acidic Nitisols. Similarly, reported highest total biomass yield (4597 kg ha-1) of common bean for the treatment with application of 40 kg P ha-1 [6]. In contrast, reported that sulphur application up to 60 kg ha-1 and its interaction with nitrogen did not have significant effect on above-ground dry biomass of common bean [58].

Total above ground dry biomass yield increase with increased plant density. The highest above ground dry biomass yield (11052.1 kg ha-1) was obtained from plant spacing of five centimeter; while the lowest value (8371.5 kg ha-1) recorded for fifteen centimeter intra row spacing (Table 8). The increment in total dry biomass at the closer spacing might be due to more number of plants per unit area. In agreement with this result, [49] and [67] have reported that dry biomass yield per hectare significantly increased with increased plant density of haricot bean. Similarly, also reported an increase in dry biomass yield of faba bean with increased plant density [66], [6].

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Table 8. Mean HSW and AGDBY common bean as influenced by NPS rate and intra row spacing.

Treatments	HSW	AGDBY
NPS rate (kg ha-^{1})		
0	41.078d	7131.9d
50	45.00c	9078.7c
100	47.633b	10856.5b
150	55.244a	11449.1a
LSD (0.05)	2.2643	563.47
CV (%)	4.9	5.98
Intra row spacing (cm)		
5	45.65b	11052.1a
10	46.875b	9463.5b
15	49.1917a	8371.5c
LSD (0.05)	1.96	487.98
CV (%)	4.9	5.98

HSW: hundred seed weight, AGDBY: above ground dry biomass yield; CV: coefficient of variation; LSD (0.05): least significant difference at 5% P level; Means followed by same letter with in a column for a given variable and treatment are not significantly different at 5% P level.

3.4.5. *Grain Yield (kg ha-1)*

Main effects of NPS rate and intra row spacing were highly significant ($P < 0.01$) effect (Table 9) and their interaction was also significant for grain yield of common bean (Appendix Table 2). The highest grain yield (4041.67) was recorded for 150 kg NPS ha-1 with five centimeter intra row spacing followed by (3513.89 kg ha-1) the same rate of NPS combined with ten centimeter plant spacing, while the lowest yield (1395.83 kg ha-1) was recorded for fifteen centimeter intra row spacing combined with un-fertilized treatment (Table 8).

Increases in seed yield at higher rates of NPS fertilizer rate could be attributed to increased growth of vegetative parts, such as branches and leaves, and yield components, such as number of pods per plant, number of seeds per pod and hundred seed weight. In line with this, it has been reported that crop growth and yield increases on soils which are naturally low in N, P, S and have been depleted [67].

Different authors have also reported the association of increase in these yield attributing traits with increase in seed yield [69]. In line with this result, reported that phosphorus application at the rate of 46 kg P2O5 ha-1 gave higher number of pods per plant and yield as compared to unfertilized plots in common bean [70]. Similarly, revealed that significant increases in the seed yield of common bean in response to phosphorus application under field and greenhouse conditions [6]. The increment in seed yield with increased rates of NPS fertilizer rate might also be due to increased levels of sulfur, its availability along with major nutrients and higher uptake of the crop, as it influences growth and yield components, which ultimately lead to effective, assimilate partitioning from source to sink in post-flowering stage and resulted in highest seed yield [71].

Differences in seed yield of the common bean could be related to its response to applied nitrogen. In agreement with to this, have observed due to the increasing rate of nitrogen up to 100 kg ha-1 yield of common bean increased [72]. Have also showed that yield of soybean increased significantly with application of 40 kg N ha-1 as compared to the unfertilized plot [73]. However, application of 80 kg N ha-1 decreased seed yield, indicating that excess application of nitrogen fertilizer had detrimental effect on the plant [73].

Grain yield per unit area increased with closer intra-row spacing (Table 8), which might be due to higher plant population, but yield of individual plants decreased probably due to intense interplant competition for resources such as nutrients, water and solar radiation as manifested by high plant mortality, high level of pod abortion and low number of pods per plant at the highest density plant. In agreement with this, reported that increasing plant population reduced yield of individual plants but increased yield per unit area of common bean [74]. Have also found that there was greater seed yield increase with higher population of determinate cultivars of dry beans [75]. Similarly, reported that high population ensured early canopy coverage and maximized light interception [76], greater crop growth rate and crop biomass, resulting in increased yield of soybean.

Table 9. Mean yield (kg ha-^{1}) of common bean as influenced by interaction of NPS rate and intra row spacing.

NPS rate (kg ha-^{1})	**GY**		
	Intra row spacing (cm)		
	5	**10**	**15**
0	1618.06i	1486.11j	1395.83j
50	2805.56f	2611.11g	2215.28h
100	3465.28b	3312.50c	3041.67e
150	4041.67a	3513.89b	3187.50d
LSD (0.05)		112.44	
CV (%)		4.87	

GY: Grain yield; CV: coefficient of variation; LSD (0.05): least significant difference at 5% level; Means followed by same letter with in columns and rows are not significantly different at 5% P level.

3.4.6. *Harvest Index*

Harvest index was high significantly (P < 0.01) affected by NPS rate. It was also significantly influenced by intra row spacing (Table 9). However, the interaction of the two factors was not significant (Appendix table 2). The highest harvest index (0.314) was recorded from application of 150 kg NPS ha-1, while the lowest value (0.213) was for the un-fertilized plot (Table 10). In line with this result, also reported that harvest index increased with increasing rates of phosphorus application in common bean [77]. The increment in harvest index with increasing rates of fertilizer was also in conformity with the findings of [78] who revealed that the improvement in harvest index values of 31.60, 31.99 and 33.86% due to increasing N level from zero, 60 and

120 kg N ha-1, respectively. In contrast, experiment showed that harvest index of common bean was not significantly affected due to phosphorus application [79].

On the other hand, the highest harvest index value (0.2875) was recorded at wider intra row spacing (15 cm), while the lowest value (0.264) was obtained from plant spacing of five centimeter (Table 10). The increase in harvest index with increasing intra row spacing might be due to lower interplant competition for resources such as nutrients, water and solar radiation as compared to closer intra row spacing. This result was in line with the findings of [37] who reported that harvest index was reduced with an increase in plant density in haricot bean.

Table 10. Mean Harvest index of common bean as influenced by of NPS rate and intra row spacing.

Treatments	**HI**
NPS rate (kg ha-^{1})	
0	0.212993c
50	0.281887b
100	0.302928a
150	0.314045a
LSD (0.05)	0.0189
CV (%)	6.95
Intra row spacing (cm)	
5	0.264071b
10	0.28224a
15	0.287579a
LSD (0.05)	0.0164
CV (%)	6.95

HI: Harvest index; CV: coefficient of variation; LSD (0.05): least significant difference at 5% level; Means followed by same letter with in a column for a given treatment are not significantly different at 5% P level.

3.5. *Agronomic Efficiency*

Agronomic efficiency (AE) was high significantly (P<0.01) affected by NPS rates, intra row spacing and their interaction (Table 11). The highest agronomic efficiency (23.75) was obtained at application of 50 kg NPS ha-1 at 5cm intra row spacing followed by agronomic efficiency of 50 kg NPS ha-1 at 10 cm plant spacing (22.5), while the lowest value (11.94) was recorded for 150 kg NPS ha-1combined with 15cm intra row spacing (Table 11). The increase in agronomic efficiency at lower rate of NPS application and its decrease at higher rates might be due to the rate of increase in seed yield was lower than the rate of increase in NPS supply. In agreement with this result, [53] and [80] have reported decreases in agronomic efficiency with increasing in P supply for common bean and soybean respectively.

Similarly, have reported higher agronomic efficiency for the interaction of phosphorus and common bean varieties at low P rate [6]. This might be due to the less effect of other nutrients with increasing level of phosphorus [81], or because the rate of increase in seed yield was less than the rate of increase in phosphorus supply. Also revealed that decreasing trend of agronomic efficiency from 69.8 to 9.3 kg kg-1 with increasing phosphorus application rates from 23 to 137.4 kg P2O5 ha-1 [82].

Table 11. Mean agronomic efficiency of common bean as influenced by interaction of NPS rate and intra row spacing.

	AE		
NPS rate (kg ha-1)			
	5	**10**	**15**
0	-	-	-
50	23.75a	22.5a	16.39d
100	18.47c	18.26c	16.46d
150	16.16d	13.52e	11.94f
LSD (0.05)		1.402	
CV (%)		6.16	

AE: agronomic efficiency; CV: coefficient of variation; LSD (0.05): least significant difference at 5% level; Means followed by same letter columns and rows are not significantly different at 5% P level.

IV. Partial Budget Analysis

Based on partial budget procedure described by [22], the variable costs included the NPS fertilizer cost (16.18 ETB kg-^{1}), improved seed cost (20 ETB kg-^{1}) and labor force for application of fertilizers, planting and harvesting, While the price of the current common bean was considered as gross benefit. Costs and benefits were calculated for each treatment. The costs of other inputs and production practices such as labor cost for land preparation, weeding and guarding were considered the same.

Results economic analysis showed that, the highest net benefit (46148 ETB ha-^{1}) with marginal rate of return of 861.2 % was obtained from 5cm intra row spacing with application of 150 kg NPS ha-^{1} followed by net benefit of 39900 ETB ha-^{1} with MRR was 614.7 % from combination of 10cm intra row spacing with the same rate of fertilizer application (Table 12). In contrast, the lowest net benefit (16987.5 ETB ha-^{1}) was obtained from 15cm intra row spacing without NPS fertilizer application. In order to use the marginal rate of return (MRR) as a basis for fertilizer recommendation, the minimum acceptable marginal rate of return has to be 100% [22]. In agreement with this result, reported the highest net benefit of 22,538 Birr ha-^{1} with marginal rate of return (MRR) of 320% for combination of 46 kg P_2O_5 ha-^{1} and variety 'Hawassa Dume' [83].

Table 12. Summary of partial budget analysis for the effects of NPS fertilizer application rates and intra row spacing on yield of common bean.

Intra-Row Spacing	NPS (kg ha-^{1})	GY kg ha-^{1}	AGY (kg ha-^{1})	GFB (ETB ha-^{1})	TVC (ETB ha-^{1})	NB (ETB ha-^{1})	MRR (%)
5cm	0	1618.056	1456.25	20387.5	1600	18787.5	1174.21875

Intra-Row Spacing	NPS (kg ha-^{1})	GY kg ha-^{1}	AGY (kg ha-^{1})	GFB (ETB ha-^{1})	TVC (ETB ha-^{1})	NB (ETB ha-^{1})	MRR (%)
	50	2805.56	2525	35350	3158	32192	860.36
	100	3465.28	3118.75	43662.5	3969	39693.5	882.5
	150	4041.7	3637.5	50925	4777	46148	861.2
10cm	0	1486.1	1337.5	18725	800	17925	2240.625
	50	2611.1	2350	32900	3158	29742	501.15
	100	3312.5	2981.25	41737.5	3967	37770.5	626.63
	150	3513.9	3162.5	44275	4375	39900	614.7
15cm	0	1395.83	1256.25	17587.5	600	16987.5	2831.25
	50	2215.28	1993.75	27912.5	3158	24754.5	303.64
	100	3041.7	2737.5	38325	3967	34358	515.9
	150	3187.5	2868.75	40162.5	4275	35887.5	514.3

V. Correlation Analysis

There was a positive and highly significant correlation between grain yield and leaf area (r = 0.79**), grain yield and plant height (r = 0.89**), hundred seed weight and grain yield (r = 0.699**), grain yield and pods per plant (r = 0.82), indicating that greater leaf area and higher number of pods per plants contributed to increased yield by increasing the number of seeds. This result was in agreement with the findings of Beruktawit et al., (2012) who reported that seed yield was highly correlated with number of pods per plant, seeds per pod, dry biomass yield and hundred seed weight. Similarly, number of seeds per pod showed positive and highly significant correlation with seed yield (r = 0.734**) and dry biomass yield (r = 0.57**). Number of branches per plant showed a positive and highly significant correlation (r = 0.92**) with leaf area which implies that the more the number of branches the larger leaf area is. Likewise, there was a positive and highly significant correlation between number of branches and dry biomass yield (r = 0.645**), which indicates the fact that as the number of branches per plant increase above ground dry biomass yield also increases (Table 13).

There was a positive and highly significant correlation between plant height and number of pod per plant (r = 0.899**) indicated that taller plants bear more number of pods per plant. Similarly, a positive and highly significant correlation was recorded between plant height and hundred seed weight (r = 0.838**), plant height and pod length (r = 0.809) and plant height and grain yield (r = 0.89**) (Table 13). This implies that taller plants have the potential to produce higher yields through more effective trapping and increased use efficiency light or solar energy than do shorter plants. In agreement with this result, observed that grain yield was highly correlated (P < 0.01) with number of pods/plant, plant height and hundred seed weight [84].

Correlation analysis showed that number of nodules per plant had highly significantly and positively correlated with seed yield (r = 0.899**), harvest index also showed a positive and highly significant correlation with number of pods per plant (r = 0.8**) and hundred seed weight (r = 0.713**) (Table 13). In agreement with this result, reported that number of nodules per plant was significantly and positively correlated with seed yield and also harvest index was highly correlated with number of pods per plant and hundred seed weight [6].

Days to physiological maturity showed a positive and highly significant correlation with grain yield (r = 0.83**) and total above ground dry biomass yield (r = 0.86**) which implies that prolonged canopy life enables continuous photosynthesis that might increase above ground dry biomass accumulation.

Table 13. Simple correlation coefficient among different parameters.

Correlation	DF	PH	LA	BR	NO	PL	PP	SPP	PM	SY	HSW	AGDBY	HI	AE
DF														
PH	0.63**													
LA	0.77**	0.84**												
BR	0.67**	0.88**	0.92**											
NO	0.63**	0.97**	0.85**	0.88**										
PL	0.68**	0.81**	0.95**	0.9**	0.83**									
PP	0.7**	0.899**	0.94**	0.94**	0.91**	0.93**								
SPP	0.6**	0.71**	0.83**	0.75**	0.7**	0.83**	0.81**							
PM	0.63**	0.88**	0.73**	0.74**	0.85**	0.69**	0.75**	0.66						
SY	0.54**	0.89**	0.8**	0.81**	0.9**	0.75**	0.82**	0.73**	0.83**					
HSW	0.6**	0.84**	0.877**	0.88**	0.83**	0.88**	0.93**	0.78**	0.69**	0.699**				
AGDBY	0.45**	0.82**	0.61**	0.65**	0.82**	0.54**	0.64**	0.57**	0.86**	0.92**	0.55**			
HI	0.44**	0.71**	0.82**	0.78**	0.72**	0.83**	0.8**	0.77**	0.5**	0.81**	0.71**	0.52**		
AE	-0.28^{ns}	0.27 ns	0.19 ns	0.29ns	0.3 ns	0.24 ns	0.24ns	0.34*	0.12ns	0.51**	0.19ns	0.43**	0.57**	

** = highly significant, ns = non-significant.

VI. Summary and Conclusion

Results of the experiment showed that NPS rate high significantly influenced number of days to 50% flowering, while the effect of intra row spacing and their interaction was non-significant. Number of days to 90% physiological maturity was high significantly affected by both NPS rate and intra row spacing. The main effects of NPS fertilizer, intra row spacing and their interaction were highly significant for total leaf area per plant, plant height was high significantly influenced by the main effect of NPS rates and intra row spacing while their interaction was non-significant. Number of branches and nodules per plant were high significantly affected by NPS rate and significantly affected by intra row spacing. The main effect of NPS rates and intra row spacing showed highly significant variation in pod length and significantly influenced by their interaction, number of pods per plant high significantly affected by the main effect of NPS rates and intra row spacing, number of seeds per pod was high significantly and significantly affected by NPS rates and intra row spacing respectively. Dry biomass yield and hundred seed weight were high significantly influenced by both NPS rates and intra row spacing. The main effect of NPS rates and intra row spacing and their interaction were significant for seed yield. Harvest index was high significantly influenced by the rate of NPS fertilizer and intra row spacing.

Based on partial budget analysis, the highest net benefit (46148 ETB ha-1) with marginal rate of return of 861.2 % obtained from combination of five centimeter intra row spacing (5cm X 40cm) with application of 150 kg NPS ha-1, followed by net benefit of combination of ten centimeter intra row spacing (10cm X 40cm) with the same fertilizer application (39900 ETB ha-1) with MRR was 614.7%, whereas the lowest net benefit (16987.5 ETB ha-1) was obtained from combination of fifteen centimeter intra row spacing (15 cm X 40 cm) without fertilizer application. Based on the results of this experiment, it can be concluded that NPS fertilizer rate of 150 kg ha-1 combined with five centimeter intra row spacing (5cm X 40cm) would result in the highest grain yield as well as maximum economic benefit from common bean (variety SER 119) production in the study area. However, since the data is only for one growing season and location repeating the experiment in different agro-ecologies may be important in order to validate the results.

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