Original Research Article||

Responses of common bean (*Phaseolus vulgaris* L.) to applications of NPSZnB in different combinations in Debub Ari District, Southwestern Ethiopia

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Abstract

Production and productivity of common beans in Debub Ari District decline mainly due to soil fertility depletion coupled with the use of inappropriate rates of fertilizers. A field experiment was conducted during 2019 to find out the effects of different combinations of NPSZnB fertilizers on yield and yield components of common bean The experiment consisted of 11 treatments viz. control, NPK (64:46:30 kg ha^{-1}), NPKS (42:38:30:7 kg ha^{-1}), NPKS (51.5:57:30:10.5 kg ha^{-1}), NPKS (61:76:30:14 kg ha^{-1}), NPKSB (41.1:36.1:30:6.7:0.71 kg ha^{-1}), NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}), NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}), NPKSBZn (39.9:33.8:30:7.3:0.67:2.23 kg ha^{-1}), NPKSBZn (48.35:50.7:30:10.95:1:3.35 kg ha^{-1}), and NPKSBZn (56.8:67.6:30:14.6:1.34:4.46 kg ha^{-1}) (i.e. in all treatments P is in the form of P_2O_5 and K is K_2O). Fifty kg ha^{-1} of Muriate of Potash with a grade of 0-0-30 was used in the form of band application in all treatments except the control plot. The experiment was laid out in Randomized Complete Block Design with three replications. Soil samples collected from the experimental field before planting showed sandy loam in texture, slightly acidic in reaction, very low in organic carbon, low in total nitrogen, available P, K and Zn, medium available B, extractable S, and moderate cation exchange capacity. Application of different nutrients significantly ($p < 0.05$) increased most yield and yield parameters of common bean compared to the control plots. The maximum grain yield of 3477.0 kg ha^{-1} and 3397.6 kg ha^{-1} were obtained with rates of 59.2:72.2:30:13.4:1.42 and 50.15:54.15:30:10.05:1.07 kg ha^{-1} of NPKSB applications, respectively while the minimum grain yield (1857.9 kg ha^{-1}) was recorded for the control. The application of NPKSB with rates of 50.15:54.15:30:10.05:1.07 kg ha^{-1} had maximum and acceptable Marginal rate of return (MRR %) and net benefit. Therefore, NPKSB with rates of 50.15:54.15:30:10.05:1.07 kg ha^{-1}) is recommended for common bean production in the study area.

Key words: Biomass, grain yield, net benefit, NPS and NPSB

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INTRODUCTION

Common bean (*Phaseolus vulgaris* L.), a short-season crop with a growth period varying between 65 and 110 days, is one of the most important grain legumes that provides high contents of protein (20-30%) and carbohydrate (50-56%) making it 2-3 times more nutritious than cereals (Buruchara, 2007). Common bean is estimated to be one of the most important sources of nutrients for more than 300 million people in parts of Eastern Africa and Latin America, representing 65% of total protein consumed and 32% of energy (Blair et al., 2010). In Ethiopia, common beans are one of the major grain legumes cultivated with their production centered on smallholder farmers who produce low average yields usually less than 2 ton ha^{-1} (CSA, 2018). Soil factors such as deficiency of nutrients (especially nitrogen and phosphorus), are important limitations for common bean production in most of the growing areas (Graham et al., 2003).

The productivity of common beans is low due to low soil fertility, shortage of fertilizer and improved seeds (Beebe et al., 2013). The adequate and balanced nutrients application results in marked crop yield increases, while low nutrient use results in declining soil fertility and nutrient mining (Mengel and Kirkby, 1996). Urea (46-0-0) and DAP (18-46-0), which contain N and P only, are the sole fertilizers being used for many years in Ethiopia. The continuous application of these nutrients without consideration of the other important ones might have led to the depletion of other important elements such as potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), and micro-nutrients in soils (Abiye et al., 2004).

The fertility status of Ethiopian soils has also declined and continued to decline posing a challenge to crop production. This is due to, continuous cropping (abandoning of fallowing), reduced manure application, removal of crop residues and animal dung for fuelwood, and erosion coupled with low inherent fertility of the soils (Tilahun et. al., 2007). According to Mesfin (1998), another challenge of soil fertility decline in Ethiopia is related to cultural practices like traditional cultivation, removal of vegetative cover (such as straw or stubble), or burning plant residues as practiced under the traditional system of crop production or the annual burning of vegetation on grazing lands. These are the major contributors to the loss of soil nutrients.

Application of balanced nutrients is a key practice for sustainable crop production through the maintenance of soil health, which has both economic and environmental considerations. An imbalanced nutrient use results in low nutrient use efficiency leading to less economic return and a greater threat to the environment. The nutrient imbalance has become an issue of concern because of increased pressure on food demand and land resources (Abiye et al., 2004).

According to CSA (2018), the yield of common bean in Debub Ari District is estimated to be 1.57 t ha^{-1}, which is very low due to the use of low yielding local varieties and the application of imbalanced nutrients. Fertilizer use in the study area has focused mainly on the application of N and P in the form of Urea and Di-ammonium phosphate (DAP) almost for all cultivated crops based on the blanket recommendation. EthioSIS studied the soil fertility status of Debub Ari district and recommended different blended fertilizers containing the deficient nutrients as NPS (19% N, 38% P2O5, and 7% S), NPSB (18.1% N, 36.1% P2O5, 6.7% S, and 0.71% B) and NPSZnB (16.9% N, 33.8% P2O5, 7.3% S, 2.23% Zn, and 0.67% B) (Ethio-SSI, 2014). However, their rates of application didn't not include common bean. Therefore, the objective of this study was to determine optimum rates of combinations of NPS, NPSB and NPSZnB effects on growth, yield and yield components of common beans in Debub Ari district, Southern Ethiopia.

MATERIALS AND METHODS

Description of the Experimental Site

The field experiment was conducted during the Meher season (long rainy season) of 2019/2020 at the research station of Jinka Agricultural Research Centre located in Debub Ari District of South Omo Zone in Southern Nations Nationalities and Peoples Regional State (SNNPRS). Geographically, the district is situated between 5.067'- 6.019' N and 36.030'-36.073' E and the altitude ranges from 500 – 3000 meter above sea level (masl). The experimental site is located at 729 km south of Addis Ababa with geographic positions of 360 33' 02.7" E and 050 46' 52.0" N and an altitude of 1403 masl. Based on the agro-ecological classification of Ethiopia, the experimental site belongs to Woyna-dega (midland) agro-climate, and the area is characterized by a long duration bi-modal rainfall pattern. Long-term (2009-2019) meteorological data obtained from southern agro-meteorological observatory stations show that the average annual rainfall in the area is 1381 mm. Similarly, ten years (2009-2019) temperature data show that the mean minimum, maximum and average temperature in the study area were 16.61, 27.68, and 22.14 °C, respectively. The experiment was conducted during 2019 main-cropping season with rainfall of 1698 mm with mean temperature of 22.7 and mean minimum and maximum temperature of 17.3 and 28.0 °C, respectively.

The soil of the experimental site is generally characterized to be low in fertility and slightly acidic (Table 1). According to Mesfin et al. (2015), the soil type of the center is Cambisols with a low fertility range and acidic reaction. These soils were found to have a clayey B horizon, brown in color; increasing clay content, and low base saturation. The slope of the research site ranges from 0 to 5% and it is characterized by gentle to flat land features.

Table 1. Selected physicochemical properties of soil at the experimental site before planting

Soil Properties	Values	Rating
Sand (%)	66	
Silt (%)	24	
Clay (%)	10	
Textural Class	Sandy loam	
Soil Reaction(pH)	6.3	slightly acidic
Total Nitrogen (%)	0.078	low
Available Phosphorous (mg kg^{-1})	14.83	low
Available Potassium (mg kg^{-1})	66.6	medium
Extractable Sulfur (mg kg^{-1})	14.02	medium
CEC ($Cmol^{(+)}$ kg^{-1})	20.74	moderate
Organic Carbon (%)	1.72	very low
B (mg kg^{-1})	1.11	medium
Zn (mg kg^{-1})	0.73	low
Exchangeable Acidity ($Cmol^{(+)}$ kg^{-1})	0.62	low

Physicochemical Properties of Soil

Prior to fertilizer application, soil samples were collected from a depth of 0-20 cm from 10 spots of the experimental area in a zigzag method and composited into one weighing a kilogram. The samples were air-dried and ground to pass through 2 mm sieve for analysis of selected soil physicochemical property parameters other than organic carbon (OC) and total nitrogen (TN), which required samples to be ground to pass through 0.5 mm sieves.

The composited soil sample was analyzed at the soil laboratories of Areka Agricultural Research Center. Particle size distribution (texture), pH, cation exchange capacity (CEC), exchangeable acidity (EA), available phosphorous (Av. P), available potassium (Av. K), extractable sulfur, available boron and zinc, soil organic carbon (OC) and total nitrogen (TN) were determined using the appropriate laboratory procedures.

The particle size distribution of the soil was analyzed using the hydrometer method as outlined by Bouyoucos (1962). The pH of the soils was measured in water suspension in a 1:2.5 (soil: water ratio) and measured potentiometrically using a glass-calomel combination electrode (Van Reeuwijk, 2002). The wet digestion method was used to determine soil organic carbon (OC) content (Walkley and Black, 1934). Total soil N was determined using the Kjeldahl procedure as described by Jackson (1967). Available soil P was determined by the Bray method II and it was measured by spectrophotometer (Bray and Kurtz, 1945).

The determination of extractable sulfur in soil extracts was done following the Turbidimetric method (Nagornyy, 2013). Morgan's solution was employed for extracting available K^+ and determined by a flame photometer (Morgan, 1941). The CEC of soil was determined from ammonium-saturated samples that were subsequently replaced by sodium (Na) from a percolating sodium chloride solution and reported as CEC ($cmol^{(+)}$/kg) (Jackson, 1967).

The exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrating it with sodium hydroxide as described by McLean (1965). Soil micronutrients (B and Zn) were extracted with the diethylene triamine penta acetic acid (DTPA) method as described by Lindsay and Norvell (1978). The concentration of micronutrients in the extract was determined by atomic absorption spectrophotometer.

Treatments and Experimental Design

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The experimental plot was 2.8 x 3 m (8.4 m^2), which contained seven rows from which the middle five (2 m x 3 m area) were used for data collection. The spacing between blocks and plots was 1 m and 0.75 m, respectively. Plant spacing was 10 cm between plants and 40 cm between rows. Hawassa Dume, a well-adapted common bean variety in the study area, was used as a test crop for this experiment. The treatments included control, NP, NPS, NPSB, and NPSZnB with different rates (Table 2).

Fertilizers that were applied as basal and their nutrient contents are NPS (19%, 38%, 7%), NPSB (18.1%, 36.1%, 6.7%, 0.71%) and NPSZnB (16.9%, 33.8%, 7.3%, 2.23%, and 0.67%). Fifty kg ha^{-1} of Urea was applied in all treatments including the control and it was top-dressed in two splits, half at planting and the remaining half at the mid branching stage on the 35th day after planting and 50 kg ha^{-1} of K was applied as muriate of potash (KCl) which contained 0-0-60 and applied at planting to all treatments except the control. TSP was used as P source for NP treatment.

Table 2. Detail of treatment set up

Treatments (kg ha^{-1})	Nutrient contents (%)					
	N	P_2O_5	K_2O	S	Zn	B
Control	- -	- -	- -	- -	- -	- -
*NP (100 kg TSP and 200 kg urea) ha^{-1}	64	46	30	-	-	-
100 kg NPS	19	38	30	7	-	-
150 kg NPS	28.5	57	30	10.5	-	-
200 kg NPS	38	76	30	14	-	-
100 kg NPSB	18.1	36.1	30	6.7	-	0.71
150 kg NPSB	27.15	54.15	30	10.05	-	1.07
200 kg NPSB	36.2	72.2	30	13.4	-	1.42
100 kg NPSZnB	16.9	33.8	30	7.3	2.23	0.67
150 kg NPSZnB	25.35	50.7	30	10.95	3.345	1.005
200 kg NPSZnB	33.8	67.6	30	14.6	4.46	1.34

*23 kg N was applied in all treatments except treatment 2 (NP) and 30 kg of K_2O was applied at planting to all treatments except the control

Crop Data Collection

Plant height (cm) was measured and expressed as average heights from the ground level to the apex of 10 randomly selected plants at physiological maturity. Number of nodules was determined by counting from five plants at 50% flowering stage. Roots were carefully exposed to the bulk of root mass and nodules were separated from the soil by washing and the total numbers of nodules is determined by counting.

Effective nodules were separated by their pink to dark red colors in the entire cross-section. Number of primary branches per plant was determined by counting the primary branches on the main stem of 10 randomly taken plants from the net plot area. Number of pods per plant was determined by counting the number of pods per plant as average of 10 randomly taken plants from each net plot area at harvest.

Number of seeds per pod was recorded for 10 randomly selected pods from each net plot at harvest and expressed as an average. Hundred seeds weight (g) was also determined by weighing 100 randomly sampled seeds and adjusting to a 10% moisture level.

The total above-ground dry biomass (kg ha^{-1}) at physiological maturity, was measured for 10 randomly selected plants after sun drying to get constant weight. For obtaining the total above-ground dry biomass, the dried biomass per plant thus obtained is multiplied by the total number of plants per net plot and it is converted into kg ha^{-1}. This is also used to calculate the harvest index. Grain yield (kg ha^{-1}) was determined after threshing the seeds harvested from each net plot. The seed yield was expressed with adjusted moisture level of 10% and converted to kg ha^{-1}. Harvest index (HI) is computed as the ratio of seed yield (kg ha^{-1}) to total above-ground dry biomass (kg ha^{-1}).

Economic Analysis

For the economic evaluation, partial budget, and marginal analyses were performed to investigate the economic feasibility of inputs at planting and for outputs at the crop harvest. The average yield was adjusted downward by 10% to reflect the difference between the experimental field and the expected yield at farmers' fields and with farmer's practices from the same treatments (CIMMYT, 1988). The prices of Urea = 10.15 birr kg^{-1}, NPS = 11.97birr kg^{-1}, NPSB = 12.05 birr kg^{-1}, NPSZnB = 12.25 birr kg^{-1}, TSP = 11.25 birr kg^{-1}, KCl (Muriate of Potash) = 11.50, Price of common bean =8.5 birr kg^{-1}. Family labor cost was not assigned cost but similar labor time was used on each treatments. According to CIMMYT (1988), the following parameters such as gross benefit, total variable cost (TVC), net benefit, and a percent marginal rate of return (MRR) were calculated.

Statistical Analysis

The data collected from the experimental field were processed following the analysis of variance (ANOVA) procedure using the SAS statistical software (SAS, 2007). The significant differences among treatment means were evaluated using the least significant difference (LSD) at $p < 0.05$.

RESULTS AND DISCUSSION

Effects of Fertilizer on the Growth Performance of Common Bean

Plant Height

The maximum (91.13 cm) and the minimum plant height (57.80 cm) were recorded from the NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}) rate and control, respectively (Table 3). However, further increment of applied fertilizers beyond the rate of (50.15:54.15:30:10.05:1.07 kg ha^{-1}) didn't bring any significant change in plant height. The increment of plant height might be due to the application of optimum fertilizers leading to an adequate supply of nutrients to the plant that might have promoted the maximum vegetative growth. Application of NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}) increased plant height by 57.7% and 18.4% as compared with control and NPK (64:46:30 kg ha^{-1}) application, respectively. The highest 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 of the plant (Jawahar *et al.,* 2017).

Nodules per Plant

The total number of nodules per plant of common bean was significantly ($p< 0.05$) affected by the application of different rates of NPS, NPSB, and NPSBZn treatments (Table 3). A higher number of nodules per plant (110.87) was recorded from NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}) treatment. This showed that the increment of nodule numbers per plant was possible when a balanced amount of nutrients was applied at the right time and rate. A similar result was obtained by Arega and Zenebe (2019), who indicated that the maximum number of total nodules was recorded from NPKSB (61.5:69:60:10.5:0.15:60 kg ha^{-1}) treatment, while the minimum corresponded to the control. Lake and Jemaludin (2018) reported that the highest plant height, number of main branches per plant and number of nodules per plant were recorded from 100 kg ha^{-1} of NPSZnB applications.

Table 3. . Effects of different fertilizer rates on growth parameters of common bean

Treatments (kg ha^{-1})	PH(cm)	NNP	NENP
Control	57.80^{e}	62.60^{f}	43.2^{f}
NPK (64:46:30)	77.00^{b}	77.07^{e}	57.07^{e}

NPKS (42:38:30:7)	78.80^{b}	86.2^{de}	62.67^{de}
NPKS (51.5:57:30:10.5)	80.33^{ab}	99.07^{a-d}	72.8^{bcd}
NPKS (61:76:30:14)	79.80^{ab}	103.93^{ab}	80.87^{ab}
NPKSB (41.1:36.1:30:6.7:0.71)	77.07^{b}	86.86^{cde}	62.87^{de}
NPKSB (50.15:54.15:30:10.05:1.07)	91.13^{a}	92.0^{bcd}	68.0^{cde}
NPKSB (59.2:72.2:30:13.4:1.42)	81.93^{ab}	110.87^{a}	85.13^{a}
NPKSBZn (39.9:33.8:30:7.3:0.67:2.23)	78.40^{b}	91.47^{bcd}	70.6^{bcd}
NPKSBZn (48.35:50.7:30:10.95:1:3.35)	81.93^{ab}	100.07^{abc}	77.47^{abc}
NPKSBZn (56.8:67.6:30:14.6:1.34:4.46)	83.07^{ab}	108.60^{a}	80.73^{ab}
LSD (0.05)	12.73	13.43	11.09
CV (%)	9.5	8.5	9.4

Means followed by different letters in the same column are significantly different ($p < 0.05$), PH = Plant height (cm), NPB = Number of primary branches per plant, NNP = Number of nodules per plant, NENP = Number of effective nodules per plant, LSD = Least significant difference; CV = Coefficient of variation (%).

Effective Nodules per Plant

A significant difference ($p < 0.05$) was observed between treatments regarding the number of effective nodules per plant. The highest number of effective nodules per plant (85.13) was recorded for the plots receiving NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}) treatment, while the lowest number (43.2) corresponded to the control receiving no fertilizers except the application of starter N. The increased number of effective nodules with the increase in fertilizer application up to NPKS (61:76:30:14 kg ha^{-1}) might be due to the vital role of phosphorus in enhancing 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) reported that phosphorus plays a vital role in increasing plant tip and root growth, and decreasing the time needed for developing nodules to become active (effective) for the benefit of the host legume. This result is also supported by results reported by Arega and Zenebe (2019) who obtained that the maximum effective number of nodules was recorded from NPKSB (61.5:69:60:10.5:0.15:60 kg ha^{-1}) while the minimum was noted for the control treatment.

Yield and yield components

Pods per plant

Significant ($p < 0.05$) effects of the application of NPS, NPSB, and NPSBZn were observed on the number of pods per plant as compared to the control (Table 4). The highest number of total pods per plant (34.0) was recorded for an application rate of NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}), whereas the lowest number (21.5) was obtained from the control plot (Table 5). These results might be due to adequate availability of N, P, K, S, Zn, and B which might have facilitated the production of primary branches and plant height which might, in turn, have contributed to the production of the higher number of total pods. The result is in harmony with the reports of Moniruzzaman *et al*. (2008), who indicated that a significant effect of N fertilizers on pod production from a comparable treatment set up with the current research.

Table 4. Effect of different fertilizer rates on yield-related parameters of common bean

Treatments (kg ha^{-1})	Pods/ plant	Seeds/pod
Control	21.5^{b}	3.47^{b}
NPK (64:46:30)	26.6^{ab}	5.53^{a}
NPKS (42:38:30:7)	32.7^{a}	5.73^{a}
NPKS (51.5:57:30:10.5)	32.8^{a}	5.73^{a}
NPKS (61:76:30:14)	31.8^{a}	5.47^{a}
NPKSB (41.1:36.1:30:6.7:0.71)	30.6^{ab}	5.67^{a}
NPKSB (50.15:54.15:30:10.05:1.07)	34.0^{a}	5.53^{a}

NPKSB (59.2:72.2:30:13.4:1.42)	30.0[ab]	5.47[a]
NPKSBZn (39.9:33.8:30:7.3:0.67:2.23)	29.8[ab]	5.73[a]
NPKSBZn (48.35:50.7:30:10.95:1:3.35)	28.8[ab]	5.80[a]
NPKSBZn (56.8:67.6:30:14.6:1.34:4.46)	30.6[ab]	5.60[a]
LSD (0.05)	9.95	0.59
CV (%)	19.5	6.4

Means in the table with different supperscript letter(s) in a column are significantly different ($p < 0.05$), LSD =Least significant difference and CV =Coefficient of variation (%).

Seeds per Pod

Analysis of variance indicated that significant ($p < 0.05$) effects of the application of different fertilizers were observed on the number of seeds per pod as compared to the control treatment. The highest number of seeds per pod (5.8) was recorded for the plot receiving the application of NPKSBZn (48.35:50.7:30:10.95:1:3.35 kg ha^{-1}), whereas the lowest number of total pods (3.4) was obtained from the control plot (Table 4).The significant difference in the number of seeds per pod between the plots with applied fertilizer and the control plot might be due to adequate supply of nutrients in blended fertilizers. In conformity with this result, Meseret and Amin (2014) reported that the highest number of seeds per pod (5.85) at an applied P rate of 20 kg ha^{-1}. Similarly, Habtamu *et al*. (2017) 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.

Hundred Seed Weight

Hundred seed weight was significantly influenced ($p < 0.05$) by the application of different rates of NPS, NPSB, and NPSBZn fertilizers. The results showed that the maximum (30.67 g) hundred seed weight was obtained from the application of NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}), compared to the minimum (21.0 g) hundred seed weight for the control (Table 5). This may be because nitrogen improves grain or seed weights in crop plants and reduces grain sterility (Fageria *et al.,* 2006). Nebret and Nigussie (2017) reported that increasing sulfur rate from 0 to 20 kg ha^{-1} increased 100 seed weight from 35.7 g to 36.8 g.

Above-ground Biomass Yield

The different rates of applied fertilizers had a significant ($p < 0.05$) influence on the aboveground biomass production. However, there were non-significant differences observed within the similar rates of different nutrient types (Table 5). The study showed that the maximum aboveground biomass was 10629.6 kg ha^{-1} was obtained for the plots receiving NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}) application whereas the minimum (6870.4 kg ha^{-1}) was obtained for the control plots. Application of NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}) improves aboveground biomass production by 54.7% and 10.8% as compared with control and NPK (64:46:30 kg ha^{-1}) application, respectively. The increase in biomass yield across applied fertilizer types and rates could be attributed to the fact that the enhanced availability of N, P, K, S, and micronutrients like B and Zn significantly increased plant height, number of primary branches per plant, number of pods per plant and to the overall vegetative growth of the plants that contributed to higher aboveground dry biomass yield. In agreement with this result, Lake and Jemaludin (2018) reported that various levels of NPSBZn applications significantly affected total biomass and the maximum was obtained from 100 kg ha^{-1} NPSBZn and the minimum was for the control. A similar result was also obtained by Arega and Zenebe (2019) who indicated that the highest total biomass (17195 kg ha^{-1}) was recorded for the plots with the treatment of NPKSB (61.5:69:60:10.5:0.15 kg ha^{-1}) application while the minimum corresponded to the control plot. Thus, the results from this study show that the soils of the experimental site are deficient in N, P, K, S, and B and without the use of fertilizers supplying these nutrients, biological yields in smallholder farmers' fields will continue to be low and will possibly start to decline.

Grain Yield

The application of different rates of applied fertilizers brought significant ($p < 0.05$) effects on grain yield increments, compared to the control and NPKS (42:38:30:7 kg ha^{-1}). But, the mean grain yield obtained from NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}) rates was at par with the mean grain yield obtained from NPK (64:46:30 kg ha^{-1}) (Table 6). The result also showed that the maximum mean grain yield (3477.0 kg ha^{-1}) was obtained from the plots receiving NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1})

and the mean minimum yield (1857.9 kg ha^{-1}) corresponded to the control. However, the maximum mean grain yield did not have statistically significant difference from the NPKSBZn (56.8:67.6:30:14.6:1.34:4.46 kg ha^{-1}), NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}), NPKSBZn (48.35:50.7:30:10.95:1:3.35 kg ha^{-1}) and NPKS (61:76:30:14 kg ha^{-1}) treatments. Application of NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}) gave 87.1% yield increment compared to the control and 12.1% compared to NPK (64:46:30 kg ha^{-1}). The grain yield increment from the plot that was treated with maximum rates of nutrients could be attributed to the deficiency of the nutrients in the soil of the study area.

Similar results were reported by Lake and Jemaludin (2018), who indicated that applications of various levels of NPSBZn significantly affected grain yield where a maximum grain yield of 2623 kg ha^{-1} was obtained by applying a 100 kg ha^{-1} NPSBZn compared to the least yield of the control. Farkhanda *et al*. (2019) also reported that the maximum grain yield (3260 kg ha^{-1}) of common bean was obtained from the application of 250 kg ha^{-1} of NPS. In conformity to this result, Arega and Zenebe (2019), indicated that the maximum grain yield (2923.8 kg ha^{-1}) was recorded from the treatment with the application of 61.5:69:60:10.5:0.15 NPKSB kg ha^{-1}) while the minimum grain yield (1926.8 kg ha^{-1}) was recorded for the control.

Table 5. Effects of fertilizer rates on grain yield and yield components of common bean

Treatments (kg ha^{-1})	GY (kg ha^{-1})	AGB (kg ha^{-1})	HSW(g)	HI (%)
Control	1857.9^{c}	6870.4^{d}	21.00^{b}	27.08^{b}
NPK (64:46:30)	3102.4^{a}	9592.6^{ab}	29.67^{a}	32.29^{ab}
NPKS (42:38:30:7)	2353.8^{bc}	7907.4^{cd}	29.50^{a}	29.75^{ab}
NPKS (51.5:57:30:10.5)	3049.9^{a}	9981.5^{ab}	26.83^{a}	30.92^{ab}
NPKS (61:76:30:14)	3351.9^{a}	10435.2^{a}	28.67^{a}	32.27^{ab}
NPKSB (41.1:36.1:30:6.7:0.71)	2837.6^{ab}	8620.4^{bc}	29.33^{a}	32.86^{ab}
NPKSB (50.15:54.15:30:10.05:1.07)	3397.6^{a}	9916.7^{ab}	29.33^{a}	34.32^{ab}
NPKSB (59.2:72.2:30:13.4:1.42)	3477.0^{a}	10629.6^{a}	30.33^{a}	32.85^{ab}
NPKSBZn (39.9:33.8:30:7.3:0.67:2.23)	2941.0^{ab}	9203.7^{abc}	27.67^{a}	31.85^{ab}
NPKSBZn (48.35:50.7:30:10.95:1:3.35)	3365.8^{a}	10240.7^{a}	29.50^{a}	33.15^{ab}
NPKSBZn (56.8:67.6:30:14.6:1.34:4.46)	3433.9^{a}	9592.6^{ab}	30.67^{a}	35.86^{a}
LSD (0.05)	660.3	1429.4	5.01	7.62
CV (%)	12.8	8.9	10.3	13.9

Means with different superscript letter(s) are significantly different ($p < 0.05$), LSD =Least significant difference; and CV =Coefficient of variation; GY=grain yield (kg ha^{-1}); AGB = above ground biomass yield (kg ha^{-1}); HSW= hundred seed weight (g) and HI = harvest index (%).

Economic Analysis

Partial Budget Analysis of Different Treatments

The partial budget analysis of common bean is significantly affected by the application of NPKS, NPKSB, and NPKSBZn (Table 7). A maximum net return of 23039.05 ETB was obtained from plots receiving treatments of NPKSB at 59.2:72.2:30:13.4:1.42 kg ha^{-1} ratio compared to the minimum net benefit (14212.935 ETB) from the control plots. From the economic point of view, it was apparent that the application of NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}) hit the highest point (23039.05 Eth-Birr) and was more profitabile than the rest of the treatments. However, the application of NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}) was also at par net benefit (23034.14 Eth-Birr) with those treatments (Table 7).

The partial budget analysis shows the level of profitability and helps to decide whether to adopt a new technology or not. The interest of producers in applying fertilizer is not limited to increasing yield alone, but also to make a profit out of it. Towards maximizing profit, types and amounts of fertilizer they apply as well as the cost of fertilizer and the market price of yields are determining factors.

Profitability of Different Treatments

The applied fertilizer rate showed that the net benefit was decreased as the total cost increased beyond un-dominated fertilizer application. The net benefits also increased, except in the case of treatments NPKSBZn (48.35:50.7:30:10.95:1:3.35 kg ha^{-1}), NPK (64:46:30 kg ha^{-1}), NPKS (61:76:30:14 kg ha^{-1}), and NPKSBZn (56.8:67.6:30:14.6:1.34:4.46 kg ha^{-1}) (Table 6). These fertilizer types and rates were not recommended to farmers due to their higher costs and associated lower benefits (marked 'D').). Therefore, no farmer may choose those dominated treatments in comparison with the un-dominated treatments. The result revealed that the application of NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}) gives 22065.87%, which is well above the 100% minimum rate of return, which was considered as the best for the recommendation (Table 8). This treatment shows the maximum net benefit, relatively low variable cost, and acceptable marginal rate of return when compared with the other treatments. The best recommendation for treatments subjected to a marginal rate of return is not necessarily based on the highest marginal rate of return, rather based on the maximum net benefit, relatively low variable cost together with the minimum acceptable marginal rate of return becomes the tentative recommendation (CIMMYT, 1988). In agreement with this result, Shah *et al.* (2011) reported that the maximum rate of return (446.21%) was recorded from the plots in which 120 kg N ha^{-1} was applied whereas the minimum rate of return (296.67%) was noted from the unfertilized plots.

Table 6. Partial budget analysis of different rates of NPS, NPSB, and NPSBZn on common bean

Treatments (kg ha^{-1})	Av.GY	Ad.GY in 10%	GB	TVC	NB
Control	1857.9	1672.1	14212.9	0	14212.9
NPK (64:46:30)	3102.4	2792.2	23733.4	3290	20443.4
NPKS (42:38:30:7)	2353.8	2118.4	18006.6	2347	15659.6
NPKS (51.5:57:30:10.5)	3049.9	2744.9	23331.7	2945.5	20386.2
NPKS (61:76:30:14)	3351.9	3016.7	25642.1	3544	22098.1
NPKSB (41.1:36.1:30:6.7:0.71)	2837.6	2553.8	21707.6	2355	19352.6
NPKSB (50.15:54.15:30:10.05:1.07)	3397.6	3057.8	25991.6	2957.5	23034.1
NPKSB (59.2:72.2:30:13.4:1.42)	3477	3129.3	26599.1	3560	23039.1
NPKSBZn (39.9:33.8:30:7.3:0.67:2.23)	2941	2646.9	22498.7	2375	20123.7
NPKSBZn (48.35:50.7:30:10.95:1:3.35)	3365.8	3029.2	25748.4	2987.5	22760.9
NPKSBZn (56.8:67.6:30:14.6:1.34:4.46)	3433.9	3090.5	26269.3	3600	22669.3

Av.GY = average grain yield kg/ha; Ad.GY = adjusted grain yield kg/ha; TVC= Total variable cost (ETB ha^{-1}); GR= gross benefit (ETB ha^{-1}); NB = Net Benefit (ETB ha^{-1}); Gross return (Return from Grain yield) =price /kg* yield in kg, and Net return = gross return – Total cost; Prices of Urea= 10.15 birr/kg, NPS = 11.97birr/kg, NPSB = 12.05birr/kg, NPSZnB = 12.25birr/kg, TSP=11.25 birr/kg, KCl (Muriate of Potash) = 11.50, Price of common bean =8.5 birr/kg. Family labor cost was not assigned cost but similar labor time was used on each treatments.

Table 7. Dominance analysis of different rates of treatments on common bean

Treatments (kg ha^{-1})	TVC	NB	MRR%	B:C ratio
Control	0	14212.9	0	
NPKS (42:38:30:7)	2347	15659.6	61.6	6.7

NPKSB (41.1:36.1:30:6.7:0.71)	2355	19352.6	46163.4	8.2
NPKSBZn (39.9:33.8:30:7.3:0.67:2.23)	2375	20123.7	3855.1	8.5
NPKS (51.5:57:30:10.5)	2945.5	20386.2	46.0	6.9
NPKSB (50.15:54.15:30:10.05:1.07)	2957.5	23034.1	22065.9	7.8
NPKSBZn (48.35:50.7:30:10.95:1:3.35)	2987.5	22760.9	D	7.6
NPK (64:46:30)	3290	20443.4	D	6.2
NPKS (61:76:30:14)	3544	22098.0	D	6.2
NPKSB (59.2:72.2:30:13.4:1.42)	3560	23039.1	5881.3	6.5
NPKSBZn (56.8:67.6:30:14.6:1.34:4.46)	3600	22669.3	D	6.3

TVC = total variable cost (Eth-Birr ha^{-1}), NB = net benefit (Eth-Birr ha^{-1}), MRR% = marginal rate of return, D = dominated, B: C ratio = benefit cost ratio.

CONCLUSIONS

The results revealed that application of NPKSB at different rates significantly affected growth parameters, yields and yield components of common bean as compared to the control treatment. The economic analysis also showed the highest net return of 23039.05 and 23034.14 ETB ha^{-1} were obtained at the plot that received NPKSB (59.2:72.2:30:13.4:1.42 kg ha^{-1}) and NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}), respectively. The lowest net profit of 14212.94 ETB ha^{-1} was obtained from the control plot and application of NPKSB (50.15:54.15:30:10.05:1.07 kg ha^{-1}) to common bean (Hawassa Dume variety) could enhance yield and yield components of the crop in Debub Ari district, southern Ethiopia. However, since the experiment was conducted only for one season at one location, the experiment has to be repeated over seasons and across different locations to make a conclusive recommendation.

CONFLICTS OF INTEREST

Authors declare that they have no conflicts of interest regarding the publication of this paper with the Journal of Science and Development.

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