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Response of Faba Bean (*Vicia faba* L.) to Rhizobium Inoculation in Gummer District SNNPR, Ethiopia

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Abstract

The biological fixation of nitrogen by legumes is a well-known ways of fixing atmospheric nitrogen to plant-available form. Effectiveness in nitrogen fixation depends on the genotype of legumes and requires host specific rhizobium strain for nodulation and optimizes faba bean productivity. Thus, the field experiment was conducted to evaluate the effectiveness of rhizobium inoculants of faba bean laid in randomized complete block design with three replications. The experiment consisted of 8 treatments: control, 121 kg ha^{-1} NPS, 60 kg ha^{-1} NPS+FB 1018, 60 kg ha^{-1} NPS+FB 1035, 60 kg ha^{-1} NPS+FB 04, 60 kg ha^{-1} TSP+FB 1018, 60 kg ha^{-1} TSP+FB 1035 and 60 kg ha^{-1} TSP +FB 04. Rhizobium inoculation revealed a highly significant ($p \leq 0.05$) effect on yield and yield attributes compared to the un-inoculated plants. Over years results showed that inoculated plants gave a significant ($p \leq 0.05$) increase in nodule number and grain yield advantage against the un-inoculated plants. The highest yield (5.87 ton ha^{-1}) was recorded from inoculates of FB 1018+60 kg ha^{-1} TSP compared to the un-inoculated that gave 2.48 ton ha^{-1}. Inoculated rhizobium strains performed better in ecologically competent and symbiotically effective in nodulation for increased yield, thus recommended for the study area and similar agro-ecologies.

Keywords: Faba bean; Fertilizer; Rhizobium strain; Yield

Introduction

Faba bean is a major grain belonging to the legume family and widely cultivated in many countries for source of dietary and feed purposes [1]. It accounts major food and feed legumes because of the high nutritional value of its seeds, which are rich in protein and starch [2]. Faba bean plays a major role by fixing atmospheric nitrogen to plant-available form [3]. Biological fixation of atmospheric nitrogen in legume-rhizobium is well known eco-friendly practice used for the improvement of N fixation resulted in increased shoot growth, number of pods, and grain yield of faba bean [4]. Yadav and Verma reported that the fixation of nitrogen by legumes accounts for 50% of 175 million tons of total biological N_2 fixation annually globally. However, the fixation of nitrogen depends on the genotype of legume, rhizobium strain, and the interactions of these with the bio-physical environment and symbiosis nodulation of rhizobium [5]. Therefore, the fixed amount of nitrogen varies with legume species and/or variety and effectiveness of partner microsymbiont [6]. The report of also confirmed the host-specific rhizobia strains of common bean and soybean adapted better to the local soil and environmental condition. To have a successful establishment, inoculants strain must be able to survive in soil environment because the better survival rate and soil persistence of rhizobium enhanced the possibility of effective nodulation and nitrogen fixation [7]. If not, poorly efficient rhizobium strains may outcompete and gain an advantage over effective rhizobium strains used for inoculation. Although soil may harbor certain ineffective nodule forming native rhizobia, however effective nodule formation largely depends upon the competitiveness of inoculants strain [8]. As a result inoculation with host-specific effective rhizobium strains species is required for effective nodulation and nitrogen fixation [9]. In this scenario, inoculating faba bean with effective and appropriate rhizobial strain is crucial to improve symbiotic nitrogen fixation and the productivity [10]. Inoculation affects the microbial community by increasing desired rhizobia strain population in the rhizosphere.

Symbiotic performance of nodulation is highly governed by the abundance effectiverhizobiastrainanditscompetitiveness, the present study was initiated to identify best performing rhizobium strains on faba bean for nodulation and better yields for two consecutive main growing seasons under rain fed conditions at Gummer District SNNPR Ethiopia [11].

Materials and Methods

Description of study area

A field experiment was carried out consecutive main cropping seas ons for two years (2019 and 2020) under rain fed conditions at Gumer, Guraghe Zone, Southern Nations Nationalities and Peoples' Regional State of Ethiopia. Experimental site is situated at 8°01'56.2''N and 38°01'58.3''E, and at altitude of 2767 m.a.s.l with temperature of minimum 7.5% and maximum 20%. The area receives a bimodal rainfall with an annual average rainfall of 1200 mm. Rainfall is distributed between the short rainfall season (March to April) and the main rainy season (June to September).Mixed crop-livestock farming is the dominant economic activity in the rural areas [12-15].

Experimental design and treatments

The experiment was laid out in randomized complete block design with three replications. Eight levels of treatments were (T_1: Control, T_2: 121 kg/ha NPS, T_3: 60 kg/ha NPS+FB 1018, T_4: 60 kg/ha NPS +FB 1035, T_5: 60 kg/ha NPS+FB 04, T_6: FB 1018+TSP 60 kg/ ha, T_7: FB 1035+TSP 60 kg/ha, T_8: FB 04+TSP 60 kg/ha). The plot size was 3 × 3 m (9 m^2) and improved Faba bean variety (Dosha) was used for experimentation at the spacing of 40 and 10 cm between rows and plats respectively. Inorganic fertilizer (NPS and 60 kg ha^{-1} P in the form of TSP) were applied at planting by drilling with faba bean seeds in the row. Carrier based inoculants of faba bean were obtained from the Soil Microbiology Laboratory of Holeta Agricultural Research Centre (HARC). Seeds were immersed in warm water to be anchored rhizobium stains. The sugar slurry was used as a sticker for carrier-based inoculants so that the inoculums sticking and coating to the seeds. The inoculated seeds allowed to air dry for a few minutes and planted immediately after drying in shade [16]. Un-inoculated treatments were sown before the commencement of inoculation to avoid cross-contamination thoroughly [17].

Physical and chemical soil characteristics

Before commencement of the experiment, the experimental field was characterized for selected soil physical and chemical properties, soil samples were collected from 0-15 cm depth for initial determination of soil fertility parameters. The soil samples were analyzed for pH, available, exchangeable acidity P, % N, and % OC (Table 1).

pH	EA	BD	%OC	%TN	AP	CEC	Textural class			
							%sand	%clay	%silt	texture
5.9	2.69	0.99	1.1	0.094	1.28	41.2	70	14	16	Sandy loam

Table 1: Chemical and physical properties of soil before planting.

Agronomic data collection

The yield and yield attributed components: plant height, nodule number, number of pods per plant, number of seed per plant, above-ground biomass, and grain yield were collected and subjected to Analysis of Variance (ANOVA). The grain yield was determined from each experimental plot and adjusted to constant moisture levels of between 16.1% and 18% [18].

Statistical analysis

Data collected from the crop was subjected to analysis of variance using SAS software packages and mean separation was done using LSD (Gomez and Gomez, 1984) at a 5% probability level [19].

Results and Discussion

Effect of rhizobium inoculation on grain yields

Over years mean showed that rhizobium inoculation significantly ($P<0.05$) affected faba bean grain yield at this location. Statistically the highest yields were recorded from inoculated plants compared to un-inoculated. As it is shown in Table 2, the maximum grain yield (5.875 ton ha^{-1}) was obtained from the inoculation of FB 1018 followed by FB 1035 and that gave 5.29 and 5.078 ton ha^{-1} respectively along with 60 kg/ha TSP whereas the lower grain yield was obtained from the un inocul ated). This study par with the finding of who reported that inoculation of rhizobial strains significantly increased bean grain yield. Desta et al. (2015) was also confirmed that application of effective rhizobium strain alone and/or in combination with zinc significantly increased grain yield of faba bean. Report of also show that the application of effective strains increases the grain yield of faba bean upto 44.47%. Combined mean gr ainyields affected by inoculation of Rhizobium strain highlighted at Table 2 [20].

Effect of inoculation on biomass yield

Rhizobium strains inoculation significantly ($P≤0.05$) affected biomass yield. From Table 2 indicates inoculated plant with FB 1018, FB 1035 and FB 04 along with 60 kg/ha TSP recorded highest biomass compared to un-inoculated that gave lowest biomass yield statistically. This result is in agreement with the finding of who reported inoculation of bacterial rhizobium strain brought significant above ground biomass on faba bean also showed that rhizobium strains inoculation significantly influenced faba bean biomass weight un-inoculated treatment. The Difference in biomass yield obtained from the inoculation of faba bean rhizobium strains could be from the additional supply of nitrogen through the notable biological nitrogen fixation by the inoculated strains [20-23].

Treatments	Combined Mean of Biomass ton ha^{-1}	Combined Mean of Grain Yield ton ha^{-1}
T_1: Control	5.758^{d}	2.48^{c}
T_2: 121 kg ha^{-1} NPS	11.462^{ab}	5.635^{a}
T_3: 60 kg ha^{-1} NPS+FB 04	9.452^{bc}	4.375^{b}
T_4: 60 kg ha^{-1} NPS+FB 1035	8.962^{c}	4.406^{b}
T_5: 60 kg ha^{-1} NPS+FB 1018	10.05^{abc}	5.035^{a}

T_6: FB 04+60 kg ha^{-1} TSP	11.518^{ab}	5.293^{a}
T_7: FB 1035+60 kg ha^{-1} TSP	10.558^{abc}	5.078^{ab}
T_8: FB 1018+60 kg ha^{-1} TSP	11.868^{a}	5.875^{a}
Mean	9.95	4.77
LSD (0.05)	2.384	1.123
CV (%)	20.4	20.1

Table 2: Combined mean of biomass and grain yield affected by in oculation of rhizobium strain.

Effect of inoculation on nodule number

Rhizobium inoculation showed asignificantly increase number of the nodules per plant. Table 3 shows that inoculation of strains significantly ($P \leq 0.05$) affected nodule number/plant. A higher nodule number was obtained from all inoculated plants compared to un-inoculated. This result revealed that inoculation of those strains may be best suited and competed in the study area compared to the existing native faba bean rhizobium strains. Woldekros et al., reported that inoculation of Rhizobium strain with faba bean seed gave higher nodules. Correspondingly, and findings confirmed that inoculating of rhizobium strain to faba bean significantly increased nodule number also reported that inoculation of faba bean rhizobium strains significantly increases nodule number/plant.

Effect of inoculation on number of pods plant^{-1}

As it is indicated in Table 3, inoculation of rhizobium strains statistically affected number of seeds/pods as compared to the un-inoculated treatment. The number of pods/plants was affected by the inoculation of all FB 04, FB 1035, and FB 1018 rhizobium strains. This increment might is attributed to the increment of faba bean growth parameters like plant height. Reported that the number of pods per plant was significant ($p<0.001$) affected by rhizobium inoculation. Rhizobial strain alone could significantly increase the number of pods/ plants. This study is in disagreement with showed that the number of seeds per pod of faba bean was not significantly affected due to fertilizer rate, rhizobium inoculation, and lime rate.

Effect of inoculation on number of seed/plant

Rhizobium inoculation independently increased the seed yield as compared to un-inoculated seed (Table 3). This may be because inoculation of seeds with rhizobium increases nitrogen uptake and thereby plant growth and performance were enhanced. Rhizobium inoculations can increase the potential of plants to produce more plant height. Gedamu et al. reported that inoculation of seed gave significantly higher seed per plant. However, this finding contradicts with finding of and who reported that the number of seeds per pod did not vary significantly ($p>0.05$) between inoculated and un-inoculated [24].

Effect of inoculation on plant height

Combined mean result in Table 3 revealed that inoculation of seeds with rhizobium increase plant height. Confirmed that seed inoculation significantly increases nitrogen up take and there by plant growth and performance enhanced with possibly increase the potential of plants to produce more plant height.

Treatments	Nodule number	Plant height (cm)	Pod Plant^{-1}	Seed Plant^{-1}
T_1: Control	69.6^{d}	90^{b}	14.5^{b}	33^{b}
T_2: 121 kg ha^{-1} NPS	89.4^{c}	111^{a}	27.5^{a}	49^{a}
T_3: 60 kg ha^{-1} NPS+FB 04	109^{c}	110^{a}	25.3^{a}	47^{a}
T_4: 60 kg ha^{-1} NPS+FB 1035	118^{c}	112^{a}	29^{a}	49^{a}
T_5: 60 kg ha^{-1} NPS+FB 1018	137^{a}	110^{a}	30.5^{a}	51^{a}
T_6: FB 04+60 kg ha^{-1} TSP	121b^{c}	105^{a}	29.8^{a}	49^{a}
T_7: FB 1035+60 kg ha^{-1} TSP	121b^{c}	121^{a}	29.5^{a}	50^{a}
T_8: FB 1018+60 kg ha^{-1} TSP	135^{ab}	112^{a}	31.3^{a}	55^{a}
Mean	112	107	27.5	48
LSD (0.05)	15.5	12.2	5.62	9.53
CV (%)	11.8	9.7	17.4	16.9

Table 3: Combined mean of growth and yield parameters of faba bean affected by inoculation.

CONCLUSION

Rhizobium inoculation significantly affected all parameters of faba bean and improved grain yield. Inoculating legumes with host-specific competitive and effective rhizobium is crucial to boost productivity.

Inoculated plants gave the highest yield advantage compared to un-inoculated. All Strains along with 60 kg/ha TSP better in ecologically competent and symbiotically effective in nodulation and increased yield, thus recommended for the study area and similar agro-ecologies.

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Conflicts of Interest

Authors declare that there are no conflicts of interest regarding the publication of this paper.

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