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International Journal of Plant Science and Agriculture (IJPSA)

Effect Of Blended Nitrogen, Phosphorus, Sulfur, And Boron With Potassium Fertilizer Application Rates On Yield And Yield Components Of Common Bean (*Phaseolus Vulgaris L.*) At Bakadawula Ari District, South Omo, Southern Ethiopia

Research Article

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Abstract

Common bean (*Phaseolus vulgaris L.*) is one of the most important pulse crop considered as source of food and income for smallholder farmers in Ethiopia. However,common bean production was constrained due to low soil fertility and poor crop management practices are the major constraints for common bean production in the study area. In order to improve productivity, to determine the effect of blended NPSB and K fertilizer application rates and to suggest economically feasible rates of blended NPSB and K fertilizer application were studied at Bakadawula District, Southern Ethiopia in 2019. The treatments were 4 levels of blended NPSB (0, 75, 150 and 225kg ha^{-1}) and five levels of K fertilizer rates (0, 30, 60, 90 and 120kg ha^{-1}) and laid out in a factorial arrangement in a randomized complete block design with three replications. Data on Phenological, growth, yield and yield components were collected and analyzed using SAS software. The result showed that the interaction effect of blended NPSB and K fertilizer application rates were significantly early for days to flowering (40 days), leaf area index (4.45), the highest pods per plant (35.87), seeds per pod (6.7) and grain yield (3444.2.4kg) obtained from 150 kg NPSB and 60kg K ha^{-1} application rates. The economic analysis indicated that the highest net return 37728 ETB ha^{-1} were obtained from blended NPSB 150kg ha^{-1} and 60kg K ha^{-1} with a marginal rate of return of 273.3%. Based on the results of this study, it could be concluded that a combination of blended NPSB 150kg ha^{-1} with 60kg K, ha^{-1} application rate to be superior for the production of common bean in the study area.

Keywords: Blended Fertilizer; Common Bean; Grainyield; Production.

Introduction

The Common bean is a major grain legume consumed worldwide for its edible seeds and pods. It is a highly polymorphic warm-season, herbaceous annual crop. The common bean crop regarded as a “grain of hope”. It is an important component of subsistence agriculture grown worldwide over an area of about 28.78 million hectares with an annual production of 23.14 million tonnes [24] and feeds about 300 million people in the tropics and 100 million people in Africa alone. In terms of global pulse production, the common bean alone with 23 million tonnes accounts for about half of the total pulse production [23].

Common bean is a short season annual crop, which is under production in both main and short (belg) growing seasons. It is produced by over 4 million smallholder farmers in Ethiopia. In the 2018/19 cropping season, the area covered by white and red common bean was 88,302.71 and 200,334.52 hectares of land [9]. Thus, totally 288,637.23 hectare of land was covered by beans with a total annual production of 4,883,201.7 quintals mainly from three regions (Oromiya, SNNPS and Amhara) of the country where Oromiya region alone covers (37.15%)of the total production followed by SNNPS (31.9%) and Amhara Regional States (26.23%) and the rest regions covered 4.72% [9].

The national average yields of white and red haricot bean was 17.08and 16.8 quintal ha^{-1} while the SNNP regional average yields of white and red haricot bean 17.21 and 15.64 quintals ha^{-1} CSA (2019) is by far below the average yield reported at research sites (2.5 to 3.0tone ha-1) [26]. Common bean is largely produced in the South Omozone, it covers annually about 14,203.25 hectares and production of 187,624.93 quintals with an average yield of

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Received: April 17, 2021
Accepted: July 22, 2021
Published: July 29, 2021

Citation: Merineh Tamiru, Dawit Dalga, Mesfin Kassa. Effect Of Blended Nitrogen, Phosphorus, Sulfur, And Boron With Potassium Fertilizer Application Rates On Yield And Yield Components Of Common Bean (*Phaseolus Vulgaris L.*) At Bakadawula Ari District, South Omo, Southern Ethiopia. *Int J Plant Sci Agric.* 2021;04(03):145-155.

13.21 quintal ha-1(South Omo zone Department of A&NRM annual report, 2011). The low national, regional and zonal average yield might be attributed to a combination of several production constraints. Among others, poor soil fertility management and low nutrient availability associated with low pH of the soils are among the tops. The farmers in Bakadawula District primarily cultivated the common bean in association with other crops as a secondary intercrop (especially intercrop with maize) and its management is often not directly to the crop but to that of the primary intercrop.

Nitrogen is the most important essential nutrient in plant nutrition. Phosphorus plays an important role in energy storage and transfer in crop plants. Although P is essential for photosynthesis and other physico-chemical processes in the plant, it is deficient in most agricultural soils or where fixation limits its availability [22]. Potassium is required for various biochemical and physiological processes that are responsible for plant growth and development. Potassium takes part in protein synthesis, carbohydrate metabolism, and enzyme activation [60]. Sulfur plays a vital role in chlorophyll formation [52] and a constituent of a number of organic compounds [46]. Boron is an essential element for better utilization of macro-nutrients by plants and thereby greater translocation of photo-assimilates from source to sink during the growth period [4]. Many different authors reported NPKSB nutrients requirements for common bean growth and yield [44, 55, 61, 19].

A few farmers in the study area have been using a uniform blanket application of only 100 kg DAP ha^{-1} (18 kg N and 46 kg P_2O_5 ha^{-1}) for common bean to increase crop yields and this did not consider soil fertility status and crop requirement. This emphasizes the importance of developing an alternative means to meet the demand of nutrients in plants by using blended NPSB and K that contains S, B and K in addition to the commonly used N and P fertilizers. However, no studies have been done on the response of common bean to the rates of blended NPSB and K fertilizer application. Thus, the present study was carried out with the following objectives:

- ➢ To evaluate the effect of blended NPSB and K fertilizer application rates on yield and yield components of common beans
- ➢ To suggest economically feasible rates of blended NPSB and K fertilizer in BakadawulaDistrict,Southern Ethiopia.

Materials and Methods

Field experiment was conducted in the main growing season (Meher), 2019/20, in Kaysa Kebele of Bakadawula District, South Omo zone, Southern Ethiopia, which is 725 km southwest of Addis Ababa. It is geographically located at an altitude of 1443 meters above sea level in between 0360 40.259' N latitude and 050 38.332' E longitudes. It receives mean annual rainfall of 950mm and maximum and minimum temperatureswere35°c, 15°C, respectively. In 2019, the area received a monthly minimum of 14.2mm and a maximum 252 mm mean rainfall, and 18.70c and 15.30c maximum and minimum temperature, respectively. The experimental site soil is sandy soil, and soil pH5.27.

Treatments and Experimental Design

The treatment consisted of a factorial combination of four levels of Blended NPSB (0, 75, 150, 225Kg ha^{-1}) and five levels of K (0, 30, 60, 90, 120kg K ha^{-1}) fertilizer and one released common bean varieties (Awassa Dume) as test crop. Treatments were laid out in Randomized Complete Block Design (RCBD) in factorial arrangement and replicated three times. Each plot sized of a single plot was 2.4mx2m (4.8m^2) and consisting six rows of which one row on both sides of each plot and 30cm on both ends of each row served as a border to avoid edge effects. The four central rows were used for data collection. Thus, the net plot size was 1.6m x 1.4m (2.24 m^2) and the total net area used for this study was 288 m^2.

Experimental Procedure and Management of the Crop

The experimental site measuring 60 m by 15m was cleared and oxen ploughed to a depth of about 25-30 cm. It was cleared from all unwanted materials and layout was taken against soil fertility gradient and slope. The field layout was prepared, divided into block, and again each block divided into plots. After the randomization of treatment was done, the proposed inter-intra row spacing prepared. The blocks were separated by a 1m wide open space, whereas the plots within a block were separated by a 0.5 m wide space and inter and Intra row space is 40Cm and 10cm, respectively, each of which accommodated 120 plants within plots. Sowing was done on 2 September, 2019 at Kaysakebele of Bakadawula District farmers' field site. One seed was planted in each hole with a depth of 4 cm. The entire Blended NPSB and KCl fertilizer were used as a source of mineral nutrients and full doses which varied depending on treatments were drilled in rows just before sowing. All recommended crop management practices such as weeding, hoeing, etc., were done uniformly for all treatments. Common bean from the net plot area was harvested and threshed manually when 90% of the leaves and pods turned yellow and dried under the sun for 5 days before threshing.

Soil Sampling and Analysis

The representative soil sample was taken using an auger at top 0-20 cm depth in a zigzag pattern from different places of the experimental field before planting (Table 1). The collected soil samples were composited to one sample and air-dried ground and sieved using a 2 mm sieve. The collected soil sample was analyzed at Areka Agricultural Research Center soil laboratory to determine the soil's physical and chemical properties. Soil pH was determined at 1:2.5 soils to water ratio using a glass electrode attached to pH digital meter [59]. The soil texture was carried out using the hydrometer method [43]. Total nitrogen was determined by using the Kjeldahl method [28]. Available phosphorus was determined by Olsen's method using extraction with sodium bicarbonate [42]. Available potassium was determined by Morgan solution extraction. Organic carbon and organic matter (OM) was determined. Available sulfur was measured using a turbid metric method [19]. Available boron was determined by Dilute HCL methods. The Cation exchange capacity (CEC) was determined by using the 1N ammonium acetate (NH4-AOc) method as described by Cottenie (1980) [11].

Data Collection and Measurement

Phonological data and growth parameter: Days to 50% flowering (No): Number of days from the date of sowing to the

Table 1. Selected Physical and Chemical Properties of the Experimental Site soil before planting during 2019 Cropping Season at Bakadawula District.

Soil Characteristics	Result	Rating	Source
Particle size distribution			
Sandy (%)	82	-	-
Clay (%)	16	-	-
Silty (%)	2	-	-
Textural class	Sandy		
Soil pH	5.27	Moderate	Hornecket al.(2011)
Organic Carbon (%)	1.37	Low	Berhanu (1980)
CEC (meq/100g)	8.6	Low	Landon (1991)
Total Nitrogen (%)	0.058	Low	Tekalignet al.(1991)
Available phosphorus (ppm)	38.5	very high	Hornecket al.(2011)
Available potassium (ppm)	61.31	Medium	Jones (2003)
Available sulfur (ppm)	36.29	High	Ethio SIS (2014)
Available boron (ppm)	0.138	Low	Hornecket al.(2011)
Electro-conductivity (ds/m)	1.24	Low	Tekalignet al.(1991)

date on which at least 50% of the plants have at least one flower was counted as a whole plant baseand the number of days to 50% flowering used for statistical analysis.

Days to 90% physiological maturity (No): The number of days from planting to the period when 90% Physiological maturity was recorded as a whole plot base and the number of days to 90% Physiological maturity used for statistical analysis.

Plant height (cm): At physiological maturity, the plant height was measured by a ruler from 5 randomly selected plants from the base of the plant to the top of the apex.

The Number of main branches per plant (No): At physiological maturity, main branches emerge directly from the main stem of 5 randomly selected plants were counted for statistical analysis.

Leaf area index (cm^2): LAI was calculated as the ratio of total leaf area to ground the area occupied by the plant. In determining LAI, all leaves on five randomly selected plants were measured by leaf area meter at 50% flowering and their leaf areas were recorded and values of leaf area were divided with ground area (14).

Number of effective nodules (No): Bulked roots of 5 randomly taken plants were carefully exposed at flowering and uprooted for nodulation study. Roots were carefully washed under gently flowing tap water on a screen and nodules were separated and counted. The effectiveness of the nodules was checked by cutting cross-section of the nodule for color judgment as a percentage of the pink to the dark red color being effective and the cream (white) ineffective.

Yield and yield components: Five plants from internal rows were selected randomly and the data was collected.

Numbers of pod per plants (No): This was recorded from a count of 5 randomly sampled plants per plot at harvest stageto calculate the mean number of pods per plant.

The Number of seeds per pod (No): This wasrecorded from a count of 5 randomly sampled plants per plot at harvesting time. 100-seed weight(g):Itwas determined by weighing 100 randomly selected dry seeds from the harvested net plot using a sensitive balance. The weight wasadjusted to 10% seed moisture content.

Grain yield (kg ha^{-1}): This was recorded from each net plot area. The grain moisture content was determined for each treatment and adjusted to 10% moisture content and converted into a hectare base for statistical analysis.

Total above-ground dry biomass (Kg ha^{-1}): The total above-ground dry biomass was measured from 5 randomly selected plants cutting the whole above-ground biomass and dried with the sun for 6 days weighing using sensitive balance and the dry biomass per plant was then multiplied by the total number of plants per net plot and converted into kg ha^{-1}.

Harvest index (%) was calculated the proportion of grain yield kilogram per hector to above-ground dry biomass yield.

Harvest index (%) = (Grainyield (Kg))/(Biomassyield (Kg))×100

Agronomic efficiency (kg/kg): It was measuredthe economic production per unit of nutrient applied and estimated as: Agronomic efficiency (kg/kg) =(Gf-Gu)/QA, Gf is the grain in the fertilized plot (kg), GU is the grain yield in the unfertilized plot (kg), QA is the quantity of nutrient applied [15].

Economic Analysis: To consolidate the statistical analysis of the agronomic data, an economic analysis was done for each treatment. For the economic evaluation, cost and return, and benefit: to cost ratio was calculated according to the procedure given by CIMMYT (1988) [10]. Cost for NPSB and KCl fertilizer was used variable cost for partial budget analysis. Price fluctuation during the production season was considered. The marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer, was calculated by dividing the net increase in yield of common bean due to the application of each rate to the total cost of NPSB and K fertilizer applied at each rate. This enabled to identify the optimum rate of NPSB and K fertilizer for common bean production [10].

Total revenue (TR) (ETB ha^{-1}): It was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield. TR = AGY × field/farm gate price for the crop (12 ETB kg^{-1}).

Total variable cost (TVC) (ETB ha^{-1}): It was calculated by summing up the costs that vary, including the cost of NPSB and KCl (27.00 ETB kg^{-1}) fertilizers at the time of planting (August 26, 2020) and according to Bakadawula District, farm daily payment of labor cost for application of NPSB and K (two person's ha-1, each 100 ETB day-1). The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, harvesting, and threshing were considered the same for all treatments or plots.

Net benefit (NB) (ETB ha^{-1}): Was calculated by subtracting the total variable costs (TVC) from total revenue (TR) for each treatment. NB = TR – TVC.

Dominance analysis: Was carried out by first listing all the treatments in their order of increasing costs that vary (TVC) and their net benefits (NB) are then put aside. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as "D").

Statistical Data Analysis

Data was subjected to analysis of variance (ANOVA) according to the SAS version 9.0 for factorial treatment and interpretations were made [45]. Significant differences between treatment means were separated with LSD test at 5% probability level.

Results and Discussion

Phenological Parameters of Common Bean

Days to 50% flowering: The statistical data analysis of variance (ANOVA) showed that the interaction effect of blended NPSB and K fertilizer application rate was highly significant ($P<0.001$) for the number of days to 50% flowering (Table 2). Early days to flowering (40 days) was recorded with the application of blended fertilizer with 150 kg NPSB + 60 kg K ha^{-1}, followed by 75 kg NPSB + 60 kg K ha^{-1}. On the other hand, the longest days to flowering (53.67 days) was recorded with the application of blended fertilizer with rates of 225 kg NPSB + 120 kg K ha^{-1} rate (Table 2).

The result obtained from the present study revealed that days to

Table 2. Phenological data of common bean as affected by interaction effect of blended NPSB and K fertilizer application rates during 2019 cropping season at Bakadawula District.

Fertilizer Level (kg ha^{-1})		Phenological Data	
Blended NPSB	K	DF	DPM
0	0	46.33^{bc}	77.3^{bc}
	30	45^{cd}	75^{bcd}
	60	45^{cd}	74.3^{b-g}
	90	44^{cd}	75^{bcd}
	120	44.67^{cd}	74^{c-f}
75	0	45.33^{cd}	78.3^{b}
	30	40.3^{fg}	70^{fgh}
	60	40.3^{fg}	68^{h}
	90	44.67^{cd}	74^{c-f}
	120	45.3^{cd}	76.67^{bc}
150	0	43.67^{c-e}	76.67^{bc}
	30	40.67^{efg}	69.67^{gh}
	60	40^{g}	69^{gh}
	90	43.3^{c-f}	76^{b-d}
	120	45.3^{cd}	85.67^{a}
225	0	44.67^{cd}	77.67^{bc}
	30	42.67^{d-g}	70.67^{e-h}
	60	42.3^{d-g}	72.3^{d-g}
	90	48.67^{b}	74.67^{b-e}
	120	53.67^{a}	84.3^{a}
LSD (0.05)		3.135	4.053
CV (%)		4.28	3.27

50% flowering were delayed with an increase of application rate of blended NPSB fertilizer which might be due to the delaying effect of nitrogen obtained from blended NPSB fertilizer. This was perhaps because the amount of N in the blended NPSB was relatively increased, as N was known to extend vegetative growth and enhance the photosynthetic activity of plants.This might be due to the fact that excessive supply of N promotes luxuriant and succulent vegetative growth, dominating the reproductive phase. The result is in line with the findings of Tewari and Singh (2000) [58] who 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 as compared to 40 and 80 kg N ha^{-1}. This result is corroborated by that of Sharmaa et al. (2013) [48] who reported that higher levels of N, P, K, and S fertilizer significantly delayed days to 50% flowering and noted higher doses of fertilizer, particularly N, prolonged the growth period and resulted in delayed flowering. On the other hand, the decrease in days to flowering with the optimum level of blended fertilizer might be attributed to P and S levels that are known to enhance flowering, fruiting, and maturity. This is in line with the results of Abebe and Mekonnen (2019) [2] reported presence of sulfur in NPSB to induce early flowering in haricot bean.

Days to 90% physiological maturity: The statistical data analysis result showed that the interaction effects of NPSB and K application rate had a highly significant ($P<0.001$) effect on days to 90% physiological maturity (Table2). The maximum (85.67) days to reach 90% physiological maturity was recorded from blended NPSB fertilizer rate of 150 kg ha^{-1} with 120 kg K ha-1 whereas the minimum (68 days) was recorded from blended NPSB fertilizer 75 kg ha^{-1} with K 60kg ha^{-1} application rates (Table 2). The possible reason for this might be linked with the increased availability of nutrients due to NPSB and K fertilization and the combined effects of N, P, S, B, and K, which in turn might have hastened the days to physiological maturity.

The result showed that an increase in blended NPKSB and K application rate was delayed the number of days required to reach physiological maturity. These suggested that the integrated actions of each nutrient in blended fertilizer increment reduced the gap on days to physiological maturity. This result is in agreement with the findings of who conducted experiments on common bean varieties under different N, P, K and S levels and reported that high levels of N, P, K and S fertilizer significantly delayed on phenological traits and doses of fertilizer, particularly N, prolonged the growth period and resulted in delayed flowering and physiological maturity [47]. Similarly, Assefaet al. (2017) [6] reported that the delaying effect of combined application of N and P fertilizer rate in common bean.

On the other hand, the decrease in days to reach physiological maturity with the blended fertilizer might be attributed to the impact of positive interaction of B, K in the blended fertilizer, which agrees with the finding of (2020) who reported positive relations between B, K and N fertilizers for hastening crop maturity.

Growth Parameters of Common bean

Plant height: The statistical data analysis result showed that a highly significant ($P< 0.001$) interaction effect of NPSB and K application rate on the plant height, while, the main effect of

Table 3. Growth parameter of common bean as affected by interaction effect of blended NPSB and K fertilizer application rates during 2019 cropping season at Bakadawula District.

Fertilizer Level (kg ha^{-1})		Growth Parameter			
Blended NPSB	K	PH	NMB	NEN	LAI
0	0	109.53^{a}	2.4^{gh}	20.33^{j}	2.5^{h}
	30	120.47^{c-e}	2.16^{b}	21.33^{j}	2.65^{gh}
	60	122.12^{cd}	2.4^{gh}	18.0^{j}	2.94^{fg}
	90	127.2^{bc}	2.46^{f-h}	39.67^{f-h}	2.78^{f-h}
	120	126.27^{bc}	2.73^{g-g}	33.33^{hi}	2.74^{gh}
75	0	134.67^{b}	2.67^{d-h}	33.33^{hi}	2.73^{gh}
	30	111.6^{de}	3.06^{b-e}	64.33^{a}	3.7^{bc}
	60	126.87^{bc}	3.16^{b-d}	51.33^{bc}	3.89^{b}
	90	124.27^{bc}	3.0^{b-f}	35.0^{g-i}	3.03^{d-g}
	120	129.28^{bc}	2.8^{d-g}	32.0^{i}	3.18^{d-f}
150	0	134.6^{b}	2.8^{d-g}	41.33^{e-g}	3.0^{e-g}
	30	147.83^{a}	3.0^{b-f}	53.33^{b}	3.97^{b}
	60	124.53^{bc}	4.13^{a}	49.67^{b-d}	4.45^{a}
	90	123.07^{b-d}	3.06^{b-e}	39.33^{f-i}	3.42^{cd}
	120	127.07^{bc}	2.53^{e-h}	32.0^{i}	3.39^{c-e}
225	0	128.6^{bc}	2.67^{d-h}	43.0^{d-f}	2.82^{f-h}
	30	130.87^{bc}	2.867^{c-g}	49.33^{b-d}	3.85^{b}
	60	131.53^{bc}	3.0^{b-f}	53.67^{bc}	3.71^{bc}
	90	131.67^{bc}	3.4^{bc}	53.67^{bc}	2.96^{fg}
	120	126.2^{bc}	3.53^{b}	47.67^{c-e}	3.62^{bc}
LSD (0.05)		12.134	0.539	7.652	0.402
CV (%)		5.78	11.27	11.38	7.44

blended NPSB was highly significant ($P< 0.01$). However, the K application was not significant on the plant height of the common bean (Table 3).

The tallest plant height (147.83 cm) was recorded when 150kg NPSB ha-1combined with a 30kg K ha^{-1} fertilizer application rate while the shortest plant height (109.53 cm) was recorded from the nil application of blended NPSB and K fertilizer (Table 3).The current result showed increase in plant height in response to the increasing blended NPSB and K application rate might be due to the maximum vegetative growth of the plants under higher N, P, S and B availability. This is in line with Tange et al. (2001) [57] who suggested that a significant increase in plant height observed by stimulating the effect of NPSB on the growth and development of plants. In conformity with the present result, Moniruzzamanet al. (2008) [38] found that plant height was significantly increased up to 160 kg N ha^{-1}. Also the application of phosphorus at the highest level (120 kg P_2O_5 ha^{-1}) increased plant height.

The increase in plant height might also be ascribed to better root formation due to sulfur, which in turn activated higher absorption of N, P, K, and S from the soil and improved metabolic activity inside the plant. Furthermore, maximum vegetative growth of the plants under higher N, P and S nutrient availability reported by Shumi (2018) [51].

Number of main branches per plant: The analysis of variance result showed very highly significantly ($P< 0.001$) interaction effect of blended NPSB and K rate on the number of main branches per plant of common bean (Table 3). Among blended NPSB and K fertilizer application rates, blended NPSB 150kg ha-1 and 60kg K ha^{-1} showed a maximum number of main branches (4.13) while the minimum (2.167) number of the main branches was recorded from 0kg NPSB and 31 kg K ha^{-1} application rates (Table 3). The significant increase in a number of main branches in response to the increased rates of NPSB and K application might be ascribed to the increased availability of those nutrients in the soil for uptake by plant roots, which might have sufficiently enhanced vegetative growth through increasing cell division and elongation. The increase in a number of main branches per plant in response to the increasing rates of blended NPSB and K application rate indicates higher vegetative growth of the plants under higher N, P, S, Band K availability. In line with this result, Shubhashree (2007) [49] who reported a significantly higher number of branches per plant of common bean with 75 kg P_2O_5 ha^{-1} over the control. In conformity with this result, Moniruzzamanet al. (2008) [38] reported that the number of branches per plant increased significantly with the increase of N up to120 kg ha^{-1} on common bean.

Number of effective nodules: The statistical data analysis result showed that interaction of blended NPSB with K application rates had very highly significant ($P<0.001$) effect on the effective number of nodules per plant (Table 3). Significantly maximum mean number of effective nodules per plant (64.33) was recorded from the application of blended NPSB75 kg ha^{-1} with 30 kg K ha^{-1} while the minimum number of effective nodules (18) was recorded from blended NPSB 0kg ha^{-1} with 60 kg ha^{-1} K followed by control (Table 3).

The highest number of effective nodules per plant might be due to the effective utilization of added nutrients in the field. Moreover, the role of phosphorus in blended fertilizer increased the number and size of the nodule and the amount of nitrogen assimilated per unit of nodules. In agreement with this result, Bashir et al. (2011) [7] who reported that phosphorus plays a vital role in increasing plant tip and root growth, decreasing the time needed for developing nodules to become effective for the benefit to the host legume. Similarly, Elkocaet al. (2007) [17] also reported that high P fertilizer application is very important on nodule formation in legumes.

Leaf area index (LAI): The analysis of variance a result showed that leaf area index of the common bean wassignificantly ($P< 0.05$) affected due to interaction effect of blended NPSB with K fertilizer application rate on the leaf area index of the common bean (Table 3).

Leaf area index (LAI) is one of the major characteristics influencing dry matter production and grain yield, which was significantly influenced by blended NPSB and K fertilizer application rates. Between the blended NPSB and K application rates, significantly higher LAI (4.45) was recorded form blended NPSB fertilizer rate at 150kg ha^{-1} and 60kg K ha^{-1} while lower LAI (2.5) was recorded from control (Table 3).

The increase in LAI might be due to the improved leaf expansion in crop plants following increasing in NPSB and K rates, or the application of NPSB and K was contributed to higher leaf size to capture light for photosynthesis. Leaf area index (LAI) of common bean increased significantly due to the increased levels of blended NPSB which can be attributed to the role of nitrogen in the blended NPSB fertilizer that promoted vegetative growth. Similarly, Ali et al. (2013) [4] reported that nitrogen fertilizer application had significantly affected leaf area index (LAI). The significant increase in LAI due to NPSB and K application might be attributed to availability, uptake and combined effects of the applied nutrients which might have enhanced cell division and cell enlargement thereby increasing LAI of common bean. This is in line with the finding of Moniruzzaman et al. (2008) [38] who reported higher LAI due to combined action of N, P, K, S, Zn and B application.

Yield and Yield Components of Common Bean

Numbers of pods per plant: The number of pods per plant is an important yield contributing parameter to the final grain yield of common bean. The analysis of variance revealed that interaction effects of blended NPSB with K fertilizer application rates had highly significant ($P< 0.001$) effect on the number of pods per plant (Table 4). Application of blended NPSB fertilizer 150kg ha-1 with K 60 kg ha^{-1} produced significantly the highest number of pods per plant (35.87) while the lowest number of pods per plant (19.73) was obtained from control (Table 4).

The increase in number of pods per plant with the application of blended NPSB and K fertilizer rates might possibly be due to adequate availability of N, P, S, B and K which might have facilitated the production of primary branches and plant height which might in turn have contributed for the production of the higher number of total pods. This highest number of pods recorded at the rates of 150 kg ha^{-1} blended NPSB fertilizer

Table 4. Yield and yield components of common bean as affected by interaction effect of blended NPSB and K fertilizer application rates during 2019 cropping season at Bakadawula District.

Fertilizer Level (kg ha^{-1})		Yield and yield components					
Blended NPSB	**K**	**NPP**	**NSP**	**HSW**	**TAGB**	**GY**	**HI**
0	0	19.73^{g}	3.4^{g}	21.53^{i}	5383^{f-h}	1365^{i}	24.63^{i}
	30	20.4^{fg}	3.93^{fg}	22.44^{g-i}	5319^{gh}	1783.2^{h}	33.69^{c-g}
	60	23.93^{de}	3.87^{fg}	22.9^{f-i}	5701^{e-h}	1851.5^{h}	32.62^{d-h}
	90	22.17^{e-g}	4.07^{fg}	22.37^{g-i}	5583^{f-h}	2028.1^{gh}	36.82^{a-f}
	120	23.33^{d-f}	3.9^{fg}	23.87^{d-g}	5007^{h}	1926.8^{h}	38.9^{a-e}
75	0	23.93^{de}	4.13^{f}	23.56^{e-h}	5611^{f-}h	2265.3^{g}	40.71^{a-c}
	30	30.13^{bc}	5.8^{bc}	28.63^{b}	9181^{c}	2899.1^{b-e}	31.65^{e-i}
	60	31.76^{b}	5.83^{bc}	25.23^{b-d}	9549^{bc}	3024^{bc}	31.67^{e-i}
	90	25.33^{d}	5.8^{bc}	25.43^{bc}	9368^{bc}	2829.3^{c-f}	30.21^{f-i}
	120	24.2^{de}	5.33^{b-e}	23.7^{e-h}	6722^{d-f}	2685.1^{d-f}	41.37^{ab}
150	0	23.33^{d-f}	5.47^{b-e}	24.27^{b-f}	6417^{d-g}	2788.1^{c-f}	43.44^{a}
	30	28.93^{bc}	6.0^{b}	25.57^{b}	9479^{bc}	2973^{b-d}	31.57^{e-i}
	60	35.87^{a}	6.7^{a}	27.3^{a}	10104^{bc}	3444.2^{a}	34.16^{b-g}
	90	25.2^{d}	5.27^{c-e}	24.76^{b-e}	10319^{bc}	2572.3^{f}	25.15^{hi}
	120	22.93^{d-f}	4.93^{e}	24.02^{c-f}	6882de	2584^{f}	38.64^{a-e}
225	0	23.4^{de}	5.1^{de}	24.28^{b-f}	7132^{d}	2855.9^{c-f}	40.12^{a-d}
	30	31.8^{b}	6.^{0b}	27.96^{ab}	10361^{bc}	3154.1^{b}	30.44^{f-i}
	60	28.8^{c}	5.67^{b-d}	25.56^{b}	10493^{b}	2968.7^{b-d}	28.49^{g-i}
	90	24.06^{de}	5.43^{b-e}	25.35^{bc}	11878^{a}	2905.5^{b-e}	24.49^{i}
	120	24.93^{de}	5.0^{de}	24.35^{b-f}	10271^{bc}	2624.2^{ef}	25.55^{hi}
LSD (0.05)		2.957	0.699	1.444	1207.1	288.22	7.509
CV (%)		6.96	8.32	3.57	9.07	6.77	13.68

and 60kg K ha^{-1}. This might be attributed to the fact that the presence of N, P and S in blended NPSB fertilizers enhanced the establishment of beans, promote the formation of nodes, canopy development and pod setting. In conformity with this result, Necat and Dursan (2017) [40] found that the effect of different doses of P and S interaction on pods per plant ranges from (11.0) control plots, while the highest number of pods per plant (30.9) was obtained from P and S 80 x 90 kg ha^{-1}. Daset al. (2016) [12] in Chickpea, increasing the application of P and S fertilizers also had a significant effect on a total number of pods per plant.

Number of seeds per pod: The statistical data analysis of variance result showed that the interaction effects of NPSB with K fertilizer application rates had highly significant ($P<0.05$) effect on the number of seeds per pod (Table 4). Application of blended NPSB fertilizer 150kg ha^{-1} with K 60 kg ha^{-1} resulted in significantly the highest number of seeds per pod (6.7) while the lowest number of seeds per pod was obtained from control (3.4) (Table 4). The result showed that the highest number of seeds per pod might be due to the fact that N is an integral part of chlorophyll and play a vital role in photosynthesis and carbohydrate production. On the other hand, the increment of seeds per pod with increasing NPSB and K fertilizer application up to optimum level might be an adequate supply of nutrients in NPSB and K fertilizer for nodule formation, protein synthesis, fruiting and seed formation. The result of the current study is in agreement with the finding of Shubhashree (2007) [49]; and Meseret and Amin (2014) [36] who reported that the number of seeds per pod of common bean was increased significantly with increased levels of P (92 kg P_2O_5 ha^{-1}). Similarly, Habtamuet al. (2017) [27] reported the highest number of seeds per pod with the application of 46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1} of N. [1]

Hundred seed weight: The Statistical data analysis result showed that the interaction effects of blended NPSB and K fertilizer application rates had very highly significantly ($P< 0.001$) effect on hundred seed weight of common bean (Table 4).The highest hundred seed weight (27.96g) was recorded at 225kg of NPSB ha-1with 30kg K ha^{-1} application rate followed by (27.3g) which was recorded at 150kg NPSB with 60kg K ha^{-1} application rate, while the lowest hundred seed weight (21.53g) was recorded from control which was not fertilized (Table 4). Theincrement of hundred seed weight might indicatethat suggesting effective utilization of nutrients in the field. This might be because nutrient use efficiency by crop was enhanced at the optimum level of NPSB since grain weight indicates the amount of resource utilized during critical growth periods.

This indicates theoptimum supply of P presencein blended NPSB thatincreased the formation of seed. Similarly, Khan et al. (2017) [30] observed a significant effect of levels of phosphorus on seed weight where maximum seed weight was recorded from 45 kg P_2O_5 ha^{-1} followed by 30 kg P2O5 ha^{-1} whereas, the lowest due to 0 kg P_2O_5 ha^{-1}. Abdulkadir et al. (2014) who reported that phosphorous fertilized crop when compared with the control produced more pods per plant which were better filled with heavier seeds and this translated to higher grain yield. In conformity with this result, Ogutuet al. (2012) [41] indicated that increasing N rate from 0 kg ha-1to 50 kg ha^{-1} increased 1000 seed weight from 301.19 g to 311.63 g.

The increased yield under sulfur application might be ascribed to increased pods per plant and grains pod along with heavier grains. Nebret and Nigussie (2017) [39] reported that increasing sulfur rate from 0 kg ha^{-1} to 20 kg ha^{-1} increased 100 seed weight from 35.7 g to 36.8 g. Therefore, significant improvement in yield obtained under sulfur fertilization seems to result from the increased concentration of sulfur in various parts of cluster bean that helped to maintain the critical balance of other essential nutrients in the plant and resulted in increased metabolic processes in plants [48].

Total above ground dry biomass: The above-ground dry biomass yield highly significantly ($P<0.001$) affected by the interaction effects of NPSB with K fertilizer application rates. The result showed that the application of blended NPSB fertilizer at 225kg ha^{-1} with 90kg K ha^{-1} recorded the highest aboveground dry biomass yield (11878kg) while the lowest (5007kg) above-ground dry biomass yield was recorded from the application of blended NPSB 0kg ha^{-1} with 120kg K ha^{-1} (Table 4). This difference might be due to the effective utilization of nutrients in the production of above-ground dry biomass yield among the fertilizer application. On the other hand, the increment in above-ground dry biomass yield with the application of blended NPSB and K fertilizer might be due to the adequate supply of N, P, S, Band K could have resulted increased the number of branches per plant, and leaf area which in turn might have increased photosynthetic area and number of pods per plant thereby dry matter accumulation. It agrees with to the result of Shumi (2018) [51] who indicated that the highest above-ground dry biomass yield was recorded due to the application of the highest rate of blended NPS fertilizer for variety Angar.

Furthermore, the increment in the aboveground dry biomass yield due to the role of P and N in blended NPSB might be that phosphorus is essential in most metabolic processes that happen above the ground. The result of the current study is concurrent with the findings of Amanullahet al. (2016) [5] who reported that P levels had a significant impact on biomass yield of mung bean under dry land condition. The outcomes of the present study confirm the finding of Abebe (2009) [2], Nebret and Nigussie (2017) [39] who reported that the combined applications of NP fertilizer, high nitrogen rate, and increase in P2O5 application resulted in enhanced dry biomass production. Similarly, Lake and Jemaludin (2018) [32] who indicated the increases in total biomass with increasing in blended NPSZnB application rates up to optimum rate of blended fertilizers.

Grain yield: The statistical analysis of variance (ANOVA) result showed that grain yield was very highly significantly ($P< 0.001$) affected due to interaction effects of blended NPSB and K fertilizer application rates and the main effect was also very highly significantly ($P<0.001$) on grain yield of common bean (Table 4). The highest grain yield was recorded when the two factors interacted with each other. As a result, the interaction of 150kg NPSB ha^{-1} along with 60kg K ha^{-1} gave the maximum grain yield (3444.2 kg ha^{-1}). On the other hand, the minimum grain yield (1365kg ha^{-1}) was obtained from control (Table 4). The highest grain yield obtained from the application of blended NPSB and K fertilizer rate might be due to the effective utilization of macro and micronutrients application. Applications of the high rate of NPSB blended fertilizer increased common bean yields by 52.2% over the control whereas, blended NPSB with K fertilizer application improved yield by 60.3% over the control. Similarly, the present result is in line with the findings of Abebe and Mekonnen (2019) [2] who reported that applications of the high rate of NPKSB blended fertilizer increased common bean yields by 34% over the control. Additionally, incorporation of K, S and B improved yield by 19.2% over the former NP fertilization. The increase in grain yield with NPSB with K fertilizer application might be related to the higher number of pods per plant, number of seeds per pod and 100-grains weight. Furthermore, Rahman et al. (2014) [44] who reported that maximum grain yield in common bean due to the combine application of NPK.

Harvest index (HI %): The statistical data analysis result showed thata very highly significantly ($P< 0.001$) affected due to interaction effect of blended NPSB with K rate on the harvest index of common bean (Table 4). Among application rates, the highest harvest index (43.4%) was recorded from blended NPSB 150kg ha^{-1} with 0kg K ha^{-1} while the lowest harvest index (24.49%) was recorded from 225kg NPSB kg ha^{-1} with 90kg K ha-1 application rates (Table 4). This might be due to the effective utilization of nutrients. The result of this study is in agreement with Fageria (2009) [20] who reported significant improvement in harvest index due to nitrogen application up to 50 kg ha^{-1}. Similarly, Masresha and Kibebew (2017) [35] reportedthat the highest mean HI of soybean from application of 46 kg P_2O_5 ha-1, which resulted in a 19.1% increase over the control.

Agronomic efficiency: Agronomic efficiency is the amount of additional yield produced for each additional amount of fertilizer applied [54]. The agronomic efficiency of blended NPSB and K fertilizer application rates decreased with increasing NPSB and K rate and then increased with a decreasing trend for NPSB and K rates. The highest agronomic efficiency (19.56kg/kg^{-1}) was recorded from 75kg NPSB ha^{-1} with a 30kg K ha^{-1} rate followed by blended NPSB 75kg ha^{-1} and 0kg K ha^{-1} rate with mean agronomic efficiency of (18.98kg/kg) (Table 4). On the other hand, the lowest agronomic efficiencies (4.53kg/kg^{-1}) and (4.74 kg/kg^{-1}) were recorded from the application of blended NPSB 0kg ha^{-1} and 120kg K ha^{-1}application rate and NPSB 225kg with 120kg K ha^{-1}, respectively (Table 5). The declining trend of agronomic efficiency could be related to the reaching of NPSB and K supply to the optimum level or limitation of yield potential of bean. Fisseha (2011) and Yayis (2012) [25] reported that the agronomic use efficiency (AUE) of nitrogen and phosphorous fertilizers showed an increasing trend for both fertilizers. The agronomic efficiency of applied phosphorous exhibited a decreasing trend for increasing rates of phosphorous application levels. Similar findings on the agronomic efficiency of phosphorous were also reported by [37].

Economic Analysis: Based on a partial budget analysis procedure described by CIMMYT (1988) [10], considering all variable costs and all benefits (grain yield) [56]. Variable cost includes the cost of fertilizer during the experimental period the fertilizer cost of blended NPSB and KCl,in which the price of NPSB was 14ETB kg^{-1}, KCl was 13ETB kg^{-1} and the average price of common bean grain at the local market was 12ETB kg^{-1}.

The net benefit was computed due to different application rates of blended NPSB and K fertilizer and interaction of blended NPSB with K fertilizer [50, 53]. The economic analysis revealed that the highest net benefit of (37728 Birr ha^{-1}) with the marginal rate (MRR) of 273.3 % was obtained from the treatment combination of 150kg NPSB ha^{-1} with 60kg K ha^{-1} application rates whereas the lowest net benefit (16380 Birr ha^{-1}) was obtained from 0 kg NPSB with 0kg K ha^{-1} application rates (control) (Table 6). According to CIMMYT (1988) [10], the minimum acceptable marginal rate of return (MRR %) should be between 50 and 100%. Therefore, production of common bean with the application of 150 kg NPSB ha^{-1} with 60kg K ha^{-1} fertilizer application rate for farmers with higher net return ascompared to 0kg ha^{-1} NPSB with 0kg K ha^{-1} application rates and blended NPSB 150kg with 60kg K ha^{-1} can be recommended for the study area (Table 6). Besides, the results of the economic analysis showed that the combined application of 150kg NPSB ha^{-1} and 60kg K ha^{-1} were economically an alternative dose to common bean (Awassa Dume). In agreement to this finding, Shumiet al. (2018) [51] reported that the economic analysis revealed that highest net benefit (34167.56 Birr ha^{-1}) was obtained from the application of 150 kg ha^{-1} NPS while the lowest net benefit (19228.69 Birr ha^{-1}) was obtained from nil application on common bean (3; 8).

Table 5. Agronomic efficiency of common bean as affected by interaction effect of blended NPSB and K fertilizer application rates during 2019 cropping season at Bakadawula District.

Blended NPSB (kgha^{-1})	K rates (kgha^{-1})				
	0	30	60	90	120
0	0^{h}	13.48^{b}	7.85^{d-f}	7.13^{fg}	4.53^{g}
75	18.98^{a}	19.56^{a}	15.16^{b}	10.45^{cd}	7.7^{ef}
150	15^{b}	12.77^{bc}	13.25^{b}	6.43^{fg}	5.57^{fg}
225	10.48^{cd}	10.32^{c-e}	7.85^{d-f}	6.54^{fg}	4.74^{g}
LSD (0.05) 2.7207					
CV (%) 16.65					

Table 6. Summary of partial budget analysis of effect of blended NPSB and K fertilizer application rate on common bean during 2019 cropping season at Bakadawula District.

Treatment Combination (kg ha^{-1})	Adjusted yield (kg ha^{-1})	Total Revenue (Birr ha^{-1})	TVC (Birr ha^{-1})	Net benefit (Birr ha^{-1})	MRR (%)
0kgNPSB +0kgK	1365	16380	0	16380	-
0kgNPSB +30kgK	1783	21396	850	20546	490.12
0kgNPSB +60kgK	1851	22212	1500	20712	D
0kgNPSB +90kgK	2028	24336	2150	22186	D
0kgNPSB +120kgK	1927	23124	2800	20324	D
75kgNPSB +0kgK	2265	27180	1250	25930	1346
75kgNPSB +30kgK	2899	34788	1900	32888	1070.46
75kgNPSB +60kgK	3024	36288	2250	34038	328.57
75kgNPSB +90kgK	2829	33948	3200	30748	D
75kgNPSB +120kgK	2685	32220	3850	28370	D
150kgNPSB +0kgK	2788	33456	2300	31156	D
150kgNPSB +30kgK	2973	35676	2950	32726	D
150kgNPSB +60kgK	3444	41328	3600	37728	273.3
150kgNPSB +90kgK	2572	30864	4250	26614	D
1500kgNPSB +120kgK	2584	31008	4900	26108	D
225kgNPSB +0kgK	2856	34272	3350	30922	D
225kgNPSB +30kgK	3154	37848	4000	33848	D
225kgNPSB +60kgK	2969	35628	4650	30978	D
25kgNPSB +90kgK	2905	34860	5300	29560	D
225kgNPSB +120kgK	2624	31488	5950	25538	D

MRR (%) = Marginal Rate of Return; Fertilizer application cost = 100 Birr ha^{-1}; NPSB cost =14.00 ETBirr kg^{-1}; KCl cost 13.00 ETBirr kg^{-1}; Common bean grain local selling price =12ETBirr kg^{-1}; TVC = Total variable cost; D= Dominated Treatment

Conclusions And Recommendation

Common bean is one of the most important grain legumes, considered as the source of food and foreign exchange earnings for smallholder farmers in different parts of Ethiopia. However, the production and productivity is low mainly associated with low soil fertility, inappropriate management practices, and lack of balanced fertilizer application are among the major constraints for common bean production in the study area. The use of blended fertilizer application that combines with proper agronomic practices is one of the most important ways to increase common bean yield. Therefore, this field experiment was conducted for determining the effect of blended NPSB and K fertilizer application rates on yield and yield components and to suggest economically feasible rates of blended NPSB and K fertilizer for common bean production at Bakadawula District, Southern Ethiopia [13, 16].

The results of the study revealed that almost all of the common bean parameters were significantly affected by the blended NPSB and K fertilizer application rates [18, 21]. The interaction effects of NPSB and K fertilizer rates significantly affected on days to 50% flowering, number of the main branch, leaf area index, number of pods per plant, number of seed per pod and grain yield were recorded from the application of blended NPSB 150kg and 60kg K ha^{-1}. On the other hand, the smallest plant height, leaf area index, number of pods per plant, number of seeds per pod hundred seed weigh, grain yield and harvest index were recorded from the control treatment. Significantly the highest number of effective nodule and agronomic efficiency were recorded from the application of blended NPSB 75kg and 30kg K ha-1rates. Early days to reach 90% physiological maturity were recorded from the application of blended NPSB 75kg and 60kg K ha^{-1} rates. On the other hand, late days to reach 90% physiological maturity and maximum days to reach 50% flowering were recorded from the application of blended NPSB 150kg with 120kg K ha^{-1} and blended NPSB 225kg with 120kg K ha^{-1} rates (29; 31).

The partial budget analysis also showed the highest net returns (37728 ETBha^{-1}) at acombination of blended NPSB 150kg ha^{-1} with a K rate of 60 kg ha^{-1} with a marginal rate of return273.3%. Based on the results of this study, it can be concluded that the use of blended NPSB 150kg ha-1 with 60kg K ha^{-1} application rates could be recommended to enhance the productivity of common bean in the experimental area [33, 34]. However, additional research is needed to be evaluated and reconfirmed in different agro-ecology and season in order to reach a conclusive recommendation.

Acknowledgements

We acknowledge the staff members of Department of Plant Science, WolaitaSodo University and Hawassa Research Center of Soil Laboratory, for providing us with the necessary support to conduct this study.

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