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Evaluation and Demonstration of MAR1495 and Local Strain (SB12) on Soybean Yield at Gofa Woreda Southern Nation Nations Nationalities and Peoples of Ethiopia

Yehuala Alemneh[1,]*, Aynalem Kutafo[2]

Abstract

Soybean is the most important legume crop in the world which can be used for human food source, animal feed, soymilk production, oil production as well as for soil fertility improvement by fixation of nitrogen. The benefits apiece use of Rhizobium inoculants show that a completely good deal of services may be saved by borderline labourers by utilizing quality proven inoculants on the farm. Rhizobia immunization to seeds is well intentional and bleeding concerning this beneficial nitrogen repairing root lump collaboration representing a symbol of favourably applied land microbiology. So, the present study was aimed to study types of strain for better production of soybean in the study area. This experiment was conducted in two consecutive cropping seasons of the area with the objective of evaluating two commercial strains—MAR1495 and local strain SB12—with and without inorganic fertilizer and consisted of eight treatments. This experiment was done in two consecutive years with three replication in randomized block design. Interaction application of local strain SB12 +100 kg TSP and local strain SB12+50 kg DAP gave the maximum grain yield of 1925 kg ha^{-1} and 1916 kg ha^{-1}, respectively. Results of the present experiments showed that combined application of local strains with DAP and TSP could increase total grain yield of soybean; this may be due to availability of optimum plant nutrients from both combination application of biofertilizer and chemical fertilizer of nitrogen and phosphorus sources. Soil fertility can be improved by application of MAR1495+100 kg ha^{-1} TSP and local strain (SB12)+100 kg ha^{-1} TSP as observed from the present study from 0.01–0.094 and 0.084, respectively. Therefore to improve soil fertility and soybean production farmers could use local strain (SB12) with 100 kg ha^{-1} TSP or local strain (SB12) with 50 kg ha^{-1} DAP.

Keywords: fixation, inoculation, rhizobia, soil fertility, soybean, fertilizer

INTRODUCTION

Soybean (*Glycine max* L.) is an economically important leguminous crop that contains large amounts of all acids, oil, minerals, vitamins and regarded as nutrient storage [1]. Soybean is the most important legume crop in the world which can be used for human food source, animal feed, soymilk production, oil production as well as for soil fertility improvement by fixation of nitrogen [2].

It is now produced in larger quantities than any other legume crop in the world and is certainly the most important source of vegetable oil, processed in a wide variety of ways to produce soymilk, bean curd, flour, and fermented products.

It was introduced for the first time in Ethiopia during 1950s for its nutritional value, different

***Author for Correspondence**
Yehuala Alemneh
E-mail: alemnehyehualal@gmail.com

[1,2]Researcher, Southern Agricultural Research Institution, Areka Agricultural Research Center, P.O. Box 079 Areka Ethiopi

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multipurpose uses and wider adaptability [3]. Different agro-ecological areas of Ethiopia are favourable for production of soybean.

The production area of soybean is 54,543 ha with the total of 125,623 t [4, 5] currently and national average productivity is 2.30 tha^{-1} which is lower than the world average productivity (2.79 tha^{-1}) [6]. This is still very low and doesn't meet country's oil demand.

So the country is facing severe deficiency of oil seed for the large number of industries which are currently established and in turn could not secure food oil production for consumption for the people. The major reason for reduction in soybean production in Ethiopia is low fertilization, insect pests, multi-nutrient deficiencies, low variety stability besides unfortunate agronomic practices [7]. Among the above listed problems, declining of soil fertility is the main reason behind slow growth of food production in sub-Saharan Africa [8]. Declining soil fertility is also one of the important bottle neck for small holder farmers for production of cereals in Ethiopia [9]. The main reason behind decline in soil fertility is lack of nutrients in soil, particularly N; possibly due to continuous production of cereals (mono cropping) without rotation as well as knowledge gap for use of organic source for improvement of soil fertility [10, 11]. Legume-based crop rotation have positive effect on soil fertility because legumes fix nitrogen and contributes nutrients and residue decomposition [12].

As a legume crop, soybean utilizes two sources of nitrogen for its growth via mineral nitrogen from the soil and atmospheric N_2 fixed biologically in root nodules formed in symbiosis with different species of *Rhizobium* and *Bradyrhizobium* [12].

Atmospheric nitrogen is obtained from the activity of soil bacteria which convert atmospheric nitrogen into ammonia.

Moreover, the process of biological nitrogen fixation is believed to consume less energy than N fixation through the mineral process. The most important of nitrogen fixation in agricultural production system is symbiotic association between rhizobia microbes with legume crops by the formation of nodules [13]. The benefits apiece use of Rhizobium inoculants showed that a completely good deal of services may be saved by borderline labourers by utilizing quality proven inoculants on the farm. Rhizobia immunization to seeds is well intentional and bleeding concerning this beneficial nitrogen repairing root lump collaboration representing a symbol of favourably applied land microbiology.

Inoculation of seeds with rhizobia strains is well known by different findings for its fixation of nitrogen by association of symbiosis nodule formation and successfully applied in microbiology agricultural system [14]. In Ethiopia, use of rhizobial inoculation for better production of soybean showed good results; however, study for type of strains and agroecology-based test are needed. So the present study was aimed to study types of strain for better production of soybean in the study area.

METHODS AND MATERIALS

Description of Study Area

The experimental site was inside Gamo Gofa zone in Southern Nation, Nationalities and Peoples of Ethiopia Regional State.

Altitude of experimental site ranged 1395 m above sea level. The soil types present in Gofa district are broadly categorized as, blackish-brown color (30–45%) and intermediate Nitisols, (15–25%), and Vertisols (55–60% of the area). According to the metrological data collected by the Gofa Meteorological Station and from 1987 to 2009, the average minimum and maximum temperatures of experimental site were 24 °C and 38 °C, respectively.

Treatment Structure and Design of the Experiment

The present experiment was conducted in two consecutive cropping seasons of the area with the objective of evaluating two commercial strains—MAR1495 and local strain SB12—with and without inorganic fertilizer. Experiments treatment consisted of T1: No fertilizer, No strain; T2: MAR1495; T3: Local strain (SB12); T4: MAR1495+50 kg DAP; T5: Local strain (SB12) +50 kg DAP; T6: MAR1495+100 kg TSP; T7: Local strain (SB12) +100 kg TSP; and T8: Recommended 100 kg DAP. The field was selected according to the back history of the cropping season. During the selection degraded land, extremely fertile land was avoided. Plantation was done during early July at the rate of 75 kg h^{-1} of seeds. Experimental size was 4*4 m^2 consisting of ten rows per plot and the spacing was 40*10 cm between rows and plants. Soybean seeds were obtained from Areka Agricultural Research Centre (AARC) and were surface sterilized by Mercuric chloride (0.1%) for 2 min; followed by thorough rinsing with distilled water. Thereafter, seeds were soaked in distilled water for 6 h then immediately sown.

The experiment was laid out in complete randomized block design (CRBD) with replications three times. Weeds were controlled per recommendation and the relevant data were collected on time such as plant height, nodule number, nodule weight, biomass, and grain yield.

Soil Sampling and Analysis

Soil samples were collected representatively at field 20 cm depth composite before plantation and from each plot after harvest following zigzag method. Composite soil sample (0–20cm depth) has been amassed from the experimental location with the aid of zigzag approach earlier than planting for deciding the physiochemical properties of soil. Collected samples were air dried at room temperature and were passed through a 2 mm sieve for maximum parameters and through a 0.5 mm sieve to decide general nitrogen and natural carbon. Soil particle length distribution was decided by means of hydrometer method [15]. Soil pH was decided through potentiometric technique at soil water ratio of 1:2.5 [16]. Cation trade ability was decided with the aid of 1M ammonium acetate technique at pH 7 [17]. Organic carbon was determined by dichromate oxidation method [18]. The value of total nitrogen was determined by organic carbon conversation and phosphorus available was analysed by the method described by Olsen & Palm et al. [19, 20].

Statistical Analysis

Collected crop data were put into statistical system software for analysis of variance. Treatments mean at 5% level of significance were tested by using least significance difference test [21].

RESULT AND DISCUSSION

Physicochemical Properties of Soil on the Site

The distribution of soil particle size was found in proportion of 38, 50, and 45 for sand, silt, and clay, respectively. Soil's textural class was clay loam which was suitable for production of soybean [22]. Accordingly, pH of experimental site before planting was 6.8 which was satisfactory for production of soybean (Table 1). According to Jones et al. [23], the rating of soil pH was slightly acidic. pH of experimental site ranged within satisfactory range for soybean production as well as for most of the crops [24]. Organic carbon and total nitrogen content of the experimental site was 1.6% and 0.01%, respectively. This is rated as under medium and low range, respectively [16].

Soil result showed very low total nitrogen content and needed additional support for growth of crops (Table 1).

After Harvest Soil Fertility Status as Influenced by Treatment Application

The physicochemical properties of soil in the study area after harvest of soybean showed that the soil pH ranged from 7.14 to 7.56 with mean soil pH of 7.43, which qualified for moderately alkaline reaction according to the suggested study classification (Table 2). Application of chemical fertilizers and rhizobial strains treatments negatively affects soil pH; however, there is slightly increasing difference in soil pH that are taken before planting as compared to control. This may be due to buffering capacity of organic matter by realising some biological elements that fix H^+, Al^+ and other cations as reported by Palm et al. [25].

On the other hand, there were great improvement on N by application of local and MAR1495 strains with chemical fertilizer application (DAP) in treatment 4 and 5, respectively. This may be due to result of atmospheric nitrogen fixation into ammonia by leguminous plants (soybean) that is beneficial for the plants (Table 2).

Results of this association is formation of nodules with which rhizospheric bacteria convert atmospheric nitrogen to ammonia [26]. Organic carbon of the soil showed an improvement from medium to high in treated soils by rhizobial strains and chemical fertilizers especially MAR1495+50 kg DAP and Local strain (SB12) +100 kg TSP soils.

Effect of Rhizobial Strain on Nodule Number and Weight of the Crop

From analysis of variance analysis, significant difference was found among treatments in number of nodules, nodule weight, and plant height even if they have maximum and minimum record (Table 3). Accordingly, the highest nodule weight and number of nodule was recorded in inoculated treatment by both rhizobial strains as compared to uninoculated treatments; this indicated that inoculation with rhizobial strains could enhance nodule formation and have positive effects on nodule number. Among the two rhizobium strains used during the experiment, the maximum number of nodule (7.3) and nodule weight per plant (0.58) were recorded by SB12 strain followed by MAR1495 strain. On the other hand, minimum number of nodule (5.13) and nodule weight per plant (0.38) were recorded by uninoculated or control treatment. These results were directly in line with a study by Shambat S [27] who revealed that application of rhizobial inoculants alone could increase nodulation of soybean significantly.

Table. 1 Physicochemical properties of soil before planting.

Soil properties	Unit	Values	Rating	Reference
% sand	%	38		
% silt	%	50		
% clay	%	45		
Textural class			Clay	
Soil pH		6.8	Slightly acidic	[23]
Organic carbon (%)		1.68	Medium	[21]
Phosphorus (ppm)		13.2	Medium	[23]
Total nitrogen (%)		0.01	Medium	[21]
Available potassium (ppm)		61	Low	[23]
CEC (meq/100 g)		38	High	[21]

CEC: cation exchange capacity

Table 2. Physicochemical properties of soil after harvesting of soybean crop.

Treatment	OC	EA	pH	P	N	CEC
No fertilizer, No strain	1.76	0.32	7.14	10.83	0.042	36
MAR1495	2.91	0.22	7.37	20.90	0.014	40.6
Local strain (SB12)	1.97	0.24	7.51	16.54	0.084	35.4
MAR1495+50 kg DAP	3.63	0.32	7.56	14.96	0.126	33.6
Local strain (SB12) +50 kg DAP	1.54	0.32	7.48	17.66	0.123	30.6
MAR1495+100 kg TSP	2.11	0.18	7.54	17.62	0.094	35.6
Local strain (SB12) +100 kg TSP	3.19	0.2	7.48	19.82	0.084	28.2
Recommended 100 kg DAP	2.76	0.16	7.23	11.52	0.036	27.2

OC: organic carbon; EA: exchangeable acidity; CEC: cation exchange capacity; P: phosphorus; N: nitrogen.

Integrated Effect of Fertilizers (Biofertilizer and Chemical) on Plant Height of Soybean

Plant height of soybean varied slightly in number but did not significantly influenced by interaction effect of biofertilizer and chemical fertilizer types as well as rates (Table 3). Even though there was no

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significant difference statistically; there was difference in number that showed maximum and minimum result with the application of MAR1495 + 50 kg DAP and recommended DAP. This finding was in agreement with that of Okubay et al. [28] who reported that maximum soybean height was recorded from the treatment that applied maximum fertilizer.

Table 3. Treatment effect on plant height, nodule weight, and nodule number.

Treatment	Plant height	Nodule number	Nodule weight
1. Without fertilizer and rhizobial strain	86.30^{a}	5.13^{a}	0.38^{c}
2. MAR1495	84.300^{a}	7.3^{a}	0.51^{bac}
3. Local strain (SB12)	84.233^{a}	7.1^{a}	0.51^{bac}
4. MAR1495 + 50 kg DAP	87.467^{a}	6.2^{a}	0.58^{ba}
5. Local strain (SB12) + 50 kg DAP	84.733^{a}	6.0_{a}	0.48^{bc}
6. MAR1495 +50 kg TSP	83.667^{a}	7.0^{a}	0.7^{a}
7. Local strain (SB12) +50 kg TSP	84.2^{a}	7.3^{a}	0.56^{ba}
8. Recommended DAP (100 kg)	83.067^{a}	6.8^{a}	0.56^{ba}
CV	8.5	6.4	31.03
LSD	83.4	5.04	0.19

CV: coefficient of variance; LSD: least significant difference.

Table 4. Integrated effect of fertilizers (biofertilizer and chemical) on plant height of soybean.

Treatments	Branch number	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})
No fertilizer and strain	12.0^{bc}	3966.7^{ba}	1750^{b}
MAR1495	11.16^{c}	3958^{ba}	1633.3^{bc}
Local strain (SB12)	14.1^{a}	3633.3^{cb}	1716.7^{b}
MAR1495 + 50 kg DAP	13.8^{ab}	4341.67^{a}	1875^{ab}
Local strain (SB12) + 50 kg DAP	12.16^{abc}	3416.67^{c}	1916^{a}
MAR1495 + 100 kg TSP	12.8^{abc}	3500^{cb}	1608.3^{c}
Local strain (SB12) + 100 kg TSP	12.3^{abc}	3500^{cb}	1925^{a}
Recommended 100 kg DAP	13.5^{ab}	3916.6^{ba}	1483.3^{cd}
CV	14.3	14.36	23.65
LSD	2.12	0.78	0.57

CV: coefficient of variance; LSD: least significant difference.

Grain Yield

The interaction effect of biofertilizer with TSP and DAP chemical fertilizer affected grain yield of soybean (Table 4). The study results showed that interaction application of local strain SB12 +100 kg TSP and local strain SB12 +50 kg DAP gave the maximum grain yield of 1925 kg ha^{-1} and 1916 kg ha^{-1}, respectively. Findings of the present study revealed an increase in total grain yield of soybean by the combined application of local strains with DAP and TSP; this may be due to availability of optimum plant nutrients from both combination application of biofertilizer and chemical fertilizer of nitrogen and phosphorus sources. These findings were in line with those of Abeje et al. [29], who reported that grain yield, effective nodule number, and leaf area index were highly affected by the interaction application of biofertilizer and organic fertilizers. However, combined application of MAR1495 with chemical fertilizers TSP and DAP did not show significant result on soybean production in the given area. This might be due to the fact that MAR1495 strains of biofertilizer needs adaptability to the environment and some biofertilizer need to be adaptable for different agroecology of environment as reported by Win et al. [30].

On the other hand, the treatment with recommended 100 kg DAP gave the minimum grain yield of (1483.3 kg ha^{-1}) of soybean when compared with other uninoculated and combined application of MAR1495 and SB12 biofertilizers and inorganic fertilizers (DAP and TSP). This may be due to the crop needs additional nutrients for the growth and yield production in addition to recommended 100 kg ha^{-1} N. Soil data of study area showed low phosphorus value. Low phosphorus level along with other nutrient deficiency may be the cause of reduction of total yield in the given area. The present study agreed with the findings of Food and Agriculture Organization database [6] which stated that application of phosphorus could increase grain yield of cowpea and plant dry matter whereas inoculation cause reduction in both grain yield and plant dry matter.

Biomass and Branch Number

The present experiment recorded high biomass (4341.67 kg ha^{-1}) in treatment combined application of both organic and inorganic fertilizers (MAR1495 + 50 kg DAP) as compared to the control treatment. Whereas minimum value was recorded in treatment local strain (SB12) + 50 kg DAP. Beside this, branch number showed maximum (14.1) result from the treatment of local strain (SB12) without any combination of other form of fertilizer. This may be due to inoculation with adaptable strains of biofertilizer that could increase branch number. Kyei-Boahen et al. [31] reported similar findings, where inoculation with biofertilizer increased all parameters of cowpea.

CONCLUSION

The present study concluded that integrated application of biofertilizer with inorganic fertilizer could have a positive effect on grain yield, branch number, and plant height of planted crop in the study area. The highest yield of soybean (1925 kg ha^{-1}) was gained from the application of Local strain (SB12) + 100 kg TSP and lowest (1483.3 kg ha^{-1}) one was recorded in the treatment with application of recommended 100 kg DAP ha^{-1}. Whereas highest biomass was recorded in the treatment of MAR1495 + 50 kg DAP with value of 4341.67 kg ha^{-1}. Using biofertilizer for production of soybean could improve soil fertility by nitrogen fixation and it can show positive result in production, if supported by combined application as well as additional support of nutrients. Soil fertility can be improved by application of MAR1495+100 kg ha^{-1} TSP and Local strain (SB12)+100 kg ha^{-1} TSP as observed from the present study as compared to earlier values of 0.01–0.094 and 0.084, respectively. Therefore, farmers could use local strain (SB12) with 100 kg ha^{-1} TSP or local strain (SB12) with 50 kg ha^{-1} DAP to improve soil fertility and increase soybean production.

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