Indian Journal of Ecology (2025) 52(2): 360-363
DOI: https://doi.org/10.55362/IJE/2025/4502

Manuscript Number: 4502
NAAS Rating: 5.38

Impact of Novel Bioformulations and Inorganic Fertilizers on Productivity of Soybean (*Glycine max* L. Merrill)

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***Abstract*:** Experiment was carried out at Central Agricultural UniversityResearch farm, Andro, Imphal to evaluate the effect of the conjunction of inorganic fertilizers and novel bioformulations *viz.,* Bio NPK and Bio Zn with the recommended dose of fertilizers (RDF) on the growth and yield of soybean. The RDF was 20:60:40 kg/ha of N: P: K. The experiment was conducted in a randomized block design having seven treatments with a combination of RDF along with Bio NPK, Bio Zn and *Rhizobium japonicum* + MDSR 14 + 12c which was replicated thrice. The maximum yield (1564 kg/ha) was obtained in treatment 75% RDF + Bio-NPK followed by 75% RDF + Bio-Zn + Bio-NPK (1504 kg/ha) signifying that the yield improvement is possible with the conjoint application of biofertilizers and inorganic fertilizers. The maximum B: C ratio was in 75% RDF + Bio-NPK followed by 75% RDF + Bio-Zn + Bio-NPK.

***Keywords*:** Bioformulation, Growth, Soybean, Yield

Soybean (*Glycine max* L. Merrill) is one of the most versatile oilseeds cum legumes grown all across the world, mostly for edible oil production. Manipur is one of the important soybean-growing states in the North-Eastern Hill region, the area, production and productivity of soybean are low compared to its potential. The estimated area, average yield and production of soybean for the agricultural year 2019-20 in Manipur were 0.042 lakh hectares, 870 kg/ha and 0.036 lakh tonnes , respectively (Directorate of Oilseeds Development 2019-20). Moreover, the favourable climate in Manipur makes it an ideal location for soybean production, especially in regions where paddy is unfit for cultivation (Sorokhaibam et al., 2022).

Soybean yields are generally low because it is a less prioritized crop, predominantly cultivated under rainfed conditions. Continuous depletion of soil nutrient resources due to intensive production has led to the emergence of multiple nutrient deficiencies in the soil, as higher and faster rates of nutrient exhaustion occur (Jain et al., 2021). There exists immense potential for enhancing soybean production through the application of organic manures, inorganic fertilizers, and biofertilizers (Verma et al., 2017). Although chemical fertilizers play a vital role in meeting the crop's nutrient requirements, persistent nutrient depletion poses a significant threat to sustainable agriculture. Consequently, there is an urgent need to reduce the usage of chemical fertilizers and instead increase the utilization of organic materials and other products. However, the sole use of organic inputs may not result in a spectacular increase in crop yield (Jain et al., 2021). Therefore, it is imperative to reduce chemical fertilizer usage and simultaneously increase the incorporation of organic and other sustainable products.

The importance of bioformulation in soybean cultivation and its potential impact on crop productivity is being explored worldwide. Bioformulations such as Bio-NPK liquid microbial consortium contain diverse populations of beneficial microbes, including nitrogen-fixing bacteria (*Azotobacter crococcum*), phosphorus-solubilizing bacteria (*Paenibacillus tylopilii*), and potassium-solubilizing bacteria (*Bacillus decolorationis*). Additionally, Bio-Zinc Liquid contains a single population of zinc-solubilizing bacteria (*Bacillus endophyticus*). These microbial inoculants aid in fulfilling the nutrient requirements of crops through efficient nitrogen fixation by promoting nodulation, solubilization of insoluble phosphorus, mobilization of potassium, and availability of zinc. Bioformulations play a vital role in enriching the soil by providing a range of essential nutrients, both micro and macro through nitrogen fixation, phosphate solubilization, and potash mobilization. Additionally, bioformulations aid in releasing substances that regulate plant growth, ensuring healthier and more productive crops (Javaid 2009). By utilizing these bio-inoculants, the nutrient demands of crops can be met through natural processes. The yield of soybean can improve yield to 5-10 % with the application of Bio-NPK and Bio-Zn bioformulations (Anonymous, 2020). Several studies have shown that bioformulation in soybean emerges as a promising strategy to enhance agricultural sustainability, improve crop yield, and minimize environmental impact.

MATERIAL AND METHODS

Field experiment was conducted during the *kharif* season in 2023 at Andro Research Farm (24°76' N and 94°05', 789 meters above mean sea level), Central Agricultural University, Imphal, Manipur to study the impact of integrating novel bioformulations and inorganic fertilizers on the growth and yield of soybean. The average maximum and minimum temperatures recorded during the growth period were 29.63°C and 20.30°C, respectively with an average rainfall of 72.04 mm and average sunshine of 5.82 hrs. The soil at the experimentation site was clayey in texture with a soil pH of 5.29 and 1.12% organic carbon content. However, the soil is low in available nitrogen, N (225.78 kg/ha) with a medium range of available phosphorus, P_2O_5 (23.29 kg/ha) and potassium, K_2O (265.43 kg/ha). The experiment was laid out in a randomized block design, with seven treatment combinations that were replicated thrice (Table 1). The NPK dose was applied in the form of urea, SSP and MOP @ 20:60:40 kg/ha as basal dose, respectively. The treatments i.e., bioformulations were applied as seed treatment as recommended. The tested variety was JS 97 52 and the crop was sown on 25th July and harvested on 11th November 2023. The observations on plant height at harvest (in cm), dry matter accumulation at 30, 45 and 60 DAS, number of nodules per plant at full bloom stage (R2 stage) and initial seed filling stage (R5 stage), number of branches per plant, number of pods per plant and yield were recorded. The economics of the crop is calculated as per the prevailing market price of soybean.

RESULTS AND DISCUSSIONS

Growth parameters: The significant difference in plant height at maturity was observed (Table 1). Maximum plant height (71.47 cm) was in T_5;75% RDF + Bio-NPK which was statistically at par with T_4; 75% RDF + Bio-Zn (67.27 cm) and T_6; 75% RDF + Bio-Zn + Bio-NPK (64.93 cm). The dry matter accumulation at 30 DAS showed no significant difference. However, at 45 and 60 DAS significance was observed (Table 1). At 45 and 60 DAS, maximum dry matter (2.12 g/plant, 15.57 g/plant) accumulated in T_5 which was statistically at par with T_6 (7.02 g/plant, 14.45 g/plant), T_2 (6.71g/plant, 13.97 g/plant) and T_7(6.36 g/plant), respectively. This might be due to the continuous supply of adequate nutrients during the crop growth period which has improved the plant height (Singh *et al.,* 2013) and the plants used these nutrients for vegetative growth which would have led to more dry matter accumulation as well. Similar findings were reported by Prajapat et al. (2015),Bondey et al. (2017), Kumar and Sharma (2018).

The number of nodules was observed at two important stages of soybean *viz.,* R2 stage and R5 stage which have shown significant influence of the treatments (Table 1). At the R2 stage, the maximum number of nodules was in T_6 which was statistically at par with T_4 and T_5. At the R5 stage, a significant maximum number of nodules was in T_5 (27.50) which was statistically at par with T_6(23.70), whereas the lowest number of nodules was in control at both stages. Applying bioformulations may have increased the microbial activity in the soil and enhanced the biochemical processes. The phosphorus solubilization helps in root development and builds a larger root network by providing more surface area to the nitrogen-fixing bacteria for the formation of the nodules and nutrient absorption (Salve and Gunjal 2011). Due to the presence of high organic matter in the soil, microbes gain a sufficient amount of energy for the mineralization of the nutrients (Singh et al., 2021). Thus, the biofertilizer treatments have a profound effect on nodule number (Jaga and Sharma, 2015). The findings are in agreement with

Table 1. Effect of treatments on growth parameters of soybean

Treatments	Plant height (cm)	Dry matter accumulation (g/plant)			No. of nodules/plant		No. of branches/ plant
		30 DAS	45 DAS	60 DAS	R2 stage	R5 stage	
T_1-Control	56.67	1.26	5.52	9.55	11.00	11.70	3.6
T_2-RDF	62.53	1.81	6.71	13.97	15.00	18.50	4.2
T_3-75% RDF	62.80	1.44	6.04	11.86	16.50	16.30	3.9
T_4-75% RDF + Bio Zn	67.27	1.85	6.07	12.06	20.20	16.50	4.1
T_5-75% RDF + Bio NPK	71.47	2.12	7.32	15.57	19.80	27.50	4.4
T_6-75% RDF + Bio Zn + Bio NPK	64.93	1.98	7.02	14.45	20.70	23.70	4.2
T_7-75% RDF + *Rhizobium japonicum* +MDSR 14 + 12c	60.87	1.80	6.36	12.16	16.70	20.80	4.0
Sem (±)	2.26	0.18	0.36	0.78	1.175	1.998	0.1
CD (p=0.05)	6.95	NS	1.11	2.41	3.621	6.155	0.4

RDF = 20:60:40 NPK kg/ha
75% RDF = 15:45:30 NPK kg/ha

Table 2. Yield attributes, yield and economics of soybean as influenced by different treatment combinations

Treatments	No. of pods/plant	Seed index (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Net returns (Rs/ha)	B: C Ratio
T_1-Control	54	11.2	1045	2197	32.6	57219	1.55
T_2-RDF	76	11.4	1396	2691	34.1	76151	1.54
T_3-75% RDF	71	11.7	1229	2529	32.7	63024	1.33
T_4-75% RDF + Bio Zn	69	12.0	1197	2656	31	60066	1.26
T_5-75% RDF + Bio NPK	82	11.6	1564	2859	35.4	93066	1.95
T_6-75% RDF + Bio Zn + Bio NPK	79	11.7	1504	2766	35.2	87524	1.83
T_7-75% RDF + *Rhizobium japonicum* +MDSR 14 + 12c	74	12	1231	2605	33.2	63191	1.33
Sem (±)	3.19	0.48	70.66	106.8	1.84	6359	0.133
CD (p=0.05)	9.83	NS	217.73	329.1	NS	19595	0.409

RDF = 20:60:40 NPK kg/ha
75% RDF = 15:45:30 NPK kg/ha

earlier studies of Singh et al. (2021), Lakshman et al. (2023) and Somanagouda et al. (2023).The number of branches per plant was significant with a minimum number of branches in control treatment (3.6). In contrast, the maximum number of branches was in T_5 (4.4) which was statistically at par with the T_2 (4.2), T_6 (4.2) and T_7 (4.0) (Table 1). In the present study, a significantly higher number of branches are produced with the application of 75% NPK and Bio NPK due to the supply of balanced primary nutrients encouraging growth and development by cell division and elongation during the growth phase. These results are also in close conformity with Kumar and Sharma (2018).

Yield attributes and yield: The number of pods per plant was significantly influenced by the conjoint application of inorganic fertilizer and the bioformulations used. The maximum number of pods per plant was significantly higher in T_5;75% RDF + Bio-NPK (82) which was statistically at par with T_6; 75% RDF + Bio-Zn + Bio-NPK (79) and T_7; 75% RDF + *Rhizobium japonicum* + MDSR 14 + 12c (74) while the minimum number of pods per plant was in control (54) (Table 2). The combined application of inorganic fertilizers and Bio NPK has resulted in the release of nitrogen, phosphorus and potassium throughout the crop growth period and it has increased the dry matter accumulation and thereby increased the number of yield attributes along with good yield response. Similar results were observed in earlier studies (Bonde and Gawande 2017, Krevchenko *et al*., 2018, Shome *et al*. 2022).

Seed and straw yield were significantly influenced by the application of different bioformulation combinations (Table 2). The maximum yield was in T_5;75% RDF + Bio-NPK (1564 kg/ha seed yield and 2859 kg/ha straw yield) statistically at par with T_6; 75% RDF + Bio-Zn + Bio-NPK and T_2; 100% RDF. The lowest yield was recorded in the control. The inoculation of bioformulations with RDF has increased nitrogen fixation and the solubilization of P, K and Zn as well which has increased their availability for the plant uptake resulting in higher growth parameters and yield attributes which have then reflected in the higher seed and straw yield (Lakshman *et al*. 2023 and Singh *et al*. 2018, Gohil *et al*. 2021)).

However, the treatments have no significant effect on the harvest index and seed index of the crop (Table 2).The treatments might not influence the harvest index and seed index because of the varietal character and the less responsiveness to the treatments. The findings are in close agreement with Kumar and Sharma (2018) and Bonde and Gawande (2017).

Economics: The highest economic returns *viz.,* gross returns and B: C ratio were in T_5 (75% RDF + Bio-NPK) (Rs 93066/ha and 1.95) and statistically at par with T_6 (75% RDF + Bio-Zn + Bio-NPK) (Rs 87524/ha and 1.83) and T_2 (100% RDF) (Rs 76151/ha and 1.54).

CONCLUSION

Based on the aforementioned current observations may be concluded that the agronomic approach for optimum soybean growth, yield and economics could be better accomplished with the supplementation of 75% RDF + Bio NPK which was comparable with 75% RDF + Bio NPK + Bio Zn and 100% RDF.

AUTHOR'S CONTRIBUTION

Conceptualization and designing of the research work - TSD, AKB; Execution of field/lab experiments and data collection -TSD, AKB, SA, AK; Analysis of data and interpretation MJ, TO, RK; Preparation of manuscript AKB, TSD, SA.

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Received 15 December, 2024; Accepted 28 February, 2025