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Evaluation of Best Performing Indigenous *Rhizobium* Inoculants for Faba Bean Production at Goba and Sinana District of Bale Highland South Eastern Ethiopia

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Abstract **– A field trial was conducted for two consecutive cropping season of 2016-2017 ("*Bona*") on farmers' fields at different sites (Sinja & Aloshe) of Goba District and (Jafara & Selka Oda) of Sinana District to evaluate the effect of rhizobium inoculation and diammonium phosphate (DAP) on growth, nodulation, yield and yield components of faba bean. The treatments consisted of application of biofertilizers, FB1035, FB1018, FB EAL110 singly and combination with chemical fertilizer (50kg ha^{-1} DAP) including control (without any fertilizer and inoculation) was used. Experiment was laid out in a randomized complete-block (RCBD) design with three replications was used. It could be concluded that, using the organic, bio-fertilizer and mineral fertilizers are benefit for enhancing the growth and yield of faba bean. It can be concluded that from these study, faba bean inoculated with rhizobia strain FB1018 at Aloshe, for Sinja FB1018 and EAL110 + 50 kg , at Jafara 1018 + 50 kg ha-1 DAP and for Selka Oda rhizobia strain in combination with phosphorus fertilizers brought yield advantage as compared to control or farm practices. Rhizobial inoculation and supplementation with phosphorus has potential in improving growth, yield, economic benefits, and photosynthesis in legumes. It is recommended to adopt and incorporate these technologies in legumes production. However, the information available demands more research to be done so as to establish the contribution of these technologies in attaining optimal production of legumes grown in the highland agro ecology of Bale zone.**

Keywords **– Rhizobium Inoculation, Faba Bean, Fertilizer DAP, Grain Yield.**

I. INTRODUCTION

Faba bean (*Vicia fabae*) is ranked first among cool season food legumes based on area of production and foreign exchange income earnings [8]. It has also a great contribution for sustainable soil fertility management due to its ability to fix atmospheric nitrogen (N_2) [6]. Even though faba bean is the leading pulse crop in the country, the national yield has remained low. Several abiotic factors contributed to low productivity of faba bean includes: poor soil fertility, acidity of the soil in high rain fall areas and low existence of effective indigenous rhizoba population in the area are among the others [7]. The beneficial effect of Rhizobium species in terms of biological nitrogen - fixation (BNF) is well known and has been the subject of extensive previous studies [9]. Besides their central role in symbiotic BNF rhizobia are also known for their plant growth promoting (PGP) activities. For instance some rhizobia secrete growth hormones such as indole acetic acid (IAA) which has positive influence on plant growth and also plays an important role in the formation and development of root nodules ([10] and [15]). The objectives of this work were: - To evaluate commercial and new faba ban inoculants on yield and yield component of faba bean.

II. MATERIALS AND METHODS

Field experiments were conducted on farmers' fields in 2016 and 2017 in different locations of Goba District (Sinja & Aloshe) and sinana district (Jafara & Selka Oda) to evaluate legume crops inoculated with different commercial and new rhizobial strains on yield and yield component of faba bean. Experiment was laid out in a randomized complete-block (RCBD) design with three replications. All the experimental sites were identified based on the information potential for faba bean production to create farmers awareness in order to use the full package of legume crop production for increasing yield as well as improve soil fertility. Each treatment was applied on a plot size of 3m x 2.4m = 7m^2, the distance between blocks and within plots are 1.5 m. **Faba bean** ("*Mosisa*" verities) 144g/plot or 200 kg ha^{-1} with 36 g plot^{-1} or 50 kg ha^{-1} phosphorus (DAP) and at sowing, faba bean seeds were coated with different rhizobial inoculants at a rate of 10 g of inoculants kg^{-1} seeds, using distilled water as the adhesive agent for seed coating and the following treatments were used (Table 1).

Table 1. List of treatments

Treatment	Full name of treatments
1	Control (Un Inoculated and without fertilizer
2	FB 1035
3	FB 1018
4	FB EAL110
5	FB 1035 + 50 kg DAP ha^{-1}
6	FB 1018 + 50 kg DAP ha^{-1}
7	EAL110 + 50 kg DAP ha^{-1}

Fig. 1. Field layout of the experiment for faba bean.

III. Results and Discussion

The summary results of the e**ffect of bio fertilizer and chemical fertilizer on yield and yield components of faba bean** (Table 2.) indicated that plant height (PH), biomass yield (BY), grain yield (GY) and thousand kernel weight (TKW) were significantly affected by different biofertilizers and chemical fertilizer (50kg ha^{-1} DAP) treatments. However, number of tillers (NT) was not statistically significant. Both sole and combined application of biofertilizers or chemical fertilizer increased significantly the PH, BY, GY and TKW in comparison to control (uninoculated faba bean). However, applied inoculants FB 1018 + 50 kg DAP ha^{-1} produced the highest BY (7.4 t ha^{-1}) which is 14% higher over the control and Grain yield of 3.5 t ha^{-1} which is 90% over the control (uninculcated and without fertilizer), followed by EAL110 + 50 kg ha^{-1} DAP gave the highest GY of 3.1 t ha^{-1} which is 50% over the control. It has been reported that phosphorus may play a crucial role in increasing nutrient uptake in legumes grown in different soils ([12] and [16]). In general for Jafara location of Sinana District the application of biofertilizer in combination with chemical fertilizer (FB 1018 + 50 kg ha^{-1} DAP) were brought about yield advantage of 90% over the control (uninculcated and without fertilizer) practices.

Table 2. Summary of the results of the effect of different rhizobial strains on yield and yield components of, faba bean during "*Bona*" cropping season of 2016 at Jafara site of Sinana District

Treatments	PH (cm)	NT	BY (t ha-1)	GY (t ha-1)	TKW
T_0 = Control (Un Inoculated)	108.1ba	1.5	6.5bc	2.6d	646.8
T_1 = FB 1035	111.4ba	2.1	5.7d	2.9c	642.1
T_2 = FB 1018	111.5ba	1.9	5.9dc	2.6d3	642.0
T_3 = FB EAL110	104.4b	1.6	5.6d	2.1e	637.2
T_4 = FB 1035 + 50 kg DAP ha^{-1}	117.7a	2.2	6.8ba	3.0cb	624.4
T_5 = FB 1018 + 50 kg DAP ha^{-1}	111.1ba	1.6	7.4a	3.5a	623.1
T_6 = EAL110 + 50 kg DAP ha^{-1}	113.5ba	1.7	6.0dc	3.1b	619.8
Mean	111.1	1.8	6.39	2.8	633.6
CV	6.3	22.8	7.5	3.0	3.5
LSD	12.3	ns	0.8	0.2	38.9

Where: - PH = Plant height,; NT = No. Tiller; BY = Biomass yield, GY = Grain yield, TKW = Thousand kernel weight; NS = not significant; LSD = least significant level; CV=coefficient of variation.

The results (Table 3.) indicated that PH, BY, GY and NT were significantly affected by different biofertilizer inoculants and chemical fertilizer (50 kg ha^{-1} DAP) treatments. However, TKW was not statistically significant. Both sole and combined application of biofertilizers or chemical fertilizer increased significantly the PH, BY, GY and TKW in comparison to control (uninoculated faba bean). However, applied inoculants FB EAL110, FB 1035, 50 ha^{-1} kg DAP and FB 1018 + 50 kg DAP ha^{-1} showed statistically no significant difference. The highest GY of 1.7 t ha^{-1} whith 70% higher yield advantage over the control (uninculcated and without fertilizer) were recorded, followed by FB 1035 alone gave grain yield (1.6 t ha^{-1}) which is 60% over the control. In general for Selka Oda site of Sinana District, the application of biofertilizer inoculants in combination with chemical fertilizer (50 kg ha^{-1} DAP) brought yield advantage of 70% over the control (un inoculcated).

Table 3. Summary results of the effect of different rhizobial strains on yield and yield components of, faba bean under field conditions during 2016 cropping season at Selka Oda sites of Sinana District

Treatments	PH (cm)	NT	BM (tha-1)	GY (t ha^{-1})	TKW
T_0 = Control (Un Inoculated)	63.3b	0.2e	6.5bac	1.0c	464.1
T_1 = FB 1035	73.9a	1.1b	5.7bc	1.6a	448.2
T_2 = FB 1018	70ba	0.8c	6.2bc	1.3b	431.1
T_3 = FB EAL110	75.1a	0.4d	5.6c	1.7a	432
T_4 = FB 1035 + 50 kg DAP/ha	75a	1.3a	6.8ba	1.7a	430.4
T_5 = FB 1018 + 50 kg DAP/ha	72.8a	0.4ed	7.4a	1.7a	450.4
T_6 = EAL110 + 50 kg DAP/ha	70.7ba	1.2ba	6.0bc	1.3b	426.1
Mean	71.5	0.8	6.3	1.5	440.4
CV	6.6	13.4	10.6	8.0	5.2
LSD	8.3	0.2	1.2	0.2	ns

Where: - PH = Plant height,; NT = No. Tiller; BY = Biomass yield, GY = Grain yield, TKW = Thousand kernel weight; NS = not significant; LSD = least significant level; CV = coefficient of variation.

The summary of results indicated in Table 4 showed that BY, GY and TKW were significantly affected by using different biofertilizer inoculants and chemical fertilizer (50 kg ha^{-1} DAP) treatments. However, PT and NT were not statistically significant. The sole application of biofertilizer, or their combination with chemical fertilizers increased significantly the PT, NT, BY GY and TKW in comparison to without treatment application (control).

However, applied EAL110 + 50 kg DAP ha^{-1} produced the highest biomass (5.3 t ha^{-1}) and Grain yield (2.6 t ha^{-1}) as compared to other treatments or with control (uninculcated and without fertilizer) practices and followed by FB 1018 and FB 1018 + 50 kg DAP/ha biomass Grain yield (2.5 t ha^{-1}). In general for Sinja Location Goba District the application of biofertilizer in combination with chemical fertilizer (EAL110 + 50 kg DAP ha^{-1}) were brought yield advantage than control (uninculcated and without fertilizer) practices.

Table 4. The summary results of the effect of different rhizobial strains on yield and yield component of, faba bean "Bona" cropping season 2016 at Sinja site of Goba District.

Treatments	PH (cm)	NT	BM (tha-1)	GY (tha-1)	TKW
T_0 = Control (Un Inoculated)	118.7	3.5	5.3ba	2.4a	420.7ba
T_1 = FB 1035	112.9	3.5	5.2ba	1.9b	402.6b
T_2 = FB 1018	117.5	3.0	4.0d	2.5a	405.9ba
T_3 = FB EAL110	113.2	3.5	4.5c	2.1b	439.9ba
T_4 = FB 1035 + 50 kg DAP ha^{-1}	120.9	3.0	5.6a	2.4a	418.5ba
T_5 = FB 1018 + 50 kg DAP ha^{-1}	121.7	3.5	5.1b	2.5a	408.8ba
T_6 = EAL110 + 50 kg DAP ha^{-1}	115.2	3.3	5.3ba	2.6a	443.9a
Mean	117.1	3.3	5.0	2.3	420.0
CV	15.1	12.4	5.3	5.2	6.0
LSD	ns	ns	0.5	0.2	41.0

Where: PH = Plant height,; NT = No. Tiller; BY = Biomass yield, GY = Grain yield, TKW = Thousand kernel weight; NS= not significant; LSD= least significant level; CV=coefficient of variation.

The summary results indicated (Table 5 below) that PT, NT, BY, GY and TKW were significantly affected by using different biofertilizers and chemical fertilizer (50 kg ha^{-1} DAP) treatments. Application of biofertilizer inoculants, or chemical fertilizers singly or in combination among them increased significantly the PH, NT, BY, GY and TKW in comparison to without treatment application (control). However, applied FB 1018 produced the highest biomass (8.3 t ha^{-1}) and GY (4.2 t ha^{-1}) as compared to other treatments or control (uninculcated and without fertilizer) application and followed by FB 1018 + 50 kg DAP ha^{-1} biomass (8.1 t ha^{-1}) and GY (4.1 t ha^{-1}). In general, for Aloshe site of Goba District the application of biofertilizer (FB 1018) were brought yield advantage than control (uninculcated and without fertilizer).

Table 5. Summary results of the effect of different rhizobial strains on yield and yield components of faba bean during "Bona" cropping season of 2016 at Aloshe site of Goba District.

Treatments	PH (cm)	NT	BM (tha-1)	GY (tha-1)
T_0 = Control (Un Inoculated)	131.4	2.8	7.0c	3.3c
T_1 = FB 1035	139	2.8	7.8ba	3.9ba
T_2 = FB 1018	139.7	2.6	8.3a	4.2a
T_3 = FB EAL110	145.7	2.4	8.0ba	4.0ba
T_4 = FB 1035 + 50 kg DAP ha^{-1}	138.3	2.6	7.4bc	3.7b
T_5 = FB 1018 + 50 kg DAP ha^{-1}	137.6	2.5	8.1ba	4.1ba
T_6 = EAL110 + 50 kg DAP ha^{-1}	142	3.1	8.2a	4.0ba
Mean	139.1	2.7	7.8	3.86
CV	6.2	15.3	5.9	6.3
LSD	15.1	0.7	0.8	0.4

Where: - PH = Plant height,; NT = No. Tiller; BY = Biomass yield, GY = Grain yield, TKW = Thousand kernel weight; NS= not significant; LSD= least significant level; CV=coefficient of variation.

The result (Table 6.) indicated NT, BY, and GY were significantly affected by different biofertilizers and chemical fertilizer (50kg ha^{-1} DAP) treatments. However, PH, TKW was not statistically significant. Both sole and combined application of biofertilizers or chemical fertilizer increased significantly the NT, BY, and GY in comparison to control (uninoculated faba bean). However the use of FB 1018 alone produced the highest Grain yield (4.0 t ha^{-1}) which was 111% yield advantage over the control (uninculcated and without fertilizer) and followed by FB 1018 + 50 kg DAP/ha Grain yield (3.8 t ha^{-1}) which was 100%. In general for Aloshe and Sinja site of Goba District the application of biofertilizer (FB 1018) were brought yield advantage 111% over the than control (uninculcated and without fertilizer).

Table 6. Effect of different rhizobial strains on yield and yield components of faba bean under field conditions during "Bona" 2017 combined result of Sinja and Aloshe sites of Goba District

Treatments	PH (cm)	NT	BM (t ha-1)	GY (t ha-1)	TKW
T_0 = Control (Un Inoculated)	112.2	1.3^{b}	4.0^{bc}	1.9^{b}	412.7
T_1 = FB 1035	116.7	1.5^{b}	5.3^{ba}	3.4^{a}	516.7
T_2 = FB 1018	112.6	1.5^{b}	4.4^{bac}	4.0^{a}	530.2
T_3 = FB EAL110	105.3	1.4^{b}	3.7^{c}	3.1^{a}	529.3
T_4 = FB 1035 + 50 kg DAP ha^{-1}	111.4	1.7^{ba}	5.4^{ba}	3.5^{a}	503.2
T_5 = FB 1018 + 50 kg DAP ha^{-1}	109.2	1.6^{ba}	5.7^{a}	3.6^{a}	518.7
T_6 = EAL110 + 50 kg DAP ha^{-1}	107.1	1.9^{a}	5.1^{bac}	3.8^{a}	515.0
Mean	110.6	1.6	4.8	3.3	503.7
CV	13.4	19.0	27.0	32.6	20.2
LSD	ns	0.3	1.4	1.3	ns

Where : - PH = Plant height,; NT = No. Tiller; BY = Biomass yield, GY = Grain yield, TKW = Thousand kernel weight; NS = Not significant; LSD = Least significant level; CV = Coefficient of variation.

Using different biofertilizer inoculants and chemical fertilizer (50kg ha^{-1}DAP) had significantly increases NT; TKW; GY and BY as compared to the uninculcated and no fertilizer application (control). This was related to the symbiotic relationship between *Rhizobium* and faba bean plants, which results in fixation of atmospheric nitrogen into the roots and translocation of amino acids to the shoots, thus leading to increased yield. Positive effects of bacterial inoculation on yield of various leguminous crops are well documented ([10], [3], [16], [4]). [4], also reported that the higher yields obtained with inoculation indicates that the *Rhizobium* technology is efficient in supplying nitrogen to legumes as inorganic nitrogen fertilizer and it is a better option for resource-poor farmer who cannot afford to purchase expensive inputs.

These results are in conformity with those of [1], and [14], who reported that inoculation significantly increased grain yield in faba bean and groundnut, respectively but most of the yield attributes were not significantly affected. These results indicated that inclusion of *Rhizobium* inoculation in the production package for faba bean production in the study area is likely to be cost-effective since the inoculation sachets are fairly affordable.

IV. Summary and Conclusion

It could be concluded that, using the organic, bio-fertilizer and mineral fertilizers (50 kg ha-1 DAP) were significantly increase enhancing the growth and yield of faba bean. The results indicated that application of biofertilizer, or chemical fertilizers singly or in combination among them increased significantly plant height, number of tiller, biomass yield, Grain yield and thousand kernel weights in comparison the control (uninoculated faba bean). In addition these technologies could be used as a cheap external source of plant nutrition especially for smallholder farmers who cannot afford expensive inorganic fertilizers.

Seed inoculation by Rhizobium strains and starter fertilizer (50 kg ha-1 DAP) had resulted the highest yield advantage over control. Therefore from this result rhizobium strains FB 1018 + 50 kg ha^{-1} DAP; FB EAL110 at Jafera, Selka Oda site of Sinana district respectively and at Aloshe and Sinja site Goba district rhizobium strain were recommended. Finally, disseminating Rhizobium strains and starter fertilizer (50 kg ha-1 DAP) as future recommendation to the end users is paramount importance at large.

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