International Journal of Plant & Soil Science
14(1): 1-10, 2017; Article no.IJPSS.30864
ISSN: 2320-7035

SCIENCEDOMAIN *international*
www.sciencedomain.org

Response of Common Bean (*Pharsalus vulgaris* L.) Cultivars to Combined Application of *Rhizobium* and NP Fertilizer at Melkassa, Central Ethiopia

A. Habtamu Assefa[1*], Berhanu Amsalu[2] and Tamado Tana[3]

[1]Ethiopian Ministry of Agriculture, Addis Ababa, Ethiopia.
[2]Ethiopian Agricultural Research Institute, Addis Ababa, Ethiopia.
[3]Haramaya University, Haramaya, Ethiopia.

Authors' contributions

This work was carried out in collaboration between all authors. Author AHA designed the study, conducted the experiment, collected the data, performed the statistical analysis and wrote the first draft of the manuscript. Authors BA and TT were give technical support in experiment design, data collection and statistical analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2017/30864
Editor(s):
(1) Yong In Kuk, Department of Development in Oriental Medicine Resources, Sunchon National University, South Korea.
Reviewers:
(1) Adelson Paulo Araujo, Universidade Federal Rural do Rio de Janeiro, Brazil.
(2) Ramazan Dogan, Uludag University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/17476

Original Research Article

Received 4th December 2016
Accepted 2nd January 2017
Published 10th January 2017

ABSTRACT

Soil fertility is one of the factors limiting the production of common bean in Ethiopia. Thus, field experiment was conducted to assess the effect of *Rhizobium* and NP fertilizers combination on nodulation, growth, yield components and yield of common bean cultivars and economically beneficial combination of NP and inoculants for each cultivar. The experiment was conducted at Melkassa Agricultural Research Center under rain fed conditions during the main cropping season. The experiment plot was laid at split plot design in three replications. Seven common bean cultivars (sub-plot factor) with five levels of NP fertilizer combined with inoculant (main-plot factor) (full recommended rate of NP fertilizer or 46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1} of N alone, *Rhizobium* with 23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1} of N, *Rhizobium* with 11.5 kg ha^{-1} of P_2O_5 and 10.25 kg ha^{-1} of N, *Rhizobium* alone, and control) used as treatments. The main effects of combination of NP with inoculant significantly influenced, nodule number, nodule color, plant height and number of primary branches. All inoculated treatments recorded highest nodulation parameters over uninoculated. The

**Corresponding author: E-mail: habvip@gmail.com;*

combination of 23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1} of N with inoculant recorded highest nodule number (17.14) per plant. Among the cultivars, Nassir was best for nodulation parameters. The interaction of combined application of NP fertilizer with inoculant and cultivars had significant effect pods per plant, 100 seed weight and grain yield. Analysis of variance for net benefits significantly affected due to common bean cultivars, combine application of NP fertilizer with inoculant and interaction of cultivars and combined application of NP fertilizer. The Economic analysis indicated that full recommended rate of NP fertilizer had economical advantage for only cultivar Awash-1. Among the cultivars Batu, DRK and Nassir recorded the highest marginal rate of return due to inoculation relative to other tested combination. Finally, Study conclude that, *rhizobium* strain (EAL 429) is more effective than that of indigenous soil *Rhizobium* population. Cultivar Nassir seemed to be more responsive to infection by inoculated strain EAL 429. However, the results presented here need to be further evaluated for sound recommendation.

Keywords: Common bean; combination; Inoculant; NP fertilizer; Rhizobium.

1. INTRODUCTION

In Ethiopia, the common bean is usually grown by subsistence farmers as a sole crop and/or intercropped with either cereals (maize and sorghum) or tree crops (enset, coffee, etc.). The national area of common bean production is estimated at 366,876.94 ha of land and from which about 463,008.49 tons are produced in 2015 cropping season [1]. According to report of CSA [1], the current national average yield of common bean is 1262 kg ha^{-1}. However, this yield is far less than the attainable yield (2500-3000 kg ha^{-1}) under good management conditions for most improved cultivars. Low soil fertility has been repeatedly reported as one of the major factors affecting bean production in the central rift valley of Ethiopia [2]. A range of environmental factors, such as low soil nitrogen and phosphorus levels, and acidic soil conditions are important constraints for bean production in most areas where the crop is grown [3].

On the other hand, indiscriminate uses of chemical fertilizers to refill soil N and P is resulting in high production costs, severe environmental contamination and an affordable to small holder farmer. Therefore, crops like common beans are important in many cropping systems because of their ability to fix atmospheric nitrogen and they can obtain their nitrogen demand from biological nitrogen fixation [4]. Besides the above facts, the long- term use of bio-fertilizers is economical, eco-friendly, more efficient, productive and accessible to marginal and small holder farmers over chemical fertilizers [5]. In Ethiopia, biofertilizer is new technology and not widely used by the farmer but inoculants were selected and distribute to the farmers. However, the performances of the released cultivars of common bean to inoculation were not evaluated. Thus, the objectives of this study were: to assess the effect of combined application of inoculant and NP fertilizers on growth, yield and yield component of common bean cultivars and economically beneficial combination of NP and inoculants for each cultivar.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

The experiment was conducted at Melkassa Agricultural Research Center (MARC) in central Rift valley of Ethiopian under rain fed conditions during the main cropping season (June–October). It is located at 8°24' N latitude and 39° 12' E longitude with an altitude of 1550 m a.s.l. The climate of the location ranges from arid to semi-arid type [6]. The long-term mean annual rainfall is 791.69 mm with erratic distribution having peaks in July and August. The long-term (1977-2005) mean monthly maximum and minimum temperature is 28 and 14℃, respectively [7]. The Soil Physico-chemical properties of the experimental site was tested before the experiment. The results of soil analysis for soil chemical and physical properties such as for soil pH, total nitrogen, organic matter, available phosphorus and soil texture is indicated in Table 1. According to the laboratory analysis, the soil class of the experimental area was clay sandy loam (sand 44, silt 21 and clay 35%) which is suitable for common bean.

2.2 Description of Experimental Materials

The study was conducted in a factorial combination of seven released common bean

Table 1. Selected physico-chemical properties of the soil of the experimental site before planting

Soil characters	Values	Rating	Reference
pH (by 1: 2.5 soil water ratio)	7.7	Moderately alkaline	Tekalign [8]
Total nitrogen (%)	0.084	Low	Tekalign [8]
Organic matter (%)	2.90	medium	Tekalign [8]
Available phosphorus (ppm)	23.82	High	Marx [9]

cultivars (Awash-1, Awash-Melka, Nassir, Dinkinesh, Dark Red Kidney Beans (DRK) and Batu) with five levels of *Rhizobium strain (EAL429*) and NP fertilizer combination used as treatments. The inoculant of *Rhizobium* strain *EAL429* was obtained from commercial Producer. The cultivars were selected based on the production status and adaptability to central rift valley. UREA (46% N) and Di-Ammonium phosphate (DAP) (18% N and 46% P_2O_5) were used as the source of NP fertilizer.

2.3 Treatments and Experimental Design

The experiment was laid out in split plot design; five levels of *Rhizobium strain (EAL429*) and NP fertilizer combination with the seven common bean cultivars were used as treatments. Fertilizer and inoculant combinations were used as main plot (T1 = Control, T2 = recommended rate of NP or 46 kg ha^{-1} of P_2O_5 + 41 kg ha^{-1}of N, T3 = 50% recommended rate of NP or 23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1}of N with *Rhizobium*, T4 = 25% recommended rate of NP or 11.5 kg ha^{-1} of P_2O_5 and 10.25 kg ha^{-1}of N with *Rhizobium*; and T5 = *Rhizobium* alone) while cultivars were arranged in subplots. Seeds were planted in rows with the spacing of 10 cm between plants and 40 cm between rows. The gross plot size was 2.8 m x 4 m (11.2 m^2) which had 7 rows and spacing between plots and blocks were 0.6 m and 1m, respectively. Two border rows and two plant stand at the end of each row were left as a border effect and net harvested plot size was 2m x 4m (8 m^2).

2.4 Management of the Experiment

The experimental field was prepared by ploughing two times using tractor. Seeds were planted in the row at the rate of one seed per hole. Fertilizers were applied at sowing time as per their treatment by side dressing. Before planting, beans were rinsed in sugar solution to help the inoculant carrier material to stick on the seeds. The seed inoculation was done just before planting under shade to maintain the viability of cells at the rate of 10 g/kg of seed. Other crop management were done for all plot equally. Crop was harvested at maturity manually for each plot from the central five rows.

2.5 Data Collection and Measurement

2.5.1 Nodulation data

Five plants were sampled randomly from the middle rows of each plot at mid flowering. The whole plant was carefully uprooted using shovel so as to obtain intact roots and undisturbed soil for nodulation parameters. The undisturbed soil samples were wrapped in pot and transported to the laboratory where the soil was washed from the roots using gently running tap water over a metal sieve. Nodules from roots were removed carefully. The total numbers of nodules were counted and the average value of five plants was recorded as number of nodules per plant. To determine the nodule color, five representative nodules were taken from the same sample and dissected with blade to observe their color in the center. The color score was made in 1-4 scale as: 1=white, 2=pink, 3=slightly red and 4=deep dark red, this color scale was adopted from [10]. Legume nodules having pink or dark red centers due to presence of leghemoglobin are an indication for effectiveness of the *Rhizobial* strain used and is correlated to nitrogen [11] and the nodules having color white/green considered ineffective nodules.

Plant height (cm) *and Number* of primary branches were measured from five central row of each experimental plot at physiological maturity; by measuring the plant height from the ground to top of plant and counting main shoots, respectively.

2.5.2 Yield components and Yield

Number of pods per plant was determined by counting pods of five randomly taken plants from the net plot area at harvest and the means were recorded as number of pods per plant and; then the pod was trashed and seeds were counted. Total numbers of seeds were divided by total number of pods to compute average number of seeds per pod.

Hundred seed weight (g) was recorded by weighing 100 randomly taken seeds from the harvested yield using a sensitive balance and the weight was adjusted to 10% seed moisture content. At harvest maturity, whole plants from the central 5 rows of net plot size 2 x 4m (8 m^2) were manually harvested. Threshing was done manually and separately for each plot. The seed yield was adjusted to moisture level of 10%. Finally, yield per plot was converted to ha^{-1} basis and reported as kilogram per hectare.

2.6 Statistical Data Analysis

Data were analyzed using analysis of variance (ANOVA) following the standard procedure given by Gomez and Gomez [12] and analyses were done using GenStat (15^{th} edition) software [13]. Comparison among treatment means with significant difference for measured and scored characters was made using Least Significant Difference (LSD) test at 5% level of significant.

2.7 Economic Analysis

Economic analysis was performed using partial budget analysis following the procedure described by CIMMYT [14]. Marginal rate of return (cost benefit ratio) is a criterion which measures the effect of additional capital invested on net returns using new managements compared with the previous one. It provides the value of benefit obtained per the amount of additional cost incurred percentage. Marginal rate of return was calculated by partial budget analysis using the formula: -

$$MRR = \frac{DNI}{DIC} x100\%$$

Where, MRR is marginal rate of returns (cost benefit ratio), DNI is the difference in net income between treatment and DIC is the difference in input cost between treatment. The minimum acceptable rate of return for farmer recommendation of new technology is 100% [14]. The average yield obtained from experimental plot was reducing by 10% to adjust with the expected farmer yield by the same treatment. Prices of grain (Birr kg^{-1}) were obtained from local market for each cultivars and total sale from one hectare was computed using adjusted yield. Price of seeds, cost of fertilizer, inoculant, sugar (sticker for inoculant with seed), application cost of fertilizer and inoculation, cost of clearing of yield and transportation of yield from field to local market were considered as the cost that vary for treatment.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Total nodule number

Total number of nodules per plant was significantly ($P \le 0.05$) affected due to the cultivars of common bean. The highest number of nodules per plant (15.3) was obtained from cultivar Nassir while the lowest number (6.0) was for cultivar Deme (Table 2). The results of this experiment showed variability in nodulation among the cultivars, which might be inadequate compatibility between the cultivars used and strain applied. In conformity with this result, [15] reported apparent differences in compatibility of bean cultivars to inoculant (bacterial strain) for nodulation responses. Similarly, nodule number per plant was significantly ($P<0.001$) affected by combined application of NP fertilizer with *Rhizobium*. However, the interaction effect of cultivars and combined application of fertilizer with *Rhizobium* was not significant. The inoculated treatments had significantly higher nodule number per plant over uninoculated treatments (control and full recommended rate of NP fertilizer without inoculant). The study revealed that 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. Many researchers agree that inoculation of common bean by proper *Rhizobium* strain had higher number of nodules per plant than, that of uninoculated one [16,17] Other researchers also testified that, the inoculation of common bean with effective *rhizobium* strains had significant increase of nodulation and N_2 fixation rates relative to the indigenous *rhizobium* population [18].

Among inoculated treatments, the highest nodule number was recorded by combined application of 23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1} of N with *Rhizobium* inoculation. However, within inoculated treatments nodule number did not show significant difference due to the application of NP fertilizer while application of 23 kg ha^{-1} of

P_2O_5 and 20.5 kg $ha^{-1}$of N with *Rhizobium* increased nodule number by 8.33% compared with inoculant without NP fertilizer.

Many investigators pointed out that response of leguminous plants for nodulation improved by artificial mineral fertilizer especially nitrogen and phosphorus. For instance, Adama et al. [19] reported that nodule dry weight increased with increase of nitrogen fertilizer from 0 kg ha^{-1} to 20 kg ha^{-1} with inoculant and other researchers also recommended to include a small amount of nitrogen in the fertilizer of legume crops at sowing time (as a starter dose 10-20 kg ha^{-1}) to ensure the young seeding to have an adequate N supply until the inoculant become established [20].

3.1.2 Nodule color

The present study also assessed the effectiveness of the nodule through nodule color. The result showed significant ($P \leq 0.05$) differences in nodule color due to both cultivars of common bean and combined application of NP fertilizer with inoculation*.* The result indicated that in all cultivars except Deme, nodules had pink to light red colors. Legume nodules having dark pink or red centers (due to leghemoglobin presence) are an indication for effectiveness of the strain used and also positive correlation with higher nitrogen fixed [11]. Uninoculated treatments both control and full rate of nitrogen and phosphorus fertilizer had white and/or green nodule color, which indicated the ineffectiveness of the existing native *Rhizobium* population in the soil. However, within inoculated treatment there was no significant difference for nodule color due to application of NP fertilizer almost all with treatments had pink to light red color. The interaction of cultivars with combined application of NP fertilizer and inoculant was not significant effect on the color of nodules.

3.1.3 Plant height

Analysis of variance showed highly significant ($p<0.001$) difference among cultivars for plant height at physiological maturity. The variation in plant height within common bean cultivars might be attributed to their inherent genetic characters and variation between the cultivars in response to inoculation and NP fertilizer combination. In agreement with this result, [21] reported that, plant height difference within common bean cultivars could be due to differences among the genotype with respect to absorption of nutrients, nitrogen fixation and accumulation of other relevant nutrients.

The plant height was also significantly ($P<0.05$) affected due to the main effect of combined application of NP fertilizer with inoculant. Recommended rate of NP fertilizer with *Rhizobium* gave the highest plant height (43.4 cm) while the lowest was recorded by control (40.0cm). Treatments that received *Rhizobium* inoculant without NP fertilizer recorded higher plant height than the control (Table 2). In conformity with this result, *Rhizobia* inoculation in cowpea significantly improved the plant height measured at four, six and eight weeks after planting in both screen house and field experiments relative to the control treatment [22]. On the other hand, the interaction effect of common bean cultivars with combined application of NP fertilizer with inoculant was not significant on plant height.

3.1.4 Number of primary branches

The main effect of cultivars of common bean on the number of primary branches per plant was significant where cultivars Awash-Melka (6.8) and Dinkinesh (6.8) recorded highest number primary branches per plant while the lowest (4.5) number of primary branches was recorded from cultivar DRK.

Significance ($P \leq 0.05$) difference on number of primary branches per plant was also observed due to the main effect of combined application of NP fertilizer with *Rhizobium* inoculation. However, the interaction effect of cultivars and combined application of NP fertilizer with inoculant was not significant. Maximum number of primary branches per plant (6.6) was recorded due to application of recommended rate NP fertilizer without inoculant while the lowest number of primary branches (5.3) was recorded by both control and application of 11.5 kg ha^{-1} of P_2O_5 and 10.25 kg $ha^{-1}$of N with inoculant. However, the maximum number of primary branches per plant at recommended NP rate was not significantly different from 23 kg ha^{-1} of P_2O_5 and 20.5 kg $ha^{-1}$of N with *Rhizobium* (Table 2). Even though there was no significant difference, the number of primary branches per plant was higher with inoculant alone than the control. This result is in line with report reviewed by Mfilinge et al. [23] that, inoculation of chickpea with *Rhizobium* in field and in the glass house reported significantly increased number of branches per plant.

Table 2. The main effect of cultivar and combined application of NP fertilizer with inoculant on nodule number per plant and nodule color, plant height, number of primary branch and number of seed per pod

Treatment	Nodule number	Nodule color	Plant height (cm)	No of primary branches/plant	Number of seeds per pod
			Fertilizer combination		
T1	4.8 ^{b}	1.1 ^{b}	40.0 ^{b}	5.3 ^{b}	4.1
T2	7.1^{b}	1.6 ^{b}	43.4 ^{a}	6.6 ^{a}	4.4
T3	17.1 ^{a}	2.9 ^{a}	43.3 ^{a}	6.5 ^{a}	4.1
T4	13.3 ^{a}	2.9 ^{a}	42.5 ^{a}	5.3 ^{b}	4.3
T5	15.7 ^{a}	2.9 ^{a}	41.3^{ab}	5.8^{ab}	4.2
LSD (0.05)	4.04	0.77	2.3	0.8	NS
			Cultivars		
Awash-1	12.0 ^{ab}	2.5 ^{ab}	40.3 ^{c}	6.4^{ab}	4.7^{a}
Awash-Melka	12.7 ^{ab}	2.0 ^{bc}	42.7 ^{bc}	6.8 ^{a}	4.9^{a}
Nassir	15.3 ^{a}	2.9 ^{a}	43.4 ^{b}	5.9 ^{b}	4.2^{b}
Dinkinesh	10.7 ^{b}	2.6 ^{ab}	49.5 ^{a}	6.8 ^{a}	5.0 ^{a}
Deme	6.0 ^{c}	1.3 ^{c}	50.9 ^{a}	6.1 ^{b}	3.5^{dc}
DRK	12.0 ^{ab}	2.2 ^{ab}	33.6 ^{d}	4.5 ^{c}	3.9^{bc}
Batu	12.7 ^{ab}	2.4 ^{ab}	34.1 ^{d}	4.8 ^{c}	3.3^{d}
LSD (0.05)	4.3	0.67	2.6	0.7	0.41
CV (%)	18.4	18	2.9	7.5	13.2

Means within columns followed by the same letter are not significantly different at 5% level of significance T1=Control (no Rhizobium or no fertilizer),T2=N and P fertilizer at recommended rate (46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1}of N),T3=Rhizobium + ½ of recommended rate (23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1}of N),T4=Rhizobium + ¼ of recommended rate (11.5 kg ha^{-1} of P_2O_5 and 10.25 kg ha^{-1}of N),T5=Rhizobium only , DRK=Dark red kidney, LSD= least significant difference, CV= Coefficient of Variation

Table 3. The interaction effect of cultivars and combined application of NP fertilizer with inoculant on number of pods per plant of common bean

				Cultivars			
Fertilizer	**Awash-1**	**Awash-Melka**	**Nassir**	**Dinkinesh**	**Deme**	**DRK**	**Batu**
T1	21.2 $^{d-g}$	13.0^{i-l}	20.6^{cde}	17.20^{ghi}	11.0^{j-n}	7.4^{n}	10.6^{j-n}
T2	30.0 ^{a}	24.9^{bcd}	23.4^{cde}	23.33^{cde}	10.9^{j-n}	12.6^{jkl}	18.7^{e-h}
T3	29.0 ^{ab}	26.1^{abc}	21.3^{d-g}	24.20^{cd}	11.8^{j-n}	10.5^{j-n}	14.4^{h-k}
T4	22.7^{cde}	24.3^{cd}	21.7^{c-g}	23.06^{cde}	9.2l^{mn}	10.2^{k-n}	15.0^{hij}
T5	22.3^{c-f}	20.7^{d-g}	22.5^{d-g}	17.80^{fgh}	7.0^{n}	7.9^{mn}	12.2^{j-m}
LSD (0.05)	4.6						
CV (%)	4.4						

Means within columns and row followed by the same letter are not significantly different at 5% level of significance T1=Control (no Rhizobium or no fertilizer),T2=N and P fertilizer at recommended rate (46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1}of N),T3=Rhizobium + ½ of recommended rate (23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1}of N), T4=Rhizobium + ¼ of recommended rate (11.5 kg ha^{-1} of P_2O_5 and 10.25 kg ha^{-1}of N),T5=Rhizobium only , DRK=Dark red kidney, LSD= least significant difference, CV= Coefficient of Variation

3.2 Yield Components and Yield

3.2.1 Number of pods per plant

The analysis of variance showed significant ($P<0.001$) difference on the number of pods per plant due to main effects of cultivars and combined application of fertilizer and inoculant. Moreover, the interaction effect of cultivars and combined application of NP fertilizer with *Rhizobium* was significant ($P<0.05$) on the number of pods per plant. The cultivars Awash-1, Nassir, Batu and DRK recorded higher number of pods per plant with interaction of full recommended rate of NP fertilizer and also, others cultivars recorded higher pod per plant due to interaction with 23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1}of N + inoculant. Though, the later fertilizer combination application half less than former NP fertilizer application. But, variation of these fertilizer combination was not significantly different for all cultivars. This might be due to the positive influence of optimum amount of mineral NP fertilizer with inoculation on pod formation of legumes. In line with this result, [24] reported that at constant phosphorus (80 kg ha^{-1} P_2O_5) application and inoculation, numbers of pods per plant were increased with the increased amount of nitrogen fertilizer from 0 kg ha^{-1} to 40 kg ha^{-1} per hectare on common bean. Khan [25] also observed that P application and *Rhizobium* inoculation of green gram significantly increased pod formation as compared with uninoculated treatments.

The cultivars Awash -1 and DRK were recorded highest and lowest number of pods per plant, respectively due to interaction of cultivars with control treatment and also, the interaction of inoculant alone with cultivars; cultivar Awah-1 was recorded highest pod per plant and cultivar Deme was recorded lowest pod per plant. This might be the existence of difference among the common bean cultivars for response to inoculant and could also indicate the effectiveness of inoculant over native soil *Rhizobium*. This result was in agreement with the study by [24] who indicated that inoculation had given significantly higher number of pods per plant for common bean over the control (no fertilizer and no inoculant).

3.2.2 Number of seeds per pod

Number of seeds per pod showed highly significant ($P<0.001$) difference among the cultivars. The highest numbers of seeds per pod (5.0) were recorded from cultivar Dinkinesh followed by Awash-Melka (4.9) and Awash-1 (4.7) whereas the least number of seeds per pod (3.3) was recorded for cultivar Batu (Table 2). On the other hand, the number of seeds per pod was not significantly affected due to both main effect of combined application of NP fertilizer with *Rhizobium* and interaction of cultivars and combination of NP fertilizer with inoculant. Relatively, the highest number of seeds per pod was recorded with the application of 46 kg ha^{-1} of P_2O_5 and 41 kg $ha^{-1}$of N without *Rhizobium* while the least number of seeds per pod was recorded by the control.

Generally, the number of seeds per pod was significantly affected due to cultivars, but not by fertilizer and inoculation. Thus, variation on the number of seeds per pod was highly affected by genetic factors than the environmental and management. In conformity with this result, [26] reported that the number of seeds per pod of different common bean genotypes varies in the range of 3.1 to 6 and attributed the difference mainly due to the genetic variation of cultivars.

3.2.3 Hundred seed weight

Hundred seed weight was found to be affected significantly due to cultivars ($P<0.001$) and fertilizer combinations; and also, it was significantly ($P<0.05$) affected by the interaction of cultivars and combined application of fertilizer with inoculant. Cultivar Deme with recommended rate of NP fertilizer without inoculation scored the highest hundred seed weight (54.2 g) while the lowest hundred seed weight (50.7g) was recorded due to interaction with the control (Table 4). The interaction of cultivars with full recommended rate of NP fertilizer without inoculate, the highest and lowest hundred seed weight were recorded by Deme and Awash-1, respectively. This might be due to the presence of difference in seed size among the common bean cultivars as hundred seed weight increases with increase in the seed size.

The cultivar Batu was recorded significantly higher hundred seed weight due to inoculate only over control treatment. This might be due to the positive influence of inoculation on the seed dry matter accumulation. This result was in agreement with the study by [16] where weight of 100 seeds increased significantly in the common bean inoculated with carrier based as well as pure cultures of *Rhizobium* than that of uninoculated (control) treatment. Likewise, Fatima et al. [27] observed that single inoculation of three different *Rhizobium* strains with phosphorus recorded the highest seed weight of soybean over inoculation without phosphorus fertilizer.

3.2.4 Grain yield

Grain yield was significantly ($P<0.001$) affected due to main effects of cultivar, combination of fertilizer and the interaction of cultivars with fertilizer combination. Cultivar Awash-1 was recorded highest grain yield (3113 kg ha^{-1}) by the combination of 46 kg ha^{-1} of P_2O_5 and 41 kg $ha^{-1}$of N with cultivars while the lowest grain yield (1882 kg ha^{-1}) was obtained by control.

The cultivar Dinikensh was recorded the higher grain yield due to application of 23 kg ha^{-1} of P_2O_5 and 20.5 kg $ha^{-1}$of N with inoculants than application of full recommended rate of

Table 4. Interaction effect of cultivars and combined application of NP fertilizer with inoculant on hundred seed weight (g) of common bean

Fertilizer	Cultivars						
	Awash-1	**Awash-Melka**	**Nassir**	**Dinkinesh**	**Deme**	**DRK**	**Batu**
T1	16.8^{q}	19.9^{no}	22.9^{ij}	21.1^{k-n}	50.7^{cd}	45.5^{f}	40.8^{h}
T2	18.5^{op}	20.0^{no}	23.5^{i}	23.7^{i}	54.2^{a}	49.4^{de}	42.4^{gh}
T3	17.5^{pq}	21.7^{j-m}	22.5^{ijk}	22.7^{ijk}	52.3^{bc}	49.5^{de}	42.7^{g}
T4	17.9^{pq}	20.2^{mn}	22.6^{ijk}	23.8^{i}	53.2^{ab}	48.2^{e}	42.7^{g}
T5	17.1^{pq}	20.64^{lmn}	22.4^{i-l}	23.0^{ij}	52.1^{bc}	45.6^{f}	42.7^{g}
LSD (0.05)	1.69						
CV (%)	3.3						

Means within columns and row followed by the same letter are not significantly different at 5% level of significance T1=Control (no Rhizobium or no fertilizer), T2=N and P fertilizer at recommended rate (46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1}of N), T3=Rhizobium + ½ of recommended rate (23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1}of N), T4=Rhizobium + ¼ of recommended rate (11.5 kg ha^{-1} of P_2O_5 and 10.25 kg ha^{-1}of N), T5=Rhizobium only , DRK=Dark red kidney, LSD= least significant difference, CV= Coefficient of Variation

Table 5. The interaction effect of cultivars and combined application of NP fertilizer with inoculant on grain yield (kg ha^{-1}) of common bean

Fertilizer	Cultivars						
	Awash-1	**Awash-Melka**	**Nassir**	**Dinikensh**	**Deme**	**DRK**	**Batu**
T1	1882^{mno}	2136^{j-m}	2100^{j-m}	1922^{l-o}	2050^{k-n}	1163^{p}	1514^{op}
T2	3113^{a}	3085^{ab}	3015^{a-d}	2641^{c-h}	2196^{i-m}	2146^{j-m}	2583^{e-i}
T3	2885^{a-e}	2863^{a-f}	2492^{e-j}	2690^{a-g}	2584^{d-i}	1632^{no}	2371^{g-k}
T4	2382^{g-k}	3049^{abc}	2322^{h-l}	2446^{f-k}	2409^{g-k}	1518^{op}	2014^{k-n}
T5	2330^{h-l}	2649^{b-h}	2600^{c-i}	2059^{j-n}	1764^{mno}	1499^{op}	2349^{h-l}
LSD (0.05)	436.9						
CV (%)	5.3						

Means within columns and row followed by the same letter are not significantly different at 5% level of significance T1=Control (no Rhizobium or no fertilizer), T2=N and P fertilizer at recommended rate (46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1}of N), T3=Rhizobium + ½ of recommended rate (23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1}of N), T4=Rhizobium + ¼ of recommended rate (11.5 kg ha^{-1} of P_2O_5 and 10.25 kg ha^{-1}of N), T5=Rhizobium only, DRK=Dark red kidney, LSD= least significant difference, CV= Coefficient of Variation

NP fertilizer. Similar result was also obtained in the cultivar of Deme. Therefore, this indicate that, application of different rate of NP fertilizer with inoculant improved grain yield. In line with this result, [27] 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 [28]. Similarly, [19] observed that nodule dry weight increased with increase of nitrogen fertilizer from 0 kg ha^{-1} to 20 kg ha^{-1} with inoculant which had positive effect on grain yield.

The present study showed that all cultivars except Deme grown with inoculant recorded higher grain yield as compared with control for respective cultivars. However, the effect of inoculant on grain yield for each cultivar were differed; where inoculation increased grain yield by 35.5%, 22.4%, 19.4%, 19.2%, 19.2%, 6.65% for Batu, DRK, Awash-Melka, Awash-1, Nassir and Dinkinesh, respectively, when compared with the control. This result was in agreement with finding by [24] where inoculation increased grain yield of common bean by 37% compared with control (no fertilizer, no inoculate). Other investigators also reported that, inoculation of common bean recorded the highest grain yield over uninoculated treatment [29,30].

3.3 Economic Analysis

Economic analysis was performed by using partial budget; Based on this, the study revealed that, all cultivars except Deme, combination with inoculant had economical advantage over the control. Among the cultivars Batu, DRK and Nassire recorded the highest marginal rate of return due to inoculation relative to other tested combination. Full recommended rate of NP fertilizer application had economical advantage for cultivar Awash-1. However, for others cultivars application of full recommended rate NP fertilizer had no economic benefit the over other tested combinations of inoculant with different rate of NP fertilizer. Awash-Melka and Deme recorded higher economic benefit with application of 11.5 kg ha^{-1} of P_2O_5 and 10.25 kg ha^{-1} of N with inoculants but for cultivar, Dinkinesh higher economic benefit recorded due to application of 23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1} of N with inoculants. Generally, highest net benefit was obtained from combination of cultivar Awash-Melka with application 11.5 kg ha^{-1} of P_2O_5 and 10.25 kg $ha^{-1}$of N and inoculants which means that inoculation was reduced the uses chemical fertilizer to quarter from recommended rate of NP fertilizer for the area.

4. CONCLUSION

The result of this study indicated that combined application of NP fertilizer and *rhizobium* inoculation had positive impact on the nodulation, growth, yield component and yield of common bean cultivars**.** Application of full recommended rate of NP fertilize (46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1} of N) for common bean production in specific area hadn't significant difference for most evaluated character than combined application of 23 kg ha^{-1} of P_2O_5 and 20.5 kg ha^{-1} of N + inoculant; and also, full recommended rate of NP fertilizer hadn't had economical advantage for all cultivars except cultivar Awash-1. Therefore, it is realistic to conclude that inoculation would reduce the application of mineral NP fertilizer by half this area. Similarly, from this study it is also reasonable to conclude that, *rhizobium* strain (*EAL 429*) is effective than that of indigenous soil *Rhizobium* population and it gives highest grain yield and high net benefit income over the control; Cultivar Nassir seemed to be more responsive to infection by inoculated strain *EAL 429*. However, the results presented here need to be evaluated and then confirmed through repeated extensive research at specific area for sound recommendation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Central Statistics Authority of Ethiopia. Agricultural Sample Survey 2014/2015. Reports on area under cultivation, yield and production of major crops for main (Meher) season, Ethiopia; 2015.
2. Girma Abebe. Effect of NP fertilizer and moisture conservation on the yield and yield components of Haricot Bean (*Phaseolus vulgaris* L.) in the semi arid zones of the Central Rift Valley in Ethiopia. Advance Environmental Biology. 2009;3:302-307.
3. Graham PH, Rosas JC, Jensen EC, Peralta E, Tlusty B, Acosta-Gallegos J, Arraes PA. Addressing edaphic constraints to bean production: The bean/cowpea CRSP project in perspective. Field Crops Research. 2003; 82:179-192.
4. Francis, C. A.. Multiple cropping potentials of beans and maize. Horticultural Science. 1977;13:12-17.
5. Mishra D, Singh R, Mishra U, Sudhir K. Role of bio-fertilizer in organic agriculture: A review. Research Journal of Recent Sciences. 2012;2:19-25.
6. Ministry of Agriculture. Agro-ecological Zones of Ethiopia. Natural Resources Management and Regulatory Department (with support of German Agency for Technical Cooperation (GTZ). Addis Ababa, Ethiopia; 1998;1.
7. Melkassa Agricultural Research Center. Progress Report. Melkassa Ethiopia. 2005;1. (in press)
8. Tekalign Tadese. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia. 1991;13.
9. Marx ES, Hart J, Stevens RG. Soil test interpretation guide. Oregon State University, USA. 1996;8.
10. Tekalign Mamo, Asgelel Dibabe. Soil microbiology research. In: Asfaw Telaye, Galatu Bejiga, Saxena Mohan C. and Solh, Mahamoud D. (eds.). Cool Season Food Legumes of Ethiopia Proceedings of the first National Cool Season Food Legumes Review conference. Addis Ababa, Ethiopia. 1994;440.
11. Adjei MB, Chambeiss CG. Nitrogen fixation and inoculation of forage legumes. An electronic publication of Agronomy Department. University of Florida; 2002.
12. Gomez KT, Gomez AA. Statistical procedures for agricultural research. 2nd ed. John Wily and Sons, New York; 1984.
13. GenStat. GenStat Procedure Library Release. 15th ed. VSN International Ltd.; 2012.

14. CIMMYT. From Agronomic Data to Farmer Recommendations: An Economics Work book. Mexico, D.F.; 1988.
15. Kellman George HD, McKenzie BA. Variability in nodulation of *Phaseolus vulgaris* L. with different *Rhizobial strains*. Agriculture and Life Sciences Division, Lincoln University Canterbury, New Zealand; 2005.
16. Asad AS, Bano A, Farooq M, Aslam M, Afzal AB. Comparative study of the effects of biofertilizers on nodulation and yield characteristics of Mung Bean (*Vigna radiata*). International Journal of Agriculture & Biology. 2004;6(5):837–843.
17. Gicharu GK, Gitonga NM, Hamadi B, Cheruiyot RCh, Maingi JM. Variation in nitrogen fixation among three Bush Bean cultivars grown in Kenya when inoculated with three *Rhizobia Strains*. Greener Journal of Agricultural Sciences. 2012; 3(11):748-754.
18. Hungria M, Campo RJ, Mendes IC. Benefit of inoculation of the Common Bean (*Phaseolus vulgaris*) crop with efficient and competitive *Rhizobium tropici* strains. Biology and Fertility of Soils. 2003; 39(2):88.
19. Adama D, Tahir AD, Mamadou G. Nodulation *in Situ* of Common Bean (*Phaseolus vulgaris* L.) and field outcome of an elite symbiotic association in Senegal. Research Journal of Agriculture and Biological Sciences. 2008;4(6):810-818.
20. Chandrasekaran K, Annadurai, Somasundaram E. A textbook of agronomy. New Age International (P) Ltd., Publishers, India; 2010.
21. Chabot R, Antoun H, Cescas MC. Growth promotion of maize and lettuce by phosphate-solubilizing. Plant and Soil. 1996;184:311–321.
22. Nyoki D, Ndakidemi PA. Effects of phosphorus and *Bradyrhizobium japonicum* on growth and chlorophyll content of cowpea (*Vigna unguiculata* L Walp). American Journal of Experimental Agriculture. 2014;4:1120-1136.
23. Mfilinge A, Kevin M, Patrick AN. 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, 2014;2(10):49-87.
24. Çiğdem Küçük. Inoculation with *Rhizobium* spp. in kidney bean (*Phaseolus vulgaris* L.) varieties. Agriculture. 2011;98:49–56.
25. Khan MA, Mehmood IA, Aslam M. Response of P application on growth and yield of inoculated and un-inoculated Mung bean (*Vigna radiata*). 8th International Congress of Soil Science. November NARC, Islamabad, Pakistan. 2000;13-16.
26. Fageria NK, Santos AB. Yield physiology of dry bean. Journal Plant Nutrition. 2008; 31:983–1004.
27. Fatima Z, Muhammad Z, Chaudhary MF. Interactive effect of *Rhizobium* strains and P on soybean yield, nitrogen fixation and soil fertility. Journal of Botany. 2007;39(1): 255-264.
28. Rifat H, Ali S, Siddique MT, Chatha TH. Biological nitrogen fixation of summer legumes and their residual effects on subsequent rainfed wheat yield. Journal Botany. 2008;40(2):711-722.
29. Darine T, Mengoni A, Ammar HB, Mhamdi R. Effect of on-field inoculation of *Phaseolus vulgaris* with *Rhizobia* on soil bacterial communities. Laboratory of Legumes, Centre of Biotechnology of Borj-Cedria, Hammam-Lif, Tunisia Department of Evolutionary Biology, University of Firenze, Florence, Italy and Technical Centre of Potatoes, Saida, Tunisia; 2011.
30. Mehrpouyan M. Effects of different inoculant on nutrients uptake and nitrogen fixation in Common bean. International Journal of Agricultural Science. 2012;2(9): 831-838.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/17476