



Yield and economics of soybean (*Glycine max.* L) as influenced by plant growth promoting rhizobacteria and farm yard manure application under semiarid condition of Kandahar Afghanistan

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Abstract

The field experiment was conducted at Kandahar University, Agriculture Faculty research farm in Kandahar, Afghanistan on 2020 to determine the effect of FYM and plant growth promoting rhizobacteria (PGPR) on soybean grain yield and economics. The site of the experiment was located between 31°, 38' of north latitude and 65°, 41' of east longitude with 1,100m elevation. The climate of the region is semiarid with average 190mm annual precipitation. The experiment was laid out in randomized complete block design (RCBD), consisted of two factors such as farm yard manure (FYM) and PGPR; with total eight treatments combined with three replications. Four levels of FYM such as 0 (control), 7, 14 and 21 t ha⁻¹ were each used with and without PGPR. The result showed that combined application of FYM + PGPR remarkably increased pod number per plant, seed number per pod, pod length, grain yield, straw yield and biological yield compared to control and only FYM application. The highest gross return, net return, monetary efficiency and production efficiency were also calculated from the combined application of FYM + PGPR. However, the highest cost of cultivation was also calculated in combined application of FYM + PGPR compared to only FYM application and control. Finally, due to the findings and cost of cultivation, the application of 14 ton/ha FYM with biofertilizer seems to be economically suitable for the farmers.

Keywords: biofertilizer (PGPR), FYM, soybean, yield & economics

Introduction

Soybean [*Glycine max* (L.) Merrill] is an annual crop, belongs to the Leguminosae family, and known as “gold of 20th century” (Khutata *et al.*, 2005) ^[17]. It is considered as a wonder crop due to its dual qualities *viz.*, high protein content (40-43%) and oil content (20%). It can substitute for meat and to some extent for milk. Soybean protein has five percent lysine, which is deficit in most of the cereals; therefore, enriching the cereal flour with soybean improves the nutritive quality and reduce protein malnutrition (Apeji, 1988) ^[2]. Soybean oil is one of the common vegetable oils containing a significant amount of unsaturated fatty acids such as linolenic acid (omega-3 acid), linoleic acid (omega-6 acid) and oleic acid (omega-9 acid), (Yaklich *et al.*, 2002) ^[31]; therefore, it is an excellent source of food for human and animal consumption, (Abdelhamid & El-Metwally, 2008; Essa & Al-ani, 2001) ^[1, 11]. The origin of soybean plant is obscure but many botanists believe that it has been derived from *Glycine ussuriensis*, a legume native to Central China. The main producers of soybean in the world are United States, Brazil, Argentina, China and India (Narayan *et al.*, 2009) ^[20]. It has emerged as one of the important commercial crops in many countries and due to its worldwide popularity, the international trade of soybean is spreading globally. It is grown in an area of 102.88 million ha in the world with a production of 239.77 million metric tones. During a 10-year period from 2001 to 2010, world soybean production increased from 168 to 258 million metric tons (54% increase) (Ohyama, *at el.*, 2013) ^[22]. The area of harvested soybean increased approximately from 79 million ha in 2001, to 102 million ha in 2010 (29% increase) (Masuda & Goldsmith, 2009) ^[19].

Soybean grows in varied agro-climatic conditions and primarily cultivated under warm and hot climates. At least 15 °C are needed to germinate the seed and mean temperatures of 20-25 °C to grow the crop. Soybean is moderately salt sensitive and need at least moderate soil moisture in order to germinate, but need dry weather for seed production. Soybean plants can withstand considerable drought (Katerji *et al.*, 2001) ^[15]. Being a leguminous crop, soybean helps to enrich the soil by fixing atmospheric nitrogen through root nodules and enhance the productivity of succeeding crop (Singh & Awasthi, 1978; Apeji, 1988) ^[28, 2]. It is reported that full nitrogen requirement is not met by symbiosis particularly under N deficient soil (Harper *et al.*, 1989) ^[13]

however; soybean plant has ability of fixing about 240-250 kg N ha⁻¹ (Chandel *et al.*, 1989) [3], so, initial application of nitrogen is beneficial to soybean, as nodules are not present until 9 days after soybean emergence, and its high yield potential and ability to convert N into protein at seed filling stage (Osborne & Riedell, 2006) [23]. For the optimum yield, soil must have sufficient nutrients that are needed for plants. Due to the fact that, most nutrient resources in the soil are in unavailable forms and each year only a little part of them are released through biological activity and chemical processes (Chen, 2006) [6]. Hence, in order to increase crop yield per unit area, largely chemical fertilizers are used. The result of these activities in recent years has been the crisis of environmental pollution, especially water and soil pollution that threatens human society. Sustainable agriculture based on using organic and biological fertilizers is an effective solution for overcoming these problems (Ekin *et al.*, 2009) [10]. Microbial inoculants used as bio-fertilizers have been investigated in attempts to reduce chemical inputs, improve soil quality and sustainability, and to increase crop production (Nosratabad *et al.*, 2017) [21]. Biological fertilizers containing useful microorganisms, can increase plant growth and quality of crops, and reduce the cost of fertilizer and pesticide application (Chen, 2006) [6]. Biofertilizers helps the plant to grow better by having direct effect on nitrogen fixation and phosphorus mobilization (Rana & Chandel, 2003) [24]. For many years, plant growth-promoting rhizobacteria (PGPR) have been widely used as commercial inoculants and have proven to be environmentally sound options for increasing crop yields through various mechanisms, including K and P solubilization, nitrogen (N) fixation, plant hormone production, pathogen suppression, resistance to abiotic stresses and reducing ethylene concentration in the rhizosphere (Khosravi & Zarei, 2017; Stamenov *et al.*, 2018) [16, 30]. Several soil bacteria, particularly those belonging to the genera *Pseudomonas* and *Bacillus* possess ability to bring insoluble soil phosphates organic/inorganic phosphate into soluble forms by secreting acids such as formic, acetic, propionic, lactic, glucolic, fumaric and succinic. These acids lower the pH and bring about the dissolution of bound forms of phosphate into crop available forms (Singh & Tilak 2001; Jorquera *et al.*, 2008) [27, 14]. Farmyard manure on the other hand, occupies an important position among bulky organic manures. It has been estimated that 1 ton of FYM supply 3.6 kg nitrogen, 1.9 kg phosphorus and 1.8 kg potassium (Gaur *et al.*, 1992) [12].

Soybean plant was first introduced to Afghanistan in the year 1970 but due to security constrains and conflicts in the country, soybean research activities were stopped and ignored for 3 decades. Fortunately, in 2003 the Nutrition & Education International (NEI) a nongovernmental organization (NGO) began its activity in Afghanistan and introduced the plant as a good source of protein for the prevention of malnutrition in Afghanistan. Later on, the soybean has become as cash crop in Afghanistan and officially endorsed by the Ministry of Agriculture, Irrigation, and Livestock (MAIL) as a rotational second crop to wheat in order to improve food security and develop the local economy in rural communities. The demand for soybean in Afghanistan is increasing due to development of poultry and dairy farms in the country and its usage in feeding. As soybean is a newly cultivated crop in Afghanistan, it requires many investigations and researches to be done for high yield production. Therefore, this research was conducted to find out the effect of PGPR and FYM on soybean yield and economics in Kandahar region of Afghanistan.

Materials and Method

The field experiment was conducted at Kandahar University, Agriculture Faculty research farm in Kandahar, Afghanistan on 2020- March 14 until 2020 - July 30. The site of the experiment was located between 31°, 38' of north latitude and 65°, 41' of east longitude with 1100m elevation. The climate of the region is semiarid with average 190mm annual precipitation. The soil of the experimental field was sandy clay loam in texture with pH 8.18 and Electric Conductivity 0.21. The content of available nitrogen as NH₄-N and NO₃-N, were 11.34 and 30.12 mg Kg⁻¹, available P and K were 22.56 and 110 Kg ha⁻¹ respectively (by LaMotte Soil Test Kit). Soil total organic carbon was 20,200 mg/Kg (by TOC-VCPH) and total N was 485 mg/Kg (by Kjeldahl). The experiment was laid out in randomized complete block design (RCBD) consist of two factors such as FYM and plant growth promoting rhizobacteria; with total eight treatments combined with three replications and 2.5m x 3.5 m plot geometry. Four levels of FYM such as 0 (control), 7 (T1), 14 (T2) and 21 (T3) t ha⁻¹ were each used with and without of rhizobacteria bio-fertilizer application, with granular formulation at the rate of 2g/m². Soybean staine#1 variety was cultivated in the experiment. Row to row spacing was 45cm and plant-to-plant spacing was 8cm. However, 60 Kg P₂O₅ ha⁻¹ and 50 kg N ha⁻¹ fertilizers were used to all plots equally. Some of growth observations such as plant height, and nodule number plant⁻¹ were also recorded from eight randomly selected plants in each plot on 40, 80 and 120 days after sowing (DAS). Yield related factors such as pod number plant⁻¹, seed number pod⁻¹, pod length, 100 seed weight, grain yield h⁻¹, straw yield h⁻¹, biological yield, and harvesting index were recorded and calculated on physical maturity at the time of harvesting. The grain and straw yield were determined by net area basis after removing the boundary rows. Furthermore, gross return, net return, cost of cultivation, benefit cost ratio (B:C) production efficiency and monetary efficiency were also analyzed.

Results and Discussion

Plant height is an important indicator of plant growth which is influenced by both FYM and biofertilizer application. It shows that combined application of FYM and Biofertilizer is more effective than individual application. Plant height was calculated 40, 80 and 120 days after sowing (DAS) as 17cm, 48.42cm and 68.50cm respectively; which showed 14.61%, 19.06% and 12.6% increase compare to control. In only FYM application, plant height was calculated 16.5cm, 46.48cm and 67.72cm which showed 11.24%, 14.55%, and 10.82% increase

compared to control. The combined application of FYM and Biofertilizer showed 3.03%, 3.94% and 1.61% increase compared to only FYM application, as shown in table (1).

Table 1: Shows soybean plant height and nodule number at 40, 80 and 120 days after sowing (DAS).

Factor	40 DAS		80 DAS		120 DAS	
	Plant Height (cm/plant)	Nodule Number /Plant	Plant Height (cm/plant)	Nodule Number /Plant	Plant Height (cm/plant)	Nodule Number /Plant
FYM	16.5	20.05	46.58	32.67	67.42	27.83
FYM+PGPR	17	22.67	48.42	38.58	68.5	32.33
SEm±	0.4	0.48	0.61	0.59	0.6	0.59
SD	0.57	0.68	0.86	0.84	0.84	0.83
CD (P=0.05)	1.22	1.47	1.85	1.8	1.81	1.78
FYM Levels						
F ₀	14.83	19.42	40.67	32	60.83	26.83
F ₇	16.17	20.83	47.33	35.83	66	29.33
F ₁₄	17.33	21.5	49.5	35.83	70.67	30
F ₂₁	18.67	21.33	52.5	36.83	74.33	31.17
SEm±	0.57	0.68	0.86	0.84	0.84	0.83
SD	0.81	0.97	1.22	1.19	1.19	1.17
CD (P=0.05)	1.73	2.08	2.62	2.55	2.56	2.52
CV (%)	8.34	7.97	4.45	5.83	3.04	6.88

Similar result was reported by Singh *et al.*, (2007) ^[29] that use of phosphate solubilizing bacteria (PBS) increased soybean plant height by 10% compared to control. Furthermore, Narayana *et al.*, (2009) ^[20] reported that the highest plant height (16.89cm, 65.78cm and 73.37 cm after 30, 60 and 90 DAS respectively) was calculated from the treatment which one half of nitrogen dose was used as chemical fertilizer and one half as FYM with PBS.

The mean of nodule number per plant was 20.5, 32.67 and 27.83 at 40, 80 and 120 DAS respectively, in only FYM application, which showed a tremendous variation (10.57%, 18.11% and 16.17% respectively) compared to control. The nodule number in FYM + Biofertilizer application, which was 22.67, 38.58 and 32.33 after 40, 80, and 120 DAS respectively; showed 16.74%, 20.57% and 20.50% increase after 40, 80 and 120 DAS respectively compare to control. In addition, combined application of FYM + Biofertilizer was also remarkable in nodule number with 5.58%, 2.08% and 3.73% increase compared to only FYM application after 40, 80 and 120 DAS respectively, as shown in table (1). The remarkable increase in both plant height and nodule number per plant was seen in between 40 and 80 DAS. In the Chaudhari *et al.*, (2019) ^[5] findings, the high nodule number per plant (30.40) was calculated when 100% NPKS fertilizers doses + Biofertilizer + organic manure were used. Similarly, Singh *et al.*, (2007) ^[29] reported that the use of Biofertilizer and FYM increased soybean nodule number per plant by 75% compare to control. The application of 10 ton/ha FYM resulted in 11.7% increase in plant nodule number per plant and 8.5% increase in nodules weight compared to the treatment which FYM was not used (Sharma *et al.*, 2002) ^[26].

It showed that in combined application of FYM + PGPR biofertilizer, the pod number per plant was 53.6, seed number per pod was 2.40, pod length was 3.72cm, while in only FYM application it was 48.03, 2.18 and 3.47cm which showed 11.59%, 9.92% and 7.25% increase respectively.

The yield attributes of soybean were remarkably increased with FYM + PGPR application as shown in table (2).

Table 2: Shows soybean yield parameters at harvesting time

Factor	Yield Parameters							
	Pod No./ plant	Pod length (cm)	Seed No./pod	100 Seed Weight (g)	Seed Yield (Kg/h)	Straw Yield (Kg/h)	Biological Yield (Kg/h)	Harvest Index (%)
FYM	48.03	3.47	2.18	10.5	2,196	3,434.75	5,622.41	38.12
FYM+PGPR	53.6	3.72	2.4	10.86	2,409.35	3,553.58	5,976.68	39.62
SEm±	0.5	0.07	0.13	0.17	9.75	27.04	25.19	0.17
SD	0.7	0.1	0.18	0.24	13.79	38.24	35.63	0.24
CD (P=0.05)	1.51	0.22	0.38	0.52	29.57	82.01	76.42	0.51
FYM Levels								
F ₀	39.13	3.24	1.93	9.62	1,383.21	2,993.83	4,360.38	31.68
F ₇	46.23	3.58	2.33	10.73	2,011.27	3,291.33	5,302.61	37.88
F ₁₄	54.77	3.73	2.4	11.11	2,779.81	3,763.17	6,570.48	42.31
F ₂₁	63.13	3.83	2.5	11.26	3,036.38	3,928.33	6,964.72	43.59
SEm±	0.7	0.1	0.18	0.24	13.79	38.24	35.63	0.24
SD	0.99	0.15	0.25	0.34	19.5	54.08	50.39	0.33
CD (P=0.05)	2.13	0.31	0.54	0.73	41.82	115.98	108.07	0.72
CV (%)	3.39	7.05	19.12	5.55	1.47	2.68	1.50	1.49

FYM application resulted in 22.74% increase in pod number per plant, 12.93% increase in seed number per plant and 7.10% increase in pod length compared to control; which this range in FYM + PGPR application was 36.97%, 24.14% and 14.87% increase respectively.

By increasing the FYM levels from 7 to 21 ton/ha soybean grain yield was also increasing from 2 ton/ha to 3 ton/ha, which showed two times increase compared to control. It is seen in table (2) that in combined application of FYM + PGPR biofertilizer seed yield, straw yield and biological yield were 2,409.35 kg/ha, 3,553.58 kg/ha and 5,976.68 kg/ha respectively, while it was 2,196 kg/ha, 3,434.75/ha and 5,622.41 kg/ha respectively, in only FYM application, which shows 9.72%, 3.46% and 6.3% statistical increase respectively. Moreover, 100 seed weight and harvesting index which were 10.86g and 39.62% in the combined application of FYM + PGPR biofertilizer remarkably increased compared to the only FYM application with 10.5g and 38.12% respectively. In the FYM application the grain, straw and biological yield of soybean were increased 58.76%, 14.73% and 28.94% respectively compared to the control; while this range shows 74.18%, 18.7% and 37.07% increase respectively in the combined application of FYM + PGPR biofertilizer. Similarly, Singh *et al.*, (2007) ^[29] reported in his experiment that 5 ton/ha FYM application increased soybean seed yield 12%, seed number per plant 6% and pod number per plant 12%. Furthermore, Dikshit & Khatik, (2002) ^[9] found that 50% of NPK recommended dose and 10 ton/ha FYM application in soybean resulted in the highest grain yield (16 q/ha) and straw yield (30.75 q/ha). The highest number of seed/pod (2.46) and 100 seed weight (17.02 g) calculated from the treatment in which one half of the recommended nitrogen dose was applied as urea and one half as FYM with PSB (Narayana *et al.*, 2009) ^[20]. Due to Dadhich *et al.*, (2011) ^[8] findings, that application of 10 ton/ha FYM increased soybean grain yield by 36% compared to control. Furthermore, Singh *et al.*, (2007) ^[29] reported that due to the application of 5 ton/ha, FYM, soybean pod number per plant, seed number per plant and seed yield were increased by 12%, 6% and 12% respectively. Koushal & Singh, (2011) ^[18] reported that highest number of pod number/plant (80.40) calculated from the treatment, which one-half of recommended nitrogen dose was applied as urea and one-half as FYM with PSB. Singh *et al.*, (2007) ^[29] reported that application of FYM and rhizobium Biofertilizer increased soybean grain and straw yield by 19.8% and 15% respectively.

It is seen that soybean gross return, net return, cost of cultivation, production efficiency and monetary efficiency are gradually increasing when FYM doses are increased (from 0, 7, 14, and to 21 ton/ha) as shown in the table (3), especially when PGPR biofertilizer is used in combination.

The highest gross return, net return monetary efficiency and production efficiency such as 191,403.07 AFN, 128,379.67 AFN, 972.57 AFN and 18.25 kg respectively are calculated from the combined application of FYM + PGPR biofertilizer compared to the only FYM application without biofertilizer, which are 174,978.88 AFN, 119,155.48 AFN, 902.69 AFN and 16.64 kg respectively, and shows 9.39%, 7.74%, 7.74% and 9.67% remarkable variation. However, the highest cost of cultivation (63,023.4 AFN) is in combined application of FYM + PGPR biofertilizer while it is 55,823.4 AFN in only FYM application, which shows 12.9% increase in cost of cultivation. In only FYM application gross return and net return shows 55.3% and 40.6% increase compared to control, although, cost of cultivation show 99.92% increase as shown in table (3). On the other hand, in combined application of FYM + PGPR biofertilizer, gross return shows 69.88% and net return shows 51.48% increase compared to control, but in cost of cultivation, it shows 125.72% increase, as shown in table (3). In respect to costs and returns, neither height dose of FYM (21 tone/ha) nor lowest dose of FYM (7 ton/ha) is seen suitable; therefore, it seems from the analysis that 14 ton/ha of FYM with biofertilizer might give satisfactory result. Likewise, Satpute *et al.*, (2009) reported that the organic cultivation of soybean is economically better than conventional cultivation and resulted in high net return. Moreover, Chaturvedi, & Chandel, (2005) ^[4] findings shows that 10 t/ha FYM and recommended dose of chemical fertilizers resulted the highest net return. Dabhi *et al.*, (2010) reported that NPK 30:60:40 kg/ha and 5 t/ha FYM application resulted a remarkable increase in net return and B:C ratio.

Table 3: Shows economic efficiency of soybean cultivation

Economic efficiency						
Factor	Gross Return (AFN/h)	Net Return (AFN/h)	Cost of Cultivation	B:C Ratio	Production efficiency (kg/ha/day)	Monetary Efficiency (AFN/ha/day)
FYM	174,978.88	119,155.48	55,823.4	3.37	16.64	902.69
FYM+PGPR	191,403.07	128,379.67	63,023.4	3.20	18.25	972.57
SEm±	739.18	739.18	-	0.01	0.074	5.60
SD	1,045.36	1,045.36	-	0.02	0.104	7.92
CD (P=0.05)	2,242.08	2,242.08	-	0.04	0.224	16.99
FYM Levels						
F ₀	112,672.47	84,749.07	27,923.4	4.06	10.479	642.04
F ₇	160,719.55	111,796.15	48,923.4	3.29	15.237	846.94
F ₁₄	219,858.07	149,934.67	69,923.4	3.15	21.059	1,135.87
F ₂₁	239,513.81	148,590.41	90,923.4	2.64	23.003	1,125.68
SEM±	1,045.36	1,045.36	-	0.02	0.104	7.92
SD	1,478.37	1,478.37	-	0.03	0.148	11.20
CD (P=0.05)	3,170.78	3,170.78	-	0.06	0.317	24.02
CV (%)	1.40	2.07	-	1.40	1.467	2.07

AFN: Afghani currency (1 \$ \cong 88.5 AFNs).

Conclusion

The result of the experiment indicates that application of FYM and PGPR biofertilizer remarkably enhanced soybean yield. The gradual increase in FYM level (0, 7, 14, 21 t/ha) resulted in tremendous increase in soybean yield, production efficiency, neat return, and monetary return. Nevertheless, increase in FYM level also resulted in increase in cost of cultivation and due to very high cost of cultivation in 21 t/ha of FYM application and less variation in neat return compared to 14 t/ha of FYM and Biofertilizer application, it seems that 14 t/ha of FYM application with PGPR biofertilizer is going to be a suitable level to be recommended.

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