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RESEARCH ARTICLE

BIOLOGICAL AND INORGANIC FERTILIZER APPLICATIONS IMPROVED GROWTH, NODULATION AND YIELD OF SOYBEAN (*GLYCINE MAX L.*) VARIETIES

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ABSTRACT

The increasing costs of inorganic fertilizers and their effect on the environment have resulted in an ever increasing interest in the role of biological fertilizers as a source of plant nutrients and soil fertility restoration. In this regard, identifying varieties which adapt to growing areas and agronomic inputs such as bio-fertilizer and optimum phosphorus rates could potentially improve soil fertility and productivity of legumes including soybean. Therefore, this study was conducted to evaluate the effect of Bradyrhizobium inoculation and phosphorus application on growth, symbiotic and yield performance of soybean varieties grown at Assosa, Western Ethiopia. The treatments included three soybean varieties (Gizo, Belessa-95 and Local), two inoculation levels (uninoculated and inoculated with Bradyrhizobium strain; MAR-1495) and three phosphorus levels (0, 10 and 20 kg P ha-^{1}). The experimental units were arranged using factorial randomized complete block design with three replicates. The results revealed marked varietal differences on growth, yield and yield components. Of the three soybean varieties Belessa-95 showed better response for nodule number, nodule dry weigh, plant height, shoot dry weight, hundred seed weight and grain yield when compared to Gizo and Local varieties. The inoculation with Bradyrhizobium strain MAR-1495 and application of higher P rates (20 kg P ha-^{1}) resulted in marked improvement on most of the studied parameters. For instance, the highest yield (2.31, 2.70 and 2.53 ton ha-^{1}) was recorded with the variety Belessa-95, the application of 20 kg P and Bradyrhizobium inoculation, respectively. It could, thus, be deduced that the use of Bradyrhizobium strain MAR-1495 and Belessa-95 variety with application of 20 kg P ha-^{1} markedly improved the yield and related components, and which in turn improves the nutrition and food security of small scale farmers in the study area.

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INTRODUCTION

Soybean (*Glycine max* L.) is a leguminous crop which has quantitatively highest (40%) protein content of all food crops. It also ranked second in terms of oil content (20%) next to groundnut (Dwevedi and Kayastha, 2013). The oil obtained from the crop is mostly unsaturated fatty acids which is free from cholesterol (Abdullahi *et al*., 2013). In Ethiopia, soybean is an important food crops widely produce in western and south western parts of the country. Now a day, its production is highly concentrated in high rain fall areas of the country like Assosa and it is a legume being recently integrated in to cropping system of smallholder farmers (Sopov *et al*., 2015).
Although the crop has such a high nutritional values, its productivity in Ethiopia is 2.1 t.ha^{-1} and this level is very low compared to its potential, which could go up to 4 t.ha^{-1} when improved varieties and agronomic practices are used (Sopov *et al*., 2015). Such a low yield of the crop might be due to low soil N and P content, lack of improved varieties and poor agronomic practices including zero-inputs of fertilizers and rhizobial inoculants (Dar *et al*., 2014; Nyoki and Ndakidemi, 2014). On the other hands, high inorganic fertilizer costs limit its wider production among the small-scale farmers (CDI, 2014). The expensive fertilizer cost can be cut down through the process of biological nitrogen fixation (BNF) by leguminous crops. Thus, through the process legumes acquire their own N needs and also provide some nutrients left over to succeeding crops through decomposition of their nodules and biomass (Vanlauwe *et al*., 2014). The Bradyrhizobium strain MAR-1495 used for this experiment has shown better agronomic and symbiotic performance in soybean growing area in Ethiopia (COMPRO, 2013). Therefore, inoculating the seed of soybean with this and other compatible and appropriate bacterial strain might be a better alternative for optimizing the economic yields of soybean in areas where a low population of

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native rhizobia strains predominant. Phosphorus (P) deficiency followed by N is the major constraint in pulse crop production since it affects growth, nodule formation and development and N_2-fixation. It is a major growth-limiting nutrient, and unlike the case for N, there is no large atmospheric source that can be made biologically available (Bashir *et al*., 2011). It has important effects on flowering, seed formation, fruiting and improvement of crop quality (Brady, 2002). Inadequate P availability restricts root growth, photosynthesis, translocation of sugars and other such functions which directly influence N_2-fixation and yield of legume plants.

Symbiotic N_2-fixation has a high P demand because the process consumes large amounts of energy and energy generating metabolism strongly depends upon the availability of P (Abdul-Aziz, 2013). Assosa is one of the areas in Western Ethiopia where farmers grow soybean widely. They produce it as a source of food, cash and also rotate it with cereal crops. As is true for soils in most parts of Ethiopia, the area also faces N and P deficiencies during crop production. Most farmers of the area cannot afford the cost of inorganic N fertilizer to overcome their soil nutrient deficiencies. As a result, farmers apply below the recommended dose of fertilizer. Therefore, BNF can be used as a cheaper alternative for improving soil fertility. There is also limited knowledge to identify varieties which gives better yield and responded well to the applied inputs. Therefore, there is a need to generate such information for improving productivity of soybean in the region.

In view of this the present study was conducted with the following specific objectives

- To assess the effect of Bradyrhizobium inoculation and P application on growth and nodulation of soybean at Assosa.
- To determine the effect of Bradyrhizobium inoculation and P varieties on yield and yield components of soybean grown under field condition in Western Ethiopia.

MATERIALS AND METHODS

The Experimental Site

The experiment was conducted during the 2015/2016 cropping season at Asossa Agricultural, Technical and Vocational Education Training College in Benishangul Gumuz Regional State. The site is located west of Addis Ababa about 653 km distance between (10^0 $02'$ N latitude, and 34^0 $34'$ E longitudes, at an altitudinal range of 1580 m above sea level. The area experiences a mono-modal rainfall pattern and has annual total rainfall of about 1275 mm. The rainy season occurs from May to October and the maximum rain is received in the months of July and August. The minimum and maximum temperatures are 16.8 and 27.9 ^{0}C, respectively (Agro-Meteorology Department, Assosa Branch).

Source of inputs, plant material, treatments, experimental design and procedures

The three soybean varieties namely (Gizo, Belessa-95 and Local) and Bradyrhizobium strain MAR-1495 were obtained from the Assosa Agricultural Research Centre, Ethiopia. The varieties were chosen based on their higher grain yield, acceptability by farmers and seeds availability. Similarly, the Bradyrhizobium strain was chosen because of its high agronomic and symbiotic performances of some other agro-ecology of Ethiopia. The chosen varieties seeds were weighed on an electronic balance and soaked in sugar solution. Then strain MAR-1495 was applied on moistened seeds at the rate of 10 g kg^{-1} of seed. The Bradyrhizobium inoculum was mixed thoroughly with the seed and allowed to air dry for 15 minutes under shade to maintain the viability of cell and sown within an hour at the required rate and spacing (Beleachew and Hailemariam, 2010). The treatments consisted of three P (0, 10, and 20 kg ha^{-1}) levels as triple supper phosphate (TSP) and two inoculation (uninoculated and inoculated with strain MAR-1495) levels combined with three soybean varieties namely Belessa-95, Gizo and Local and replicated three times. Thus, the experiment consists of 18 treatments with a total of 54 plots. The size of each experimental plot was 2.4m x 3.6m ($8.64m^2$) and spacing between plants, rows, plots and blocks were 5, 60, 70 and 150 cm, respectively. The experiment was laid out using three factorial randomized complete block design (RCBD) with three replications. Plant population was maintained by thinning at four to six leaf stages. Seeds were hand planted in rows on June 25, 2017. All recommended agronomic practices were applied throughout the growth period.

Soil Sampling and Preparation for Analysis

About 1 kg pre-sowing surface soil sample was collected by means of auger from different spots of the experimental field at the depth of 0-30 cm and bulked together to get a representative composite soil sample. Then after the collected soil sample was air-dried and crushed and mixed thoroughly and packed in a polythene bag, labeled and stored in the laboratory for analysis. Analysis of organic carbon content of the soil in a laboratory was determined by Walkley and Wet Oxidation method as described by Jackson (1958) and total N by Kjeldhal method as described by (Dewis and Freitas, 1975). The pH of the soil was measured in water at soil to water ratio of 1:2.5 (Page, 1982) and cation exchange capacity was determined using Kjeldhal procedure as described by (Ranist *et al*., 1999). Available P was determined according to the methods of Olsen and Dean (1965). Soil texture analysis was performed by Bouyoucous hydrometer method (Day, 1965).

Data Collection

Nodule number and dry weight $plant^{-1}$

Nodulation assessment was undertaken at mid flowering stage of soybean from next to boarder rows of each plot. Five plants were randomly sampled by careful uprooting and adhering soil particles were removed by washing the root with their nodules gently with water over a metal sieve. The nodules from each plant were removed and separately spread on the sieve for some minutes until the water was drained from the surface of the nodules. The total number of nodules was counted and their average was taken as number of nodules $plant^{-1}$. After determination of their numbers, the nodules were oven dried at 70 ^{0}C for 48 hour to determine nodule dry weight $plant^{-1}$. The average of five plants was taken as nodule dry weight $plant^{-1}$.

Plant height: five plants from the central rows of each plot were randomly selected for measuring plant height with meter at mid flowering stage.

Shoot dry matter: shoot dry matter of plant was determined at mid flowering stage of the crop from plants that were sampled for nodulation. The plant samples were placed in a labeled perforated paper bags and oven dried for 48 hours at 70 ^{0}C to a constant weight. The average shoot dry matter of five plants was recorded as shoot dry matter plant^{-1}.

Yield components: At harvesting, for the determination of yield components such as number of pods plant^{-1} and number of seeds pod^{-1} and hundred seed weight, fifteen randomly picked plants were used. Seed weight was determined by randomly taking 100 seeds of each plot and weighing it with sensitive balance after drying to constant weight.

Grain yield and Biological: plants from the central three rows plot^{-1} were manually harvested. The harvested plants were weighed to determine the biological yield and threshed and weighed to determine grain yield of each plot.

RESULTS AND DISCUSSION

Soil physico-chemical properties: The results of pre-planting soil analysis revealed that the soil of the study area is clay loam in texture (29% sand, 30% silt and 41% clay). Soil texture is a fundamental soil property which in practice the farmer can do little to modify. It is also closely related to the water-holding capacity of soils, since loams and clays hold more water than do sandy soils (Brady, 2002). Thus, the soil of the study area has good water holding capacity, which creates a good growing media for the crop. Soybean is characteristically grown on such soils which holds sufficient amount of residual soil moisture. The soil was slightly acidic in reaction with the pH (H_2O 1:2.5) value of 5.9, which is within the range of optimum soil pH for legume production including soybean (Havlin *et al*., 1999).

The total N, available P, OC and CEC of the soil before planting were 0.14%, 6 mg kg^{-1}, 1.5%, and 23.4 cmol (+) kg^{-1}, respectively (Table 1). According to Havlin *et al*. (1999) soils are classified depending on their total N content in percentage (%), as very low (<0.1), low (0.1-0.15), medium (0.15-0.25), and high (>0.25). Thus, the soil of the study site has low total N content. Olsen *et al*. (1954) classified available P content of the range < 5 as very low, 5 – 15 as low, 15 – 25 as medium and > 25 mg kg^{-1} as high. According to Landon (1991) the soil organic carbon content ranges of 1 – 2, 2 – 4, and 4 – 6% are rated as low, medium and high respectively. Thus, the OC content of the soil is considered as low before planting. The CEC ranges of 5 – 15, 15 – 25 and 25 – 40 cmol kg^{-1} are rated as low, medium and high respectively. Based on these ratings the cation exchange capacity (23.4 cmol kg^{-1}) before planting of the experimental field was in the medium range. Generally the soil analysis result indicated that the area is nutrient deficient especially N and P to support the potential crop production. This may be associated with poor farm management practices and continuous cropping with little or no fertilizers input which resulted in a decline in soil fertility of the area. It may be because of this that growth; nodulation, yield and yield components responded to Bradyrhizobium inoculation and applied P fertilizer under this experiment.

Effect of Bradyrhizobium Inoculation and P application on Nodulation and Growth of Soybean Varieties Nodule number plant^{-1}: There was significant difference among soybean varieties for nodule number (Table 2). Variety Belessa-95 exhibited greater nodule number than the other varieties. However, the Local and Gizo varieties did not differ in nodule number. The observed differences in nodule number among the soybean varieties could be attributed to genotypic differences. In line with this result Tarekegn *et al*. (2017) found that performance of five different varieties of cowpea varied markedly for nodule number. However, this result did not agree with the work of Solomon *et al*. (2012) who reported that none-significant differences among the soybean varieties on nodule number plant^{-1}. Bradyrhizobium inoculation had significant effect on nodule number of soybean compared to the control (Table 2). The maximum mean nodule number (15.85) was recorded from the strain MAR-1495 and, uninoculated control resulted in the minimum nodule number plant^{-1}. The increased nodule number with Bradyrhizobium inoculation could be associated with the efficiency of introduced rhizobia to compete with indigenous bacteria dwelling in the soil. These results are in line with the findings of Argaw (2012) who revealed that the Bradyrhizobium inoculation significantly enhanced nodule number of field grown legumes. Similar results were reported by several authors (Argaw, 2014; Yoseph and Worku, 2014; Maphosa, 2015) who reported that inoculation of soybean with effective bacterial strains increased significantly nodule numbers when compared to uninoculated control.

This was in line with the finding of Solomon *et al*. (2012) who found that the nodulation parameter nodule number plant^{-1} was significantly influenced by the main effect of Bradyrhizobium inoculation strain alone. Significant difference ($P< 0.01$) was also observed on nodule number plant^{-1} among different levels of applied P. Application of 20 kg P ha^{-1} increased mean nodule number plant^{-1} by 47.24 and 16.03% over zero P fertilized control and application of 10 kg P ha^{-1}, respectively (Table 2). The increased nodule number due to applied P might be related to the availability of adequate P which possibly promotes early root growth and the formation of lateral fibrous and healthy roots. In line with these results Yoseph and Worku (2014) reported that increased nodule number plant^{-1} due to application of P ha^{-1} when compared to the control. The variety x phosphorus interaction showed much greater nodule number in Belessa-95 variety over Gizo and Local varieties at 20 kg P ha^{-1}, but decreased nodule number at zero-P level for all the three varieties (Fig. 1a). The data from variety x Bradyrhizobium inoculation interaction showed that Belessa-95 variety recorded much greater nodule number over Gizo and Local regardless of inoculation with strain MAR-1495 (Fig. 1b). Nodule number generally increased with bacterial inoculation at all P levels compared to uninoculated plants (Fig. 1 C). But, there were no marked differences in nodule numbers for P levels 0 and 10 kg P ha^{-1}.

Nodule dry weight plant^{-1}

The nodule dry weight of soybean was significantly influenced by the soybean varieties (Table 2). The highest nodule dry weight (0.18 g plant^{-1}) was recorded from variety Belessa-95, while the lowest (0.10 g plant^{-1}) nodule dry weight was recorded from variety Gizo reflecting inherent genetic differences among the varieties for nodule dry weight. The result is in agreement with the work of Yoseph *et al*. (2017) who reported that marked differences among the cowpea varieties on nodule dry weight plant^{-1}. Bradyrhizobium inoculation with strain MAR-1495 resulted in significantly increased nodule dry weight compared to the uninoculated control (Table 2).

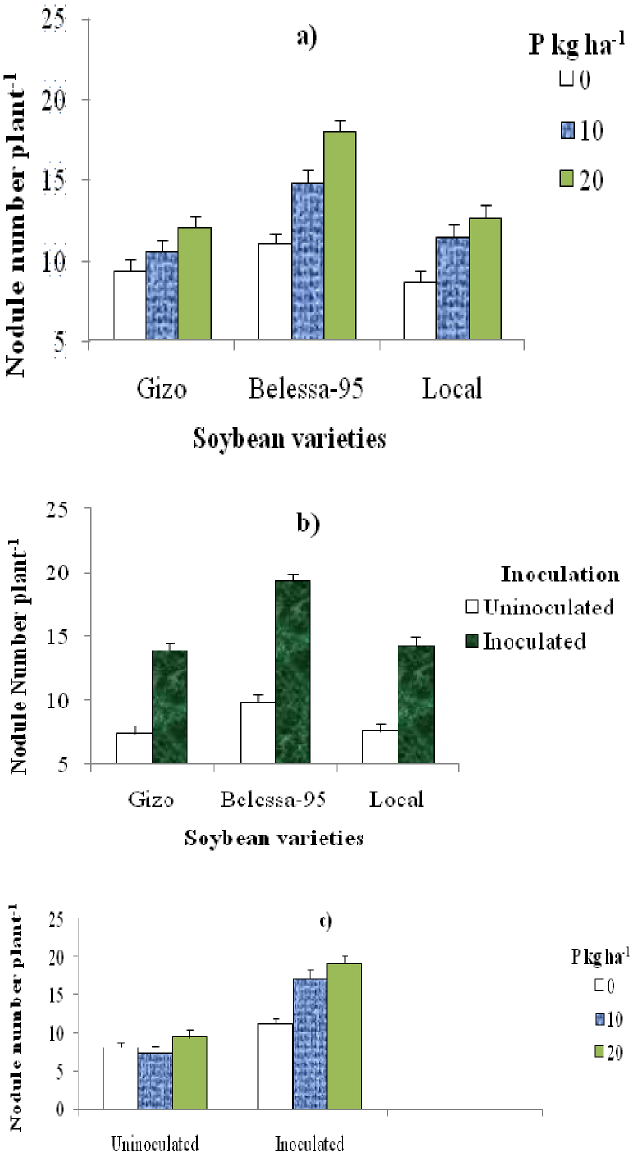

Figure 1. Interaction effects of; a) variety x phosphorus, b) variety x Bradyrhizobium inoculation and c) Bradyrhizobium inoculation x phosphorus on nodule number. Vertical lines on bars represent standard error of the statistical means.

The maximum nodule dry weight (0.20 g plant^{-1}) was recorded from Bradyrhizobium strain MAR-95, while the minimum nodule dry weight (0.08 g plant^{-1}) was recorded from the control treatment. The difference between the nodule dry weight obtained from inoculated and uninoculated plants might be attributed to the size of the nodules. Inoculated plants formed bigger nodules than uninoculated due to the effectiveness of the introduced Bradyrhizobium strain to initiate nodulation with soybean roots. In the present study, the uninoculated control was resulted with poor nodulation status which was evidenced that indigenous rhizobia population was ineffective in fixing N. A similar promoting effect of seed inoculation on dry weight of nodules plant^{-1} have been reported by (Bejandi *et al*., 2011; Nyoki and Ndakidemi, 2014; Chiamaka, 2014). The applications of 10 and 20 kg P ha^{-1} to soybean plants significantly increased nodule dry weight over zero-P control (Table 2). However, much greater values were obtained at higher P level (20 kg P ha^{-1}). The improved nodule dry weight due to higher P rates might be attributed due to higher nodule numbers. In line with this finding Azam (2002) also reported that greater nodule dry weight plant^{-1} due to higher P rate.

Plant height

Analysis of variance revealed highly significant (P<0.01) effect of the varieties (Table 2). Regarding variety effect, the highest value for plant height was recorded with Belessa-95 variety (51.52 cm) followed by variety Gizo. Whereas, the lowest value of plant height was recorded from Local variety (44.45 cm), but statistically at par with variety Gizo. The observed difference in plant height among soybean varieties might be attributed to inherent genotypic difference (Magani and Kuchinda, 2009). Inoculation with MAR-1495 strain didn't bring significant effect on plant height compared to the control (Table 2). The Bradyrhizobium inoculation does not affect plant height was earlier confirmed by Karikari *et al*.(2015) who found that lack of marked differences on pant growth. In contrary Abbasi *et al*. (2010) concluded that rhizobium inoculation increased soybean plant height up to 12%.

Shoot dry matter

Plant growth measured as shoot dry matter was significantly (P<0.001) affected by soybean variety, Bradyrhizobium inoculation and P application (Table 2). The highest (12.77 g plant^{-1}) and lowest (10.72 g plant^{-1}) shoot dry matter was recorded from variety Belessa-95 and variety Local respectively, but statistically parity between variety Gizo and variety Local. The observed differences could be genetic or difference due to the ability of N_2- fixing among the varieties. This is in line with finding of Singh *et al*. (2011) who reported that some varieties have the ability to out yield than the other varieties and exhibit superior plant growth. Addo-Quaye *et al*. (2011) also found that cowpea varieties have different capacities for shoot dry matter accumulation. Bradyrhizobium inoculation with strain MAR-95 gave higher shoot dry matter that was greater by 29.9% over the control (Table 2). The observed differences on soybean by Bradyrhizobium inoculation seem to be to the supply of N to the crop through symbiotic N_2-fixation (Togay *et al*., 2008). Yoseph and Shanko (2017) also reported that the significant effect of seed inoculation on shoot dry weight compared to the control treatments. Application of P fertilizer at the level of 20 kg ha^{-1} showed significantly increased mean shoot dry matter yield (34.15%) compared to the control. However, the shoot dry matter of plants grown at 10 and 20 kg P ha^{-1} were in statistical parity (Table 2). The marked increased in shoot dry weight in response to the increased rates of P application might be ascribed to the increased availability of P in the soil for uptake by plant roots, which may have sufficiently enhanced vegetative growth through increasing cell division and elongation (Sara *et al*., 2013). Similarly Togay *et al*. (2008) who reported that the greatest shoot dry weight on soybean due to higher P supply than the control.

Effect of Bradyrhizobium and P application on Yield and Yield Components of Soybean Varieties Number of pods plant^{-1}

Analysis of variance revealed that varieties exerted significant influence on number of pods plant^{-1}(3). Among the three soybean varieties, Gizo had highest pod number plant^{-1} (78.33) followed by Belessa-95 variety. Whereas, the lowest pod number plant^{-1} was recorded from Local variety (71.55), but there was lack of marked difference statistically between Belessa-95 and Gizo varieties as well as Belessa-95 and Local varieties.

Table 1. Physico-chemical properties of the experimental soil before planting

pH	Carbon	Total N	Available P	CEC	Sand	Slit	Clay	Textural
	(%)	(%)	mg.kg^{-1}	cmol.kg^{1}	(%)	(%)	(%)	class
5.9	1.5	0.14	6	23.4	29	30	41	Clay loam

Table 2. Effects of varieties, *Bradyrhizobium* inoculation and P levels on nodulation and growth of soybean

Treatments	Nodule number (plant^{-1})	Nodule dry weight (g plant^{-1})	Plant height (cm)	Shoot dry weight (g plant^{-1})
Varieties				
Gizo	10.64^{B}	0.10^{C}	46.93^{B}	11.95^{B}
Belessa-95	14.61^{A}	0.18^{A}	51.52 ^{A}	12.77^{A}
Local	10.94^{B}	0.13^{B}	44.45^{B}	10.72^{B}
LSD.05	0.88	0.02	3.06	0.92
Significance level	**	**	**	**
Inoculation				
Uninoculated	8.28^{B}	0.08^{B}	47.05	10.28^{B}
MAR-1495	15.85^{A}	0.20^{A}	48.22	13.35^{A}
LSD.05	0.72	0.02		0.75
Significance level	**	**	NS	**
P rates (kg.ha^{-1})				
0	9.67^{C}	0.09^{C}	46.72	9.77^{B}
10	12.28^{B}	0.13^{B}	47.19	12.57^{A}
20	14.25 ^{A}	0.17^{A}	48.99	13.11^{A}
LSD.05	0.88	0.02	NS	0.92
CV (%)	10.81	24.21	9.49	11.46
Significance level	**	**	NS	**

Mean values followed by dissimilar letters in a column are significantly different at ** NS; Non-Significance.

The observed differences in pods plant^{-1} among the three soybean varieties could be attributed to genotypic differences. The result is in agreement with the work of Yoseph *et al.* (2017) who reported that marked differences among the cowpea varieties on pod numbers plant^{-1}. Bradyrhizobium inoculation with strain MAR-1495 showed that significantly increased pod number plant^{-1} compared to the uninoculated (Table 3). The minimum pod number plant^{-1} (68.33) was recorded from the control treatment. This increased pod number plant^{-1} with Bradyrhizobium inoculation could be associated with enhanced growth and higher assimilate accumulation which is resulted due to better N nourishment from BNF. The result is in agreement with the work of Dereje (2007) also reported that increased number of pods plant^{-1} with inoculation in green gram and soybean. Significantly increased mean of pod numbers plant^{-1}(16.56 and 8.81%) was obtained with application of 20 kg P ha^{-1} compared to the zero-P and 10 kg P ha^{-1}respectively (Table 3). Highest number of pods plant^{-1} in sufficient P treated plots was obtained possibly due to improved reproductive performance of the plants because of improved P nutrition.

Number of seed pod^{-1}: The analysis of variance revealed that number of seeds pod^{-1} was significantly affected by varieties (Table 3). The highest number of seeds pod^{-1} was recorded from Belessa-95 variety (3 seeds pod^{-1}); whereas the lowest was recorded from Gizo variety (2.5 seeds pod^{-1}). This might be due to inherent genetic difference among the soybean varieties for seed production pod^{-1}. Application of 20 kg P ha^{-1} to soybean crop markedly increased numbers of seed pod^{-1} over 10 kg P ha^{-1} and zero-P (Table 3). However, plants fertilized with 10 kg P ha^{-1} and zero kg P ha^{-1} did not differ statistically with each other (Table 3). The increased in numbers of seed pod^{-1}due to adequate P fertilization could be explainable in terms of possible increase in nutrient mining capacity of plant as a result of increased translocation of carbohydrates from source to growing points in adequate P fertilized plots. This result is in line with that of Shahid *et al.* (2009) who reported that application of adequate amount of P resulted in markedly increase yield of soybean plants.

Hundred seed weight

The result of analysis of variance on hundred seed weight showed that there was highly significant difference ($P \leq 0.01$) on effect of varieties and phosphorus application, but there was no significance difference on Bradyrhizobium inoculation and all interactions (Table 3). Regarding the variety, the heaver and lighter seed weight was recorded due to variety Belessa-95 (16.35 g) and variety Local (15.86 g) respectively. The significant difference in hundred seed weight among the soybean varieties might be due to the difference in translocation and partitioning efficiency of assimilates from source to sink. Similar El Naim and Jabereldar (2010) who reported that observed a significant variation in hundred seed weight of soybean crop. Application of 20 kg P ha^{-1} to soybean crop markedly increased numbers of hundred seed weight (Table 3). However, plants fertilized with 10 kg P ha^{-1} and zero kg P ha^{-1} did not differ statistically with each other (Table 3). The heaver seed weight due to adequate P fertilization could be increase translocation and partitioning of assimilates from source to grain.

Grain yield

The grain yield was affected significantly by soybean varieties (Table 3). Among the three soybean varieties tested in this experiment, Belessa-95 variety recorded the highest grain yield (2.31 ton ha^{-1}), whereas the lowest grain yield was recorded from Gizo varieties (2.12 ton ha^{-1}) (Table 3). Belessa-95 variety was showed increased grain yield by (9.1 and 8.1%) compared to Gizo and Local varieties respectively, but the differences in grain yield between Gizo and Local varieties were statistically at par. The greater grain yield recorded for the variety Belessa-95 was due to its ability to produce more and longer pods, as well as higher seed number pod^{-1}, which increased its economic yield and profitability as a crop. Similar to this result Haruna and Usman (2013) observed a significant variation in grain yield of some improved varieties of cowpea at the same location and attributed it to genetic makeup of the varieties examined.

Table 34. Effects of varieties, *Bradyrhizobium* inoculation and P levels on yield and yield components of soybean

Treatments	Pod Number plant^{-1}	Seed Number pod^{-1}	Hundred Seed Weight (g)	Grain Yied (t ha^{-1})	Total Biomass (t ha^{-1})	Harvest Index
Varieties						
Gizo	78.33^{A}	2.50^{B}	16.05^{B}	2.12^{B}	2.89^{AB}	0.73
Belessa-95	74.88^{AB}	3.00^{A}	16.35^{A}	2.31^{A}	3.06^{A}	0.75
Local	71.55^{B}	2.88^{A}	15.86^{B}	2.14^{B}	2.80^{B}	0.76
LSD.05	4.65	0.24	0.26	0.15	0.17	
Significance level	*	**	**	*	*	NS
Inoculation						
Uninoculated	68.33^{B}	2.77	15.98	1.67^{B}	2.29^{B}	0.72^{B}
MAR-1495	81.51^{A}	2.81	16.19	2.70^{A}	3.54^{A}	0.76^{A}
LSD.05	3.79			0.12	0.14	0.02
Significance level	*	NS	NS	**	**	**
P rates (kg.ha^{-1})						
0	69.44^{C}	2.72^{B}	16.02^{AB}	1.77^{C}	2.41^{C}	0.73
10	74.39^{B}	2.72^{B}	15.97^{B}	2.26^{B}	3.04^{B}	0.74
20	80.94^{A}	2.94^{A}	16.27^{A}	2.53^{A}	3.30^{A}	0.76
LSD.05	4.65	0.24		0.15	0. 17	
CV (%)	9.16	12.55	2.42	9.93	8.71	7.10
Significance level	**	*	NS	**	**	NS

Mean values followed by dissimilar letters in a column are significantly different at *: p≤0.05; **: p≤0.01; and NS; Non- Significance difference.

Grain yield was highly affected by Bradyrhizobium inoculation (Table 3). Bradyrhizobium inoculation with strain MAR-1495 resulted in significantly increased grain yield compared to the uninoculated control. The highest grain yield (2.7 ton ha^{-1}) was recorded from plants inoculated with strain MAR-1495 and the lowest grain yield (1.67 ton ha^{-1}) was recorded from the control (Table 3). The significant increase in grain yield in response to inoculation with stain MAR-1495 might be attributed to the increased availability of N in the soil for uptake by plant roots, through fixed N. Increased in grain yield due to Bradyrhizobium inoculation might be attributed to the effectiveness of the inoculant in fixing N thereby meeting the nutrient requirement of the plant (Nyoki and Ndakidemi, 2013). Ulzen *et al*. (2016) also observed that significantly increased in grain yield of cowpea after inoculation with Bradyrhizobium inoculant. A similar promotive effect of Bradyrhizobium inoculation on grain yield of soybean has also been reported by (Abbasi *et al*., 2010). Similar to this finding Shahid *et al*. (2009) who reported that grain production of soybean crop can increase by 70-75% when the proper rhizobia isolates are inoculated. A similar trend of increased in grain yield was also noticed with the increasing levels of P (Table 3). Application of 20 kg P ha^{-1} brought higher grain yield over the zero application-control (42.77%) and application 10 kg P ha^{-1} (12.1%). Increased grain yield is due to increased of P availability which is known to help developing a more extensive root system and thus enabling plants to extract water and nutrients from more depth. This could enhance the plants to produce more assimilates, which was reflected in higher biomass. In line with this result sufficient available P is also required by legumes to enhance plant growth, promote nodulation, early maturity and grain formation (Shahid *et al*., 2009).

Above ground total biomass yield

Above ground total biomass yield was significantly affected by varieties, Bradyrhizobium inoculation and P application (Table 3). The highest above ground total biomass yield was recorded (3.06 ton ha^{-1}) from Belessa-95 variety, while the lowest above ground total biomass yield was recorded (2.80 ton ha^{-1}) from Local variety, but statistically parity between variety Gizo and variety Local as well as variety Belessa-95 and variety Gizo (Table 3).

The higher above ground total biomass yield could also be attributed to the better plant shoot growth and grain formation ability of Belessa-95 variety. Bradyrhizobium inoculation with strain MAR-1495 resulted in significantly increased above ground total biomass yield compared to the uninoculated control treatment. The highest above ground total biomass yield (3.54 ton ha^{-1}) was recorded from plants inoculated with strain MAR-1495 and the lowest above ground total biomass yield (2.29 ton ha^{-1}) was recorded from the control (Table 3). Inoculation with strain MAR-1495 was significantly increased above ground total biomass yield of soybean by (53.98%) compared to the control treatments. The increased above ground total biomass due to inoculation could be attributed to the effectiveness of the Bradyrhizobium inoculant. In line with this result Abbasi *et al.* (2010) also reported that above ground total biomass yield of soybean was increased upto 75% by the inoculation of different strains of rhizobia. Significantly ($P \leq 0.01$) highest above ground total biomass yield was achieved from application of 20 kg P ha^{-1} by (36.86 and 8.63%) compared to zero-P and 10 kg P ha^{-1} respectively, while 25.99 % above ground total biomass yield obtained from application of 10 kg P ha^{-1} compared to the control (Table 3). This might be due to that P fertilization enhanced shoots biomass and grain production in the soybean crops as the result increased above ground total biomass yield was obtained. Similar to these results Lamptey *et al.* (2014) who reported that increased above ground biomass yield of soybean as a result of increased levels of P fertilizer.

Harvest index

Analysis of variance indicated that Bradyrhizobium inoculation had significantly effect on harvest index (Table 3). Bradyrhizobium inoculation increased the harvest index of soybean crop by (5.36%) compared to uninoculated control. The results indicated that adequate supply of N through biological N_2-fixation enhanced dry matter partitioning in favor of grain shown a greater harvest index. Similar Roy *et al*. (1995) reported that soybean seeds inoculation increased harvest index.

Conclusion

In general, there was highly significant ($P < 0.01$) varietal effect for most of studied parameters. Among the varieties

Belessa-95 had better nodule number, nodule dry weigh, grain yield and above ground total biomass as compared to the Gizo and Local varieties. On the other hands, Bradyrhizobium inoculation with strain MAR-1495 showed highly significant differences on nodule number, nodule dry weight, shoot dry weight, number of pods, grain yield and above ground total biomass yields. However, plant height was not affected by inoculation of strain MAR-1495. Significantly increased in yield and yield components were also attained with application of P. For instance, P at level of 20 kg ha^{-1} increased number of pods $plant^{-1}$, grain yield and above ground total biomass yield by (16.56, 42.77 and 36.86%) compared to over the control treatment respectively. Therefore, the use of Belessa-95 variety with strain MAR-1495 inoculation and phosphorus fertilizer application at the level of 20 kg ha^{-1} could be recommended to soybean producers in Assosa area to achieve superior yield and better economic return.

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