Original Research Article

Integrated Nutrient Management Strategies: Unraveling the Impact of Bio-Fertilizers and Traditional Fertilizers on Soybean (*Glycine max*) Productivity

Abstract:

The study investigated the impact of different treatments on soybean growth and productivity, focusing on plant height and various growth parameters. Notably, Treatment T_6, incorporating cow dung, Rhizobium, and PSB, consistently outperformed other treatments. At 40 days after sowing (DAS), T_6 exhibited the highest plant height, a trend sustained at 60 DAS and harvest. This superiority was attributed to the synergistic effect of the bio-fertilizer components. The control (T_1) consistently had the shortest plants.In terms of productivity, T_6 consistently excelled across parameters such as branches, nodules, pods, pod length, seeds per pod, and seed yield (1.87 t/ha). Additionally, T_6 demonstrated the highest protein (39.41%) and oil content (18.60%). While the recommended fertilizer dose (T_2) showed improvement over the control, T_6 surpassed T_2, emphasizing the synergistic benefits of combining organic and microbial inputs. These findings highlight the potential of bio-fertilizers, particularly the combined approach, in enhancing soybean productivity. The study provides valuable insights for sustainable agricultural practices and optimizing fertilizer strategies for improved crop yields.

Introduction:

Soybean (*Glycine max*L), a pivotal leguminous crop, assumes paramount importance in global agriculture due to its essential role in protein and edible oil production. In the quest for sustainable agricultural practices, the integration of bio-fertilizers with traditional inorganic fertilizers has emerged as a strategic approach to optimize soybean productivity while addressing concerns related to environmental impact and soil health. Soybean production in Bangladesh has remained low, partly due to soil nutrient depletion and degradation which have been considered serious threats to agricultural productivity (Haque, F. 2018)
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The conventional application of inorganic fertilizers has been fundamental in meeting the nutrient demands of crops. However, apprehensions regarding their ecological repercussions and long-term effects on soil fertility have spurred interest in exploring eco-friendly alternatives. Bio-fertilizers, encompassing symbiotic nitrogen-fixing bacteria such as Rhizobium, as well as Phosphorus-Solubilizing Bacteria (PSB) and Potassium-Solubilizing Bacteria (KSB), offer a promising avenue for sustainable nutrient management.

Rhizobium, through its symbiotic association with soybean roots, facilitates biological nitrogen fixation, reducing the reliance on synthetic nitrogen fertilizers and enhancing overall soil fertility (Gaur and Adholeya, 2004). PSB and KSB, through their ability to solubilize phosphorus and potassium, respectively, contribute to improved nutrient availability for soybean plants (Richardson and Simpson, 2011).In conjunction with these bio-fertilizers, the incorporation of organic amendments such as cow dung serves to augment soil structure, microbial diversity, and nutrient content (Kumar *et al.,* 2015). This holistic, synergistic approach aims to capitalize on the advantages of both bio-fertilizers and inorganic fertilizers, striking a balance between sustainable agriculture and optimal crop yield.

This study endeavors to assess the individual and interactive impacts of inorganic fertilizers, cow dung, Rhizobium, PSB, and KSB on soybean productivity. By employing a multidimensional analytical approach, we seek to contribute valuable insights into the intricate dynamics of nutrient management in soybean cultivation, with implications for sustainable agriculture (Vats *et al*., 2021; Bhardwaj *et al*., 2014). Our findings are poised to inform practical strategies that enhance soybean productivity while mitigating the environmental footprint associated with conventional fertilizer practices.

Methods and Materials:

The soil of the experimental site belongs to Tejgaon series under the Agroecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was having a texture of sandy loam with pH and Cation Exchange capacity 5.6 and 2.64 meq 100 g $soil^{-1}$, respectively.

The experiment consisted of seven treatments namely T_1-control, T_2– recommended dose of fertilizer, T_3- Cowdung (15 ton/ha) T_4- Cowdung (15 ton/ha) and Rhizobium (30 g/kg seed), T_5- Cowdung (15 ton/ha) and PSB (20 g/kg seed), T_6- Cowdung (15 ton/ha), Rhizobium (30 g/kg seed) and PSB (20 g/kg seed). Recommended dose of NPK for soybean was (20 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}). Nitrogen, P and K were applied at the time of sowing in the form of urea, single super phosphate and muriate of potash, respectively. Treatments were tested in RBD with three replications. The recommended dose of Rhizobium and PSB as per treatments was first mixed in clean water to make thick slurry. This slurry was mixed with required quantity of seeds before sowing.

The pre-inoculated seeds were sown as per the treatment. The seed was inoculated with Rhizobium and PSB by slurry method. BARI Soybean-06 was sown at a spacing of 30 cm X 10 cm. The plant growth characters were recorded at 40 DAS, 60 DAS and at harvest. The biochemical constituent's protein percentage and Oil percentage were determined by adopting standard procedures.In the extraction process of soybean oil using the Soxhlet method, as outlined by Aziz *et al*. (2018), dried and ground soybean samples were weighed and placed into an extraction thimble. The thimble, containing the sample, was then positioned in the Soxhlet apparatus. A solution of 250 ml petroleum ether was introduced into the Soxhlet flask, connected to a holder and condenser. The system was heated on a hot plate, and distillation occurred at a low temperature (40-60^0 C) for 3-4 hours per sample. Following extraction, the apparatus was cooled, and the thimble, containing the extracted material, was air-dried for 30-40 minutes before being re-weighed. The difference in weight represented the crude fat content of the soybean sample. The total protein content was estimated by Micro Kjeldahl method.The recorded data on different parameters were statistically analyzed using Statistic 10 software. The significance of the difference among the treatments means was estimated by the least significant difference test (LSD) at 5% level of probability.

Result and discussion:

The plant height data revealed significant differences among treatments at different stages of growth(Table-1). At 40 DAS, Treatment 6 (T_6) exhibited the highest plant height (27.61 cm), significantly surpassing other treatments. This trend continued at 60 DAS and at harvest, where T6 consistently demonstrated the tallest plants. Conversely, the control (T_1) consistently exhibited the shortest plants across all stages. The observed variations in plant height among treatments can be attributed to the different nutrient compositions provided by the treatments. The synergistic effect of cow dung, Rhizobium, and PSB in T_6 evidently contributed to enhanced plant growth, indicating the positive impact of a combined bio-fertilizer approach. This finding aligns with previous studies emphasizing the beneficial effects of bio-fertilizers on plant development. The recommended dose of fertilizer (T_2) demonstrated a moderate increase in plant height compared to the control (T_1), emphasizing the importance of conventional fertilizers in soybean cultivation. However, the superiority of T_6 over T_2 suggests that the integration of bio-fertilizers can enhance the efficacy of conventional fertilizers. The results emphasize the potential of bio-fertilizers, particularly the combination of Rhizobium and PSB, in promoting soybean productivity.These findings are crucial for sustainable agriculture practices, offering insights into optimizing fertilizer strategies for improved crop yields.

The investigation into the impact of various treatments on soybean productivity revealed significant differences in multiple growth parameters (Table-1). Treatment (T_6), incorporating cow dung (15 ton/ha), Rhizobium (30 g/kg seed), and PSB (20 g/kg seed), consistently outperformed other treatments across various parameters. T_6 exhibited the highest number of branches, nodules per plant, number of pods, pod length, seeds per pod, and seed yield (1.87 t/ha). Additionally, T_6 demonstrated the highest protein content (39.41%) and oil content (18.60%), underscoring the effectiveness of the combined bio-fertilizer approach. While T_2, representing the recommended dose of fertilizer, showed improvements compared to the control (T_1), the integrated bio-fertilizer strategy in T_6 surpassed T_2, suggesting the synergistic benefits of combining organic and microbial inputs. These findings underscore the potential of bio-fertilizers, especially when combined, in enhancing soybean productivity, offering valuable insights for sustainable agricultural practices.

The observed enhancements in soybean productivity under the integrated bio-fertilizer treatment (T_6) align with previous research emphasizing the positive impact of microbial and organic amendments on crop performance. Studies such as those by Shrivastava *et al*. (2000) and Khan *et al*. (2019) have reported increased nodulation, nutrient uptake, and yield in leguminous crops, including soybean, when inoculated with Rhizobium and phosphate-solubilizing bacteria (PSB). Furthermore, the synergy between Rhizobium and PSB has been recognized for its potential to improve nitrogen fixation and phosphorus availability in the rhizosphere (Upadhyay *et al.,* 2020). The positive influence of cow dung, as observed in T_3, T_4, and T_5, is consistent with studies highlighting the role of organic amendments in enhancing soil fertility, microbial activity, and nutrient release (Bayoumy *et al.,* 2017; Machhar *et al*., 2019). Additionally, the higher protein and oil content in T6 agrees with findings by Malav *et al.* (2020), who demonstrated that the combined application of organic and microbial fertilizers positively influenced the biochemical composition of soybean seeds. These scientific references support the notion that the observed improvements in soybean productivity under the integrated bio-fertilizer treatment are rooted in well-established principles of microbial and organic nutrient management.

CONCLUSION:

In conclusion, our study provides valuable insights into optimizing fertilizer strategies for sustainable soybean cultivation. The integrated bio-fertilizer treatment (T_6) emerged as a superior approach, showcasing enhanced plant growth and productivity. The synergistic effects of cow dung, Rhizobium, and PSB in T6 underscore the potential of combining organic and microbial inputs. This approach surpassed the recommended fertilizer dose (T_2), demonstrating its efficacy in promoting soybean productivity. Scientific references supported our findings, linking the positive influence of microbial and organic amendments to established principles of nutrient management. These results contribute to the growing body of knowledge on sustainable agricultural practices, emphasizing the importance of bio-fertilizers for improved crop yields.

Table 1: Effect of synergistic application of bio-fertilizers and inorganic fertilizers on plant height (cm), number of branch, number of nodule per plant, number of pod, pod length (cm), number of seeds per pod, seed yield (t/ha), protein percentage and oil percentage of soybean (*Glycine max* L.).

Treatment	Plant height (cm)			Number of branch	Number of nodule per plant	Number of pod	Pod length (cm)	Number of seeds per pod	Seed yield (t/ha)	Protein %	Oil %
	40 DAS	60 DAS	At Harvest								
T_1	20.89 e	44.17 e	51.73 e	3.17 e	12.75 e	11.67 e	3.12 d	2.33 e	0.97 e	32.67 e	12.33 d
T_2	26.13 b	48.93 b	57.17 b	3.52 cd	21.33 c	21.33 d	3.87 c	3.23 c	1.71 b	38.07 b	16.17 b
T_3	22.15 de	47.17 c	53.53 d	3.41 de	19.33 d	22.67 c	4.03 bc	2.87 d	1.31 d	35.08 d	15.08 c
T_4	23.37 cd	45.50 de	53.93 d	3.73 bc	24.33 b	29.67 b	4.12 b	3.73 b	1.57 c	36.75 c	16.75 b
T_5	24.17 c	46.93 cd	55.20 c	3.87 b	25.33 b	30.67 b	4.22 b	3.78 b	1.52 c	36.33 c	16.17 b
T_6	27.61 a	51.40 a	60.62 a	4.12 a	29.33 a	33.33 a	4.82 a	4.29 a	1.87 a	39.41 a	18.60 a
$Lsd_{(0.05)}$	1.4597	1.5696	1.1755	0.2489	1.6137	1.1345	0.2416	0.2504	0.0668	0.8679	1.0366
CV%	4.12	3.65	5.12	4.25	6.85	3.52	4.57	2.35	3.45	1.13	1.23

Mean values in columns marked with the same letter(s) do not differ significantly by LSD at 5%, where SD: Standard deviation. Here, T_1 control, T_2– recommended dose of fertilizer, T_3- Cowdung (15 ton/ha) T_4- Cowdung (15 ton/ha) and Rhizobium (30 g/kg seed), T_5- Cowdung (15 ton/ha) and PSB (20 g/kg seed), T_6- Cowdung (15 ton/ha), Rhizobium (30 g/kg seed) and PSB (20 g/kg seed). Recommended dose of NPK for soybean was (20 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}.

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