Academic Journal of Research and Scientific Publishing | Vol 2 | Issue 18
Publication Date: 5-10-2020 ISSN: 2706-6495

Effect of Blended NPS Fertilizer and *Rhizobium* Inoculation on Yield Components and Yield of Common Bean (*Phaseolus Vulgaris* L.) Varieties at Mekdela District, South Wollo, Ethiopia

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ABSTRACT

Low available phosphorus, total nitrogen, lack of adequate information on the use of Rhizobium inoculants and NPS fertilizer are the major yield limiting factors for common bean production in the study area. Thus, the experiment was conducted at Mekdela District in 2019 (July-October), to evaluate the effect of Blended NPS fertilizer rates and Rhizobium inoculation on the yield components and yield of common bean varieties. Factors studied were three common bean varieties (Red Wolaita, Hawassa Dume, Nasir), three levels of blended NPS fertilizer rate (0, 100, 200 kg ha-1) and two levels of Rhizobium inoculation (with and without). Randomized complete block design in factorial arrangement with three replication was used. Result showed varieties had significant differences on days to 50% flowering, days to 90% physiological maturity and plant height. The highest number of days to 50% flowering (42.89) and days to 90% physiological maturity (82.56) were recorded for variety Red Wolaita.

Similarly, NPS rates and Rhizobium inoculation had significant effect on days to 50% flowering and days to 90% physiological maturity. Significantly higher number of days to 50% flowering (42.59) was recorded from Rhizobium inoculation. The highest number of days to 90% physiological maturity (90.83) was recorded at blended NPS rate (200 kg ha-1). There was significant interaction effect of NPS rates with varieties on grain yield and effective nodules. Where, the highest effective nodules per plant (19.32) and grain yield (2373 kg ha-1) were recorded from NPS rate 100 kg ha-1 of for variety Nasir. The combined application of Rhizobium inoculation with NPS rates and varieties had significant effect on number of total nodules per plant and seeds per pod. Where, the highest number of total nodules per plant (68.53) and seeds per pod (7.5) were recorded from Rhizobium inoculation with NPS rate 100 kg ha-1and for variety Nasir. Based on the results of this study, it can be tentatively concluded that Rhizobium inoculation with application of NPS rate of 100 kg ha-1 found to be appropriate for common bean variety Nasir as well as for other varieties, where variety Nasir was superior of production in the study area.

Keywords: Bio-fertilizer, Biological nitrogen fixation, Hawasa Dume, Nasir, Red Wolaita

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is one of the most important grain legumes to provide the calorie and protein sources for human beings. Common bean protein content of 20-25% and carbohydrate of 50-56% makes it 2 to 3 times more nutritious compared to cereals. With most of varieties it is considered as short-season crop from emergence to physiological maturity it ranges 65-110 days (Buruchara, 2007).

In Ethiopia, common bean is one of the major grain legumes cultivated, with its production centered in small holder farm where the use of nitrogen (N) fertilizer is limited and average yields are low, usually less than 1 ton ha-1 (CSA, 2013). It is one of the fast expanding legume crops that provide an essential part of the daily diet and foreign earnings for most Ethiopians (Girma, 2009). The major common bean producing areas of Ethiopia are East Hararghe, West Wellega, East shewa, West Arsi, Sidama, Wolayita, Wollo and East Gojam (EIAR, 2014).

The main causes of low productivity at farmer fields are a poor technology level, utilization of low agricultural input and cropping in low fertility soils, especially with low N content (Beebe *et al.*, 2013). Soil factors such as nutrient deficiency like low soil nitrogen and phosphorus, and acidic soil conditions are important limitations for common bean production in most of the common bean growing areas (Graham *et al.,* 2003). In common bean, symbiotic N fixation rates, seed protein level and tolerance to phosphorus deficiency are low in comparison to other legumes (Broughton *et al.*, 2003).

In Ethiopia, inoculation is not new technology. However it is not widely used by the farmers but *Rhizobium* strains were selected and distributed to the farmers for six legumes crop, namely Faba bean, Chick pea, Common bean, Lentil, Soybean and Field pea. Inoculation significantly improved nodule number per plant as compared with uninoculated treatment; this is because of inoculated bacteria strain had good nodulation inducing capacity over the native soil *Rhizobium* population (Habtamu *et al.,* 2017). Inoculation of *Rhizobium* strain (BH-129) significantly increased hundred seed weight and seed yield ha^{-1} of common bean.

The maximum hundred seed weight (56.2 g) and seed yield (2416.1 kg ha^{-1}) were recorded from inoculation of common bean with *Rhazobium* strain BH-129 (Abera and Tadele, 2016). Similarly, Anteneh (2016) reported, the highest grain yield (3286.27 and 2951.36 kg ha-1) at Haramaya and Hirna, respectively, with inoculation of common bean with *Rhizobium* strain.

Currently, new blended fertilizer NPS (19% N, 38% P2O5 and 7% S) and bio-fertilizer are distributed to the growers in study area, but their rate of application is not experimentally determined for common bean.

Thus, this study was carried out with objective of evaluate the effect of blended NPS rates and *Rhizobium* inoculation on the nodulation, yield components and yield of common bean varieties

2. MATERIALS AND METHODS

2. 1. Description of the Study Area

The study was conducted in Northern high land Ethiopia, of Amhara Regional State, Mekdela district. The area is located at 11 29’ 59.99”N latitude and 38º 44' 59.99” E longitudes and an altitude of 2953masl. The study was conducted in 2019 crop season Mekdela district particularly in Genatit kebele. It is found in South Wollo zone of Amhara Regional State and 550 km away from Addis Ababa. The main agricultural activities are carried out mixed crop livestock production system is found in both high and low land areas of South Wollo zone. The highland mixed crop livestock production system is largely based on intensive cultivation of cereals, pulses, tubers, vegetables and same oil crops. According to Ethiopian agro-ecological classification the area is grouped under dega with the major soil type Vertisols and the most dominate land cover taken by cultivated land.

2.2. Experimental Materials

The experimental materials used for the study were common bean varieties (Hawassa Dume, Red Wolaita and Nasir). Blended NPS fertilizers (19% N, 38% P2O5 7% S) and *Rhizobium* strain (EAL-429) were used for the study.

Variety	**Altitude (m) range**	**Seed size**	**Seed colour**	**Days to maturity**	**Yield on station (t ha-1)**	**Yield on farm (t ha-1)**	**Year of release**
Hawassa Dume	1100-1750	Small	Dark red	85-90	3.017	1.97	2008
Nasir	1200-1800	Small	Red	86-88	2.0-3.2	2.3	2003
Red Wolaita	1400-2250	Small	Red	110	2.2-2.4	1.9	1974

Source: (MoARD, 2008)

2.3. Treatments and the Experimental Design

The experiment was done in a factorial combination of three varieties of common bean (Hawasa Dume, Nasir, Red Wolaita), three levels of blended NPS fertilizer (0, 100, 200 kg ha-1) and two levels of *Rhizobium* inoculation (with and without) by using randomized complete block design (RCBD) with three replications.

2.4. Experimental Procedures and Management

The land was ploughed by oxen. The soil cleared from all unwanted materials and plant residues, leveled and the field layout was prepared. The field was divided into three blocks and eighteen plots in each block. The row spacing was 40 cm and the spacing between plants was 10 cm. The sticker material (sugar solution) was prepared by mixing 10 g of sugar with 100 ml of water. The seed was evenly coated with the sticker. One packet of the inoculums (125 g) was mixed with 200 ml of water to make slurry. The seed required for plot was mixed in slurry so as to have uniform coating of the inoculums over the seeds and the seed was dried under shade for about 30 minutes (to avoid direct sun light). The shade dried seed was sown within 24 hr. One packet of the inoculum (125 g) was sufficient to treat 10 kg of seed as per the recommendation.

The common bean seed was obtained from the Melkassa Agricultural Research Center (MARC) and sown on July 29, 2019 after land prepared in depth of 5 cm.

Two seeds per hill were sown and thinned to one plant per hill after establishment throughout the plots. NPS was applied between two seeds at the time of sowing. All necessary agronomic managements were carried out properly starting from field preparation to harvesting uniformly.

2.5. Crop data collected

2.5.1 Phenological data

Days to 50% flower initiation: this was determined by counting the number of days from planting to the time when first flowers appeared in 50% of the plants in a plot by counting the number of plants.

Days to physiological maturity: it was determined as the number of days from planting to the time when 90% of the plants started senescence of leaves (yellowing of the foliage) and pods started to turn yellow. This was done by counting the number of plants.

2.5.2. Growth parameters

Number of total nodules per plant: bulk of the root of 10 randomly taken plants from destructive rows in each plot was carefully exposed at 50% flowering and uprooted for nodulation study. Roots were carefully washed using tap water on a sieve and nodules were separated and counted.

Plant height (cm): it was measured at physiological maturity from the base to the tip of a plant for randomly pre-tagged ten plants in harvestable rows using meter tape and averaged on a plant basis.

Number of primary branches per plant: it was determined by counting the total number of branches on randomly pre-tagged ten plants in the net plot at physiological maturity and averaged on per plant basis.

2.5.3. Yield components and yield

Number of pods per plant: it was recorded based on five pre-tagged plants in each net plot area at harvest and the average was taken as number of pods per plant.

Number of seeds per pod: the total number of seeds in the pods of five plants was counted and divided by the total number of pods to find the number of seeds per pod.

Hundred seed weight (g): The weight of 100 seeds was determined for each plot using a sensitive balance. The weight was adjusted to a moisture content of 10%.

Above ground dry biomass yield (kg ha^{-1}): At physiological maturity, five plants randomly taken from the destructive rows of each plot were used to determine aboveground dry biomass yield, which was measured after sun drying till a constant weight. The dry biomass per plant was then multiplied by the total number of plants per net plot and was converted into kg ha-1. This value was used to calculate the harvest index as well.

Grain yield (kg ha^{-1}): Grain yield was measured by harvesting and threshing of the crop from the net plot area. The moisture was adjusted to 10%.

Harvest Index (HI): Harvest index was calculated by dividing grain yield per plot by the total above ground dry biomass yield per plot.

2.6. Data analysis

Data collected were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Linear Model (GLM) procedure of SAS version 9.0 (SAS Institute, 2004) and interpretations were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the treatments were found significant, the means were compared using least significance difference (LSD) test at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1. Phenological Parameters of Common bean

3.1.1. Days to 50% flowering

Number of days to 50% flowering was highly significantly (P< 0.01) affected by the main effects of NPS application rate, varieties and *Rhizobium* inoculation. However, all the interaction effects were not significant on the trait.

Varieties Nasir and Hawassa Dume were early flowering which required 41.22 and 41.50 days than Red Wolaita which flowered on 42.89 days after planting (Table 2) which might be due to genetic differences as common bean has very high diversity in such phenological characters. In conformity to this result, Nchimbi-Msolla and Tryphone (2010) also reported significant differences in the number of days required to reach 50% flowering among 20 common bean genotypes that ranged from 26.67 to 45.

The application of NPS rate significantly influenced the days required to reach 50% flowering in common bean. Increasing NPS rate from 0 kg NPS ha-1 to 100 kg NPS ha-1 increased the number of days required to reach 50% flowering from 39.61 days to 44.11 days (Table 2). The increased rates of NPS supply might be attributed to the prolonged vegetative growth due to combined application of nitrogen with phosphorus and sulphur. Similarly, Tewari and Singh (2000) 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. The result was also in accordance with that of Nebret and Nigussie (2017) who reported when the nitrogen supply was increased from 0 to 46 kg N ha-1, the days to 50% flowering was prolonged significantly in common bean. Likewise, Habtamu *et al.* (2017) reported that, significantly longest days (45.86) to flowering due to application of 46 kg ha-1 of P2O5 and 41 kg ha-1of N.

Rhizobium inoculation significantly influenced the days required to reach 50% flowering in common bean. Inoculated treatment had taken relatively longer days (42.59) to reach 50% flowering than the un-inoculated treatment (41.15 days) to reach 50% flowering (Table 2).

The possible reason for delayed flowering with the *Rhizobium* inoculation might be due to the fact that inoculation enhanced nitrogen fixation and thereby increasing N uptake by plants contributed to improved vegetative growth of common bean thereby delayed flowering. In agreement with this result, such delayed days to flowering with inoculation was also reported for chickpea (Verma *et al.*, 2013).

3.1.2. Days to physiological maturity

Number of days to physiological maturity was highly significantly (P<0.01) affected by the main effects of NPS application rate, varieties and *Rhizobium* inoculation.

Varieties Nasir and Hawassa Dume were early maturing which required 78.56 and 80 days than Red Wolaita which matured on 82.56 days after planting (Table 2). This might be due to the genetic makeup difference among varieties of common bean on days to maturity. Generally, determinate cultivars mature earlier than indeterminate cultivars. Difference in days to reach maturity in common bean lines had also been reported by Kilasi (2010).

The application of NPS rate significantly influenced the days required to reach physiological maturity in common bean. Increasing NPS rate from 0 kg NPS ha-1 to 100 kg NPS ha-1 increased the number of days required to reach physiological maturity from 73.56 days to 76.72 days (Table 2).

Rhizobium inoculation also significantly delayed days to maturity (83.19 days) as compared to without inoculation (77.56 days) (Table 2) which might be due to extended vegetative growth because of nitrogen obtained from biological nitrogen fixation. In line with this result, Buttery *et al*. (1987) reported that inoculation delayed maturity time of white bean (*Phaseolus vulgaris*).

Table 2. Days to 50% flowering and 90% physiological maturity of common bean as influenced by *Rhizobium* inoculation, NPS rate and varieties.

Treatment	Days to 50% flowering	Days to 90% physiological maturity
Varieties		
Red Wolaita	42.89a	82.56a
Hawasa Dume	41.50b	80b
Nasir	41.22b	78.56c

LDS (0.05)	0.745	1.121
NPS rate (kg ha-1)		
0	39.61c	73.56c
100	44.11a	76.72b
200	41.89b	90.83a
LSD (0.05)	0.745	1.121
Inoculation		
With	42.59a	83.19a
Without	41.15b	77.56b
LSD (0.05)	0.608	0.916
CV (%)	2.6	2.1

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) = Least significant difference at 5%; and CV (%) =coefficient of variation

3.2. Growth Parameters of Common bean

3.2.1. Plant height (cm)

Analysis of variance showed that interaction effect of NPS rate with variety and the interaction effect of NPS rate with *Rhizobium* inoculation were highly significant ($P<0.01$) on plant height, while the other interaction effects and main effects were non-significant. The highest plant height (104.02 cm) and the lowest plant height (45.82) were observed at NPS rate of 100 kg ha-1 with variety Red Wolaita and NPS rate 0 kg ha-1 with variety Nasir respectively (Table 3).

The significant increase in plant height in response to combined application of NPS with *Rhizobium* inoculation might be ascribed to the increased availability of nitrogen in the soil for uptake by plant roots, which may have sufficiently enhanced vegetative growth through increasing cell division and elongation. In line with this result, Nebret and Nigussie (2017) reported that, increasing N level from 0 kg ha-1 to 23 kg ha-1 increased plant height of common bean at both Hirna and Haramaya.

Table 3. The interaction effect of varieties with NPS rate on plant height (cm) of common bean

NPS rate kg ha-1	Varieties		
	Red Wolaita	**Hawasa Dume**	**Nasir**
0	52.48g	47.35h	45.82h
100	104.02a	100.80b	97.53c
200	82.45d	80.08e	71.92f
LSD (0.05)		**2.028**	
CV (%)		**2.3**	

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV (%) =coefficient of variation

3.2.2. Number of primary branches per plant

The main effects of *Rhizobium* inoculation, NPS rate and varieties were highly significant ($P<0.01$) on the number of primary branches per plant, while the interaction effect was non-significant. The highest number of primary branches (4.956) was observed at 100 kg NPS ha-1 while the lowest number (2.961) was at no application of NPS (Table 4). The possible reason for the highest number of primary branches per plant at 100 kg NPS ha-1 might be due to that legumes require phosphorus for optimal symbiotic performance and there was close relationship between phosphorus level and symbiotic mechanism in legumes. Low primary branches at 200 kg NPS kg ha-1 rate compared to 100 kg NPS kg ha-1 might be due to nutrient imbalance and excess $SO4^{-2}$ interfere $PO4^{-3}$ uptake.

The increment in number of primary branches per plant might also be due to the importance of P in NPS fertilizer for cell division activity, leading to the increase of plant height and number of branches and consequently increased the plant dry weight and importance of S in NPS for growth and physiological functioning of plants.

Likewise, Habtamu *et al.* (2017) reported the maximum number of primary branches per plant (6.6) due to application of recommended rate of NP fertilizer (46 kg ha-1 of P_2O_5 and 41 kg ha^{-1} of N).

Table 4. Number of primary branches of common bean as influenced by the main effects of *Rhizobium* inoculation, NPS rate and varieties

Treatments	**Number of primary branches /plant**
Inoculation	
With	4.226a
Without	3.785b
LSD(0.05)	0.1906
NPS rate (kg ha-1)	
0	2.961c
100	4.956a
200	4.100b
LSD (0.05)	0.2334
Varieties	
Red Wolaita	3.744c
Hawasa Dume	4.017b
Nasir	4.256a
LSD (0.05)	0.2334
CV (%)	8.6

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance; LSD (0.05) =Least significant difference at 5%; and CV (%) =coefficient of variation

3.2.3. Nodulation

The main effect of *Rhizobium* inoculation, NPS rate, varieties, and the interaction effect of NPS rate with variety was highly significant (P<0.01) on total and effective numbers of nodules per plant.

The highest number of total nodules (68.53) was observed from the interaction effect of *Rhizobium* inoculation with NPS rate of 100 kg ha-1 for variety Nasir while variety Red Wolaita without inoculation at 0 kg NPS rate has produced the lowest number of total nodules (9.87) (Table 5). *Rhizobium* inoculation resulted in increased number of nodules per plant compared to un-inoculated treatment which could be due to the fact that inoculated bacteria strain had good nodulation inducing capacity over the native soil *Rhizobium* population, low native *Rhizobium* population in the soil, less competitive native *Rhizobium* against the inoculated.

Variety Nasir produced highest number of total and effect nodules than varieties Hawasa Dume and Red Wolaita indicating considerable variation in nodulation ability among the cultivars. Also this might be due to the presence of cultivar-*Rhizobium* specificity. In line with this result, Habtamu *et al.* (2017) reported the highest number of nodules per plant (15.3) for Variety Nasir. Likewise, Fatima *et al.* (2007) reported in soybean that nodule formation was more sensitive to phosphorus deficiency than plant growth and application of phosphorus improved nodulation parameters when compared with no phosphorous fertilizer.

Table 5. Number of total nodules per plant of common bean as influenced by the interaction of *Rhizobium* inoculation with NPS rates and varieties

		Varieties		
Inoculation	**NPS rate kg ha-1**	**Red Wolaita**	**Hawasa Dume**	**Nasir**
With	0	22.87m	25.00l	28.00k
	100	47.53e	62.20b	68.53a
	200	38.47h	40.07g	40.60g
Without	0	9.87o	15.87n	16.53n
	100	42.20f	51.17d	53.80c
	200	30.93j	36.10i	38.50h
LSD (0.05)			1.478	
CV (%)			2.4	

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV(%) =coefficient of variation

3.3. Yield Components and Yield of Common bean

3.3.1. Number of pods per plant

Main effects of *Rhizobium* inoculation, NPS rates and varieties were highly significant on numbers of pods per plant, while the interaction effect was non-significant.

Among the varieties, the highest number of pods per plant (13.70) was recorded for the variety Nasir while the lowest number of pods per plant was recorded for variety Red Wolaita (Table 6), which might be due to genetic differences associated with formation of number of branches and other sink that determines the yield of variety. In agreement with this result, Zewde (2016) obtained the highest mean number of pods per plant for variety 'Hawassa Dume' than varieties Red Wolaita and 'Omo-95'. Gebre-Egziabher *et al.* (2014) also reported significant differences among haricot bean varieties for number of pods per plant.

Table 6. Number of stand count of plant at harvest and number of pods per plant of common bean as influenced by the main effects of *Rhizobium* inoculation, NPS rate and varieties

Inoculation	**Pods per plant**
With	13.68a
Without	11.83b
LSD(0.05)	0.624
NPS fertilizer Rate	
0	8.17c
100	17.72a
200	12.38b
LSD (0.05)	0.764
Varieties	
Red Wolaita	11.68c
Hawasa Dume	12.88b
Nasir	13.70a

LSD (0.05)	0.764
CV (%)	8.8

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD(0.05) =Least significant difference at 5%; and CV(%) =coefficient of variation

3.3.2. Number of seeds per pod

The number of seeds per pod was significantly (P<0.01) affected by three way interaction of *Rhizobium* inoculation, NPS rates and varieties.

Significantly highest number of seeds per pod (7.5) was observed from the interaction effect of *Rhizobium* inoculation with NPS rate at 100 kg ha-1 and for variety Nasir while the lowest number of seeds per pod (5.4) was for variety Red Wolaita at NPS rate of 100 kg ha-1 without inoculation (Table 7).The increment of seeds per pod with increasing NPS fertilizer application up to optimum level might be adequate supply of nutrients in NPS fertilizer for nodule formation, protein synthesis, fruiting and seed formation. In line with this result, Meseret and Amin (2014) also reported the highest number of seeds per pod (5.85) at applied P rate of 20 kg ha-1. Similarly, Habtamu *et al.* (2017) reported relatively highest number of seeds per pod with the application of 46 kg ha-1 of P2O5 and 41 kg ha-1of N

Table 7. Number of seeds per pod per plant as influenced by the interaction of varieties, NPS rate and Rhizobium

	NPS rate kg ha-1	**Red Wolaita**	**Hawasa Dume**	**Nasir**
With	0	5.700h	5.733gh	5.833gh
	100	6.600d	7.233b	7.500a
	200	6.167f	6.333e	6.200ef
Without	0	5.400i	5.533i	5.733gh
	100	6.500d	6.833c	7.100b
	200	5.833gh	5.867g	6.167f
LSD	0.1354			
CV	1.3			

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV(%) =coefficient of variation

3.3.3. Hundred Seed Weight (g)

The main effect of NPS rate, *Rhizobium* inoculation and variety was highly significant, while the interaction effect was non-significant. Concerning the main effects of varieties, Nasir gave the highest 100 seed weight (28.71 g) followed by Hawasa Dume (27.77 g) while, Red Wolaita gave the lowest 100 seed weight (26.51 g) (Table 8). The variation in seed weight could be due to genetic difference as common bean has different seed size classes.

With respect to the effect of NPS fertilizer rate, the highest 100 seed weight (31.77 g) was at NPS rate of 100 kg ha-1 while the lowest 100 seed weight (23.54 g) was at 0 kg NPS ha-1 (Table 8). The possible reason for this might be that nitrogen improves grain or seed weights in crop plants and reduces grain sterility (Fageria *et al*, 2006).

In line with this result, Shamim and Naimat (1987) reported that the increment in 100 seed weight due to the influence of cell division, phosphorus content in the seeds as well as the formation of fat. Similarly, Amare *et al*. (2014) on common bean reported that the increasing doses of phosphorus from the control to 40 kg P2O5 ha-1 resulted in significant increment in 100 seed weight. In addition, Abdulkadir *et al*. (2014) 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. Nebret (2012) reported that increasing sulphur rate from 0 kg ha-1 to 20 kg ha-1 increased 100 seed weight from 35.7 g to 36.8 g. Also Ogutu *et al.* (2012) reported that increasing N rate from 0 kg ha-1 to 50 kg ha-1 increased 1000 seed weight from 301.19 g to 311.63 g.

The increased yield under sulphur application might be ascribed to increased pods/plant and grains pod along with heavier grains. Therefore, significant improvement in yield obtained under sulphur fertilization seems to result from increased concentration of sulphur 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 (Sharma and Singh, 2005).

Table 8. Hundred seed weight of common bean as influenced by the main effect of *Rhizobium* inoculation, NPS rates and varieties

Inoculation	**Hundred seed weight (g)**
With	28.76a
Without	26.57b
LSD (0.05)	0.601
NPS rate (kg ha-1)	
0	23.54c
100	31.77a
200	27.68b
LSD (0.05)	0.736
Varieties	
Red Wolaita	26.51c
Hawasa Dume	27.77b
Nasir	28.71a
LSD (0.05)	0.736
CV (%)	3.9

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD(0.05) =Least significant difference at 5%; and CV(%) =coefficient of variation

3.3.4. Above ground dry biomass (kg ha-1)

The main effect of *Rhizobium* inoculation, NPS rate and varieties and the interaction effect of

Rhizobium inoculation with NPS rate were highly significant on above ground dry biomass yield of common bean, while the other interaction effects were not significant.

With respect to the interaction effect, the highest above ground dry biomass (5006 kg ha-1) was observed from the combination of *Rhizobium* inoculation with NPS rate at 100 kg ha-1 and this was statistically at par with NPS rate of 100 kg ha-1 without inoculation (Table 9). In contrast, the lowest above ground dry biomass of 2526 kg ha-1 was at NPS rate of 100 kg ha-1 without inoculation.

This increment in dry matter yield with application of NPS fertilizer might be due to the adequate supply of N, P and S could have increased the number of branches per plant, and leaf area which in turn increased photosynthetic area and number of pods per plant thereby dry matter accumulation. Sulphur, being major nutrient, might have played an important physiological role by enhancing cell multiplication, elongation, expansion and chlorophyll biosynthesis which, in turn, increased the assimilate production (Dubey and Khan, 1993). Also nitrogen increases shoot dry matter, which is positively associated with grain yield in cereals and legumes (Fageria, 2008).

In agreement with this result, Veeresh (2003) reported that the dry matter production of common bean increased significantly with the application of different levels of nitrogen and phosphorus fertilizers. Likewise, Gifole *et al.* (2011) reported the highest total biomass (4597 kg ha-1) from the treatment with the application of 40 kg P ha-1. Also, Fazli *et al.* (2008) reported that lack of S limits the efficiency of added N; therefore, S addition becomes necessary to achieve maximum efficiency of applied nitrogenous fertilizer.

3.3.5. Grain yield (kg ha-1)

The main effects of *Rhizobium* inoculation, NPS rate and varieties and the interaction effect of *Rhizobium* inoculation with NPS rate and *Rhizobium* inoculation with varieties were highly significant ($P<0.01$) on grain yield of common bean, while the interaction effect of NPS rate with varieties was highly significant ($P<0.01$).The observed yield improvements with inoculation and varieties might be due to presence of variety-strain specificity between tested variety and strain used.

The highest grain yield (2257 kg ha-1) was obtained from interaction effect of *Rhizobium* inoculation with NPS rate of 100 kg ha-1 while the lowest grain (665 kg ha-1) was at no NPS application and without inoculation (Table 9).The observed yield improvements with inoculation and NPS application might be due to the increased N as result of atmospheric nitrogen fixation from effective strain and P and S availability by direct application.

Table 9. Above ground dry biomass and grain yield of common bean as influenced by the interaction effect of *Rhizobium* inoculation with NPS rate

Above ground dry biomass (kg ha				**Grain yield (kg ha-1)**		
		NPS rate (kg ha-1)			**NPS rate (kg ha-1)**	
Inoculation	0	100	200	0	100	200
With	3495d	5006a	4601b	1119e	2257a	1927b
Without	2526e	4959a	4275c	665f	2097b	1683d
LSD (0.05)		205.8			93.1	
CV (%)		4.2			6.0	

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV (%) =coefficient of variation

In line with this result, Fatima *et al.* (2007) reported that mixture of *Rhizobium* strains with phosphorus recorded higher seed yield of soybean over inoculant without phosphorus, and other researchers also reported that inoculation along with phosphorus fertilizer had a significant effect on nodulation, shoot dry matter and grain yield on mung bean (Rifat, 2008). Abera and Buraka (2016) also reported the maximum seed yield (2160 kg ha-1) of common bean from the application of the N rate (23 kg ha-1). Amare *et al*. (2014) also reported the maximum seed yield (2326 kg ha-1) of common bean with the application of P2O5 at rate of 20 kg ha. Similarly, Gifole *et al.* (2011) reported that, the highest grain yield (2547 kg ha-1) of common bean from the application of 40 kg P ha-1.

3.3.6. Harvest index (%)

Harvest index is useful in measuring nutrient partitioning in crop plants, which provides an indication of how efficiently the plant utilized acquired nutrients for grain production. So the highest harvest index also implies higher partitioning of dry matter into grain. The main effect of *Rhizobium* inoculation, NPS rate and varieties was highly significant on harvest index of common bean, while all the interaction effects were non-significant.

Regarding varieties, variety Nasir produced the highest harvest index (40.40%), which was statistically at par with variety Hawasa Dume (38.58%), While the lowest harvest index was recorded for variety Red Wolaita (34.57%) (Table 10). This might be due to genetic makeup of the varieties. In line with this result, Daniel *et al.* (2012) reported that the varieties Beshbesh (0.50) and Nasir (0.48) recorded highest harvest indices. Similarly, the highest HI (43.69%) was observed from the application of NPS rate of 100 kg ha-1 and with *Rhizobium* inoculation (39.67%) (Table 10).

The increased harvest index of common bean with inoculation and application of NPS fertlizer might be due to the fact that *Rhizobium* inoculation increased the number of effective nodules per plant and application of NPS increased hundred seed weight of common bean. Similarly, Roy *et al.* (1995) reported that grain inoculation increased the nodules number per plant and gave the highest harvest index and hundred grains weight of chickpea. Birhan (2006) also reported a significant increase of harvest index with the application of phosphorus on common bean.

Table 10. Harvest index of common bean as influenced by the main effect of *Rhizobium* inoculation, NPS rates and varieties

Inoculation	Harvest index (%)
With	39.67a
Without	36.03b
LSD (0.05)	1.503
NPS rate (kg ha-1)	
0	29.16c
100	43.69a
200	40.69b
LSD (0.05)	1.841
Varieties	
Red Wolaita	34.57b
Hawasa Dume	38.58a
Nasir	40.40a
LSD (0.05)	1.841
CV (%)	7.2

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD(0.05) =Least significant difference at 5%; and CV(%) =coefficient of variation

4. SUMMARY AND CONCLUSION

Low soil fertility status and reduced biological nitrogen fixation are some of the major constraints limiting common bean yield in the study area. Ensuring a well-balanced supply of blended NPS fertilizer and *Rhizobium* inoculation to the crop may result in higher seed yield. Limited research has been done on the effect of blended NPS fertilizer and *Rhizobium* inoculation on yield and yield components of common bean varieties. Therefore, field experiment was conducted to evaluate the effect of blended NPS rates and *Rhizobium* inoculation on the yield and yield components of common bean varieties and to identify economically appropriate combination of blended NPS and *Rhizobium* inoculation that provided maximum yield for the common bean varieties. Three levels of NPS rates (0, 100, 200 kg ha-1), three common bean varieties (Red Wolaita, Hawasa Dume and Nasir) and two levels of *Rhizobium* inoculation (with and without), were tested in factorial combination in three replications in Randomized Complete Block Design.

Results showed that the main effect due to NPS rates, *Rhizobium* inoculation and varieties significantly influenced days to 50% flowering, days to physiological maturity, plant height, number of primary branches, numbers of total nodules, numbers of effective nodules, number of pods per plant, number of seeds per pod, hundred seed weight, above ground dry biomass, grain yield and harvest index. Varieties Nasir and Hawassa Dume were early in flowering and maturity than variety Red Wolaita. Increasing NPS rate from 0 kg NPS ha-1 to 100 kg NPS ha-1 increased the number of days required to reach 50% flowering from 39.61 days to 44.11 days.

Increasing NPS rate from 0 to 100 kg NPS ha-1 increased the number of days required to reach physiological maturity from 73.56 days to 76.72 days. The highest number of primary branches (4.956) was observed at NPS rate (100 kg ha-1) and (4.256) was observed for variety Nasir, while the lowest number of primary branches (2.961) was observed at NPS rate of 0 kg ha-1 and 3.744 was observed for variety Red Wolaita. More number of pods per plant were recorded for the variety Nasir, application of *Rhizobium* inoculation and application of NPS rate of (100 kg ha-1). The highest hundred seed weights were recorded for variety Nasir (28.71), application of NPS rate of 100 kg ha-1 (31.77) and application of *Rhizobium* inoculation (28.76).

The highest harvest index (40.40%) was obtained for variety Nasir, (43.69%) from the application of NPS rate of 100 kg ha-1 and (39.67%) from the application of *Rhizobium* inoculation.

The interaction effect of *Rhizobium* inoculation and varieties significantly influenced grain yield and effective number of nodules of common bean. Significantly highest grain yield (1974 kg ha^{-1}) and effective nodule (16.41) were obtained from the combination of variety Nasir with *Rhizobium* inoculation. The interaction effect of *Rhizobium* inoculation with NPS rates and varieties significantly influenced total number of nodules and seeds per pod of common bean. Significantly highest number of total nodules (68.53) and seeds per pod (7.500) were obtained from combination of *Rhizobium* inoculation with NPS rate of 100 kg ha-1 and variety Nasir.

The economic analysis also showed the highest net returns (18695.3 ETB ha-1) from *Rhizobium* inoculation with NPS rate of 100 kg ha-1 for variety Nasir with marginal rate of return of 772.3% followed by variety Hawassa Dume with a net benefit of 17512.7 ETB ha-1 and marginal rate of return of 473.2%. Based on the results of this study, it can be concluded that NPS fertilizer rate of 100 kg ha-1 with *Rhizobium* inoculation gave highest agronomic yield as well as economic benefit for varieties Nasir and Hawassa Dume. However, the result of the present study need to be evaluated and reconfirmed with levels of NPS rates less than 200 kg ha^{-1} under different agro-ecologies in order to reach to a conclusive recommendation.

5. REFERENCES

Abdulkadir, M., Kevin, M. and Patrick, A.N. 2014. Effects of *rhizobium* inoculation and supplementation with P and K, on growth, leaf chlorophyll content and nitrogen fixation of bush bean varieties. *American Journal of Research Communication*, 2(10): 49-87.

Abera Habete and Tadele Buraka. 2016. Effect of *Rhizobium* inoculation and Nitrogen fertilization on nodulation and Yield response of common bean at Boloso Sore, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare*, 6 (13): 72-75.

Amare Girma, Assaye Demelash and Tuma Ayele. 2014. The response of haricot bean varieties to different rates of phosphorus at Arbaminch, Southern Ethiopia. *ARPN Journal of Agricultural and Biological Science*, 9 (10):344-350.

Anteneh Argaw.2016. Effectiveness of *Rhizobium* inoculation on common bean productivity as determined by inherent soil fertility status. *Journal of Crop Science and Biotechnology*, 19(4): 311- 322.

Beebe, S.E., Rao, I.M., Blair, M.W and Acosta Gallegos, J.A. 2013. Phenotyping common beans for adaptation to drought. *Frontiers in Plant Physiology*, 4:1–20

Birhan Abdulkadir. 2006. Response of haricot bean to nitrogen, phosphorus and inoculation of *Rhizobium leguminosarum* on yield and yield components at Melkassa", M.Sc. Thesis, University of Hawassa, Hwassa College of Agriculture, Ethiopia.

Broughton, W.J., Hernandez, G., Blair, M., Beebe, S., Gepts, P., Vander Leyden, J. 2003.Common beans model food legumes. *Plant Soil*, 252: 55–128.

Buruchara, R. 2007. Background information on Common beans in Biotechnology, Breeding & Seed systems for African Crops. Nairobi, Kenya: The Rockefeller Foundation.

Buttery, B., S. Park, and W. Findlay. 1987. Growth and yield of white bean (*Phaseolus vulgaris* L.) in response to nitrogen, phosphorus and potassium fertilizer and to inoculation with *Rhizobium*. *Canadian Journal of Plant Science*, 67 (2):425-432.

CSA (Central Statistical Agency). 2015. Area and production of major crops private peasant holdings, *Meher* season. Addis Ababa, Ethiopia. Available at http:// www.csa.gov.et Accessed on February, 2017.

Daniel Tadesse1, Teferi Alem, Tesfaye Wossen, Assefa Sintayehu. 2012. Evaluation of improved varieties of haricot bean in West Belessa, Northwest Ethiopia. *International Journal of Science and Research*, 3(12):2756-2759.

Dubey, O. P. and Khan, R. A. (1993). Effect of nitrogen and sulphur on dry matter, grain yield and N content at different growth stages of mustard under irrigated vertisol. *Indian JAgron.* **38:** 270-76.

Fageria, N. K., V. C. Baligar, and R. B. Clark. 2006. *Physiology of crop production*. New York: The Haworth Press.

Fageria, N. K. 2008. Yield physiology of dry bean. *J. Plant Nutr*. 31 (in press).

Fatima, Z., Zia, M. and Chaudhary, M.F. 2007. Interactive effect of *Rhizobium* strains and P phosphorus on soybean yield, nitrogen fixation and soil fertility. *Pakistan Journal of Botany*, 39(1):255-264.

Fazli, I.S., Jamal, A., Ahmad, S., Masoodi, M., J.S., Khan, J.S. and Abdin, M.Z. 2008. Interactive effect of sulphur and nitrogen on nitrogen accumulation and harvest in oilseed crops differing in nitrogen assimilation potential. *Plant Nutrition Journal*, 31: 1203-1220.

Gebre-Egziabher Murut, Hadush Tsehaye and Fetien Abay. 2014. Agronomic performance of some haricot bean varieties with and without phosphorus fertilizer under irrigated and rain fed conditions in the Tigray and Afar regional states, northern Ethiopia. *Momona Ethiopian Journal of Science*, 6(2):95-109.

Gifole Gidago, Sheleme Beyene, Walelign Worku. 2011. The response of haricot bean to phosphorus application on *Ultisols* at Areka, southern Ethiopia**.** *Journal of Biology, Agriculture and Healthcare*, 1(3): 38-49.

Habtamu Assefa, Berhanu Amsalu and Tamado Tana. 2017. Response of common bean (*Pharsalus vulgaris* L.) cultivars to combined application of *Rhizobium* and NP fertilizer at Melkassa, Central Ethiopia. *International Journal of Plant & Soil Science*, 14(1): 1-10.

Kilasi, N.L. 2010. Comparison of selection indices for tolerance to water stress in common bean (*Phaseolus vulgaris* L.) for the dry environment of Tanzania. MSc thesis. University of Zambia.

Meseret Turuko and Amin Mohamed. 2014. Effect of different phosphorus fertilizer rates on growth, dry matter yield and yield components of common bean (*Phaseolus vulgaris* L.). *World Journal of Agricultural Research*, 2(3): 88-92.

Nchimbi-Msolla, S. and Tryphone, G.M. 2010. The effect of the environment on iron and zinc concentrations and performance of common bean genotypes. *Asian Journal of Plant Science*, 9:455-462.

Nebret Tadesse and Nigussie dachassa. 2017. Effect of Nitrogen and Sulphur Application on Yield Components and Yield of Common Bean (*Phaseolus Vulgaris* L.) in Eastern Ethiopia. *Acad. Res. J. Agri. Sci. Res*. 5(2): 77-89.

Ogutu, M.O., Muasya, R. and Quma, G. 2012. Effects of nitrogen fertilizer applications in a bean maize based intercropping systems and locations on seed quality of common bean in western Kenya. *International Research Journal of Agricultural Science and Soil Science*, 2(11):481-492.

Rifat, H., Ali, S., Siddique, M.T., and Chatha, T.H. 2008. Biological nitrogen fixation of summer legumes and their residual effects on subsequent rain fed wheat yield. *Pakistan Journal of Botany* 40(2): 711 – 722.

Roy, S. K., S.M.L. Rahaman and A.B.M. Salahuddin. 1995. Effect of *Rhizobium* inoculums and nitrogen on nodulation, growth and grains yield of gram (*Cicer arietinum* L.). *Indian Journal of Agronomy*, 65(12): 853-857.

Shamim M. and Naimat, A. 1987. Effect of seed inoculation with *Rhizobium* and N.P. fertlizers on the yield of gram. *Pakistan Journal of Agricultural Research*, 8: 383-385.

Sharma, O.P. and Singh, G.D. 2005. Effect of sulphur in conjunction with growth substance on productivity of cluster bean (*Cyamopsis tetragonoloba*) and their residual effect on barley. *Indian Agronomy Journal*, 50(1): 16-18.

Tewari, J.K. and Singh, S.S. (2000). Effect of nitrogen and phosphorus on the growth and seed yield of french bean (*Phaseolus vulgaris* L.). *Journal of Vegetable Science*, 27: 172-175.

Veeresh, N.K. 2003. Response of French bean (*Phaseolus vulgaris* L.) to fertilizer levels in northern transitional Zone of Karnataka. An MSc. Thesis Presented to the Dharwad University of Agricultural Sciences, India. 37-79p.

Verma, J.P., Yadav, J., Tiwari, K.N. and Kumar A. 2013. Effect of indigenous *Mesorhizobium spp*. and plant growth promoting rhizobacteria on yields and nutrients uptake of chickpea (*Cicer arietinum* L.) under sustainable agriculture. *Eco. Engin.* 51:282-286.

Zewde Paulos. 2016. Effect of phosphorous rates on yield and yield related traits of common bean Varieties on Nitisols at Wolaita Sodo, southern Ethiopia. A Thesis Submitted to the School of Plant Sciences, Haramaya University, Ethiopia.