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Effect of NPS fertilizer rates and intra-row spacing on Growth, Yield and Yield Components of Common bean under Midland Conditions of Bale, Southeastern Ethiopia

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ABSTRACT

The study was conducted in 2019 and 2020 main cropping season at two locations in East Bale and Bale Zone, Ethiopia, to determine the optimum blended NPS fertilizer rate and intra-row spacing of common bean for maximum yield and yield components. The experiment was laid out in split plot design with haricot bean varieties (Doyo and Wabaro) as main plots and combined NPS fertilizer rate and intra-row spacing as sub-plots with three replications. The treatments consisted of four rates of NPS fertilizer (0, 50, 100 and 150 kg ha-1) and three intra-row spacing (5, 10 and 15cm). Among the main treatment, variety Wabaro showed significant effect on yield components and yield of common bean except thousand seed weight. Interaction effect of variety, blended NPS fertilizer rate and intra-row spacing highly significantly (P<0.01) affected days to 50% flowering, days to 90% of maturity date, Plant height, number of pod per plant, grain yield kg ha-1.The highest grain yield (2635.17kg ha-1) was obtained from variety Wabaro at intra-row spacing 5cm and 50 kg NPS ha-1 and the lowest grain yield (1683.11kg ha-1) was obtained from Doyo variety at intra-row spacing 15cm and no NPS fertilizer application. The attractive net benefit (36315.79 birr ha-1) was obtained from planting Wabaro variety at intra-row spacing 5cm and 50 kg NPS ha-1. Based on agronomic performance and economic analysis, use of Wabaro at intra-row spacing 5cm and 50 kg NPS ha-1 is promising for production of Wabaro common bean variety at Ginir, Goro and similar agro ecologies.

Background & Justifications

Common bean is the most important pulse crops grown in central, southern, eastern and western lowland and mid altitudes of Ethiopia. It grows best in warm climate at temperature of 18 to 24^{o}C (Teshale *et al.,* 2005).The wide range of growth habits among common bean varieties has enabled the crop to be cultivated well under different agro-ecological surroundings. Common bean is very favored by Ethiopian farmers because of its fast maturing uniqueness that enables households to get cash returns essential to pay for food and other household needs when other crops have not yet matured (Legesse *et al*., 2006). Besides, its use as a readily available source of protein for farmers, it is also an important cash crop and export commodity that generate foreign exchange for the country Abebe G (2009). It is also the major staple food supplementing the protein source for the poor farmers who cannot afford to buy expensive meat. Despite its tremendous importance the current national average yield of red and white haricot bean is 16.58 and 17.19 quintals per hectare and total area and total productions is estimated to be 1,011,195.00 and 2611135.00 hectares and 89382.69 and 216803.91 quintals respectively (CSA,2018), which is far lower than its yield potential, mainly owing to various production constraints. Among the constraints, lack of well adapted varieties, fertilizers levels, planting date, row spacing (population density), weed and disease control and weather conditions are important factors determining the productivity and quality of bean crops (Gebremedhin, 2015).

Legumes including common bean have high P requirement due to the production of protein containing compounds, in which N and P are important constituents, and P concentration in legumes is generally much higher than that found in grasses. High seed production of legumes primarily depends on the amount of P absorbed (Khan *et al*., 2003). The yield of common bean increases with P application (Gemechu, 1990) and its nodulation and fixation of N can be improved with the application of P (Amare, 1987).

Sulfur is among macronutrient which limits and plays many important roles in the growth and development of plants especially legume crops. The main roles of S in legume crops production are: chlorophyll formation, photosynthesis, development of amino acids, the building blocks of plant protein, increased root growth, promotion of nodule formation, enhancing N_2 fixation, and the encouragement of more vigorous plant growth. Therefore, application of NPS fertilizer is very important to maximize the yield of common bean. Hence, optimization of plant density for high yielding genotypes with suitable intra-row spacing is crucial in order to increase common bean productivity per unit area. Therefore, this study was conducted with the objectives:-

To evaluate the economic feasibility of different intra-row spacing and NPS rates of common bean variety for maximum yield and yield components.

To find out the optimum intra row spacing and NPS rate for common bean production under midland conditions of Bale.

MATERIALS AND METHODS

The experiment was conducted at Ginir and Goro for two consecutive main cropping seasons of 2019 and 2020. The experiment was laid out in split plot with haricot bean varieties (Wabaro and Doyo) as main plots and factorial combined of NPS fertilizer rate and intra-row spacing as sub-plots with three replications. The treatments consisted of four rates of NPS fertilizer (0, 50, 100 and 150 kg ha^{-1}) and three intra-row spacing (5, 10 and 15cm). The size of each plot was 3 m x 2.4 m (7.2 m^{2}) and distances between the plots and blocks were 1m and 1.5m respectively. At physiological maturity, crops from the central four rows were harvested and used for determining yield and yield components.

Soil samples taken prior to sowing were taken randomly in W-shaped pattern from entire experimental field using auger and composited to one representative sample using standard procedures in order to determine necessary nutrients particularly, particle size distribution, pH, organic carbon, Cation exchange capacity, total nitrogen, and available Phosphorus (P).

Data were collected on major agronomic and phonological characters. Analysis of variance (ANOVA) was done using SAS software. Homogeneity of variance was tested using F test as described by Gomez and Gomez.

Table 1.Constituents of respective nutrients in the determined rate of NPS (kg ha^{-1})

No	Blended NPS fertilizer rate (kg ha^{-1})	N	P_2O_5	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

RESULTS AND DISCUSSIONS

Physico-chemical properties of the experimental site

According to soil analysis result, the soil of the experimental site was found to be clay (Table 2). This might indicate that there was better water and nutrient holding capacity of the soil for growing the crop at the site. The pH showed a neutral according to rating of Landon (1991). The available P level during the experiment at Ginir and Goro is 10.23 and 8.43 mg kg^{-1} respectively which is medium according to Roy et al. (2006) (Table 2). According to Tekalign *et al*., 1991 total nitrogen of the experimental soil was medium.

Table 2.Chemical and physical characteristics of the soil of experimental Site

Properties	Value		
Physical properties	**Ginir**	**Goro**	**Description**
Sand (%)	21	20	-
Silt (%)	27	34	-
Clay (%)	52	46	-
Textural Class	Clay	Clay	-
Chemical properties			
pH (1: 2.5 H2O)	6.82	7.1	Neutral according to Tekalign *et al*. (1991)
Organic Carbon /OC/ (%)	1.18	1.19	Low according to Tekalign *et al*. (1991)
CEC (cmol kg-1)	47.46	49.46	very high according to Roy *et al* (2006)
Total nitrogen /TN/ (%)	0.16	0.17	Medium according to Tekalign *et al*. (1991)
Available phosphorus /P/ (ppm)	10.23	8.43	Medium according to Roy *et al.* (2006)
Available sulfur /S/ (ppm)	21.42	20.41	Very low Lewis *et al*. (1999)

Days to flowering and Physiological maturity

The combined main effect of varieties and intra-row spacing were highly significant (P<0.001).However, the main effects of row spacing and NPS fertilizer application, interaction of varieties with row spacing and NPS fertilizer rates, interaction of spacing and NPS fertilizer rate and three way interactions of varieties, spacing and NPS fertilizer rates did not show significant difference on days to flowering. Variety Doyo exhibited significantly earlier to number of days to flowering than variety Wabaro (Table3). There was a difference of 6 days early between the two varieties. This might be due to the inherent genetic differences between the varieties. The longest days to flowering with wider intra-row spacing might be due to the fact that more nutritional area available in the wider row spacing might have caused the crop to flower later than the narrower spacing. This result is in line with Samih (2008) who reported that when beans are planted at the lower planting densities, the plants required more number of days for flowering. Days to Physiological maturity was also significantly (P<0.01) affected by main effect of varieties intra-row spacing and blended NPS fertilizer application rate. The two and three way interaction of varieties, intra-row spacing and NPS- rate did not show significant difference on days to 90% physiological maturity. Variety Doyo matured significantly earlier than Wabaro (108 days) (Table 3).Probably genetic make-up of the varieties was responsible for the variation in their maturity days.

Plant height

Plant height was highly (P<0.01) affected by the main effect of varieties and intra-row spacing, while the main effect of NPS fertilizer application rates and two and three factor interaction of varieties, intra-row spacing and NPS fertilizer application rates did not show significant effect on plant height. Variety Wabaro was significantly taller (54.21 cm) than Doyo (51.55 cm) (Table 3). It was about 2.66% taller than the height of Doyo variety. Ullah *etal*. (2007) reported that differences in plant height could be due to variation in genetic make-up or the hormonal balance and cell division rate that result in changes in the plant height of the different varieties. With regard to the effects of intra-row spacing, the maximum plant height (49.09 cm) was recorded at narrow intra-row spacing of 5cm (Table 3). Similar findings were reported by Khalil *et al*. (2015), who indicated that the denser plant population increased the plant height of faba bean due to competition among plants.

Table 3: Mean effect of varieties, NPS fertilizer rates and intra-row spacing on days to flowering days to physiological maturity and plants height

Treatments	Days of flowering	Days of maturity	Plant height
Varieties			
Doyo	49.67[b]	111[a]	51.55[b]
Wabaro	51.80[a]	110[b]	54.21[a]
LSD (5%)	0.43	0.23	1.28
Intra-row spacing			
5 cm	48.49[ab]	110[c]	53.18[a]
10 cm	48.61[ab]	111[b]	51.80[ab]
15 cm	49.09[a]	112[a]	49.09[b]
LSD (5%)	0.63	0.34	1.88
Blended NPS fertilizer rates			
0 kg	49.60[b]	111[a]	52.58[a]
50 kg	49.60[b]	110[a]	52.92[a]
100 kg	49.08[b]	111[a]	53.71[a]
150 kg	50.65[a]	111[a]	52.32[a]
LSD (5%)	0.80	0.43	2.83
CV (%)	3.81	0.89	10.44

Number of pods per plant

The result of analysis of variance indicated that there was significant($P<0.01$) effect on number of pod per plants due to main effect of variety, intra-row spacing, NPS fertilizer rates, interaction between variety x NPS fertilizer rates and variety x intra-row spacing x NPS fertilizer rates (Table 4).The highest number of pods per plant (21.8) was obtained from Wabaro variety x 5cm×50 kg NPS fertilizer application rates , while the lowest number of pods per plant (16.3) was found from Doyo x 5cm with no NPS fertilizer application (Table 4).

Increasing application rates of blended NPS fertilizer from 0 to 150kg ha^{-1} resulted in progressive increase of the number of pods per plant. The increase in number of pods per plant with the increased NPS rates might possibly be due to adequate availability of N, P and S which might have facilitated the production of primary branches and plant height which might in turn have contributed for the production of higher number of total pods. This result was in line with Malek *et al*. (2013) who reported that the number of pods per plant of lentil was significantly influenced by plant density.

Table 4:Means of number of pod per plant of common bean as influenced by interaction of variety, intra –row spacing and blended NPS fertilizer rates at Goro and Ginir.

Varieties	Intra-row spacing(cm)	Blended NPS fertilizer rates kg ha-1			
		0	50	100	150
Doyo	5	16.3[c]	16.6[c]	18.1[abc]	16.9[c]
	10	16.1[c]	17.3[bc]	17.6[abc]	18.6[abc]
	15	17.0[c]	17.7[abc]	18.8[abc]	19.3[abc]
Wabaro	5	18.2[abc]	21.8[abc]	18.4[abc]	18.9[abc]
	10	17.7[abc]	19.0[abc]	20.7[a]	20.5[ab]
	15	17.4[bc]	19.1[abc]	19.4[abc]	19.6[abc]
ISD(0.05)	3.54				
CV (%)	12.92				

Aboveground dry biomass yield (kg ha^{-1})

Aboveground biomass yield was highly (P<0.01) affected by main effects of variety, intra-row spacing, NPS fertilizer level and three way interaction of variety, intra-row spacing and NPS fertilizer rates, while two way analysis did not showed significant effect on above ground biomass (Table 5).Regarding the effect of interaction effect of Variety x NPS x intra-row spacing, the aboveground dry biomass increased with a decrease in intra-row spacing where the highest aboveground dry biomass yield (6168.9kg ha^{-1}) was recorded from Wabaro variety at narrow intra-row spacing of 5 cm, which had a significant difference with 10 cm, while the lowest aboveground dry biomass yield (4512.2 kg ha^{-1}) was recorded at wider intra-row spacing of 15 cm (Table5). This result was in agreement with Solomon (2003) who reported that dry biomass per hectare was significantly increased with increased plant density on common bean.

Table 5.Means of above-ground dry biomass yield (kg ha^{-1}) of common bean as influenced by interaction of variety,intra –row spacing and blended NPS fertilizer rates at Goro and Ginir, 2019 and 2020

Varieties	Intra-row spacing(cm)	Blended NPS fertilizer rates kg ha^{-1}			
		0	50	100	150
Doyo	5	4614.58b^{c}	5301.08^{bc}	5520.83^{ab}	5654.17^{ab}
	10	4703.13^{b}	4995.14^{bc}	5750.00^{ab}	4802.78^{bc}
	15	4482.15^{c}	4881.25^{bc}	5045.14^{bc}	5602.78^{ab}
Wabaro	5	4570.83^{bc}	6168.89^{a}	5564.58^{ab}	5739.58^{ab}
	10	4923.61^{bc}	5474.31^{ab}	5638.89^{ab}	5604.17^{ab}
	15	5138.89^{bc}	5253.47^{ab}	5302.08^{b}	5559.72^{ab}
LSD(0.05)		814.63			
Cv(%)		17.90			

Adjusted grain yield (kg ha^{-1})

There was highly significant (P<0.01) main effects of variety, row spacing, NPS level, and interaction effect of variety x row spacing and NPS level on grain yield of common bean varieties. The highest grain yield (2635.2 kg ha^{-1}) was recorded from Wabaro variety at the intra-row spacing of 5 cm and 50 NPS kg ha-^{1} fertilizer application rates. The lowest grain yield (1683.11kg N ha-1) was recorded from Doyo variety at 15 cm intra-row spacing and 0 kg NPS ha^{-1} (Table 6). The numbers of pod per plant, number of seed per pod might be attributed to the final yield. For both varieties, as the NPS level was increased from 0 to 150 kg ha^{-1}common bean grain yield also increased gradually. The maximum grain yield was found in narrow intra-row spacing of 5cm. The result was in agreement with Gunri and Chaudhury (2004) that closer spacing proved better in grain yield of rice, nutrient use efficiency and uptake than the wider row spacing. Amare *et al*. (2014) stated that interaction effect of variety, row arrangement and NPS levels had significant effect on grain yield ha^{-1}on grain yield of common bean (Table 6).

Table 6. Means of Grain yield (kg ha^{-1}) of common bean as influenced by interaction of variety, intra –row spacing and blended NPS fertilizer rates at Goro and Ginir, 2019 and 2020

Varieties	Intra-row spacing(cm)	Blended NPS fertilizer rates kg ha^{-1}			
		0	50	100	150
Doyo	5	1882.29^{bc}	2163.54^{ab}	2229.01^{ab}	2357.97^{ab}
	10	1752.71^{bc}	2042.20^{bc}	2110.43^{bc}	2207.93^{ab}
	15	1628.11^{c}	1863.25^{abc}	1965.19^{bc}	2143.49^{ab}
Wabaro	5	2025.16^{bc}	2596.93^{ab}	2544.91^{ab}	2635.17^{a}
	10	2077.05^{bc}	2151.67^{ab}	2495.23^{ab}	2382.20^{ab}
	15	1761.01^{bc}	2116.34^{b}	2100.57^{bc}	2048.77^{bc}
LSD(0.05)	487.31				
CV (%)	16.24				

Partial Budget Analysis

The result of the present study included the costs for NPS fertilizer and labor cost for fertilizer application varied. The grain yield was adjusted downward by 10% and net benefits are calculated by field price of common bean grain yield that was 14 Birr kg^{-1} in Ginir and Goro during the production season. The highest net benefit (36315.79 birr ha^{-1}) was obtained from treatment combination of variety wabaro,5cm intra-row spacing and 50kg NPS ha^{-1}, while the lowest (24236.78birr ha^{-1}) net benefit was obtained from the combination of variety doyo,5cm intra- row spacing and 0 kg NPS ha^{-1}. According to CIMMYT (1988), the minimum acceptable marginal rate of return (MRR %) should be between 50 and 100%. Therefore, the most attractive rate of return with higher benefits in this result was obtained with the combination variety wabaro, 50 kg NPS ha^{-1} with 5cm intra-row spacing recommended for the farmers in study area.

Table 7. Result of economic analysis for effect of blended fertilizer (NPS) and intra-row spacing for common bean (*Phaseolus vulgaris* L.) varieties at Goro and Ginir during 2019-2020 main cropping seasons

Varieties + Intra-row+ NPS kg/ha^{-1}			Total Cost	Marginal Cost	Net Benefit	Marginal Benefit	Marginal ret of Return
Doyo	5 cm	0	0	0	27104.98	0	0
Doyo	5 cm	50 kg	1080	1080	30074.98	2969.2	274.93
Doyo	5 cm	100 kg	1930	850	30167.74	92.76	10.91
Doyo	5 cm	150 kg	2780	850	31174.77	1007.03	118.47
Doyo	10 cm	0	0	0	25239.02	0	0
Doyo	10 cm	50 kg	1080	1080	28327.68	3088.66	285.98
Doyo	10 cm	100 kg	1930	850	28460.19	132.51	15.59
Doyo	10 cm	150 kg	2780	850	29014.19	554	65.17
Doyo	15 cm	0	0	0	24236.78	0	0
Doyo	15 cm	50 kg	1080	1080	25750.8	1514.02	140.18
Doyo	15 cm	100 kg	1930	850	26368.74	617.19	72.61
Doyo	15 cm	150 kg	2780	850	28086.26	1717.52	202.06
Wabero	5 cm	0	0	0	29162.3	0	0
Wabero	5 cm	50 kg	1080	1080	36315.79	7153.49	662.36
Wabero	10 cm	0	0	850	29909.52	0	0
Wabero	10 cm	100 kg	1930	850	34001.31	4091.79	481.38
Wabero	15 cm	0	0	0	25358.54	0	0
Wabero	15 cm	50 kg	1080	1080	29395.3	4036.76	373.77

CONCLUSIONS AND RECOMMENDATIONS

Use of blended NPS fertilizer is common practice among farming community throughout the world but application of blended NPS fertilizer to legumes is limited especially in the developing countries. The results of present investigation reveal that application of NPS fertilizer and use of Optimum intra row spacing in combination significantly increased growth and yield characteristics of common bean. Among different NPS and intra-row spacing tested, the combination of 50 NPS kg ha^{-1} and 5cm intra-row spacing provide the highest yield and led to highest net benefit. Based on this experiment, the economic analysis showed that 50 NPS kg ha^{-1} and 5cm intra-row spacing tested at Goro and Ginir locations gave the highest common bean yield (2635.17kg ha^{-1}) with the net benefit (36315.79 birr ha^{-1}) with the highest marginal rate of return (115.09%) are economically feasible alternative to the other treatments. Therefore it is advisable for farmers in the study area growWabaro variety with combination of 5cm intra-row spacing and 50 kg NPS fertilizer ha^{-1} to improve the grain yield of common bean based as of the soil nutrient status during the study.

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