Al-Qadisiyah Journal For Agriculture Sciences (QJAS)
ISSN : 2618-1479 Vol.12, Issue. 1 ,(2022), pp. 98-110
https://jouagr.qu.edu.iq/

Response of Common Bean (Phaseolus vulgaris L.) to NP Fertilizer Rates and Plant Population Density at Jimma Zone, Southwest Ethiopia

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Received : 8/4/2022
Acceptance : 30/5/2022
Available online: 1/6/2022

Abstract. Field experiments were carried out for 2018-2020 main cropping seasons at kersa and Omonada Jimma on farmers' fields. The treatments consisted of factorial combinations of 23/23, 23/46, 46/46 and 69/69 NP kg ha-1 levels with inter and intra (333333, 250000, 200000 and 166667 plant density ha-1) respectively laid down in a randomized complete block design (RCBD) with three replications using (Nassir) common bean variety. Across season and location data analysis of ANNOVA showed that all parameters were significantly affected by different densities and NP fertilizer rates including above ground biomass, harvest index and grain yield except harvest index was not affected by NP fertilizer rates. The highest plant height (72.51cm) was recorded from the highest (69/69 kg ha-1) NP fertilizer rate. The highest above ground biomass and grain yield of 6.40 and 2.45 t ha-1 were obtained from the highest (333333) plant density ha-1. Also, it showed still there was an increase in plant density increases with 26.29 and 6.52% grain yield advantage over the lowest density and control recommendation respectively. Also from economic and sensitivity analysis results treatments (333333) ha-1 plant population density, (23/23) and (46/46) kg/ha NP fertilizer rates gave the highest yield response and net benefit with MMR 1035, 111 and 224% respectively. In conclusion, intra and inter row spacing 3*10cm or equivalent (333333) ha-1 plant population density with applications of one of the two (23-23) or (46/46) kg/ha NP fertilizer rates based on their resource was recommended to farmers of study areas and similar agro ecology.

Keywords. Plant, Density, NP, fertilizer, Rate.

1. Introduction

The common bean (P. vulgar is L.) is a pulse that serves as an important protein supplement in the cereal-based Ethiopian diet and forms a significant export commodity group to fetch hard currency for the country. Also, it was highly preferred by farmers for fast-maturing than all crops for consumption, fresh local market cash income and also its compatibility for intercropping with maize. When the common bean's economic importance is considered, it is used as a source of foreign currency, food crop, means of employment and source of cash, and plays a great role in diversifying the farming system [1]. Common bean in Ethiopia is produced in almost all the regional states with varying intensity and is widely grown in low land and mid-altitude areas. The crop also does well in some areas as low as 500 m and as high as 1900 m a.s.l. that receive a well-distributed average rainfall of 500 to 1500 mm throughout the growing season [2]. It is an important pulse crop occupying about 366,877 ha (19.69% of the land area allocated to pulses) and producing about 463,008 tons of grain (16.83% of the total pulses production) [3]. The average yield (1.26 t ha–1) of common bean is low which is partly because phosphorus is deficient in about 70% of soils of Ethiopia [4].

Phosphorus is considered the first and nitrogen is the second limiting plant nutrient for bean yield in the tropical zone of cultivation. It's the basis for the formation of useful energy, which is essential for sugar formation and translocation reported that a common bean crop dependent on nitrogen fixation needs more inorganic phosphorus than the same crop provided with mineral nitrogen. Beans are therefore especially susceptible to low soil phosphorus when accompanied by low soil. Phosphorus is a constituent of nucleic acids, phospholipids and ATP [5]. It is, however, less available for plant uptake in most tropical soils mainly because of its fixation with Ca in alkaline soils and Fe and Al in acidic soils. Even though the addition of P fertilizer increases grain yield in many crops such as common bean [6].

Nitrogen is the most important element limiting crop production in the tropics [7]. Common bean has a high nitrogen requirement for expressing their genetic potential. [8] Found that common bean responds to N fertilizer even under conditions where it grows and fixes N2 well. As a result, the common bean is generally considered more responsive than other legumes to N fertilization [9]. However, a bean can fix and use atmospheric nitrogen for soil fertility and mineral nutrition requirements. But it was considered to be a poor fixer of atmospheric N when compared with other crop legumes [10]; [11]. In Ethiopia, the common bean is one of the major grain legumes cultivated, with its production concentrated in small farmers' fields where the use of N fertilizer is limited and average yields are low, usually less than 1.3 ton ha–1 [12]. [13] Found the increased yield of common bean due to increasing levels of nitrogen up to 100 kg ha-1 with the difference between 80 and 100 kg N ha-1 being not significant. Also, the application of 80 kg N ha-1 decreased seed yield, indicating that there is a limit to the maximum level of nitrogen to be supplied to avoid its detrimental effect on the plant [14]. These findings also support the hypothesis that higher plant-available N is needed when the plant population is reduced. The N demand of the common bean crop and the response to N fertilization may depend on plant population and growth habits [15]. Common bean cultivars with a compact and lower canopy may demand higher N rates to produce higher grain yields when grown with a low plant density. This effect may be related to the need to increase the branches and the number of pots per plant, compensating for plant population reduction. Hereby, pods and grains per pod are the yield components most affected by plant density [16]. According to [15] There is an improvement in the spatial distribution of plants when the sowing density is reduced from 10 to 5 plants m-1 within the row, resulting in more vigorous plants with a greater number of branches, which allows each plant to produce more pods and hence a higher grain yield. However, when plant populations are low, there is a greater demand for nutrients, of which nitrogen (N) is the most required for leaf production and increased grain yields. In this regard, it is essential to understand the effects of plant density on yield and its components by analyzing influencing factors and identifying major yield–density response curves [17] Previous studies have shown that optimal plant density for increasing yield varies according to such factors as water supply, cultivar and soil type as well as to solar radiation and planting methods [18] and [19].

Therefore, the objective of this study was to determine an optimum response of a combination of nitrogen, phosphorous rates and plant density for common bean growth parameters, yield and yield-related components.

2. Materials and Methods

2.1. Description of the Experimental Site

The experiment was conducted at Jimma Zone, Karsa and Omonada woreda, district, in the Oromia region in the southwestern part of Ethiopia, during the three main consecutive cropping seasons. The karsa sits were located at about 28 km east of Jimma town and 7° 40′ 0″ N latitude and 36° 50′ 0″ E longitude at an average elevation of 1740 to 2660 m amsl and average maximum and minimum temperature are 28.80C and 11.8 0C respectively and reliably receives good rains, ranging from 1,200 – 2,800 mm per annum cropping season. While the Omonada is located 365 km southwest of Addis Ababa. The sites were located on 7º46' N and 36º 00'E and laid at an altitude of 1753 m.a.s.l. with soil type of the area is Upland: Chromic Nitosol and Combisol. It has a warm and cold climate, also convenient topography which is very suitable for all agricultural practices. The average maximum and minimum temperatures are 9ºC and 28ºC respectively and reliably receive good rains of 1561 mm per annum cropping season. The farming system of the study sites were cereal crops dominated by maize cropping. (fig. 1.) below.

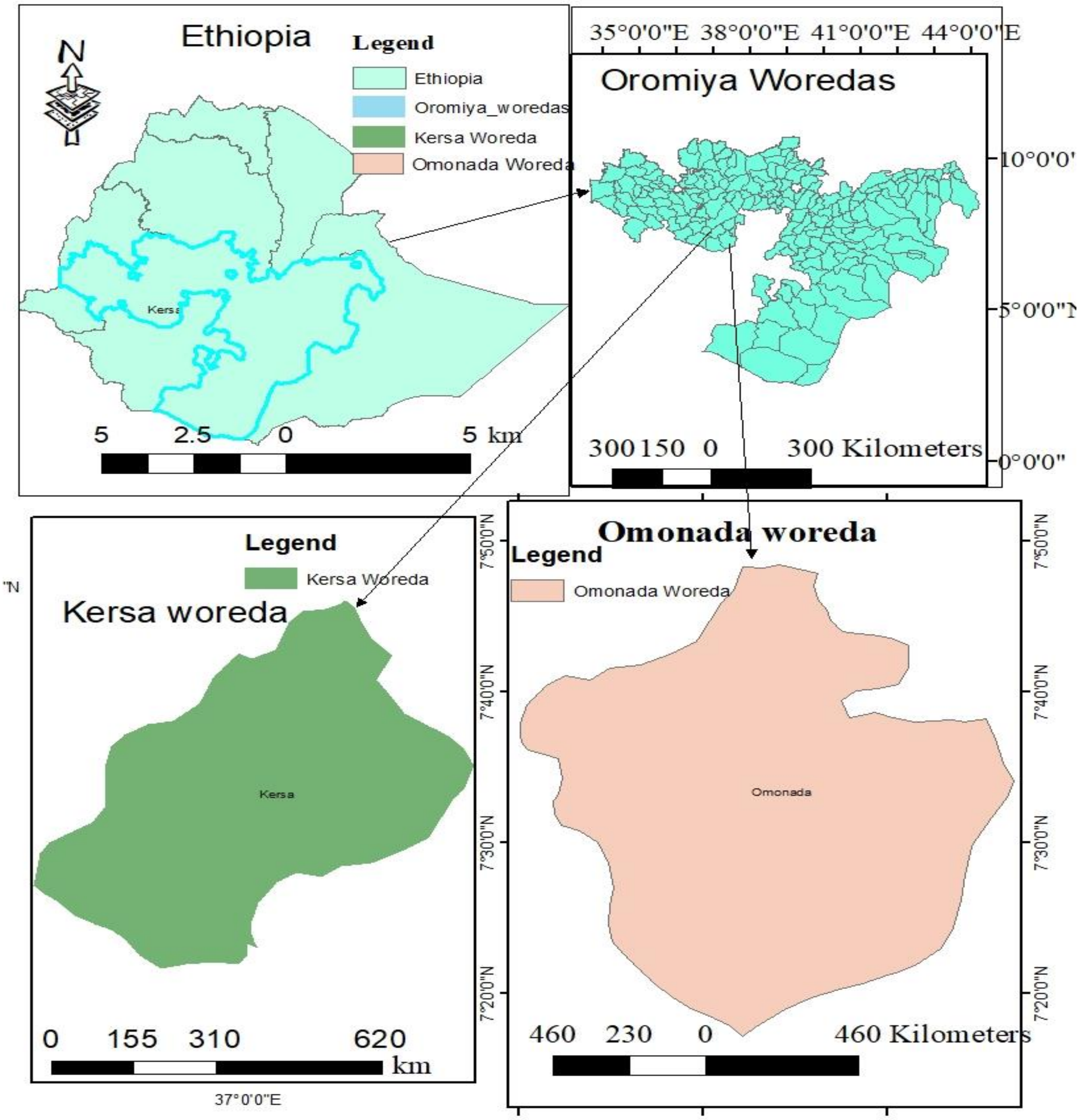

Figure 1. Location map of the study areas of Kersa and Omonada site, nearby Jimma town in Jimma zone.

2.2. Description of the Experimental Materials

The planting material used for the study was Common bean varieties (Nassir), which was red seed colored, small sized and released by Ethiopian Institute of Agricultural Research in (EIAR) 2016. It was a high yielder and the most promising variety which adapted well to the agro-ecologies of study areas and popularized.

2.3. Soil Sampling and Analysis

A composite surface soil (0-30 cm depth) sample was collected from both sites with a gauge auger before planting. The samples were dried, cleaned and analyzed for certain physio-chemical properties such as soil pH, total nitrogen, available phosphorus and organic matter content.

Table 1. Soil chemical properties of the experimental sites before planting at Kersa and Omonada woreda.

Soil characters	Kersa	Rating	Omonada	Rating	Reference
pH(1:2.5)	5.01	Strongly acidic	5.055	Strongly acidic	[20]
Av P(mg kg^{-1})	4.1	Low	14.86	High	[21]
TN (%)	0.18	Medium	0.182	Medium	[22]
OC (%)	1.955	High	2.055	High	[23]
SOM (%)	3.365	Medium	3.54	Medium	[22]
C: N ratio	10.79	Low	11.32	Low	[24]

Here pH= hydrogen power, TN=Total Nitrogen, Av P=Available Phosphorous, OC=Organic Carbon, SOM=Soil Organic Carbon. Values are the means of duplicated samples.

2.4. Experimental Treatment and Procedures

The experimental field was ploughed and prepared following the conventional tillage practice by oxen before planting at experimental locations. The land was levelled using manual power before the field layout was made. Furrowed was done by an oxen based on the treatments (specified intra and inter row spacing) and the seeds were drilled in furrow later thinning was done at seedlings good establishment to achieve the target population. The plot size of each treatment was 16m^2 (4 m x 4 m) and plant spacing was 10 and 15cm was used. The experiment was laid out in split-plot design with three replications. Four different plant populations including control and four levels of nitrogen, phosphorous fertilizer rates (P_2O_5) (Table.2) below. Fertilizer sources are urea and NPS. Inter and intra row spacing was assigned as the main plot and NP fertilizer rates were assigned as subplots. To increase the nitrogen use efficiency, it was split into two equal rates and applied at planting time; after thinning. The experiments were planted on 3rd–10th July in the ranges of common bean planting dates. Hand weeding and cultivation were started two weeks after planting in which hoeing and two hand weeding were done to control weeds.

Table 2. Details of treatments.

S. No	Intra and inter row	Plant population density/ha	N and P Rates kg/ha
1	30*10 cm	(333333)	69/69
2	40*10 cm	(250000) (control)	46/46
3	50*10 cm	(200000)	23/46
4	40*15 cm	(166667)	23/23

2.5. Data Collection and Measurement

2.5.1. Plant Height

Plant height (cm): Was recorded from ten random plants at maturity by measuring the height from the ground to the tip of the plant.

2.5.2. Stem Diameter (girth)

Stem Diameter was measured and the average value from ten randomly taken plant stem was 5cm above ground.

2.5.3. Pod Height

Was recorded from ten random plants at maturity by measuring the height from the ground to the first pod set.

2.5.4. Grain Yield

Grain yield (q/ha) was recorded after harvesting from the harvestable rows. Seed yield was adjusted to 12.5% moisture using a moisture tester (Dickey-john) and converted to quintal ha-1 for statistical analysis. Adjusted yield=Actual yield × 100-M/100-D; where M is the measured moisture content in grain and D is the designated moisture content (12.5%). where D is the designated moisture

2.5.5. Biomass Yield

Ten randomly selected plants were considered for the determination of above ground dry biomass weight by drying in sunlight for ten days till a constant dry weight was attained

2.5.6. Harvest Index

It was calculated as the ratio of grain yield to total above ground dry biomass yield multiplied by 100 at harvest from the respective treatments [25].

Harvest Index = Grain yield/ above ground dry biomass yield × 100.

2.6. Statistical Analysis

Analysis of variance (ANOVA) for all collected data was computed using R software version 3.5.3 statistical software R Core Team (2019-03- 11). Whenever the ANOVA results showed significant differences between sources of variation, the means were separated using Fisher's least significant difference (LSD). The homogeneity test showed that all location-year variances were homogeneous. Therefore, all data were combined for analysis of the variance procedures.

3. Results and Discussion

3.1. Plant Height

The All effects of experimental years, plant densities and NP fertilizer rate on collected parameters like the plant height, number of pod per plant and first pod height were insignificant ($P > 0.01$) that might be related to meteorological conditions with high solar radiation and sufficient supply of N [26]. The plant height and first pod height were significantly higher in 2020 and this increase was 18.54% and 10.22 respectively over 2018 cropping year.

The analysis of variance showed a highly significant ($P<0.01$) difference between plant densities and NP fertilizer rate on plant height (Table 3). The highest plant height (71.26) and (72.51cm) were recorded from (200000 plants ha^{-1}) plant density and from the highest NP fertilizer rate (69/69 kg ha^{-1}) respectively. In contrast, the lowest (64.93) and (64.39 cm) were recorded from the highest (333333 plants ha^{-1}) plant density and from the lowest NP fertilizer rate (23/23 kg ha^{-1}) respectively. The current result showed plant height increased linearly by 3.31-6.09 % rate with NP fertilizer rate increased. The highest 69/69 kg/ha NP fertilizer rate has 12.61% over the lowest 23/23 kg/ha NP fertilizer rate. Also, plant population increased up to (200000 plants ha^{-1}) but decline gradually with further population increases (fig. 2.). In general, as both plant population and NP fertilizer rates increase the plant height increases. This might be due to the maximum vegetative growth of the plants under higher NP availability and increased light, air and space demand for narrowly spaced plants or high density. Nitrogen helps in chlorophyll formation, phosphorus establishes a strong root system enhanced the formation of chlorophyll and encouraged vegetative growth [27]. In conformity with the current result, [28] found that plant height was significantly increased up to 160 kg N ha^{-1}. The tallest plants (61.14 cm) with highest plant density of 320,000 plants ha^{-1} and the lowest plant height of 52.55 cm in the lowest plant density of 125,000 plants ha-1 of green bean [29] reported.

3.1.1. Number of Pods Per Plant

The number of pods per plant was significant (P<0.01) influenced by effects of NP fertilizer rate and plant population density. The result showed that (15.69) and (15.68) number of pods per plant were obtained from the highest NP fertilizer rate (69- 69 kg/ha) and (200000 plants/ha) respectively. While the lowest number pods per plant (12.91) and (13.00) were obtained from the highest (333333) plants/ha and lowest (23-23 kg/ha) NP fertilizer rates respectively (fig. 2.). The result showed that there was an increase in the number pods of per plant with increased levels of NP fertilization rates and plant population density significantly. The current result was in agreement with the increment of number of pods per plant due to the application of P fertilizer confirming the fact that P fertilizer promotes the formation of nodes and pods in legumes [30]. In agreement with this result, [31] also found that the number of pods per plant of common bean significantly increased in response to the increasing rate of phosphorus up-to the highest rate (92 P_2O_5 ha^{-1}). Similarly, [32] reported a significant increase in a number of pods per plant, due to increased P fertilization.

3.1.2. First Pod Height

The highest first pod height (7.47 and 7.41 cm) were recorded from the higher (200000) plants ha^{-1} and the lowest application of NP was (23-23 kg/ha). In contrast, the lowest (6.97 and 6.96 were recorded from the highest (333333) plants ha^{-1} and (23-46 kg/ha) Np fertilizer rates (Table 3). The result showed that significantly an increase with a decrease in plan density up to (200000) plants ha^{-1} and a decline with further plant density increase. The result was in conflict with [33] in soya beans; a strong increase of the first pod high with higher plant densities has been shown. The first pod height was highest in the treatment with the double amount of sown seeds and lowest with the widest row spacing. Also in the case of NP fertilizer rates showed a kind of increment with NP fertilizer rate increase. This may be due to NP helping in encouraging vegetative growth like plant height that contributes to first pod height.

Table 3. Across Season and location mean of plant height, a number of pods per plant and pod height of common bean during 2018-2020 main seasons.

Treatment	Plant height (cm)	Number of pods per plant	First Pod Height (cm)
Year			
2018	64.18	16.27	6.85
2019	65.23	13.33	7.25
2020	76.08	14.30	7.55
LSD(0.05)	3.10	0.99	0.40
Plant population density			
30*10 cm (333333)	64.93	12.91	6.97
40*10 cm (250000)	67.93	14.57	7.10
50*10 cm (200000)	71.26	15.69	7.47
40*15 cm (166667)	69.86	15.36	7.31
LSD(0.05)	3.86	1.13	0.48
NP fertilizer rates (kg/ha)			
69-69 kg/ha	72.51	15.68	7.29
46-46 kg/ha	70.57	14.97	7.19
23-46 kg/ha	66.52	14.89	6.96
23-23 kg/ha	64.39	13.00	7.41
Mean			
LSD(0.05)	3.79	1.14	0.48
CV %	15.04	22.28	14.29

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation.

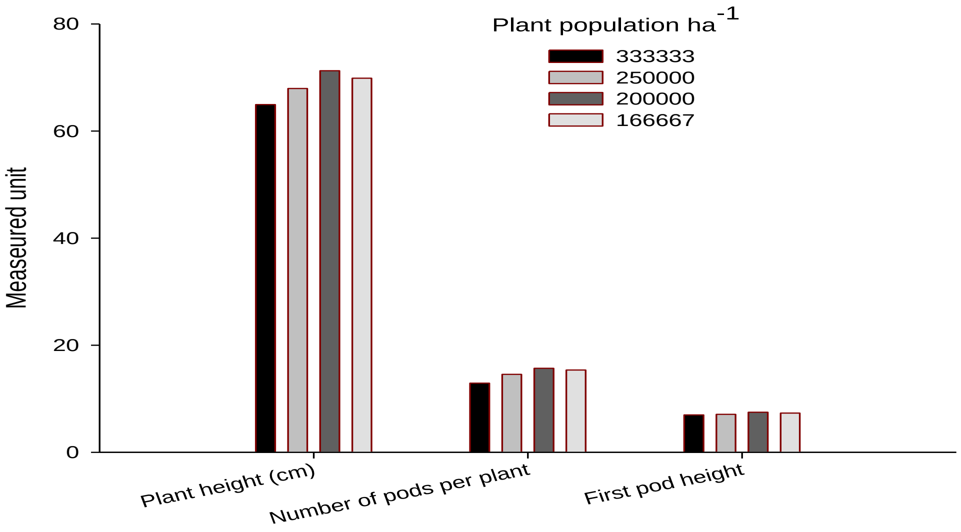

Figure 2. Graph of plant height, number of pods per plant and first pod height.

3.2. Yield Components and Yield

3.2.1. Grain Yield

The three experimental years ($P \leq 0.01$), the response of grain yield, above ground biomass and harvest index to NP fertilizer rates, plant population and all the interactions were not significant ($P > 0.05$) (Table 4). The grains yield and harvest index% were significantly higher in 2018 and this increase was 14.14% and 61.15 respectively over 2019 cropping year.

The result of the analysis showed that, the main effect of NP fertilizer rates and plant population density were highly significant ($P<0.01$). The highest grain yield (2.45 t ha^{-1}) and (2.30 t ha^{-1}) were obtained from (333333) plant population density ha^{-1} and 46/46 kg ha $^{-1}$ NP fertilizer rate respectively, while the lowest grain yield (1.71t ha^{-1}) and (1.83 t ha^{-1}) were recorded at the lower (200000) plant density ha^{-1} and NP fertilizer rate (23/23 kg ha^{-1}) (Table 4). The current result showed still there was an increase in plant density increases. The highest (333333 plant population density ha^{-1}) has a 26.29 and 6.52% grain yield advantage over the lowest density and control recommendation respectively. Also, the same trends showed with NP fertilizer rates but they decline with a further increase or beyond 46/46 kg/ha NP by 1.77% grain yields at 69/69 kg/ha rate. The application of 46/46 kg ha^{-1} NP fertilizer rate has a 25.68 % grain yield advantage over the lowest 23/23 NP fertilizer rate. Application of phosphorus fertilizer may have cushioned the competitive effects of common bean plants as population density was increased which might have led to efficient use of phosphorus fertilizer at higher plant population densities and improvement in grain yields ha^{-1}. The result of this study was in line with [34] who reported combined effects of plant density and fertilizer rate were positive and the increased levels of both parameters led to an increase in grain yield. Similarly, [35] also reported that, increasing plant population reduced yield of individual plants but increased yield per unit area of common bean.

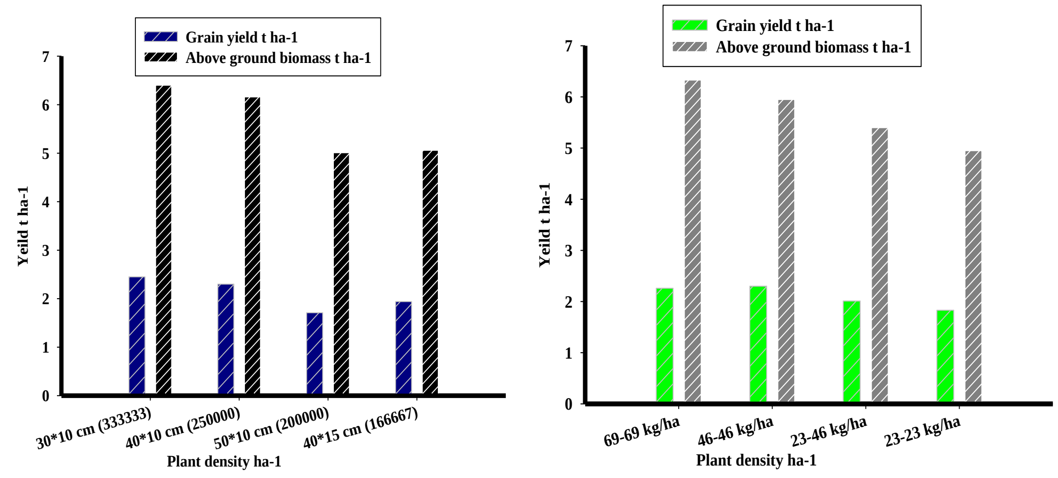

Figure 3. Graph of grain and above ground biomass yield.

3.3. Above Ground Biomass

The analysis of variance showed a highly significant (P<0.01) difference among plant densities and NP fertilizer rate on above ground biomass (Table 4). The highest (6.40 and 6.33 t ha^{-1}) above ground biomass were recorded from both the highest plant density (333333) plant ha^{-1} and (69/69) NP kg ha^{-1} respectively. In contrast, the lower plant density of (200000) plants ha^{-1} and (23/23) NP kg ha^{-1} NP fertilize rates gave the lowest (5.01 and 4.95 t ha^{-1}) above ground biomass. The result showed an increase in above ground biomass yield with both increased application NP fertilizer rates and plant population density significantly (fig. 3.). The (333333 plant population density ha^{-1}) has a 27.74 and 3.90% above ground yield advantage over the lowest density and control recommendation respectively. Also, the application of the highest 69/69 kg/ha NP fertilizer rates has a 27.88 % above ground yield advantage over the lowest 23/23 kg/ha NP fertilizer rate. As most studies showed as density increases plant height increases due to the computation to resources and solar radiation for photosynthesis. Also, it may be due to NP fertilizers rate promoting plants root growth, nodulation and which increases in nutrient uptake for growth and development. This result was in line with [36] who reported that the low plant population tended to enhance the vegetative growth of the dry bean (Phaseolus vulgaris) plants resulting in the development of large leaf area compared to the high and moderate plant populations. Also in agreement with [37] the highest total dry biomass at the highest density and the highest level of phosphorous might be due to the more number of plants per unit area and more application of phosphorus fertilizer may have cushioned the competitive effects of haricot bean plants as population density was increased which might have led to efficient use of phosphorus fertilizer at higher plant population densities and improvement in fodder and grain yields ha^{-1}.

3.3.1. Harvest Index (%)

The analysis of variance revealed that significant (P<0.01) effects of plant population density and no significant NP fertilizer rate were observed on harvest the index (Table 4). The highest harvest index (%) (41.58) and (41.38) were obtained at the lowest plant density of (166666plants ha^{-1}) and from the higher (46/46 kg NP ha^{-1}) fertilizer rate. In contrast the lowest (36.61) and (38.65) were obtained harvest index % were obtained from the higher plant density of (200000) plants ha^{-1} and NP fertilizer rate of (69/69 kg NP ha^{-1}) fertilizer rate (Table 3). The current result indicates a trend of increase inconsistently within NP fertilizer rates. But in the case of plant population density, it showed a trend of decrease with an increase in density. This result was in line with [38] who found that harvest index was reduced with an increase in plant density on haricot beans. Also, [37] reported the higher harvest index implies higher partitioning of dry matter into grain yield and the lowest harvest index at the

DOI: 10.33794/qjas.2022.133490.1037

highest plant density might be due to interplant competition for resources such as nutrients, water and solar radiation is low as compared to high plant density.

Table 4. Across Season and location of mean grain yield ha^{-1}, dry biomass and harvest index of the common bean during 2018-2020.

Treatment	Grain yield (ton ha^{-1})	Above Ground Biomass yield (ton ha^{-1})	Harvest Index (%)
Year			
2018	2.26	4.88	49.57
2019	1.98	5.37	38.12
2020	2.06	6.73	30.76
LSD(0.05)	0.18	0.51	3.11
Plant population density			
30*10 cm (333333)	2.45	6.40	40.40
40*10 cm (250000)	2.30	6.16	39.34
50*10 cm (200000)	1.71	5.01	36.61
40*15 cm (166667)	1.94	5.06	41.58
LSD (0.05)	0.19	0.61	4.36
NP fertilizer kg/ha			
69-69 kg/ha	2.26	6.33	38.65
46-46 kg/ha	2.30	5.95	41.38
23-46 kg/ha	2.01	5.40	39.18
23-23 kg/ha	1.83	4.95	38.73
Mean	2.10	5.7	0.38
LSD(0.05)	2005.03	0.62	Ns
CV %	24.30	25.73	17.50

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation.

3.4. Economic Analysis

Analysis of variance showed that plant population density had a significant (P = 0.001) effect on the grain yield. An economic analysis of the results using the partial budget technique was thus appropriate [39]. The result of the partial budget analysis and the data used in the development of the partial budget is given in (Table 5). It was performed by considering fertilizer, seed and labour costs for land preparation and application as the main input, mean grain yield obtained across the season. The total costs of fertilizers (NPS = 15.90 EtB/kg and urea = 12.65 EtB/kg and sale of grain common bean at around Kersa and Omonada an open market average price (20.00 EtB/kg). Common bean seed purchase was used for analysis. Grain yield was adjusted by 10% for management difference to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment [40].

Dominance analysis (Table 3) led to the selection of treatments (250000) and (333333) ha^{-1} plant population density and (23/23), (23/46) and (46/46) kg/ha and were ranked in increasing order of total costs that vary. The (200000) and (166667) ha^{-1} plant population density and (69-69) NP kg/ha treatments dominated and or were eliminated (Table 4).

Therefore, this investigation remained with (250000) and (333333) ha^{-1} plant population density and (23/23), (23/46) and (46/46) kg/ha as promising new practices for farmers under the prevailing price structure since they gave more than 100% MRR. This was because such a return would not offset the cost of capital (interest) and other related deal costs while still giving an attractive profit margin to serve as an incentive. All treatments (166667) and (333333) ha^{-1} plant population density and (23/23), (23/46) and (46/46) kg ha^{-1} gave acceptable MMR%. Based on the field prices of inputs and common bean grain yield showed that, (333333) ha^{-1} plant population density and (46-46) NP kg ha^{-1} gave the highest net benefit (42380 EtB ha^{-1}) and (36226 EtB ha^{-1}) respectively with acceptable (1400 and 303 %) MMR (fig. 4).

Market prices are ever-changing and as such a recalculation of the partial budget using a set of likely future prices i.e., sensitivity analysis, was essential to identify treatments that may likely remain stable and sustain satisfactory returns for farmers despite price fluctuations. The sensitivity analysis study indicates an increase in the field price of the total variable costs, and a fall in the price of common bean grain, which represented a price variation of 15% (Table 7).

The price changes are sensitive under market conditions prevailing around Omonada. The new prices were thus used to obtain the sensitivity analysis (Table 5) All treatments (333333) ha^{-1} plant population density, (23-23) and (46/46) kg/ha NP fertilizer rates gave acceptable with MMR 1035, 111 and 224% respectively give an economic yield response and also sustained acceptable returns even under projected worsening trade conditions in both sites. Similarly, [41] whose findings from Omonada on maize showed that the application of 138/104 kg NP ha^{-1} consistently. Therefore, intra and inter row spacing 3*10cm or equivalent (333333) ha^{-1} plant population density with the application of (23-23) and (46/46) kg/ha NP fertilizer rates give an economic yield response and also sustained acceptable in the study area.

Table 5. Partial budget analysis with dominance to estimate net benefit for plant population density and NP fertilizer rates at current prices.

Plant population densities	Grain yield t ha^{-1}	Adjusted Grain Yield t ha^{-1}	Gross Field Benefit	TCV (EtB ha^{-1})	Net Benefit (EtB ha^{-1})
40*10 cm (250000)	2.30	2.07	41400	1540	39860 UN
50*10 cm (200000)	1.71	1.54	30780	1576	29204 DO
40*15 cm (166667)	1.94	1.75	34920	1600	33320 DO
30*10 cm (333333)	2.45	2.21	44100	1720	42380 UN
NP fertilizer kg/ha					
23-23 kg/ha	1.83	1.65	32940	2587	30353 UN
23-46 kg/ha	2.01	1.81	36180	3880	32300 UN
46-46 kg/ha	2.30	2.07	41400	5174	36226 UN
69-69 kg/ha	2.26	2.03	40680	7761	32919 DO

Retail price of grain =Birr 20.00 per kg; Fertilizers urea = Cost of Birr 12.65, per kg; NPs =Cost Birr 15.90 per kg; TCV= total cost that varied, NB= Net benefit; MMR= Marginal Rate of Return; EtB = Ethiopian Birr.

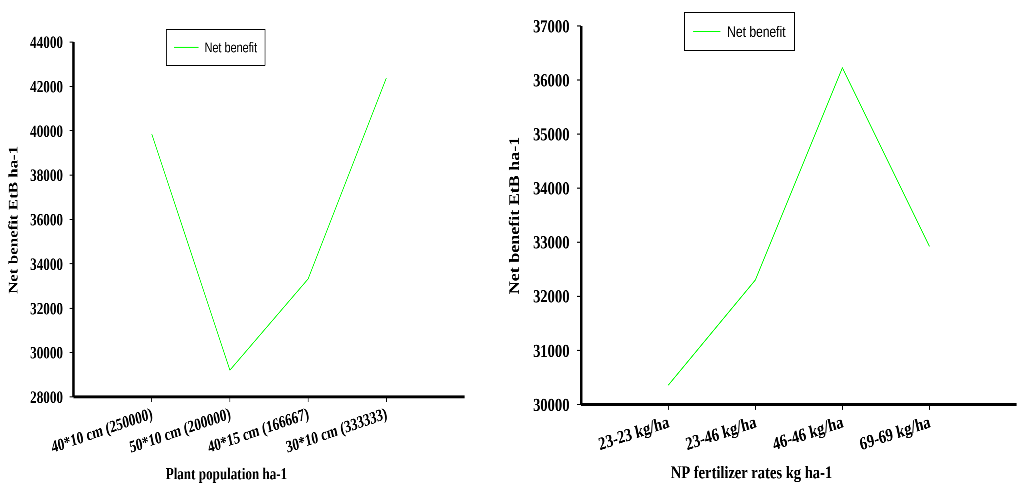

Figure 4. Graphs of net benefit on NP fertilize rates and plant population density .

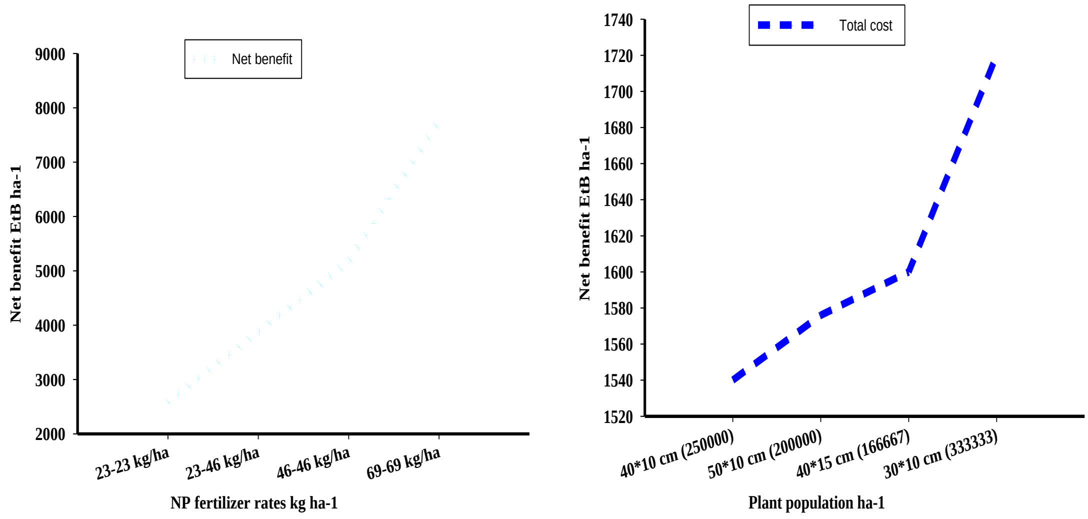

Figure 5. Graphs of the total cost that varied on NP fertilizer rates and plant population density.

Table 6. Partial budget with estimated marginal rate of return (%) for plant population density and NP fertilizer rates at current prices.

Plant population densities	TCV (EtB/ha)	Net Benefit (EtB/ha	Raised Cost	Raised Benefit	MRR (%)
40*10 cm (250000)	1540	39860	----	----	----
30*10 cm (333333)	1720	42380	1500	5170	1400
NP fertilizer kg/ha					
23-23 kg/ha	2587	30353	1500	1676	----
23-46 kg/ha	3880	32300	1500	88.05	150
46-46 kg/ha	5174	36226	2250	15218	303

Retail price of grain =Birr 20.00 per kg; Fertilizers urea = Cost of Birr 12.65, per kg; NPs =Cost Birr 15.90 per kg; TCV= total cost that varied, NB= Net benefit; MMR= Marginal Rate of Return; EtB = Ethiopian Birr.

Table 7. Sensitivity analysis of common bean production based on a 15% rise in the total cost and Common bean price of gross field benefit fall.

Plant population densities	TVC(ETB ha^{-1})	NB (ETB ha^{-1})	Increment Cost	Increment Benefit	MRR (%)
40*10 cm (250000)	1771	33881	----	----	----
30*10 cm (333333)	1978	36023	207	2142	1035
NP fertilizer kg/ha	0				
23-23 kg/ha	2975	25800	----	----	----
23-46 kg/ha	4462	27455	1487	1655	111
46-46 kg/ha	5950	30792	1488	3337	224

Retail price of grain =Birr 20.00 per kg; Fertilizers urea = Cost of Birr 12.65, per kg; NPs =Cost Birr 15.90 per kg; TCV= total cost that varied, NB= Net benefit; MMR= Marginal Rate of Return; EtB = Ethiopian Birr.

Summary and Conclusion

Common bean (P. vulgar is L.) is the most important food and export crop of Ethiopia and it is the source of protein and cash for farmers. In view of this, an experiment was conducted to determine the effect of plant density and nitrogen, phosphorous fertilizer rate on yield components and yield of common bean. The result showed that the most important parameters are significantly effect. The highest plant height (71.26) and (72.51cm) were recorded from (200000 plants ha^{-1}) plant density and from the highest NP fertilizer rate (69/69 kg ha^{-1}) respectively. The highest grain yield (2.45 t ha^{-1}) and (2.30 t ha^{-1}) were obtained from (333333) plant population density ha^{-1} and 46/46 kg ha $^{-1}$ NP fertilizer rate respectively. Also it showed still there was an increase in plant density increases with 26.29 and 6.52% grain yield advantage over the lowest density and control recommendation respectively. Also the same trends showed with NP fertilizer rates but they decline with a further increase or beyond 46/46 kg/ha NP by 1.77% grain yield at 69/69 kg/ha rate. Similarly, the highest (6.40 and 6.33 t/ha) above ground biomass were recorded from both the highest plant density (333333) plant ha^{-1} and (69/69) NP kg ha^{-1} respectively. Also from economic and sensitivity analysis results treatments (333333) ha^{-1} plant population density, (23-23) and (46/46) kg/ha NP fertilizer rates gave the highest yield response and net benefit with MMR 1035, 111 and 224% respectively. Therefore, intra and inter row spacing 3*10cm or equivalent (333333) ha^{-1} plant population density with applications of (23-23) or (46-46) kg ha^{-1} NP fertilizer rates is recommended based on their resource to study areas farmers and similar agroecology.

Acknowledgements
The gratefully acknowledge Mr Kemerudin Aba Mecha and Wodajo Mekuria who helped in overall trial management and support for collecting data from the field.

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