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The Economic Importance of Effective Rhizobial Nodulating and Yield of Soybean at Assosa Western Ethiopia

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Abstract: *The study examined three rhizobia strains and one inorganic phosphorous fertilizer. The treatments consist of negative control (T1), rhizobia MAR-1495-SB (T2), rhizobia SB12 (T3), TAL 379 (T4), rhizobia MAR-1495-SB+50kg DAP (T5), rhizobia SB12+50kg DAP (T6), and Rhizobia TAL 379 +50kg DAP (T7).* The researchers *laid out the treatments in a randomised complete block design with three replications. The analysis of variance revealed that rhizobia had non-significantly (P > 0.05) affected grain yield. The rhizobia MAR-1495-SB biofertilizer at Asossa district recorded the maximum grain yield of 2187.9 kg ha-1. The application of MAR-1495-SB rhizobia biofertilizer had the highest net benefit of 26,094.8 ETB, followed by rhizobia MAR-1495-SB+50kg DAP biofertilizer, which also had a total of 23,518.6 ETB net benefit at Asossa district. The application of MAR-1495-SB rhizobia biofertilizer had the highest net benefit. Therefore,* The researchers *recommended the treatment MAR-1495-SB rhizobia since it produced a high marginal rate of return, a high net benefit, and a relatively small total cost of production for soybean production in the Asossa area.*

Keywords: *Rhizobia, inoculant, strain, net benefit, and marginal rate of return.*

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INTRODUCTION

With approximately 750 genera and 16,000–19,000 species spread worldwide, the Leguminosae is one of the most significant and expansive plant families. The Leguminosae family significantly influences agriculture, the environment, animal and human nutrition, and health, with soybeans being one of the world's most significant and remarkable pulse crops. It accounts for 29.7% of the world's processed vegetable oil and is rich in dietary protein both for human food and animal feed (Graham and Vance 2003). According to CSA (2012), Ethiopia allocates 31,876 ha for soybeans and produces 63,653 t annually, with a productivity of less than 2 t ha-1.

Meanwhile, Cooper (2003) estimates the potential soybean yield in the USA to be in the range of 6–8 t ha-1. Biological nitrogen fixation (BNF) and mineral soil, or N fertilizers, are the main sources for meeting the nitrogen requirements of high-yielding soybean varieties. BNF is an effective and efficient source of N supply for plants under favorable atmospheric and environmental conditions (Chen et al. 2002). By symbiotic association with either the genus Bradyrhizobium or Sinorhizobium, BNF can provide more than 50–83% of the necessary N requirement for soybean (Schipanski et al. 2010). Several research findings clearly demonstrated that soil nitrate repressed nodulation, with the effect intensifying as soil nitrate concentrations increased (Hungria et al. 2006). BNF is very useful for smallholder farmers as it is cost-effective, environmentally friendly, meets the N requirement of the legumes, and reduces the N demand of the succeeding crops. Inoculation with compatible and effective rhizobia may be necessary to optimize nitrogen fixation and, hence, legume grain yields, where a low population of native rhizobial strains predominates (Chianu et al., 2011). Therefore, the evaluation and identification of appropriate and effective rhizobial strains are crucial to enhancing nitrogen fixation and yield in soybeans.

In the present investigation, therefore, the influences of the soybean maturity group and the effectiveness of Bradyrhizobium spp. in soil with high N and no rhizobial association with soybeans were thoroughly examined under greenhouse and field conditions using drip irrigation. This study postulated that medium-maturing soybean genotypes experience a decrease in Bradyrhizobium sp. inoculation effectiveness due to high soil N, a phenomenon that may not manifest in late-maturing genotypes. Because of this, the main goal of this study was to find out how well isolates of Bradyrhizobium spp. worked as symbionts with soybeans in the nitosol of Asossa.

MATERIALS AND METHODS

Description of the Study Area

The Assosa Agricultural Research Centre, located in the Assosa District of the Benishangul-Gumuz Regional State, conducted the study. The Benishangul-Gumuz Regional State is located in the western part of Ethiopia between 9° 30' to 11° 39'' N and 34° 20' to 36° 30'' E, covering a total land area of 50,000 square kilometres (km^2). The Assosa District is characterized by a hot-to-warm, moist lowland plain with a unimodal rainfall pattern. The rainy season starts at the end of April and lasts at the end of October, with a maximum of June, July, August, and September. The total annual average (2007–2014) rainfall is 1316 mm. The annual mean minimum and mean maximum temperatures of the district for the periods from 2007 to 2014 are 16.75 and 27.92 ^{O}C, respectively.

Experimental treatments and designs

The treatments consisted of six rhizobial strains (Strain MAR-1495, Strain SB12, TAL 379, Strain MAR-1495 + 50 kg TSP, Strain SB12 + 50 kg TSP, TAL 379 + 50 kg TSP) and control (without any fertilizer). The researchers set up the experiment using a randomised complete block design (RCBD), replicating it three times. The plot size was 3 m x 4 m, and the spacing between rows and between plants was 60 cm and 5 cm, respectively. A 1.5-meter-wide open space separated the blocks, while a 0.75-meter-wide space separated the plots within a block. The researchers constructed soil bunds around each plot and the entire experimental field to minimize nutrient, water, and cross-contamination from one plot to another. The researchers manually controlled weeds by handpicking. The researchers then monitored crop growth until harvest.

Soil sampling and preparation

Prior to the field experiment, we collected ten random samples (0-20 m depth) and prepared composite soil samples. The researchers used these composite samples for soil physical and chemical analysis. Similarly, we collected plot-wise soil samples from each replication's surface at a depth of 0-20 cm for selected soil chemical analysis. The researchers air dried the soil samples, sieved them through a 2 mm sieve, and then placed them in labelled plastic bags.

Sources of seeds and inoculum

The soybean genotype used for this study was provided by the Asossa Agricultural Research Centre, Ethiopia, which has been approved to be superior under Asossa field conditions. The researchers used one late maturing soybean genotype (Belsa 95) for the field experiment. The researchers used rhizobial isolates as inoculants, specifically Bradyrhizobium japonicum (TAL-379 isolate), MAR 1495 isolate, and SB12 isolate. The Holleta Agricultural Research Centre (UK-isolate) and the National Soil Research Centre in Addis Ababa (TAL-379-isolate) provided these isolates.

Plant Data Collection and Analysis

Data collection involved the use of central row plants. The researchers collected growth-indicating parameters such as plant height, number of seeds per pod, number of pods per plant, and grain yield. The researchers measured the plant height (cm) from the base of the plant to the topmost leaves. The researchers collected data from five randomly selected plants a few days after the seed had fully filled. The researchers randomly selected five plants from the central rows to count the number of nodules per plant. The researchers computed the number of pods per plant and the number of seeds per pod from five plants. The researchers recorded the number of seeds per pod by counting five plants and randomly selecting five seeds from each pod. After threshing the soybean, we recorded the grain yield from five plants and calculated the grain yield per hectare. The researchers adjusted the grain yield to a grain moisture content of 11.5%.

Partial Budget Analysis

The partial budget analysis (CIMMTY, 1988) used the mean grain yield of the selected treatment. The researchers performed an economic analysis to investigate the economic feasibility of the treatments (fertiliser rates). The researchers used a partial budget, dominance, and marginal analysis. The researchers used the average open market price (Birr kg-1) for groundnut and the official prices of urea and biofertilizers for our economic analysis. The researchers used the dominance analysis procedure, as detailed in CIMMYT (1988), to select potentially profitable treatments from the tested range. This technique referred to the selected and discarded treatments as undominated and dominated, respectively. the researchers ranked the undominated treatments from the lowest (the farmers' practice) to the highest-cost treatment. The researchers calculated a % marginal rate of return (MRR) for each pair of ranked treatments. Any pair of undominated treatments' % MRR expresses the return per unit of fertiliser investment as a percentage.

Statistical Data Analysis

Analyses of variances for the data were recorded and conducted using the SAS GLM procedure (SAS 1998). When the analyses of variance indicate the presence of significant differences, the researchers use the least significant difference (LSD) test at 5% probability for mean separation.

Result and Discussion

Soil Physical and Chemical Properties

According to the laboratory analysis, the soil texture of the experimental area is clay (Table 1). Maize usually grows well under favorable soil conditions. A soil that is fertile, medium-textured, sandy or clay loam, and alluvial, with an optimum pH of 5.5 to 7, is typically the most ideal (Gurmu, 2010). The pH of the soil is 6.2, which is moderately acidic. According to Hazelton and Murphy (2007), this value is considered a low pH value. At low pH values, phosphate ions combine with iron and aluminum to form compounds, which are not readily available for plants.

However, Miller and Donahue (1997) indicated that plants grow well between pH 5.5 and pH 8.5. Maize response to applied P depends on soil acidity, soil OM level, and clay content. Clay content affects the interpretation of soil test values obtained by extraction, and values for clay soils will likely be very different from those for sandy soils. Therefore, P fertilizer recommendations will depend on soil texture (Abdulaziz, 2013). The CEC of the soil at the experimental site is 22.6 cmol kg-1 of soil. According to Landon (1984), this value lays in the lower range (15-25 cmol kg-1), which means the soil is not satisfactory for agricultural production. Additionally, the test soil had total N values of 0.29%, OM values of 2.46%, available P values of 11.5 ppm, and exchangeable K values of 0.1443 milliequivalents/100 g soil (Table 1). Upon comparison with Metson's (1961) broad ratings, the analysis results, with the exception of total N and available phosphorous, fall within the lower range for plant growth.

Table 1: Major soil chemical characteristics of the experimental site

No	Soil character	Values	Remark
1	Soil pH (by 1:2.5 soil water ratio)	6.2	Moderately Acidic
2	Total Nitrogen (%)	0.29	High
3	Organic matter content (%)	2.46	Moderate
4	. Available phosphorous (ppm)	11.5	high
5	Cation exchange capacity (cmol (+) kg-1)	22.6	low
6	Exchangeable potassium (meq/100 g soil)	0.1443	Very low
7	Soil texture		
	Clay (%)	59.4	
	Sand (%)	30.5	
	Silt (%)	10.1	
	Textural class	Clay	

The study focuses on the seed yield of soybeans and its constituent components.

Analysis variance of two locations revealed a non-significant difference (*P* < 0.05) due to the application of treatments for the means of seed yield. **The application of strain MAR1495 increased the mean grain yield by 55.7%, strain TAL365 by 24.5%, and strain SB12 by 18.1 compared to the zero-strain or -ve control (Table 2).** However, Table 2 shows no significant difference between strains MAR1495, SB12, TAL365, and zero strain. This study contradicts the findings of Rugheim AME and Abdelgani ME (2012), who reported a significant increase in faba bean yield through the inoculation of rhizobia strains. Desta et al. (2015) also confirmed that the application of effective Rhizobia strains alone and/or in combination with zinc significantly increases the faba bean yield. The report by Youseif et al. Youseif et al. (2017) also show that application of effective strains increases faba bean grain yield by up to 44–47%. The plot receiving strain MAR1495 recorded the highest grain yield of 2187.9 kg ha-1, which was comparable to the yield of strain MAR-1495 + 50 kg Dap ha-1. A zero strain plot or one that received no treatment recorded the lowest grain yield of 1404.6 kg ha-1. Antenah Argew (2014) also reported that soybean plants treated with the UK isolate inoculation yielded the highest total biomass, surpassing the total biomass yield of plants in the control treatment by approximately 47.3%. Tahir et al. (2009) reported that the combination of rhizobia inoculation and phosphorous application led to a 21% increase in grain yield.

Table 2: Evaluation of strains on yield and major yield determinant parameters of soybean at Asossa zone of Benshal-gul Gumuz

Treatments	PH (cm)	PPP	SPP	GY (kg)
Control	**68.2**	**18.9**	**2.5**	**1404.6**
Strain MAR-1495	**64.9**	**21.5**	**2.5**	**2187.9**
Strain SB 12	**66.7**	**22.4**	**2.4**	**1714.1**
TAL 379	**68.2**	**20.7**	**2.5**	**1748.5**
Strain MAR-1495 + 50 kg Dap/ha	**67.3**	**19.6**	**2.4**	**2025.3**
Strain SB 12+ 50 kg DAP/ha	**65**	**19.1**	**2.5**	**1764.8**
TAL 379 + 50 kg DAP/ha	**68.4**	**20.3**	**2.5**	**1705.1**
LSD	8.3	6.7	0.3	**584.1**
F-test	NS	SN	NS	NS
CV%	7	18.5	**7.37**	18.3

****= P<0.01, *=P<0.**05 & Ns = None significant at P>0.05. PH= plant height, PPP=number of pod per plant , SPP= number of seed per pod, GY grain yield

Based on the current findings, the researchers can conclude that symbiotic N does, in fact, increase yield in late-maturing soybean genotypes, even when adequate soil N is available. Treatment The least number of pods per plant was found in Strain SB 12+50 kg DAP ha-1. However, this was not significantly (P > 0.05) different from Strain MAR-1495, Strain SB 12, TAL 379, Strain MAR-1495 +50 kg Dap ha-1, TAL 379 +50 kg DAP ha-1, or the control (Table 2). Treatment Strain SB 12 had the largest number of pods per plant, but this was comparable with yields of treatments Strain MAR-1495, TAL 379, Strain MAR-1495 + 50 kg Dap ha^{-1}, TAL 379 + 50 kg DAP ha^{-1} (Table 2).

Table 3. Partial budget analysis of bio-fertilizer strains

Treatments	GY (kg)	VC	TGR (ETB ha^{-1})	NB (ETB ha^{-1})	MRR%
Control	1404.6	0	16,855.2	16,855.2	
Strain MAR-1495-SB	2187.9	160	26,254.8	26,094.8	5774.5
Strain SB 12	1714.1	160	20,569.2	20,409.2	D
TAL 379	1748.5	160	20,982		D
Strain MAR-1495-SB + 50 kg Dap/ha	2025.3	785	24,303.6	23,518.6	497.5
Strain SB 12+ 50 kg DAP/ha	1764.8	785	21,177.6	20,392.6	D
TAL 379 + 50 kg DAP/ha	1705.1	785	20,461.2	19,676.2	D

N. B.Prices: - Urea= 8.24 birr kg^{-1} , TSP=12.75 birr kg^{-1} , Price of soybean=12 birr kg^{-1} , Seed=15 birr kg^{-1}& Labor cost =30 birr/ person/day for 8 hours, TC=Total cost, Gross return (Return from Grain) =price /kg* yield in kg and Net return = gross return – Total cost, VC = variable cost, GR= growth return, TGR = total growth return from grain, NB = net benefit

Partial budget analysis

Increased crop production from inputs may or may not benefit farmers (CIMMYT, 1988). Therefore, the researchers employed partial budget analysis (CIMMYT, 1988) to estimate the net benefit, dominance analysis, and marginal rate of return from various alternative treatments (CIMMYT, 1988). The **MAR 1495-SB** rhizobia had the highest net benefit of **26,094.8** Ethiopian birr, followed by the strain **MAR-1495-SB + 50 kg Dap ha^{-1}** rhizobia, which also had a total of **23,518.6** Ethiopian birr net benefit. The application of the negative control and TAL 379 inoculant + 50 kg DAP ha-1 yielded the lowest net benefit, with net benefits of 16,855.2 and 19,676.2 Ethiopian birr, respectively.

The study's profitability revealed that applying MAR 1495-SB rhizobia, which yielded the highest net benefit (26,094.8 ETB), recommended the use of biofertilizers. The farmers may not accept the highest net benefits from the application of inputs for crop production as good practices, despite them being the most profitable. In most cases, farmers prefer the highest profit (with low cost and high income). To achieve this, it is necessary to conduct a dominant treatment analysis (CIMMITY, 1988).

The dominance analysis revealed that all treatments, with the exception of MAR 1495-SB and MAR-1495-SB + 50 kg Dap ha-1, dominated in net benefits. Any pair of undominated treatments' % MRR expresses the return per unit of fertiliser investment as a percentage. The application of MAR 1495-SB (5774.5) recorded the maximum marginal rate of return, according to economic analysis. The marginal rate of this treatment was well above the 100% minimum (CIMMYT, 1988). As a result, the study concluded that the application of MAR 1495-SB was the most effective recommendation. The best recommendation for treatments subjected to marginal rate of return is not necessarily based on the highest marginal rate of return, but rather on the minimum acceptable marginal rate of return. The treatment with the highest net benefit, relatively low variable cost, and an acceptable MRR becomes the tentative recommendation (CIMMYT, 1988).

RECOMMENDATION AND CONCLUSION

In recent years, crop productivity in Ethiopia in general and in the Benshal-Gumuz region in particular has shown a declining trend, in spite of the best use of improved varieties. The most likely causes of this decline are the depletion of soil fertility and the continuous use of traditional fertilisers, which have limited the yield and crop quality. Therefore, we designed this experiment to evaluate rhizobial strain types and inorganic P for soybeans under the field conditions of Asossa District. The rhizobia strain on nodulation parameters had a highly significant difference ($P < 0.001$); however, there were no significant differences ($p > 0.05$) between the rhizobia strain and the rhizobia strain plus inorganic phosphorus fertilizer on grain yield. Accordingly, the study revealed the application of **MAR-1495** as the best strain recommended agronomically for soybean production in the Assosa area. In all parameters, the MAR-1495 rhizobial strain alone resulted in higher yield and yield components compared to the 1495 + 50 kg Dap ha-1 strain. A substantial increase in nodulation directly affected growth and yield due to the N2 fixation potential of soybean. Due to the high ppmP (phosphorous availability) in the study area during the experiment, adding rhizobium alone also led to more nodulation, growth, and yield of soybeans. The profitability of the study showed that the MAR 1495-SB strain, which provided the relatively highest net benefit (26,094.8 ETB), was the best strain for Asossa district. The best recommendation for treatments subjected to marginal rate of return is not necessarily based on the highest marginal rate of return, but rather on the minimum acceptable marginal rate of return. Therefore, the treatment with a high net benefit, relatively low variable cost, and an acceptable MRR becomes the tentative recommendation. Therefore, from an economic perspective, we recommend the MAR 1495-SB treatment, which has an acceptable marginal rate of return, a relatively high net benefit, and a relatively small total cost of production for soybean production in the Asossa district. We recommend demonstrating the MAR-1495 rhizobial strain to boost the productivity and sustainability of soybeans in the study area, while also maintaining a similar agro-ecology.

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