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Research Article

Effect of NPS Rate and *Rhizobium* Inoculation on Yield and Yield Components of Common Bean (*Phaseolus vulgari* L.) at Kellem Wollega Zone, Western Oromia, Ethiopia

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Abstract

Common bean (Phaseolus vulgaris L.) is one of the most important and widely cultivated pulse crops in most developing countries. However, its cultivation is constrained mainly by low soil fertility and lack of improved agronomic practices. The experiment was conducted to evaluate the effects of Rhizobium inoculation, NPS fertilizer rate, and their interaction effect on grain yield and yield components of common bean and to recommend the appropriate combination that can maximize the productivities of common bean in the study areas. Six levels of NPS rates (0, 50, 75, 100, 125 and 150 kg ha^{-1}) and three levels of Rhizobium strains (un-inoculated, BH429 and BH-A-15) were laid out in Randomized Complete Block Design with three replications in factorial arrangement. The collected data were analyzed by SAS software. Main effect of rhizobium strain exerted significant effect on effective branch/plant, however, NPS levels significantly influenced days to 50% flowering, days to 90% maturity, nodule/plant, effective branch/plant, pod/plant and grain yield. The main effect of experimental location imposed significant effect on most of agronomic parameters including pod/plant and grain yield. Significantly higher mean grain yield was recorded at Haro Sabu Agricultural Research Center and Igu experimental locations compared to Sago, which had the lower mean value of grain yield. Application of NPS rate with rhizobium strain affected number of effective branch/planr, while the interaction of NPS rate with location influenced number of days to 90% maturity, effective branch/plant, pod/plant, seed/pod and grain yield. Significantly higher mean grain yield was obtained by applying 100, 125 and 150 Kg/ha of NPS at Haro Sabu Agricultural Research Center and Igu, by applying 125 and 150 Kg/ha of NPS at Sago. Based on partial budget analysis the highest net benefit (Birr 31792.34 ha^{-1}) was obtained from combined application of 100 kg blended NPS ha^{-1} with un-inoculated strain which had 811% marginal rate of return. Hence, application of 100 kg NPS ha^{-1} without inoculation of the strain was recommended for common bean productivity enhancement in the study area.

Keywords

Grain Yield, NPS, Common Bean, Strain

1. Introduction

Common bean (*Phaseolus vulgaris* L.) is the third most important food legume, fodder and cover crops worldwide next to soybean and peanut [1, 2]. Nutritionally, common bean grains are rich in protein, carbohydrates, oil, fiber and

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sucrose [3, 4]. This crop also an important for economic and environmental benefit due to their association with nitrogen-fixing bacteria by contributing in sustainable agriculture [5]. The ability of the fixing nitrogen (N) has raised the crop's importance in terms of boosting soil fertility. The crops is suited for different cropping systems including crop rotation, intercropping, double cropping, relay cropping and mixed cropping with cereals [6]. Farmers prefer the crop due to its fast maturing which allows households to earn additional cash income as a result of the possibility for double cropping [7].

Globally common beans production was 57,496,465 tons produced on 38,229,984 hectares [8]. Recently, it is one of the most widely cultivated and most economically important food crops in Ethiopia [9]. The majority of produced common beans were used for household consumption followed by sale, seed and feed and in-kind payment for wage. In Ethiopia, it was cultivated on about 281,083.49 hectares of land from white and red common bean, producing 4, 85,547.093 tons with the productivity of 1.73 tons ha^{-1} [10]. The average yield of this crop is (1.48 tons) which is significantly less than the yield that most improved varieties can achieve under good management conditions (2.5–3.0 tons ha^{-1}).

The lowering yield might due to poor agronomic techniques, such as insufficient soil fertility management [11, 12] lack of superior varieties for the different agro-ecological zones, and untimely and inappropriate field operations, could be the major contributing factors for low yield of the crop in Ethiopia [13] particularly in Western and Kellem Wollega Zones Oromia [14, 15]. Among the limiting factors are edaphic and environmental factors that constrain bean production in most areas where the crop is grown include nitrogen and phosphorus deficiency, soil acidity that constraints bean production [16]. Compared to the inorganic fertilizers, the use of bio-fertilizers is economical, eco-friendly, more efficient, productive and accessible to marginal and small holder farmers [17]. In Ethiopia, however, bio-fertilizer is new technology and not widely used by the farmer but inoculants were selected and distributed to the farmers in few areas of the country. In comparison to other legume crops, common bean is widely recognized as a low N_2 fixer [18]. However, the response of common beans to inoculation can vary with legume genotypes and rhizobium strains [19] environment [20] and their interactions [21]. Inoculations of legume crop with rhizobium strain certainly improve growth, nitrogen fixation, and enhance the yield potential in legumes.

Recently, some research conducted on inoculated common bean varieties under field conditions reported enhanced growth and yield [22-24]. To present, no research has been undertaken on the response of common bean variety to NPS fertilizer rates and their combination with Rhizobium strains in western Oromia. Therefore, the study was initiated with the objectives to evaluate the effects of rhizobium inoculation and NPS fertilizer on yield and yield components of common bean and to recommend the appropriate rate of NPS fertilizer in combination with effective Rhizobium strains that can maximize the productivities of common bean in the study areas.

2. Materials and Methods

2.1. Description of the Study Area

The study was executed at HaroSabu, Igu (SadiChanka district), Sago (Lalo Kile district) of Kellem Wollega zone during 2020 and 2021 cropping season. Experimental locations were based on common bean potential for production. Description of the study area was presented in table 1. The soil type of the area is Nitisols which is characteristically reddish brown and soil textural class which is sandy loam with a pH that falls in the range of moderate acidic According to Horneck soil classification rating [25].

Table 1. *Description of study area, initial soil physical and chemical characteristics (0–20 cm).*

Soil parameters	Value		
	HSARC	Igu	Sago
Altitude	1558	1449	1629
Latitude	N-08⁰52’40.904”	N-08⁰48’11.841”	08⁰55’28.797”
Longitude	E-035⁰13’56.039”	E-035⁰03’03.524”	E-035⁰18’30.689”
pH (H20)	5.9	5.6	5.4
Total N	0.252	0.224	0.238
Available posphrus (ppm) or mg/kg of soil	1.12	1	0.7
Exchangeable acidity	0.32	0.32	1.44

Soil parameters	Value		
	HSARC	Igu	Sago
Exchangeable Ca (meq/100 giram soil)	19.75	18.5	8.5
Exchangeable Mg (meq/100 giram soil)	3.25	3.0	9.5
Exchangeable Na (cmol/kg of soil)	0.217	0.196	0.13
Exchangeable K (cmol/kg of soil)	0.716	0.309	0.473
CEC (meq/100 giram soil)	16.9	22.7	17.7
Organic C	4.388	4.258	3.413
Soil texture	Clay loam	Clay	Clay

Source: Bedele Soil Research Center (BeARC), 2020

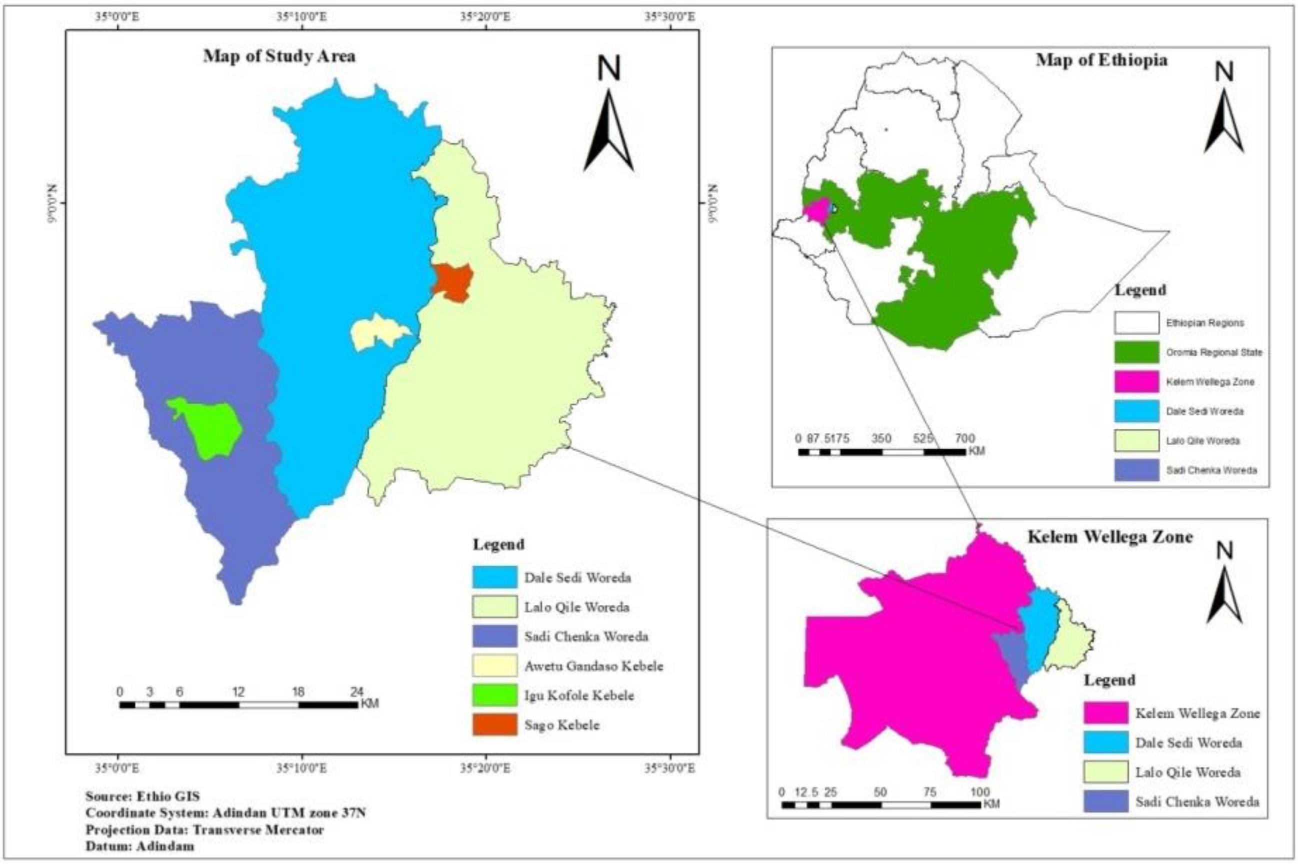

Figure 1. Map of the study area.

Similarly, the area has a warm humid climate with annual mean minimum and maximum temperatures of 14.860C and 29.6430C, respectively and it receives annual rainfall of (1996.72 mm) mainly from May to October with maximum precipitation in the month of July with rain fall mean (166.39 mm) (Figure 2).

The study area is located at mid to high land agro-ecological zone and encompassed by abundant natural vegetation. The agro climatic condition is known for its mixed crop- livestock farming system in which cultivation from cereals maize (*Zea mays* L), Sorghum (*Sorghum bicolor* L. *Moench*), tef (*Eragrostis tef Zucc),* from pulse and oil crops, soybean (*Glycine max* (L.), common bean (*Phaseolus vulgaris* L.), from spices and coffee, (*Coffea arabica* L), hot pepper (*Capsicum annuum* L.), from horticulture banana (*Mussa spp*), and the others crops are the major crops.

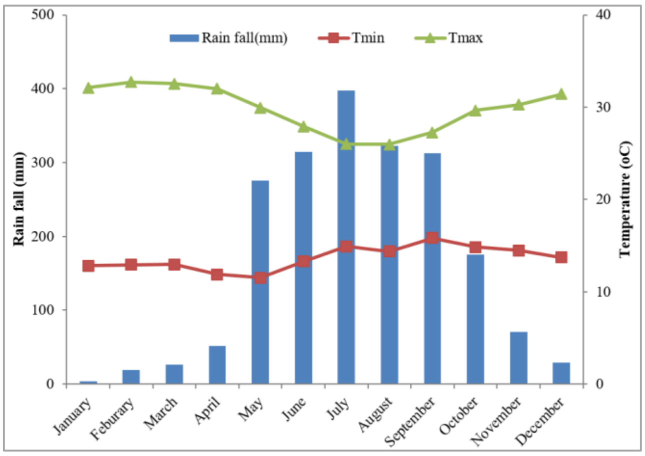

Figure 2. *Annual men Rainfall and Temperature (Tmin and Tmax) of HSARC.*

Y-axis =Rainfall, X axis = Months of the year. Source: Ethiopian Meteorology

2.2. Experimental Materials

Newly released common bean variety (Haro Sabu-1) was used. The variety was released by Haro Sabu Agricultural Research Center (HSARC) during 2020. Haro Sabu-1 variety has an indeterminate growth habit and red seed color. The yield potential of Haro Sabu-1 variety was 20.1-21.17 and 17.92-18.65 Q/ha on research and farmers field, respectively. NPS fertilizer was obtained from Haro Sabu Agricultural Research Center. Rhizobium strains namely, BH429 and BH-A-15 were obtained from Holeta Agricultural Research Center, Soil Microbiology Laboratory (HARC)

2.3. Treatments and Experimental Design

Treatments were comprised of two factors, namely; three levels of Rhizobium strains (un-inoculated, BH429 and BH-A-15) and six levels of NPS rates (0, 50, 75, 100, 125 and 150 kg ha^{-1}). The treatment was arranged as 3 x 6 in factorial combinations in RCBD with three replications. Eighteen (18) treatment combinations were used. The gross plot comprised of six rows of 3 m length (6×0.4 m $\times$ 3 m = 7.2 m^2) and the central four rows (4×0.4 m $\times$ 3 m = 4.8 m^2) were used for data collection as net plot.

2.4. Experimental Procedures

The experimental land was cleared and ploughed by tractor, disked and leveled by hands. Lime was applied and thoroughly mixed a month before plantation based on composite soil sample results, and field layout was arranged. Carrier based inoculants of each strain was applied at the rate of 10 g inoculants per kg of seed [26]. The inoculants were mixed by sugar with the addition of some water in order to facilitate the adhesion of the strain on the seed. To ensure that the applied inoculants stick to the seed, the required quantities of inoculants were suspended in 1:1 ratio in 10% sugar solution. The thick slurry of the inoculants was gently mixed with the dry seeds so that all the seeds received a thin coating of the inoculants.

To maintain the viability of the cells, inoculation was done under the shade and allowed to air dry for 30 minutes and sown at the recommended spacing. Seeds were immediately covered with soil after sowing to avoid death of cells due to the sun's radiation. A plot with un-inoculated seeds was planted first to avoid contamination. The seeds were planted at spacing of 40 cm and 10 cm between rows and within rows, respectively. The spacing between blocks and plots were 1.5 m and 1 m, respectively. Two seeds were sown per hill and then thinned to one plant after seedling establishment. All other management practices were done as per the recommendations.

2.5. Data Collection

Major crop data collected during experimentation include; days to flowering, days to maturity, stand count at harvesting, plant height at harvesting, number of effective branch/pod, number of seed/pod, nodule number, hundred seed weight and harvesting index following procedures developed in common bean descriptor. Soil data were collected from at the depth of 20 cm from each experimental plot following the procedures developed for this purposes. The collected soil data were submitted to soil laboratory for further analysis of important soil physico-chemical characters analysis.

2.6. Data Analysis

The collected data were subjected to analysis of variance (ANOVA) which fit factorial experiment in randomized complete block design (RCBD) according to the General Linear Model (GLM) procedures of SAS version 9.0. Results were interpreted following the procedures developed by [27]. Based on the significance detected from ANOVA, treatment means were compared by deploying Least Significant Difference (LSD) at 5% probability test.

2.7. Partial Budget Analysis

The economically acceptable treatment(s) were determined by partial budget analysis to estimate the gross value of the grain yield by using the adjusted yield [28] at the market value of the grain and inputs during the cropping period. Only total variable costs that varied (TCV) were used to compute costs. Current prices of common bean, inoculants, NPS fertilizer and application cost of inoculants and NPS fertilizer were considered as variable with their cost.

To estimate economic parameters, common bean yield was valued at an average open market price of 30 Birr/kg. Cost of land preparation, field management, harvest, transportation and storage were not included in the analysis as they were not variable. To equate the common bean grain yield with what a farmer would get, the obtained yield was adjusted downward by 10%. Both the costs and benefits were converted to monetary values in Ethiopian Birr (ETB) and reported per hectare. Treatments net benefits (NB) and Total variable cost (TCV) were compared using dominance analysis following the two steps described below. The first step was calculation of the NB as shown in the formula below as suggested by CIMMYT [28];

$$NB = (GY \times P) - TCV$$

where GY x P = Gross Field Benefit (GFB), GY = Adjusted Grain yield per hectare and P = Field price per unit of the crop.

Secondly, treatments TCV were listed in increasing order in accordance with dominance analysis. All treatments which had NB less than or equal to treatment with lower TCV were marked with a letter "D" since they were dominated and eliminated from any further analysis. Un-dominated treatments were subjected to Marginal Rate of Return (MRR) analysis [28] in stepwise manner, moving from lower TCV to the next as shown below:

$$MRR\ (\%) = \frac{\text{Change in NB (NBb} - \text{NBa)}}{\text{Change in TCV (TCVb} - \text{TCVa)}} \times 100$$

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest TCV.

For investments that require change in the use of technology, minimum rate of return of ≥ 100% is acceptable to farmers (CIMMYT, 1988). Marginal Rate of Return, which refers to net income obtained by incurring a unit cost of inoculants and NPS fertilizer were calculated by dividing the net increase in yield of common bean due to application of each rate to the total cost of inoculants and NPS fertilizer applied at each rate. This enables to compare the economic feasibility of the treatments used.

3. Results and Discussion

3.1. Analysis of Variance

Analysis of variance showed significant main effect of NPS rate on all agronomic parameters except for days to 50% flowering, harvesting index and hundred seed weight. Rhizobium strain significantly affected days to 90% maturity only, while the experimental location significantly influenced all parameters excluding seed/pod and harvesting index (Table 2). Interaction of NPS*Location imposed significant effect on days to 90% maturity, effective branch/plant, pod/plant and seed/pod (Table 2). Location*Year exerted significant effect on days to 50% flowering, nodule/plant, plant height, harvesting index, hundred seed weight and grain yield (Table 2).

Table 2. *Analysis of variance for grain yield and yield components of common bean.*

Source of variation	**DF**	**DFG**	**DM**	**NN**	**PH**	**EBPP**
NPS	5.00	1.54	14.88**	1982.92*	2655.94**	16.46**
Strain	2.00	5.68	7.10*	987.61	474.64	5.26
Rep	2.00	17.69	5.33*	11504.25*	76.02	14.31
Location	2.00	117.44**	1221.82**	152211.55**	3098.01**	116.76**
Year	1.00	37.35**	11.48**	841.64	67964.49**	22.09*
NPS*Strain	10.00	1.75	1.41	735.48	298.68	10.14
NPS*location	4.00	1.35	15.03**	763.86	528.20	9.81*
NPS*Year	5.00	1.04	0.68	616.66	709.74	1.72
Strain*Location	4.00	0.97	3.00	431.74	318.31	4.17
Strain*Year	2.00	0.06	1.43	435.99	343.67	1.25
Location*Year	2.00	125.38**	4.28	19892.39**	3397.44*	4.77
NPS*Strain*Location*Year	64.00	0.65	1.26	651.01	392.20	3.46
Error		3.13	1.47	1617.09	433.35	4.04
Source of variation	DF	PPP	SPP	GY	HI	HSW
NPS	5.00	73.91**	1.27*	2341538.61**	2209.26**	1.79

Source of variation	DF	DFG	DM	NN	PH	EBPP
Strain	2.00	3.00	0.95	40916.91	1574.60	1.23
Rep	2.00	29.59**	0.46	380819.80*	2209.57	4.48*
Location	2.00	138.41**	0.34	131762.44*	471.25	65.71**
Year	1.00	4266.27**	24.39**	28075515.20**	367.89	12.56*
NPS*Strain	10.00	2406.99	8.70	0.39	0.63	53357.82
NPS*Location	4.00	2213.34*	12.54*	0.25*	1.11	77527.93
NPS*Year	5.00	6.85	10.61*	0.37	2.92*	145996.73*
Strain*Location	4.00	1959.08	5.66	0.30	0.35	38378.06
Strain*Year	2.00	3.02	2.07	0.03	0.51	9243.28
Location*Year	2.00	1549.88	23.88*	10.95**	10.89**	797823.23**
NPS*Strain*Location*Year	64.00	671.47	5.05	0.55	0.92	31395.04
Error		1158.23	4.79	0.53	0.91	43167.79

DF-=degree of freedom, DFG= days to 50% flowering, DM= days to 90% phsilogical maturity, NN=number of nodule per plan, PH=plant height (cm), EBPP=effective branch perplant

3.2. Phenological Parameters

Days to 90% maturity (DM): Main effect of NPS rate and rhizobium strain exerted significant effect on days to 90% maturity (Table 2). Significantly higher mean (DM) was recorded by applying 150 and 125 Kg/ha. Inversely, utilization of NPS at the rate of 0 and 50 Kg/ha showed significantly lower days to 90% maturity (Table 3). Increasing NPS rate from 0 to 150 kg/ha prolonged the number of days required to reach 90% maturity. The result also manifested that decreasing the rate from 150-0 kg/ha significantly contributed to earlier maturity (Table 3). Application of BH-A-15 gave significantly longer (DM) compared to BH429 (Table 3). The possible reason for delayed maturity with BH-A-15 rhizobium inoculation might be due to inoculation enhanced nitrogen fixation and thereby increasing N uptake by plants which elongated the vegetative growth of common bean and delayed maturity. The finding of present study was in agreement with Deresa [29], who reported significant NPS fertilizer rate on phonological parameters of common bean. Additionally, earlier researchers [30, 31] reported the prolonged phonological traits with rhizobium inoculation in common bean.

Table 3. *Main effect of rhizobium strains and NPS on days to flowering, days to maturity, nodule/plant, plant height, effective branch/plant.*

Treatment	Days to flowering	Days to maturity	Nodule/plant	Plant height	Effective branch/plant
Inoculation					
Un-inoculated	40.03a	88.06ab	72.39a	44.19a	4.67a
BH-A-15	39.69a	88.26a	78.22a	43.63a	5.02a
BH429	40.12a	87.75b	73.89a	47.51a	4.61a
LSD (0.05)	NS	*	NS	NS	NS
NPS rate (kg ha^{-1})					
0	39.85a	87.48c	65.17b	33.42c	4.21c
50	40.09a	87.37c	73.76ab	42.24b	4.37bc
75	39.76a	88.11b	80.17ab	44.23b	4.63bc
100	40.15a	88.02b	82.27a	53.88a	5.75a

Treatment	Days to flowering	Days to maturity	Nodule/plant	Plant height	Effective branch/plant
125	40.04a	88.43ab	75.12ab	49.14ab	4.64bc
150	39.78a	88.72a	72.56ab	47.76ab	5.01ab
LSD	NS	*	*	*	**

3.3. Grain Yield and Yield Components

Nodule number/plant (NNP): NPS rate significantly influenced number of nodule/plant (Table 2). Significantly higher and lower mean of (NNP) was recorded from 100 and 0 Kg/ha of NPS, respectively (Table 3). This result was in accordance with the study of Nuru *et al.* (2020), who reported significant NPS fertilizer effect on common bean nodulation.

Plant height (PH): Experimental location and NPS fertilizer rate imposed significant effect on plant height (Table 2). Application of 100 Kg/ha of NPS fertilizer rate resulted into the maximum PH, and conversely, unfertilized treatment (0 Kg/ha of NPS) showed lowest mean of PH (Table 3). Conversely, Non-significant main effect of NPS and interaction effect of NPS with variety on plant height of common bean was reported by Deressa [29], which was most probably in line with the present study.

Number of effective branch/plant (EBPP): EBPP was significantly affected by the main effect of NPS fertilizer rate and interaction of rhizobium*NPS fertilizer rate (Table 2). Hence, the application of 100 kg/ha of NPS resulted into the higher mean effective branch/plant, while unfertilized treatment revealed significantly lower mean of EBPP (Table 3). Significantly higher (EBPP) was recorded from combined effect of BH-A-15 strain with 100 kg/ha of NPS fertilizer, however, significantly lower (EBPP) was recorded from combined effect of BH-A-15 with 0 kg/ha (Table 4).

Table 4. *Interaction effect of Rhizobium strain*NPS rate on number of effective branch/plant.*

Rhizobium strain	NPS Rates (kg ha^{-1})					
	0	50	75	100	125	150
Un-inoculated	4.22bc	4.43bc	4.74bc	5.01b	4.48bc	5.03b
BH-A-15	3.72c	4.53bc	4.47bc	7.64a	4.67bc	5.09b
BH429	4.69bc	4.13bc	4.69bc	4.51bc	4.77bc	4.9bc

Harvesting Index (HI %): Main effect of NPS fertilizer rate exerted highly significant effect on harvesting index (Table 2). 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 [30]. Presently, significantly higher mean of harvesting index (HI) was computed by applying 125 kg/ha of NPS, whereas the significantly lowest (HI) was recorded from Zero and 50 kg/ha of NPS fertilizer rate (Table 5).

Table 5. *Main effect of rhizobium strains and NPS fertilizer rates on harvesting index, pod/plant, seed/pod, hundred seed weight and grain yield.*

Treatment	Harvesting index	Pod/plant	Seed/pod	Grain yield
Inoculation				
Un-inoculated	46.50a	9.69a	4.65a	978.99a
BH-A-15	53.19a	9.41a	4.63a	962.53a
BH429	46.65a	9.71a	4.47a	940.21a

Treatment	Harvesting index	Pod/plant	Seed/pod	Grain yield
LSD (0.05)	NS	NS	NS	NS
NPS rate (kg ha^{-1})				
0	7.66d	7.66d	4.4b	585.78d
50	8.81c	8.81c	4.41b	901.64c
75	9.83b	9.83b	4.7a	959.39bc
100	10.18ab	10.18ab	4.64ab	1024.71b
125	10.87a	10.87a	4.78a	1146.71a
150	10.28ab	10.28ab	4.56ab	1145.24a
LSD (0.05)	**	**	*	**
CV (%)	19.77	22.77	15.94	21.63

Number of pod/plant (PPP): Main effect of NPS fertlizer rate, experimental location, and the interaction effect of NPS fertilizer rate *Location significantly (p<0.01) influenced pod/plant (Table 2). Significantly highest and lowest mean (PPP) was observed from applying 125 and 0 Kg/ha of NPS fertilizer, respectively. Maximum pod/ plant were recorded from 100, 125 and 150 Kg/ha of NPS fertilizer (Table 5). Regarding experimental location, significantly higher mean pod/plant was obtained at Haro Sabu Research Center followed by Igu location, while Sago location had the least pod/plant (Table 6). Earlier scientists; [31] reported significant effect of P application on number of pod loading relative to unfertilized plot of common bean which was in line with present study. As interaction effect is concerned; significantly higher mean pod/plant was obtained due to 125 kg/ha of NPS fertilizer rate at HSARC, due to 100 and 125 kg/ha of NPS fertilizer at Igu and due to 75 kg/ha NPS at Sago (Table 7).

Table 6. *Main effect of location on pod/plant and grain yield of Common bean.*

Location	Pod/plant	Grain yield
HaroSabu	10.45a	986.78a
Igu	10.05a	974.03ab
Sago	8.32b	920.92b
LSD	0.59	55.73

Conversely, significantly lower mean PPP was recorded by applying 0 kg/ha of NPS fertilizer across the three locations, indicating some differential response of pod loading due to NPS fertilizer levels across experimental location (Table 7).

Number of seed/plant (SPP): Analysis of variance showed significant difference between NPS fertilizer rate for number of seed per pod (Table 2). Significantly highest mean (SPP) was obtained by applying 75 and 125 Kg/ha of NPS fertilizer rate, whereas applying 0 and 50 Kg/ha of NPS fertilizer resulted into significantly lower mean SPP (Table 5). This finding disagree with Nuru *et al.* (2020), who reported significantly higher mean (SPP) with application of 100 Kg/ha of NPS fertilizer, while the result supported the finding of [32] who reported that number of seeds per pod was significantly (P<0.05) influenced by the interaction of common bean variety and P fertilizer rate.

Grain Yield (GY): The main effect of NPS fertilizer, experimental location, and the interaction of NPS*Location significantly (p<0.01 or p<0.05) influenced grain yield (Table 2). Significantly lower mean grain yield was obtained from 0 and 50 Kg/ha of NPS. Conversely, significantly higher mean grain yield was recorded by applying 125 and 150 Kg/ha of NPS (Table 5).

The variability of experimental location is most probably attributed either by soil fertility or potential difference for optimum bean production. With this, HSARC followed by Igu location showed significantly higher mean grain yield compared to Sago location which had poor grain yield (Table 6). This further indicates the higher yield potential of HSARC and Igu experimental locations. For interaction effect, significantly higher grain yield was found by applying 125 and 150 Kg/ha of NPS at HSARC and Igu locations consistently, and by applying 150 Kg/ha of NPS fertilizer at Sago.

On the contrary, significantly lower mean grain yield was recorded due to 0 and 50 Kg/ha of NPS at HSARC and Igu locations, and due to 0, 50 and 75 Kg/ha of NPS fertilizer at Sago location (Table 7). The final recommendation of NPS fertilizer rate of this finding depends on partial budget analysis. In accordance with this study, [28] reported significant effect of P application on grain yield of common bean compared to unfertilized plots in their study.

*Table 7. Interaction effect of NPS rate*Location on number of pod/plant and grain yield.*

NPS (Kg/ha)	Pod/plant			Grain yield (Kg/ha		
	HSARC	IGU	Sago	HSARC	Igu	Sago
0	7.70c	5.07a	6.66b	572.13d	678.22c	506.98e
50	8.6c	5.4a	8.5a	841.92c	951.29b	911.7cd
75	10.4b	5.36a	9.14a	1027.99b	976.95b	873.23d
100	11.32ab	5.57a	8.47a	1026.08b	1035.98ab	1012.07bc
125	12.88a	5.52a	8.59a	1260.3a	1101.89a	1077.93ab
150	11.79ab	5.31a	8.56a	1192.24a	1099.87a	1143.63a
LSD	1.58	0.6	1.56	161.47	117.08	118.46

3.4. Partial Budget Analysis

Partial budget analysis of the net benefits, total costs that vary and marginal rate of returns are presented in (Table 8). Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation for farmers. As indicated in (Table 8), the partial budget analysis showed that the highest net benefit (Birr 31792.34 ha^{-1}) was recorded at the rate of application of 100 kg blended NPS ha^{-1} with un-inoculated strain followed by 75 kg blended NPS ha^{-1} with un-inoculated strain (Birr 29183.01 ha^{-1}), whereas the lowest net benefit (Birr 18975.6 ha^{-1}) was recorded from zero fertilizer application and un-inoculated strain. According to CIMMYT (28) suggestion, the minimum acceptable marginal rate of return should be more than 100%. Thus, application of 100 kg ha^{-1} of blended fertilizer with un-inoculated strain gave the maximum economic benefit (Birr 31792.34 ha^{-1}) with marginal rate of return (811%) as presented in (Table 8). Therefore, on economic grounds, application of 100 kg NPS ha^{-1} without inoculation of the strain would be best and economical for production of common bean in the study area and other areas with similar agro-ecological conditions.

Table 8. Partial budget and marginal rate of return analysis.

Treatment		Yield		Income	cost			NB (ETB/ha)	MRR (%)
NPS rates	R Strain	UGY kg/ha	AGY	GFB (ETB/ha)	NPS cost	app cost	TVC (ETB/ha)		
0	0	702.8	632.52	18975.6	0	0	0	18975.6	
0	BH429	784.26	705.83	21175.02	0	0	0	21175.02	
0	BH15	727.33	654.59	19637.91	0	0	0	19637.91	
50	0	1116.83	1005.15	30154.41	1250	900	2150	28004.41	389.14
50	BH429	1121.87	1009.68	30290.49	1250	900	2150	28140.49	
50	BH15	1136.78	1023.10	30693.06	1250	900	2150	28543.06	
75	0	1183.63	1065.27	31958.01	1875	900	2775	29183.01	102.392
75	BH429	1248.48	1123.63	33708.96	1875	900	2775	30933.96	
75	BH15	1092.54	983.29	29498.58	1875	900	2775	26723.58	
100	0	1303.42	1173.08	35192.34	2500	900	3400	31792.34	811.00

Treatment		Yield		Income	cost			NB (ETB/ha)	MRR (%)
NPS rates	R Strain	UGY kg/ha	AGY	GFB (ETB/ha)	NPS cost	app cost	TVC (ETB/ha)		
100	BH429	1153.46	1038.11	31143.42	2500	900	3400	27743.42	
100	BH15	1300.43	1170.39	35111.61	2500	900	3400	31711.61	
125	0	1137.36	1023.62	30708.72	3125	900	4025	26683.72	D
125	BH429	1274.82	1147.34	34420.14	3125	900	4025	30395.14	
125	BH15	1329.92	1196.93	35907.84	3125	900	4025	31882.84	
150	0	1281.85	1153.67	34609.95	3750	900	4650	29959.95	D
150	BH429	1164.62	1048.16	31444.74	3750	900	4650	26794.74	
150	BH15	1227.95	1105.16	33154.65	3750	900	4650	28504.65	

Where, UGY = Unadjusted grain yield; AGY = adjusted grain yield; GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D = dominated treatments. Cost of NPS fertilizer = Birr 25 kg^{-1}, The labour cost for application of NPS (12 persons ha^{-1}, each 75 ETB day^{-1}), Market price of common bean grain = 30 Birr kg^{-1}

4. Conclusions and Recommendations

Common bean (Phaseolus vulgaris L.) production has been practiced at Kellem Wollega Zone, Western Oromia, and Ethiopia. However, the average yield is below the potential yield of the crop. The major yield limitation are decline soil fertility and lack of improved agronomic practices is concern for most parts of Ethiopia. It is yield potential exploitation depends on different edaphic factors including inorganic fertilizer and Bioferilizer application. The study was conducted at Haro Sabu Agricultural Research Center, Sago and Igu during (2020 and 2021) the main cropping season in western Oromia, Ethiopia.

However, the response of the crop to these fertilizers may vary in different soil types. In present study, grain yield and most of yield related parameters were significantly affected by the main effect of NPS fertilizer rate and experimental locations. Increasing the rate of NPS fertilizer rate from zero to 150 kg/ha resulted into the prolonged phonological parameters including days to maturity. On the other hands, significantly higher mean value was recorded by applying 125 and 150 kg/ha of NPS fertilizer for grain yield, 125 kg/ha of NPS fertilizer for pod/plant, and 125 and 150 Kg/ha of NPS fertilizer for seed/pod. This study found poor effect of rhizobium strain on most of agronomic parameters which might be resulted from either low adaptability of the strain or low soil acidity of the experimental locations. Significantly higher mean value of pod/plant, seed/pod and grain yield/ha was obtained at HSARC and Igu experimental locations compared to Sago location which had the least mean value for these parameters. This further illustrates the common bean production potential difference of the experimental locations.

With the interaction effect; significantly higher mean value of effective branch/plant was recorded from combined effect of BH-A-15 strain with 100 kg/ha of NPS fertilizer. Besides, significantly higher mean value of grain yield was recorded at HSARC and Igu locations with application of 125 and 150 Kg/ha of NPS fertilizer consistently. Partial budget analysis showed highest net benefit (Birr 31792.34 ha^{-1}) from combined application of 100 kg blended NPS ha^{-1} fertilizer with un-inoculated strain which had 811% marginal rate of return. Therefore, application of 100 kg NPS ha^{-1} without inoculation of the strain was recommended for common bean production and productivity improvement in the experimental locations and in similar agroecolgy.

Abbreviations

HSARC Haro Sabu Agricultural Research Center

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Author Contributions

Lemesa Emisha: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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