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Common Bean (*Phaseolus Vulgaris* L.) Varieties Response to Rates of Blended NPKSB Fertilizer at Arba Minch, Southern Ethiopia

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Abstract

Low soil fertility and inadequate improved high yielding varieties are the major constraints for bean production in Ethiopia. In order to improve productivity, common bean varieties response to rate of NPKSB fertilizer was studied at Arba Minch during 2017 cropping season with three common bean varieties (Hawassa-Dume, Nasir, and Red Wolaita) and eleven fertilizer level (control, 41:46 kg NP ha^{-1}, 20.5:23:3.5:0.05 kg NPSB ha^{-1}, 41:46:7:0.1 kg NPSB ha^{-1}, 61.5:69:10.5:0.15 kg NPSB ha^{-1}, 20.5:23:30:3.5:0.05 kg NPKSB ha^{-1}, 41:46:30:7:0.1 kg NPKSB ha^{-1}, 61.5:69:30:10.5:0.15 kg NPKSB ha^{-1}, 20.5:23:60:3.5:0.05 kg NPKSB ha^{-1}, 41:46:60:7:0.1 kg NPKSB ha^{-1}, 61.5:69:60:10.5:0.15 kg NPKSB ha^{-1}). The treatments were combined in factorial experiments with split plot design and replicated three times. Analysis of the data indicated that nodulation, plan height, number of pods per plant, hundred seed weight and grain yield were significantly ($p<0.05$) affected due to blended NPKSB fertilizer application rate and common bean varieties. The highest number of total nodules (129.8 cm), effective nodules (122.3 cm) and plant height (124.6 cm) were recorded from variety Nasir, whereas the highest number pods per plant (28.9), seeds per pod (5.35), grain yield (2693.6 kg ha^{-1}), hundred seed weight (26.6 g) and harvest index (0.20) were recorded from variety Hawassa-Dume. Highest number of total nodules (137.7), number of effective nodules (130.7), plant height (129.4 cm), above ground dry biomass (17195 kg ha^{-1}), number of pods per plant (31.3) and grain yield (2923.8 kg ha^{-1}) were recorded from the maximum rate of blended NPKSB rate (61.5:69:60:10.5:0.15 kg NPKSB ha^{-1}) applied, however, it was statistically at par with rate 61.5:69:30:10.5:0.15 kg NPKSB ha^{-1}, 41:46:60:7:0.1 kg NPKSB ha^{-1} and 41:46:30:7:0.1 kg NPKSB ha^{-1},while maximum hundred seed weight (27.4 g) was recorded from 61.5:69:30:10.5:0.15 kg NPKSB ha^{-1} however, it was statistically at par with treatment 61.5:69:60:10.5:0.15 kg NPKSB ha^{-1}, 41:46:60:7:0.1 kg NPKSBha^{-1} and 41:46:30:7:0.1 kg NPKSB ha^{-1}. Economics of bean cultivation analysis showed that variety Hawassa-Dume and application of blended fertilizer rates of 41:46:30:7:0.1 kg NPKSB ha^{-1} resulted maximum net benefit of 27435.1 birr ha^{-1} and 27251.8 birr ha^{-1}, respectively. Thus, blended fertilizer at rate of 41:46:30:7:0.1 kg NPKSB ha^{-1} and variety Hawassa-Dume is tentatively suggested to study area.

Keywords: Blended fertilizer; Economics; Fertility; Productivity

Introduction

Common bean (*Phaseolus vulgaris* L.) is one of most important legume crops grown in all continents of the world with over 23 million metric tons (MT) of total production where 7 million MT were produced in Latin America and Africa [1,2]. In Ethiopia, the crops have been cultivated in different parts, mainly at central, eastern, and southern parts of the country. Ethiopia accounts 673,847.61-hectare (32.2%) production area and dry bean production of 845116.905 tons (25.7%) [3].

Its production contributes both as food, fodder for livestock, export commodity and serves as a source of income and employment to a large supply chain and for risk aversion strategies to poor farmers' during drought due to early maturity and moderate degree of drought tolerance [4-6]. The crop provides vital nutrients such as high starch, protein and dietary fiber and is an excellent source of minerals and vitamins and used as [7-10]. As a legume, it provides nitrogen and other soil health benefits under cropping system to subsequently grown crops [11,12].

Despite the multiple uses, average national and regional yield of common bean was estimated as 982 kg ha^{-1} and 963 kg ha^{-1}, respectively in Ethiopia in contrast to a production potential of 2500 to 4000 kg ha^{-1} in research fields [3,9,13,14]. Low yield is attributed to various biotic and abiotic stresses like diseases, insect pests, drought, nutritional deficiencies and absence of improved high yielding varieties [14,15].

Genetic and physiological potential different crop plants vary on nutrient use efficiency [16,17]. A lot of diversity among common bean varieties in nutrient use efficiency was presented by Kasinath et al. [18]. Different authors reported NPKSB nutrients requirements for common bean growth and yield [19-21]. However, Ethiopian soil information system project revealed that Ethiopian soils were deficient in various other nutrients (as KSB) not provided by DAP and Urea [22,23].

Therefore, determination of most efficient common bean varieties, study of crop nutrient sources beyond N and P, especially fertilizers containing K, S, Zn and other micro-nutrients quite important to increase common bean productivity. Thus, the present study was attempted to determine high yielding common bean varieties and rates of NPKSB fertilizer for growth, yield and yield components of common bean varieties at Arba Minch.

Materials and Methods

Description of the study area

The field experiment was conducted at Chano Mille kebele, Arba Minch Zuria district located along the rift valley of Ethiopia at an altitude of 1216 masl and in between 6°6' 55" and 37°35' 51" latitude and longitude during 2017 crop growing season. The soil texture of the experimental area was found to be clay, slightly acidic, medium for total nitrogen, medium for available p, very high soil CEC and low organic matter content.

The experiment was designed to consist three common bean varieties (Hawassa-Dume, Nasir, and Red Wolaita) as main plot and eleven blended fertilizer level as presented in Table 1 as subplot factors. The treatments were combined in factorial experiments with split plot design and replicated three times.

Treatment code	Nutrient Contents of Blended Fertilizer					Remark
	N	P_2O	K_2O	S	B	
F_0	0	0	0	0	0	Control
F_1	41	46	0	0	0	Recommended NP
F_2	20.5	23	0	3.5	0.05	--
F_3	41	46	0	7	0.1	--
F_4	61.5	69	0	10.5	0.15	--
F_5	20.5	23	30	3.5	0.05	--
F_6	41	46	30	7	0.1	--
F_7	61.5	69	30	10.5	0.15	--
F_8	20.5	23	60	3.5	0.05	--
F_9	41	46	60	7	0.1	--
F_{10}	61.5	69	60	10.5	0.15	--

Table 1: Details of nutrient content of blended fertilizer treatments used for the experiment.

The common bean varieties were planted in plots containing eight rows spaced at 0.4 m and 0.1 m between plants with planting depth of 0.04 m. The net plot size 2.4 m × 1.5 m (3.6 m^2) was used for observation. The entire blended fertilizer doses of each treatment were drilled in rows just before sowing. Nitrogen fertilizer sources were applied in splits before flowering whereas blended fertilizer NPSB, TSP and Muriate of potash source treatments were incorporated in the soil at time of planting.

All recommended crop management practices such as weeding, pest and disease control were done uniformly for all experimental plots. 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 4 days before threshing.

Data on days to 50% flowering, total Number of nodules, Number of Effective Nodule, plant heights, dry biomass (kg ha^{-1}) above ground plant at physiological maturity, number of pods per plant, number of seeds per pod 100 seed weight (g), grain yield (kg ha^{-1}) and Harvest index (%) was recorded.

Collected data were subjected to analysis of variance using Proc glm SAS procedures for spilt plot design version 9 for factorial experiment. Means of significant treatment effects were separated using Duncan Multiple Range Test [24].

Results and Discussion

Phenological trait analysis of common bean varieties

The number of days to attain 50% flowering and days to physiological maturity was significantly ($p<0.05$) affected due to blended NPKSB fertilizer rate. Maximum number of days (39.4 days) to reach flowering was recorded at F_{10} where highest amount of NPKSB was applied, while the earliest days to flowering (37.9) was recorded from control treatment (no fertilizer applied). The result showed delayed days to flowering with increasing rates of NPKSB fertilizer (Table 2) indicating favor of each NPKSB nutrient sources for vegetative growth. Similarly 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 [25]. Furthermore, reported that increasing NPS fertilizer rate from nil to 47.5:95:17.5 kg NPS ha^{-1} significantly prolonged the days to 50% flowering of common bean [26]. The result also showed minimum effect of an application for days to flowering compared to control and low dose of blended fertilizer suggesting stimulatory effect of phosphorus on growth hormones, and presence of sulfur nutrients induce early flowering in haricot bean. However, there was no significant variation observed among blended NPKSB fertilizer rates F_6 (41:46:30:7:0.1 kg NPKSB ha^{-1}), F_7 (61.5:69:30:10.5:0.15 kg NPKSB ha^{-1}), F_9 (41:46:60:7:0.1: kg NPKSB ha^{-1}) and F_{10} (61.5:69:60:10.5:0.15 kg NPKSB ha^{-1}) treatments which might be due to variation and its of highest amount of each NPKSB nutrients. On the other hand, days to 50% flowering remained statistically the same when the rate of NPKSB application increased from nil to F_4 (61.5:69:10.5:0.15 kg NPSB ha^{-1}) and F_6 (41:46:30:7:0.1NPKSB ha^{-1}) and days to 50% flowering was prolonged significantly when the NPKSB supply was increased to41:46:60:7:0.1 NPKSB ha^{-1} and 61.5:69:60:10.5:0.15 kg NPKSB ha^{-1} as compared to control treatments which indicated minimum days to 50% flowering response at low NPKSB rates and importance of potassium fertilization (Table 2).

Treatments	DF (days)	DPM (days)
Common bean variety		
Hawassa-Dume	38.3	89.4
Nasir	38.4	90.1
Red Wolayita	38.9	90.9
SEM (±)	0.16	0.3
LSD (0.05)	NS	NS
CV (%)	3	2.9
Blended NPKSB Fertilizer Rates (kg ha-1)		
F_0 (Control)	37.9^{c}	88.6^{c}
F_1 (41:46 NP)	38.3^{bc}	90.2^{bc}
F_2 (20.5:23:3.5:0.05 NPSB)	38.2^{bc}	89.4^{bc}

F_3 (41:46:7:0.1 NPSB)	38.4^{bc}	89.4^{bc}
F_4 (61.5:69:10.5:0.15 NPSB)	38.3^{bc}	90.2^{bc}
F_5 (20.5:23:30:3.5:0.05 NPKSB)	38.2^{bc}	89.5^{bc}
F_6 (41:46:30:7:0.1 NPKSB)	38.6^{abc}	90.4^{bc}
F_7 (61.5:69:30:10.5:0.15 NPKSB)	39^{ab}	90.6^{ab}
F_8 (20.5:23:60:3.5:0.05: NPKSB)	38.3^{bc}	89.6^{bc}
F_9 (41:46:60:7:0.1: NPKSB)	39^{ab}	90.8^{ab}
F_{10} (61.5:69:60:10.5:0.15 NPKSB)	39.4^{a}	92.2^{a}
SEM (±)	0.31	0.58
LSD (0.05)	0.87	1.63
CV (%)	2.4	2
Grand Mean	38.5	90.1
variety* NPKSB Fertilizer Rates (LSD (0.05))	ns	ns

Table 2: Days to 50% flowering and maturity of common bean as affected by blended NPKSB fertilizer rates and common bean varieties at Arba Minchduring 2017 cropping season, Southern Ethiopia.

Mean values followed by different letters indicates significance difference at P<0.05; NS denotes no significant difference at 5% level; DF denotes days to 50% flowering; DPM denotes Days to Physiological maturity.

Maximum (92.2 days) number of days to physiological maturity was recorded from high rate of blended NPSBK rate (61.5:69:60:10.5:0.15 kg NPKSB ha^{-1}) when compared to control (88.6 days) treatments. The result showed increase in blended NPKSB application rate from 0 to 61.5:69:60:10.5:0.15 kg NPKSB ha^{-1} resulted in delayed number of days required to reach physiological maturity. However, no significant differences in number of days to reach physiological maturity attained between high blended NPKSB rate of F_{10} (61.5:69:60:10.5:0.15 kg NPKSB ha^{-1} and plot treated with F_7 (61.5:69:30:10.5:0.15 kg NPKSB ha^{-1}) and F_9 (41:46:60:7:0.1 kg NPKSB ha^{-1}). These suggested that integrated actions of each nutrient in blended fertilizers reduced the gap on days to physiological maturity when compared to control treatments. This result was in line 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 [25,26]. Delaying effect of combined application N and P fertilizer rate in common bean also documented by Assefa et al. [27].

Nodulation and growth analysis of common bean varieties

The analysis of variance showed that total and effective number of nodules and plant height of common bean was significantly (p<0.05) affected due to varieties and blended NPKSB fertilizer application rates, however no significant effect interaction was noted by of varieties with blended NPKSB application rates. Maximum total (129.8) and effective (122.3) number of nodules per plant was obtained from cultivar Nassir while minimum total (106.2) and effective (100.8) number of nodules was form cultivar Hawassa-Dume (Table 3) which might be due to genetic difference (nodulation characteristics) among cultivars. Significant differences in total and effective nodule number among common bean varieties was also documented in Girma et al. and Wondimu et al. [28,29].

Treatments	TNN	ENN	PH (cm)
Common bean			
Hawassa-Dume	106.2^{b}	100.8^{b}	112.5^{b}
Nasir	129.8^{a}	122.3^{a}	124.6^{a}
Red Wolayita	122.5^{a}	115.8^{a}	121^{ab}
SEM (±)	5.6	5.6	2.4
LSD (0.05)	10.96	10.02	8.6
CV (%)	13.4	13	10.5
Blended NPKSB Fertilizer Rates (kg ha-1)			
F_0 (Control)	86.1^{c}	79.5^{c}	100.7d
F_1 (41:46 NP)	115.3^{abc}	109.9^{abc}	115.2^{abc}
F_2 (20.5:23:3.5:0.05 NPSB)	99.0^{bc}	94.9^{bc}	110.9^{c}d
F_3 (41:46:7:0.1 NPSB)	125.9^{ab}	119.6^{ab}	125^{abc}
F_4 (61.5:69:10.5:0.15 NPSB)	133.1^{ab}	126.6^{ab}	125.2^{abc}
F_5 (20.5:23:30:3.5:0.05 NPKSB)	101.9^{bc}	95^{bc}	111.1^{bc}d
F_6 (41:46:30:7:0.1 NPKSB)	126.0^{ab}	121.2^{ab}	125.5^{abc}
F_7 (61.5:69:30:10.5:0.15 NPKSB)	133.9^{ab}	125.9^{ab}	126.0^{ab}
F_8 (20.5:23:60:3.5:0.05 NPKSB)	118.6^{abc}	111^{abc}	116.9^{abc}
F_9 (41:46:60:7:0.1 NPKSB)	137.3^{a}	128.3^{ab}	127.2^{a}
F_{10} (61.5:69:60:10.5:0.15 NPKSB)	137.7^{a}	130.7^{a}	129.4^{a}
SEM (±)	10.7	10.7	4.6
LSD (0.05)	30.4	30.4	13.1
CV (%)	27	28.5	11.6
Grand Mean	119.5	113	119.4
variety* NPKSB Fertilizer Rates (LSD (0.05))	ns	ns	ns

Table 3: Total number of nodules, effective number of nodule and plant height as affected by common bean varieties and blended NPKSB fertilizer rates at Arba Minch during 2017 cropping season, Southern Ethiopia.

Total (137.7) and effective (130.7) number of nodules was recorded from maximum blended NPSBK rate, F_{10} (61.5:69:60:10.5:0.15:60 kg NPSBK ha^{-1}), while the minimum total (86.1) and less effective (79.53) was noted from control treatment. The results clearly indicated that integrated use of blended NPKSB fertilizer rate significantly increased total nodulation and effective nodule number in common bean suggesting integrated effects of nutrients in blended NPKSB fertilizer especially N initiated nodulation and P in blended NPKSB fertilizer improved root development and nitrogen fixation in common bean. Increased number of total and effective nodule observed by application of highest NPSBK over the control might also be from increased KSB application along with other major nutrients. Phosphorus availability might have been the major determinants of N fixation among genotypes through affecting nodule number [30].

Similarly, reported increases effect of K on root numbers and volumes, increasing the chances for root hairs to intercept the soil bacteria which initiate nodulation [23]. K and P deficiency as a major constraint for nodulation in common bean [31]. Effect of S and B on nodule growth, nodule formation and functioning were reported by [32-34]. Tall plant height (124.6 cm) was recorded from variety Nasir followed by Red Wolayita while short plant height was recorded from Hawassa-Dume (112.5 cm) (Table 3). The high plant height observed by Nasir and Red Wolayita might be due to semi-climbing nature of the varieties as compared to Hawassa Dume. The result indicated effect of genotype difference and effect of growing environment. Similarly, reported significant plant height differences between common bean varieties [28,35].

The result showed increasing trend on plant height for increasing dose of NPSBK fertilizer rates. Tall (129.4) plant height was attained when applying F_{10} (61.5:69:10.5:0.15:60 kg NPSBK ha^{-1}) whereas short plant height was noted on F_0 (Control), F_2 (20.5:23:3.5:0.05 kg NPSB ha^{-1}) and F_5 (20.5:23:3.5:0.05:30 kg NPSB ha^{-1}), treatments. The result showed that F_{10} gave 14.14%, 14.34 and 22.16% more plant height as compared to F_5, F_2 and F_0, respectively (Table 3). The response of common bean plant height towards increased blended NPSBK fertilizer application rate suggested that bean plant growth demand for supplementary K, S and B nutrients. Similarly, maximum vegetative growth of the plants under higher N, P and S nutrient availability reported by [26]. Additionally, showed that high NPKS nutrients application enhanced growth attributes in common bean [25]. It is also observed that enhanced common bean plant heights growth due to B application over non-B supplemented fertilizer sources [36].

Above ground dry biomass yield: The analysis of variance showed that above ground dry biomass yield of common bean was significantly ($p<0.05$) affected due to blended NPKSB fertilizer application rates, however, the effect of variety and interaction in between common bean varieties with blended NPKSB application rates was not significant. Aboveground dry biomass yield of common bean significantly increases with increasing blended fertilizer rates up to 61.5:69:60:10.5:0.15 kg NPKSB ha^{-1}. Maximum biomass (17195 kg ha^{-1}) was produced from a plot that received F_{10} (61.5:69: 60:10.5:0.15 kg NPKSB ha^{-1}) and the minimum dry biomass yield (10560 kg ha^{-1}) was recorded from control treatment where F_{10} showed 38.6% higher yield advantage over the control (Figure 1).

The result also indicated that applications of K fertilizer enhanced dry biomass production in common bean as compared with the same rate of NPSB though statistically on par. In general, the result indicated significant enhancing effect of above ground dry biomass production due to integrated use of NPKSB. Similarly, significantly increasing biomass production with increasing rate of blended NPKS Mg Zn fertilizer application in common bean was reported by [21]. Combined applications of NP fertilizer, high nitrogen rate and increase in P_2O_5 application resulted in enhanced dry biomass production [17,37,38]. Similarly, also observed beneficial effect of fertilizer potassium on dry matter production and distribution in common bean plants was probably associated with the maintenance of better water relations in the plants due to potassium application [39]. Application of Sin *Phaseolus vulgaris* L. proved beneficial effect in bringing about significant improvement in dry matter production per plant. They obtained maximum dry weight per plant by application of 30 kg S ha^{-1} [40]. The present studies revealed that applications of different blended NPKSB fertilizer rate had enhanced above ground dry biomass yield on common bean.

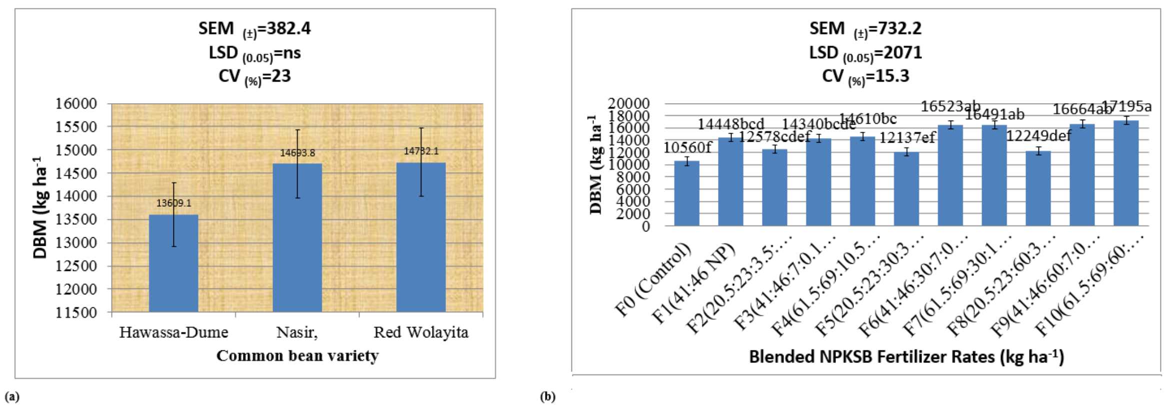

Figure 1: Dry biomass of common bean as affected by common bean varieties (a) and blended NPKSB fertilizer rates (b) at Arba Minch during 2017 cropping season, Southern Ethiopia.

Mean values followed by different letters are significantly different at $P<0.05$; NS denotes not significant at 5% level; TNN denotes number of total nodules per plant, ENN denotes Effective number of nodules per plant, PH denotes plant height and DBM denotes above ground dry biomass yield.

Yield and yield components of common bean varieties

Number of pods per plant: Number of pods per plant is one of the important yield components in determining grain yield of common been. The result showed that number of pods per plant was significantly ($p<0.05$) affected due to common bean varieties and blended NPKSB fertilizer application rates, however no significant interaction effect noted between varieties and blended NPKSB fertilizer application rates (Table 4).

Treatments	NPP	NSP	HSW (gram)
Common bean variety			
Hawassa-Dume	28.9[a]	5.35[a]	26.6[a]
Nasir	23.2[b]	4.88[b]	25.1[b]
Red Wolayita	24.4[b]	4.96[b]	25.2[b]
SEM (±)	0.72	0.06	0.25
LSD (0.05)	3.9	0.22	1.05
CV (%)	22.4	6.3	6
Blended NPKSB Fertilizer Rates (kg ha^{-1})			
F_0 (Control)	18.2[d]	4.9	23.9[d]
F_1 (41:46 NP)	23.5[c]	5.1	25[cd]
F_2 (20.5:23:3.5:0.05 NPSB)	21.5[cd]	4.9	24[d]
F_3 (41:46:7:0.1 NPSB)	24.8[c]	4.9	26.1[abc]
F_4 (61.5:69:10.5:0.15 NPSB)	25.5[bc]	5	25.8[bc]
F_5 (20.5:23:30:3.5:0.05 NPKSB)	23[c]	5	24.1[d]
F_6 (41:46:30:7:0.1 NPKSB)	29[ab]	5.2	26.9[ab]
F_7 (61.5:69:30:10.5:0.15 NPKSB)	30.4[a]	5.3	27.4[a]
F_8 (20.5:23:60:3.5:0.05 NPKSB)	23.9[c]	5	25[cd]
F_9 (41:46:60:7:0.1 NPKSB)	29.2[ab]	5.1	26.5[abc]
F_{10} (61.5:69:60:10.5:0.15 NPSB)	31.3[a]	5.1	27.3[a]
SEM (±)	1.4	0.12	0.48
LSD (0.05)	3.9	NS	1.4
CV (%)	16.2	7.1	5.7
Grand Mean	25.5	5.1	25.6
variety* NPKSB Fertilizer Rates (LSD (0.05))	ns	ns	ns

Table 4: Common bean yield components as affected by blended NPKSB fertilizer rate and varieties at Arba Minch during 2017 cropping season.

Maximum (28.9) number of pods per plant was recorded for variety Hawassa-Dume, while minimum (23.2) was obtained from variety Nasir suggesting the existing genetic potential among cultivars in response to soil applied NPKSB nutrient sources and environmental conditions. This result is in agreement with the finding who reported significant differences in pod number among common bean varieties of [25,29,41].

Maximum (31.3) and minimum (18.2) number of pods per plant was recorded when applying F_{10} (61.5:69:60:10.5:0.15 kg NPKSB ha^{-1}). Application of high NPKSB fertilizer rate significantly enhanced number of pods per plant by 41.6% when compared with control, 30.4%, 26.3% and 23% over fertilizer application rate of 20.5:23:3.5:0.05 kg ha^{-1} NPSB, 20.5:23:30:3.5:0.05 kg/ha NPKSB and recommended 41:46 Kg ha^{-1} NP fertilizer, respectively (Table 4). However, there was no significant variation observed among blended fertilizer rate treatments F_6, F_7, F_9 and F_{10} indicating insufficiency of applied integrated nutrient to bring significant difference in pod number. The result also indicated that all applied potassium levels increased number of pods per plant as compared to the same rates of NPSB fertilizer rate, except plot treated with 20.5:23:3.5:0.5 kg NPSB ha^{-1} fertilizer rate (Table 4). The result also showed enhancing role in pod number per plant when applying KSB even under reduced nitrogen and phosphorus fertilizer rate suggesting the importance of sulfur and boron fertilizer incorporation with NPK fertilizer.

The current study results revealed that increased number of pods per plant with increment in blended NPKSB fertilizer application rates from control up to 61.5:69:60:10.5:0.15 kg/ha NPKSB fertilizer rate indicating optimum blended fertilizer rate for number of pods per plant production. This result was in line with the findings of [19,25,26] who reported that high levels of N, P, K and S fertilizer significantly facilitated the production of primary branches and plant height which might in turn have contributed for enhanced pod number per plant.

Number of seeds per pod: As presented in Table 4, number of seeds per pod was significantly ($p<0.05$) affected due to varieties, however no significant effect was noted due to blended NPKSB fertilizer application rate and interaction of varieties with blended NPKSB fertilizer rates.

Maximum number of seeds per pod (5.35) was recorded from variety Hawassa-Dume while the minimum number (4.88) was recorded from variety Nasir (Table 4). The significant difference among the varieties for seed number pod^{-1} might be attributed to their genetic difference than the management. In line with this result finding of documented significant differences in number of seed pod^{-1} among common bean varieties, similarly, reported high number of seeds per pod from Hawassa Dume (5.36) variety, followed by Nasir (5.16) [28,29].

Hundred seed weight: Analysis of variance showed hundred seed weight was significantly ($p<0.05$) affected due to varieties and blended NPKSB fertilizer application rates, however no significant effect was noted between interaction of varieties with blended NPKSB application rates (Table 4).

Maximum (26.6 g) and minimum (25.1 g) hundred seed weight was recorded on variety Hawassa-Dume and Nasir, respectively (Table 4) suggesting their genetic difference in response to applied nutrient and environmental conditions in which the crop well perform. This result is in conformity with the finding of [28,29] who reported significant differences in hundred seed weight among common bean varieties.

Maximum (27.4 g) and minimum (23.9 g) hundred seed weight was recorded from application of 61.5:69:30:10.5:0.15 kg NPKSB ha^{-1} fertilizer rate and control treatment, respectively. Applying blended NPKSB fertilizer at 61.5:69:30:10.5:0.15 kg ha^{-1} significantly enhanced hundred seed weight by 12.8% over control. However, fertilizer rates F_3 (41:46:7:0.1 NPSB); F_6 (41:46:30:7:0.1 NPKSB); F_9 (41:46:60:7:0.1 NPKSB) and F_{10} (61.5:69:60:10.5:0.15 NPSB) were on par for hundred seed weight as compared to 61.5:69:30:10.5:0.15 kg ha^{-1}. On the other hand, the result also noted increase in hundred seed weight due to K in blended fertilizer when compared to similar blended NPSB fertilizer rates, though statistically at par (Table 4).

Significant high hundred seed weight differences were observed in application of potassium at the rate of 30 and 60 kg ha^{-1} along with 61.5:69:10.5:0.15 kg NPSB ha^{-1} when compared to the plot treated with the same NPSB without potassium. Even though nitrogen and phosphorus fertilizer reduced by half similar hundred seed weight were recorded by application of blended fertilizer containing potassium, sulfur and born. This observation verified that demand for potassium, sulfur and born fertilizer application in addition to NP nutrients for hundred seed weight of common bean varieties.

The result obtained from current study revealed that increasing rate of blended NPKSB fertilizer application resulted in significant effect on hundred seed weight. The findings suggested that the increase in 100 seed weight with fertilizer application might be due to nutrient enhanced nutrient use efficiency by crop at optimum level of N, P and S [26]. Findings also indicated significantly increased hundred seed weight due to increased combined NP fertilizer application [29]. The significant variations in thousand seed weights of common bean as a result of phosphorus and boron application, respectively were observed [28,36].

Grain yield: As presented in Table 5, the analysis of variance of grain yield showed that grain yield was significantly ($p<0.05$) affected due to blended NPKSB fertilizer application rates and common bean varieties, however no significant effect was noted due to interaction between varieties with blended NPKSB fertilizer rates.

Treatments	GY (kg ha^{-1})	HI (%)
Common bean variety		
Hawassa-Dume	2699.7^{a}	0.20^{a}
Nasir	2390.9^{b}	0.17^{b}
Red Wolayita	2417.9^{b}	0.17^{b}
SEM (±)	59.1	0.006
LSD (0.05)	242	0.03
CV (%)	14.1	21.7
Blended NPKSB Fertilizer Rates (kg ha-1)		
F_0 (Control)	1926.8^{d}	0.18
F_1(41:46 NP)	2362.2^{c}	0.16
F_2 (20.5:23:3.5:0.05 NPSB)	2220.6^{cd}	0.18
F_3 (41:46:7:0.1 NPSB)	2482.2^{bc}	0.18
F_4 (61.5:69:10.5:0.15 NPSB)	2485.0^{bc}	0.17
F_5 (20.5:23:30:3.5:0.05:30 NPKSB)	2305.2^{c}	0.19
F_6 (41:46:30:7:0.1:30 NPKSB)	2809.2^{ab}	0.17
F_7 (61.5:69:30:10.5:0.15 NPKB)	2877.1^{a}	0.18
F_8 (20.5:23:60:3.5:0.05 NPKSB)	2317.3^{c}	0.19
F_9 (41:46:60:7:0.1 NPKSB)	2821.8^{ab}	0.18
F_{10} (61.5:69:60:10.5:0.15 NPKSB)	2923.8^{a}	0.18
SEM (±)	113.1	0.01
LSD (0.05)	320	NS
CV (%)	13.6	18.2
Grand Mean	2502.8	0.2
variety* NPKSB Fertilizer Rates (LSD (0.05))	ns	ns

Table 5: Grain yield and harvest index as affected by blended NPKSB fertilizer rate and common bean varieties at Arba Minch during 2017 cropping season.

Maximum (2699.7 kg ha^{-1}) and minimum (2390.9 kg ha^{-1}) grain yield was obtained from variety Hawassa-Dume and Nasir, respectively (Table 5) suggesting their genetic difference in response to applied soil nutrients and environmental conditions. The significant difference among the varieties could also be associated with difference reported for yield components such as number of pods per plant, number of seeds per pod and hundred seed weight. Accordingly, high yielding cultivars Hawassa-Dume produced maximum number of pods per plant and number of seeds per pod compared to the low yielding cultivar Nasir and Red Wolayita. This result was in agreement with the finding of who observed that significant differences in grain yield among common bean varieties Awash Melka and Red Wolayita for different rate of NP fertilizer application [29]. Additionally, observed significant variations in grain yield of common bean varieties in response to Phosphorus fertilizer [28]. They obtained significantly maximum and lowest seed yield from variety Hawassa-Dume and Ibbado, respectively.

Grain yield increased from control (no fertilizer application) to the high dose of NPKSB fertilizer rates. Maximum grain yield (2923.8 kg ha^{-1}) was recorded when applying high rate of blended NPSBK fertilizer rate (61.5:69:10.5:0.15:60 kg NPKSB ha^{-1}), however, it was statistically on par with fertilizer rates F_7, F_9 and F_6. The minimum grain yield (1926.8 kg ha^{-1}) was obtained from control treatment (Table 5). The increase in grain yield in response to the increased blended NPKSB application rate might be due to the effect of macro and micro nutrients in blended fertilizers.

Applications of 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. All increasing level of potassium from nil to 60 kg K ha^{-1} rates resulted in positive influence on grain yield of common bean when compared with the same NPSB rate. However, significant grain yield differences were observed only in the application of potassium on the rate of 30 and 60 kg ha^{-1} along with 61.5:69:10.5:0.15 kg NPSB ha^{-1} when compared to the plot treated with the same NPSB without potassium. The result suggested demand for micro and macro nutrients in addition to NPK fertilizers commonly used for Arbaminch soils.

Mean values within columns followed by different letters are significantly different at $p<0.05$; NS denotes not significant at 5% level; GY denotes Grain yield, HI denotes harvest index.

Increase in grain yield with fertilizer application might be due to increased nutrient use efficiency by crop at optimum level of N, P and S was suggested by [26]. Maximum grain yield in common bean due to combine application of NPK was by [19]. Similarly, application of combined NP fertilizer significantly increased grain yield [29]. In addition, a study showed increased grain yields in response to the increasing the rate of P application in common beans fertilization was important to increase the grain yield of common beans also indicated by [17,42]. Furthermore, observed enhanced effect on seed yield due to application of B in common bean [36].

Harvest index: The analysis of variance showed that harvest index was significantly ($p<0.05$) affected due to common bean varieties. However, the ANOVA showed no significant effect of blended NPKSB fertilizer application rate and interaction between common bean varieties with blended NPKSB application rates.

Maximum harvest index (0.20) was recorded from Hawassa-Dume while the minimum harvest index (0.17) was recorded from Nasir (Table 5) which attributed to their genetic difference. The result suggested that the applied blended fertilizer leads to more vegetative growth than translocation of the sink in variety Nasir and Red Wolayita as compared to Hawassa-Dume that might have resulted in self-shading thereby reducing the yield. Significant difference in harvest index among varieties was documented by [28].

Conclusion

The study result indicated that nodulations, plant height, number of pods, seeds per pod, hundred seed weight, grain yield and harvest index were significantly ($p<0.05$) affected due to common bean varieties. The maximum total (129.8 cm) and effective (122.3 cm) nodules and plant height (124.6 cm) were recorded from bean variety Nasir, whereas the highest number pods per plant (28.9), seeds per pod (5.35), grain yield (2693.6 kg ha^{-1}), hundred seed weight (26.6 g) and harvest index(0.20) were recorded from bean variety Hawassa-Dume. The result clearly indicated that application of blended NPKSB fertilizer levels resulted better yield and yield components when compared to the control treatment. Significantly high nodulations, plant height, aboveground dry biomass, number of pods per plant, hundred seed weight and grain yield attained from blended fertilizer rate of 41:46:30:7:0.1 kg NPKSB ha^{-1}. Thus, blended fertilizer at rate of 41:46:30:7:0.1 kg NPKSB ha^{-1} and variety Hawassa-Dume is tentatively suggested to study area. However, additional research is needed in more season and location to come up with conclusive recommendation.

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