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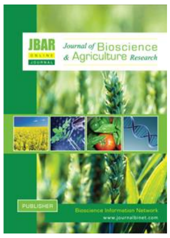

Combined impact of chemical and bio-fertilizers on soybean in the coastal area of Bangladesh

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ABSTRACT

When chemical fertilizers are combined with biofertilizers in the correct proportion, the efficiency of nutrient uptake by the plant will increase, leading to an increase in quality seed yield. During the late Kharif-II season of 2017 a field experiment was conducted in the farmer's field of Char Wapda, a FSRD site under Subarnachar upazilla in Noakhali district, to determine the effect of some inorganic fertilizers and bio-fertilizers on the growth and quality seed production of soybean for the upcoming Rabi season. Five fertilizer combinations, viz. T_1 = Native Control, T_2 = Soil Test Based (24-37-40-2.8-1.6-1 kg ha^{-1} of N-P-K-S-Zn-B), T_3 = 100% recommended dose (24-40-45-2.8-1.6-1 kg ha^{-1} of N-P-K-S-Zn-B) according to FRG, 2012, T_4 = 50% recommended dose (12-20-22.5-1.4-0.8-0.5 kg ha^{-1} of N-P-K-S-Zn-B + 1.2 kg ha^{-1} of BARI RGm-901 bio-fertilizer), and T_5 = Farmers' practice (26-12 kg ha^{-1} of N-P) The experiment utilized a randomized complete block design (RCBD) with three (03) replicates, and the test crop was BARI Soybean-5. The various treatment combinations exhibited statistically significant differences in yield and yield-contributing traits. Application of 50% of the recommended doses and biofertilizer (BARI RGm-901) at a rate of 1.2 kg ha^{-1} substantially increased the majority of the parameters, including the highest number of lateral branches per plant, number of pods per plant, weight of 100 seeds, and seed yield. T_4 produced the greatest seed yield (2.04 t ha^{-1}), while T_1 resulted the lowest seed yield (0.93 t ha^{-1}). T_4 produced the greatest gross return (TK.2,04,000 ha^{-1}) and gross margin (TK.1,62,477 ha^{-1}) while T_1 produced the lowest gross return (TK.93,000 ha^{-1}) and gross margin (TK.55,900 ha^{-1}). In addition, the benefit-cost ratio (BCR) was highest in plot T_4, where biofertilizer was applied alongside chemical fertilizer (3.91), and lowest in plot T_5 (1.49). Combining the two fertilizers can have a positive synergistic effect, but additional research is required to determine the optimal combination for cultivating high-quality soybean seed in specific soil and environmental conditions.

***Key Words**: Soybean, Rhizobium, Bio-fertilizer, Seed Yield and Coastal Area.*

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I. Introduction

Soybean (*Glycine max L.*) is an important source of proteins and edible oil, and it has valuable applications as a food, feed, and oil seed crop around the world (Liu et al., 2020). Soybean is the number one edible oil in Bangladesh in terms of use in everyday cooking. Besides, soybean seed is mainly used in the livestock and feed industries for making poultry, cattle, and fish feed. But it is a matter of great regret that we do not have the capability of producing soybean oil from soybeans grown in Bangladesh due to the country's low soybean production. Bangladesh produced 96,921 metric tons of soybeans on 62,870 hectares of land, while the global production was 359.51 million metric tons on 125.86 million hectares of land (FAOSTAT, 2017). According to BBS (2018), the total soybean cultivation area in Bangladesh was 59469 ha, and the total production was 98699 metric tons. Among various districts, Noakhali and Laxmipur districts are the major soybean-producing regions in Bangladesh (Miah et al., 2015; Salam and Kamruzzaman, 2015). As the soil of the coastal regions of Bangladesh is affected by salinity, there is always some need for fertilizer for plant growth. On the other hand, for optimal plant growth, nutrients must be balanced and sufficient for the plant; in other words, the soil must contain the nutrients required by plants (Ayoola et al., 2010). The farmers of coastal regions do not know the proper dose of chemical fertilizer. For growing soybeans, the majority of farmers use only urea and triple superphosphate. They do not apply other important chemical fertilizers like muriate of potash, gypsum, zinc sulfate, boric acid, etc. The crop is highly responsive to various fertilizers and that judicious fertilization can substantially boost its yield. Organic and chemical fertilizers applied together are highly effective in achieving high yield and nutrient uptake (Singh et al., 2013). In order to increase crop yield per unit area, chemical fertilizers are extensively used in both our country and the Noakhali region. In recent years, these activities have led to a crisis of environmental contamination, particularly water and soil pollution, which threatens human society (Darzi et al., 2007; Ekin et al., 2009). An environmentally preferable substitute for synthetic chemical fertilizers could be *Rhizobium* biofertilizer. Biological fertilizer-based sustainable agriculture is an effective means of overcoming these environmental issues. *Rhizobium* is a nitrogen-fixing bacterium capable of converting atmospheric nitrogen into plant-available forms, thereby reducing the need for chemical fertilizers. When combined with chemical fertilizers, *Rhizobium* can enhance the plant's ability to absorb nutrients, resulting in a higher yield. The combined use of *Rhizobium* biofertilizer and chemical fertilizer may result in a substantially higher soybean yield than applying only one fertilizer alone. Biofertilizers, also known as microbial inoculants, are capable of mobilizing essential soil nutrients from a non-usable form to a usable form for improving the yield of crop plants (Dai et al., 2004). It is possible to increase the crop yield of soybeans by enhancing nodulation and, consequently, nitrogen fixation by applying effective nitrogen-fixing microorganisms as inoculants to the seed or soil. This method reduces the need for producers to apply costly nitrogenous fertilizer by maximizing root colonization and thereby increasing the potential for increased yield (Alam et al., 2015).

Generally, soybeans are cultivated in the winter (Rabi) season in Bangladesh. But in some parts of coastal areas where rainwater cannot stagnate during the rainy season, some farmers prefer to cultivate soybeans, which they use as seed in the upcoming winter season. Though most of the peasants are unable to harvest high-quality seeds due to a lack of knowledge regarding fertilizer dosages, besides, inadequate storage systems and soybean seed physiological factors reduce the viability of the seeds. It is noteworthy that the hydrophilic nature of soybean's high protein content (Hartwig and Potts, 1987) aids in greater water absorption and that the high oil content in seed accelerates seed deterioration (Potts, 1972) through increased hydrolytic enzyme activity, increased respiration, and an increase in free fatty acids. Thus, producers become frustrated when attempting to store soybean seeds. Therefore, the study was conducted to determine the optimal fertilizer dose for producing high-quality soybean seeds on char lands within AEZ 18f that could be used in the immediate winter (Rabi) season for growing soybean.

II. Materials and Methods

The field experiment was carried out at Char Wapda under the FSRD site in Noakhali during the late Kharif II season of 2017 in the Young Meghna Estuarine Floodplain (AEZ 18f). The experimental site was located at Latitude: 22°36' 0" N and Longitude: 91°2' 59" E. Before beginning the experiment, initial composite soil samples ranging from 0 to 15 centimeters were taken from each of the experimental plots. These samples were then evaluated (Table 01).

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Table 01. Initial soil characteristics of the experimental area (0–15 cm depth)

Parameter	pH	EC	OC	OM	Total N	K	Ca	Mg	P	S	Zn	B
		dSm^{-1}	(%)	(%)	(%)	Meq/100 g soil			$\mu g\ g^{-1}$ soil			
Mean Value	6.7	2.15	0.8	1.62	0.09	0.18	4.0	2.1	2	25.83	0.6	0.16
Critical value	-	-	-	-	0.12	0.12	2.0	0.5	10	10	0.6	0.2

OC = Organic Carbon, OM = Organic Matter

The experiment was designed using randomized complete block design (RCBD), and it had a total of three replicates. The test crop was BARI Soybean-5, and the unit plot size was 4 meters by 3 meters. The treatments were distributed randomly throughout the blocks as follows: T_1 = Native Control, T_2 = Soil Test Based dose (24-37-40-2.8-1.6-1 kg ha^{-1} of N-P-K-S-Zn-B), T_3 = 100% recommended dose (24-40-45-2.8-1.6-1 kg ha^{-1} of N-P-K-S-Zn-B) according to Fertilizer Recommendation Guide (FRG), 2012, T_4 = 50% recommended dose (12-20-22.5-1.4-0.8-0.5 kg ha^{-1} of N-P-K-S-Zn-B) + 1.2 kg ha^{-1} of BARI RGm-901 biofertilizer), and T_5 = Farmers' practice (26-12 kg ha^{-1} of N-P). In the beginning, soybean seeds were thoroughly combined with the peat-based inoculum and a little amount of water according to the experimental design for T_4. The seeds were placed in a container and mixed at the rate of 20 grams of biofertilizer for every kilogram of soybean seeds. After that, separate polythene bags were used for each individual inoculation, and great caution was taken to prevent the inoculated seeds and the uninoculated seeds from becoming contaminated. On September 25, 2017, the seeds were sown at a rate of 60 kilograms per hectare at a spacing of 30 centimeters by 10 centimeters. When and where necessary, a variety of intercultural activities and plant protection measures were implemented in order to cultivate healthy crops. The crop was harvested between December 14 and December 24, 2017. In order to achieve a high level of precision and accuracy, data were gathered on an individual plant basis from ten (10) randomly selected plants within each plot. This was done in such a way as to exclude the border effect. During harvest, measurements were taken to record the number of plants per square meter, the height of each plant, and the number of branches on each individual plant. After the crop was harvested, measurements were taken of the number of pods produced by one plant, the number of seeds produced by one pod, and the weight of one hundred seeds. After recording the yield from each plot, the numbers were converted to tons per hectare. The program known as R Project for Statistical Computing, version 3.3.3, was used to do calculations such as analysis of variance and comparison of means. In addition, the meteorological conditions of the experimental site were hot, humid, and tropical monsoon-type (Table 02).

Table 02. Meteorological data of the site from September to December 2017

Month	Temperature (°C)		Total Rainfall (mm)	Humidity (%)
	Minimum	Maximum		
September	26	32	412	89.2
October	26	32	401	84.5
November	21	31	13	80
December	11	29	77	75

III. Results and Discussion

Days to maturity, plants per square meter and plant height

Results show that soybean plant height responded significantly to the use of biofertilizer (BARI RGm-901) and 50% of the recommended dose of chemical fertilizers (Table 03). In terms of days to maturity, T_4 took a longer period (90 days) to mature, which was statistically insignificant compared to T_3 (89 days) and T_2 (87 days) treatments. The treatment T_1 needed the shortest period of time for maturity, which may be a result of inadequate nutrients coupled with erratic rainfall stress as observed in other parameters. Besides, the highest plant population during harvesting time was found in T_3 treatment and the lowest in T_2 treatment. It is notable that there is no statistical difference among the treatments. The fertilizer level of T_3 (40.20 cm) and the control treatment T_1 (28.33 cm) had the highest and lowest plant heights, respectively (Table 03). This might be due to the higher amount of nutrients applied through chemical fertilizers at sowing which provide more nutrients as compared to other treatments. Plants in T_4 had 38.89 cm of height, which was statistically similar to the T_3. This study is similar to the findings of Singh and Rai (2004), where they observed that the integrated use of chemical fertilizers and biofertilizers increased plant height significantly in soybean.

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Branches per plant, pods per plant and seeds per pod

The highest number of branches per plant (2.83) was observed in the T_4, which was statistically identical with the T_3, whereas the lowest number of branches per plant (1.83) was observed in the control treatment. It seems that a gradual release of nitrogen by the nitrogen stabilizer caused the number of branches per plant in the T_4 treatment to increase. Besides these, the numbers of pods per plant and seeds per pod were significantly influenced by the use of bio-fertilizer with 50% of the recommended dose of chemical fertilizers and other treatments (Table 03). In the case of pods per plant, the maximum number of pods per plant (20.87) was recorded in the T_4, which was statistically at par with the T_3 (20.20) and T_2 (19.00) plots. In the case of the lowest pods per plant and seeds per pod, similarity was observed as plants in the T_1 treatment produced 13.07 pods per plant and 2.00 seeds per pod, which may be due to the lower number of branches per plant as no fertilizer was used in the treatment. The result of pods per plant was similar to the finding of Tomar et al. (2004), who observed that soybean plants treated with inoculants significantly increased the number of pods per plant. Furthermore, the highest number of seeds per pod was observed in the T_2 (2.73), which was statistically identical with the T_3 and T_4, where seeds per pod were 2.60 in both treatments. On the other hand, seeds per pod was similar to the study of Jain and Trivedi (2005), where they noticed that soybean plants treated with inoculums alone or in combination with different levels of chemical fertilizers gave the highest number of seeds per pod.

Hundred seed weight and Seed yield

For the yield calculation of soybeans, the weight of 100 seeds is an important parameter, along with pods per plant. The maximum 100 seed weight (12.51g) was recorded in the T_4, which was statistically similar to the T_2 (12.02 g) and T_3 (12.35 g). Almost similar 100-seed weights were observed in T_1 (11.26 g) and T_5 (11.27 g) treatments. The differences in 100-seed weight may be due to the effect of different combinations of fertilizers that provide adequate elements for seed fillings at the reproductive stage. Moreover, seed yield was remarkably influenced by different treatment combinations. The seed yield varied from 0.93 to 2.04 t ha^{-1} in the different treatments. The maximum seed yield (2.04 t ha^{-1}) was observed by the application of biofertilizer with 50% of the recommended dose of chemical fertilizers. It is notable that *Rhizobium* inoculants in different locations and soil types were reported to significantly increase the grain yields of Bengal gram (Patil and Medhane, 1974), lentil (Rashid et al., 2012), pea, alfalfa, and sugar beet rhizospheres (Ramachandran et al., 2011), berseem (Hussain et al., 2002), groundnut (Sharma et al., 2011), and soybean (Grossman et al., 2011). In addition, T_4 was statistically insignificant with T_3 (1.96 t ha^{-1}) and T_2 (1.90 t ha^{-1}) treatments. The lowest seed yield (0.93 t ha^{-1}) was recorded in the control treatment which may be due to the low nutrient availability from the experimental field.

Table 03. Yield and yield contributing characters of BARI Soybean-5

Treatments	Days to Maturity (days)	Plants per square meter (no.)	Plant height (cm)	Branches per plant (no.)	Pods per plant (no.)	Seeds per pod (no.)	100 seeds weight (g)	Seed yield (t ha^{-1})
T_1	80	31	28.33	1.83	13.07	2.00	11.26	0.93
T_2	87	29	35.93	2.27	19.00	2.73	12.02	1.90
T_3	89	32	40.20	2.63	20.20	2.60	12.35	1.96
T_4	90	30	38.89	2.83	20.87	2.60	12.51	2.04
T_5	83	30	34.00	2.00	13.47	2.27	11.27	0.98
LSD (0.05)	10.12	3.67	6.14	0.25	1.97	0.48	0.73	0.45
CV (%)	9.43	6.44	9.19	5.75	6.03	10.42	3.26	15.35

T_1 =Native Control, T_2 =Soil Test Based dose, T_3 =100% recommended dose, T_4 =50 % recommended dose + 1.2 kg ha^{-1} of BARI RGm-901 bio-fertilizer, and T_5 =Farmers practice

Cost-benefit Analysis

According to the results of the cost and return analysis, the treatment T_4, which consisted of 50% of the prescribed dose of (N-P-K-S-Zn-B) plus 1.2 kg ha^{-1} of biofertilizer, had the highest possible gross return of TK 2,04,000 ha^{-1} and the highest possible gross margin of TK 1,62,477 ha^{-1}. Both of these figures are in Bangladeshi Taka. The control treatment had the lowest gross return and gross margin of TK.93,000 ha^{-1} and TK.55,900 ha^{-1}, respectively, when compared to the other treatments. In addition, the benefit-cost ratio (BCR) was found to be at its maximum (3.91) when biofertilizer was applied with chemical fertilizer in T_4, while it was at its lowest (1.49) in T_5 (Table 04).

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Table 04. Cost and return analysis of BARI soybean-5

Treatments	Gross Return (TK. ha^{-1})	Total Variable Cost (TK. ha^{-1})	Gross Margin (TK. ha^{-1})	BCR
T_1 (Native Control)	93,000	37,100	55,900	1.50
T_2 (Soil Test Based dose)	1,90,000	44,723	1,45,227	3.24
T_3 (100% recommended dose)	1,96,000	45,203	1,50,797	3.33
T_4 (50 % recommended dose + 1.2 kg ha^{-1} of *BARI RGm-901* bio-fertilizer)	2,04,000	41,523	1,62,477	3.91
T_5 (Farmers practice)	98,000	39,316	58,684	1.49

Input price per kg: Soybean seed = TK. 60, Urea = TK. 16, TSP = TK. 22, MoP = TK. 15, Gypsum = TK. 12, Zinc Sulphate = TK. 140, Solubor Boron = TK. 120, Bio-fertilizer = TK. 100; Output price per kg: Soybean seed = TK. 100

IV. Conclusion

From the present study, it can be concluded that 50% of the recommended dose of chemical fertilizers combined with 1.2 kg ha^{-1} of BARI RGm-901 biofertilizer is superior to the other fertilizer management packages in terms of yield and economic return for soybean cultivation in the char areas of Young Meghna Estuarine Floodplain soil (AEZ 18f). This integrated approach can reduce the environmental impact of chemical fertilizers, enhance soil health, and increase crop yield. The optimal combination of *Rhizobium* biofertilizer and chemical fertilizer may vary based on soil type, salinity levels, and other environmental factors. Therefore, further research is required to determine the most effective combination and the effect of other types of biofertilizers with their specific application doses on soybean in Bangladesh's coastal regions.

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