Original Research Article

Grain Yield and Economic Importance of Bio-fertilizer Rates of Soybean at Begi and Asossa Districts Western Ethiopia

Abstract

A field experiment was conducted on Nitisols of Asossa Agricultural Research Centre during 2017/18 to 2018/2019 cropping season to investigate the response of yieldpartial budget analysis to biofertilizer rates. The N fertilizer treatments considered in the study consisted of six levels (rates) of biofertilizer, one nationally recommended inorganic N and negative control of N. The treatments consists of: 125 g ha^{-1} (T1), 250 g ha^{-1} (T2), 500 g ha^{-1} (T3), 625 g ha^{-1} (T4), 750 g ha^{-1} (T5), 900 g ha^{-1} (T6), negative control (T7) and 18kg N ha^{-1} . The treatments were laid out as a Randomized Complete Block Design with three replications. The analysis of variance revealed that bio-fertilizer rates significantly ($P \leq 0.01$) affected grain yield at Begi district, while non-siginificant ($p<0.05$) at Asossa district. The maximum (3483.7 kg ha^{-1} and 1750.9 kg ha^{-1}) grain yield was recorded from 500 g ha^{-1} bio-fertilizer at Begi and Asossa district respectively. The application of 500 g ha^{-1} biofertilizer had the highest net-benefit of 20850.8 ETB, followed by 125 g ha $^{-1}$ biofertilizer which also had a total of 20196.8 ETB net benefit at Asossa district, while the application of 500 g/ ha biofertilizer had the highest net-benefit of 41644.4 ETB, followed by 125 g/ha biofertilizer which also had a total of 38315.6 ETB net benefit at Begi district. The application of 500 g ha^{-1} bio-fertilizer ha^{-1} had highest net benefit. Therefore, we recommended the treatment 500 g ha^{-1} since it produced high marginal rate of return, high net benefit and relatively small total cost of production, for soybean production in Begi and Asossa area.

Key words, *Soybean, bio-fertilizer, net benefit, partial budget analysis*

Introduction

Soybean (*Glycine max* L.) is one of the grain legumes native to East Asia, perhaps domesticated in North and Central China (Laswai*et al*., 2005). Soybean is grown for its edible bean around the world, which is an important source of inexpensive and high- quality protein (40%) and important source of oil (20%). Soybean is grown on 10^4 million hectares of land on five continents with annual total production of 241 million tons and productivity of 2.0 ton ha^{-1} (FAO 2012).

Soybean is widely produced in the west and southwestern parts of Ethiopia as food crop. Its production is highly concentrated in high rainfall areas, like Asossa, Wollega and Jimma areas. It was recently integrated into the cropping systems of smallholder farmers in Asossa areas and serves as a cash crop for farmers (Nigussie *et al.*, 2009). In Ethiopia, the area allocated for soybean and the corresponding total annual production has been 31,876 ha and 63,653 tons, respectively, with the productivity less than 2 ton ha^{-1} (CSA 2012), while the potential soybean yield has been estimated to be in the range of 6 – 8 tons ha^{-1} in USA (Specht et al.1999; Cooper2003).

About 50 countries worldwide grow soybean (Boerma and Specht, 2004). The United States of America (USA) accounted for 40 to 45% of the world's total soybean production in 2003 (Boerma and Specht, 2004). Egypt, the largest producer of soybean in Africa, produces about 180,000 tons annually (USDA-ERS, 2009). Soybean improves soil fertility by fixing nitrogen from the atmosphere (Sanginga *et al.*, 2003). Soybeans are sensitive to low pH. In acid soils, liming is essential to raise the pH to 6.0 or 6.5 for optimum yield production. Soils in Africa are typically highly variable in fertility and how they respond to application of inputs (AGRA, 2007). Soil nutrient depletion, nutrient mining and degradation have been considered serious threats to agricultural productivity and have been identified as major causes of decreased crop yields and per capita food production in sub-Saharan Africa (Henao and Baanante, 2006).

Biological nitrogen fixation (BNF) and nitrogen fertilizers are the main sources for meeting the N requirement of high-yielding soybean varieties. BNF is an effective and efficient source of N supply to plants under favorable atmospheric and environmental conditions (Hungria and Vargas 2000; Chen *et al*. 2002). BNF is very useful for small holder 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 the nitrogen fixation and hence legumes grain yields, where a low population of native rhizobial strains predominates (Chianu *et al.*, 2011). Therefore, evaluation and identification of appropriate and effective rhizobial strains are crucial to enhance nitrogen fixation and yield of soybean. In the present investigation, the influences of inoculation rate in soil with low rhizobia population associated with soybean is thoroughly examined under field conditions during the main rain season. Therefore, the specific objective of this piece of research work was to evaluate the rates of inoculant that are used as soybean rhizobial biofertilizer and to determine the optimum rate that effectively improve BNF of soybean at Assossa and Begi Districts.

Materials and Methods

Treatments and Experimental Design

A field experiment was conducted under rain fed conditions during the main rainy season (June to October) of 2017 and 2018 to investigate the effects of biofertilizer application rates on grain yield of soybean at Asossa and Begi district. The N fertilizer treatments considered in the study consisted of six levels (rates) of biofertilizer, one nationally recommended inorganic N and negative control of N. All plots uniformly received phosphorous as basal application (20% P from triple super phosphate) during planting. The experiment was then laid in a randomized complete block design with three replications consisting of a total of 8 treatments. A plot size of 3.6*3m (10.8 m^2) was used as an experimental unit. The blocks were separated by a 1.5 m wide open space where as the plots within a block were separated by a 0.75 m wide space. Soil bunds were constructed around each plot and around the entire experimental field to minimize nutrient, water movement, and cross contamination from plot to plot. Weed control was achieved manual by hand picking. Crop growth was then monitored until harvest.

Statistical Data Analysis

Analyses of variances for the data were conducted using the SAS GLM procedure (SAS 1998). Least significant difference (LSD) test at 5% probability used for mean separation when the analyses of variance indicate the presence of significant differences.

Economic Analysis

Mean grain yield of the selected treatments were used in partial budget analysis (CIMMTY, 1988). Economic analysis was performed to investigate the economic feasibility of the treatments (fertilizer rates). A partial budget, dominance and marginal analysis were conducted. The average open market price (Birr kg^{-1}) for maize and the official prices of blended, Urea and TSP fertilizers were used for the analysis. The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments from the range that were tested. The selected and discarded treatments using this technique are referred to as undominated and Dominated' treatments, respectively. The undominated treatments were ranked from the lowest (the farmers' practice) to the highest cost treatment. For each pair of ranked treatments, a % marginal rate of return (MRR) was calculated. The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertiliser expressed as a percentage.

Result and Discussion

Comment [K1]: Search for more similar works in the literature, to complement the discussions.

Analysis of the grain yield data showed non-significant difference among the treatments at Asossa district. Though there was no observable statistical difference among treatment at Asossa area, still T3 increased the grain yield of soybean by 37.4 % over the control plot, that can be taken as acceptable yield increment for the small holder farmers. In addition, compared to the recommended N and P treatment, T3 increased the mean value of soybean grain yield by 20.5%. On the other hand, the analysis of variance of soybean grain yield showed significant difference among rates of inoculation and fertilizer application at Begi district (Table 1). Accordingly, the biofertilizer rate, T3, resulted in 60.7% and 56.5% yield increase compared to the negative control N (T7) and the recommended inorganic (N) application, respectively. Hence, the normal recommendation rate (500 g/ha) of the National Soil Testing Center is optimal rate specifically for Begi and similar areas, while it still remains comparable to Asossa area.

Table1. Effect of biofertilizer rate on seed yield of soybean.

Treatment	Grain yield (kg/ha)	
	Begi	**Asossa**
125 g/ha (T1)	**3196.3ab**	**1686.4**
250g/ha (T2)	**2742.6bc**	**1430.8**
500 g/ ha (T3)	**3483.7 a**	**1750.9**
625 g/ ha (T4)	**2328.5dc**	**1261.2**
750 g/ ha (T5)	**2477.0cd**	**1454.9**
900 g/ ha (T6)	**2105.1cd**	**1329.1**
No (T7)	**2167.6cd**	**1274.5**
18kg N/ha (T8)	**2226.2cd**	**1451.9**
LSD	**608.97**	**-**
CV %	**13.42**	**29.53**

Partial budget analysis at Begi

The application of 500 g/ ha biofertilizer had the highest net-benefit of 41644.4 ETB, followed by 125 g/ha biofertilizer which also had a total of 38315.6 ETB net benefit. The lowest net benefit was obtained by the application of the negative control with total of 26011.2 ETB followed by 900 g/ ha biofertilizer with net benefit of 24861.2 ETB. The increased production of the crop due to the application of inputs might not be beneficiary to farmers (CIMMYT, 1988). Therefore, partial budget analysis (CIMMYT, 1988) was employed to estimate the net benefit, dominance analysis and marginal rate of return that could be obtained from various alternative treatments (CIMMYT, 1988). The profitability of the study showed that application of 500 g/ ha biofertilizer which provided the relatively high net benefit (41644.4 ETB), was the peak to apply fertilizers.

Economic analysis revealed that maximum marginal rate of return was recorded with application of 125 g/ha biofertilizer (**307.61** %), followed by 500 g/ha biofertilizer (**110.2%**). The marginal rates of those treatments were well above the 100% minimum (CIMMYT, 1988). According to CIMMYT (1988) experience and empirical evidence, for the majority of situations indicated that the minimum rate of return acceptable to farmers would be between 50 and 100%. In the present study the treatments that had above 100% marginal rate return was recommended for the farmers, with treatments that had small number of variable cost. This treatment was 125 g/ha and 500 biofertilizer g/ha.

Table.2 Partial Budget analysis of biofertilizer rate at Begi

Treatment	VC (ETB ha^{-1})	TGR (ETBha^{-1})	NB (ETBha^{-1})	MRR%
No biofetilizer	**0**	**26011.2**	**26011.2**	**0**
125 g/ha biofertilizer	**40**	**38355.6**	**38315.6**	**307.61**
250g/ha biofertilizer	**80**	**32911.2**	**32831.2**	**D**
500 g/ ha biofertilizer	**160**	**41804.4**	**41644.4**	**110.2**
625 g/ ha biofertilizer	**240**	**27942**	**27702**	**D**
750 g/ ha biofertilizer	**320**	**29724**	**29404**	**D**
18kg N/ha	**322.4**	**26714.4**	**26392**	**D**
900 g/ ha biofertilizer	**400**	**25261.2**	**24861.2**	**D**

N. B: Prices - Urea= 8.24 birr/kg, TSP=12.75 birr/kg, Price of soybean=12 birr/kg, Seed=10 birr/kg & 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.

The % MRR between any pair of undominated treatments denotes the return per unit of investment in biofertilizer expressed as a percentage. The results of undominated treatments indicated that for each one birr invested in purchase or production of fertilizers that was possible to recover one birr plus an extra of 3.08 birr ha^{-1} and 1.1birr ha^{-1} as the fertilizer application changed from unfertilized plot to 125 g/ha biofertilizer g/ha and 500 g/ha biofertilizer respectively. Passing from the first treatment that had the lowest costs that vary to the end treatment which had the highest cost that vary, the marginal rate of return obtained was above the minimum acceptable marginal rate of return. Accordingly, the study revealed that application of 500 g/ha biofertilizer was considered as the best for recommendation. The best recommendation for treatments subjected to marginal rate of return is not necessarily based on the highest marginal rate of return, rather based on the minimum acceptable marginal rate of return and the treatment with the highest net benefit, relatively low variable cost together with an acceptable MRR becomes the tentative recommendation (CIMMYT, 1988).

Partial budget analysis at Asossa

Table 3. Partial Budget analysis of biofertilizer rate at Asossa

Treatment	VC (ETB ha^{-1})	TGR (ETBha^{-1})	NB (ETBha^{-1})	MRR%
No biofetilizer	**0**	**15294**	**15294**	**0**
125 g/ha biofertilizer	**40**	**20236.8**	**20196.8**	**122.57**
250g/ha biofertilizer	**80**	**17169.6**	**17089.6**	**D**
500 g/ ha biofertilizer	**160**	**21010.8**	**20850.8**	**47.1**

625 g/ ha biofertilizer	**240**	**15134.4**	**14894.4**	**D**
750 g/ ha biofertilizer	**320**	**17458.8**	**17138.8**	**D**
18kg N/ha	**322.4**	**17422.8**	**17100.4**	**D**
900 g/ ha biofertilizer	**400**	**15949.2**	**15549.2**	**D**

N. B.Prices: - Urea= 8.24 birr/kg, TSP=12.75 birr/kg, Price of soybean=12 birr/kg, Seed=10 birr/kg & 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.

The application of 500 g/ ha biofertilizer had the highest net-benefit of 20850.8 ETB, followed by 125 g/ha biofertilizer which also had a total of 20196.8 ETB net benefit. The lowest net benefit was obtained by the application of the 625 g/ ha biofertilizer with total of 14894.4ETB followed by negative N control with net benefit of 15294 ETB. The profitability of the study showed that application of 500 g/ha biofertilizer which provided the relatively high net benefit (20850.8 ETB,), was the peak to apply fertilizers. Economic analysis revealed that maximum marginal rate of return was recorded with application of 125 g/ha biofertilizer (122.57%), followed by 500 g/ha biofertilizer (47.1%). The marginal rate of 125 g/ha biofertilizer treatments were well above the 100% minimum (CIMMYT, 1988). On the other hand the marginal rate of return of 500 g/ha biofertilizer treatments were below the 50 - 100% minimum (CIMMYT, 1988). According to CIMMYT (1988) experience and empirical evidence, for the majority of situations indicated that the minimum rate of return acceptable to farmers would be between 50 and 100%. In the present study the treatments that had above 50% marginal rate return was recommended for the farmers, with treatments that had small number of variable cost. This treatment was 125 g/ha biofertilizer g/ha for Asossa district, while based on net benefit and relatively lower cost production the farmers of Asossa area can use 500 g/ha biofertilizer.

The % MRR between any pair of undominated treatments denotes the return per unit of investment in biofertilizer expressed as a percentage. The results of undominated treatments indicated that for each one birr invested in purchase or production of fertilizers that was possible to recover one birr plus an extra of 1.23birr ha^{-1} and 0.47 ha^{-1} as the fertilizer application changed from unfertilized plot to 125 g/ha biofertilizer g/ha and 500 g/ha biofertilizer respectively. Accordingly, the study revealed that application of 125 g/ha biofertilizer was considered as the best for recommendation, while based on net benefit and relatively lower cost production the farmers of Asossa area can use 500 g/ha biofertilizer. The best recommendation for treatments subjected to marginal rate of return is not necessarily based on the highest marginal rate of return, rather based on the minimum acceptable marginal rate of return and the treatment with the highest net benefit, relatively low variable cost together with an acceptable MRR becomes the tentative recommendation (CIMMYT, 1988).

4. Summary and Conclusions

The present study was conducted in Benishangul Gumuz Regional State, at Asossa Agricultural Research Center station in the 2016/2017 to 2017/2018 main cropping season under rain fed field conditions. The profitability of the study showed that application of 500 g/ha biofertilizer which provided the relatively highest net benefit (**41644.4**ETB and **20850.8** ETB), was the optimum rate to apply biofertilizers for Begi and Asossa district. The best recommendation for treatments subjected to marginal rate of return is not necessarily based on the highest marginal rate of return, rather based on the minimum acceptable marginal rate of return and the treatment with the high net benefit, relatively low variable cost together with an acceptable MRR becomes the tentative recommendation. Therefore, we recommend the treatments (500 g/ha biofertilizer) that have acceptable marginal rate of return, relatively high net benefit and relatively small total cost of production for soybean production at Begi and Asossa district respectively.

5.Reference

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Amare B. Progress and future prospect in soybean research in Ethiopia. In: Proc 19th National crop improvement Conefrence. Addis Ababa, Ethiopia: Institute of agricultural Research; 1987. pp. 252–265.

Bhangoo MS, Albritton DJ. Nodulating and non-nodulating Lee soybean isolines response to applied nitrogen. Agron J. 1976;68:642–645.

Central Statistical Authority (CSA) Agricultural Sample Survey. Ethiopia: Addis Ababa; 2013. 2008/9 Report on Area and Production for Major Crops (Private Peasant Holdings, Main Season)

Chianu, J.N.,Nkonya, E.M., Mairura, F.S., Chianu, J.N. &Akinnifesi,F. K. (2011) Biological nitrogen fixation and socioeconomic factors for legume production in sub-Saharan Africa: a review. *Agronomy for Sustainable Development*, 31(1):139-154.

Food and Agriculture Organization (FAO) United Nations Food and Agricultural Organization, FAOSTAT Agricultural Database. 2012.

Graham PH, Vance CP. Legumes: Importance and Constraints to Greater Use. Plant Physiol. 2003;131:872–877.

Hungria M, Vargas MAT. Environmental factors affecting N2 fixation in grain legumes in the tropics, with an emphasis on Brazil. Field Crops Res. 2000;65:151–164.

Laswai, H.S., Mpagalile, J.J., Silayo, V.C.K. &Ballegu, W.R. (2005) Use of soybeans in food formulation in Tanzania. In: Myaka F.A., Kirenga, G. & Malema, B (Eds.). Proceedings of the First National Soybean Stakeholders Workshop, 10th-11th November 2005, Morogoro, Tanzania: 52–59.

Nigussie, M., Girma, A., Anchala, C. &Kirub A. (Eds.). (2009) Improved technologies and resource management for Ethiopian Agriculture. A Training Manual. RCBP-MoARD, Addis Ababa, Ethiopia.

Ogoke IJ, Togun AO, Carsky RJ, Dashiell KE. N_2 Fixation by Soybean in the Nigerian Moist Savanna: Effects of Maturity Class and Phosphorus Fertilizer. Tropicultura. 2006;24(4):193–199.

Specht JE, Hume DJ, Kumudini SV. Soybean yield potential—a genetic and physiological perspective. Crop Sci. 1999;39:1560–1570.

Boerme, R. H. and Specht, J. E. (Eds) (2004). Soybeans: improvement, production, and uses, Third Edition, No. 16 in the series AGRONOMY, ASA, CSSA, and SSSA, Madison.

USDA-ERS, (2009). Foreign Agriculture Service-Commodity Intelligence Report. Found at http://www.pecad.fas.usda.gov/.

Henao, J. and Baanante, C. (2006). Agricultural production and soil nutrient mining in Africa: implication for resource conservation and policy development. IFDC Technology Bulletin. International Fertilizer Development Center. Muscle Shoals, A. L. USA.

Sanginga, N., Dashiell, K., Diels, J., Vanlauwe, B., Lyasse, O., Carsky, R. J., Tarawali, S., Asafo-Adjei, B., Menkir, A., Schulz, S., Singh, B. B., Chikoye, D., Keatinge, D. and Rodomiro, O. (2003). Sustainable resource management coupled to resilient germplasm to provide new intensive cereal-grain legume-livestock systems in the dry savanna. Agriculture, Ecosystems and Environment 100: 305-314.