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Effect of bio-fertilizer formulation on growth and yield of soybean (*Glycine max* (L.) Merril.)

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Abstract
A field experiment entitled "Effect of bio-fertilizer formulation on growth and yield of soybean (*Glycine max* (L.) Merrill.)" was conducted during Kharif season of 2021 at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) to study the effect of different biofertilizer on soybean's growth, yield, nutrient content, uptake and economics in *Vertisol* of Chhattisgarh. The experiment was evaluated to use a randomized block design (RBD) with three replications and seven distinct treatments. The treatment comprised T1: Control (No nutrients), T_2: 100% RDN, T_3: 75% RDN, T_4: 75% RDN + Bio Zn, T_5: 75% RDN + Bio NPK, T_6: 75% RDN + Bio Zn + Bio NPK, T_7: 75% RDN + *Rhizobium* + MDSR 14 + MDSR 34. Result revealed that application of 75% RDN + Bio Zn + Bio NPK significantly gave the highest values of number of nodules plant^{-1} (32.10), dry weight of nodules plant^{-1} (179.8 mg) and number of pods plant^{-1} (68.47), number of seeds pod^{-1} (2.06), 100-seeds weight (10.99). The seed yield (20.2 q ha-1), Stover yield (48.07 q ha^{-1}) were recorded higher in 75% RDN +Bio Zn + Bio NPK treatment as compare to 100% RDN, There was a saving of 25% of inorganic nutrients with the use Bio fertilizers along with 75% RDN instead of 100% RDN.

Keywords: RDN, soybean, bio-fertilizers, growth and yield attributes, quality parameters and economics

Introduction

Soybean (*Glycine max* (L.) Merill.) is a leguminous crop originated in China and belongs to the Fabaceae family. It is an essential crop for human and animal nutrition because it is a key source of edible vegetable oil, high-protein feed, and food in the world. It is a major crop in the United States, Brazil and China. It contains about 20-22 per cent cholesterol free oil, 40-42 per cent quality protein and 20-30 per cent carbohydrates. Soybean protein is high in the essential amino acid lysine (5%), which is lacking in most cereals. Soybean is the important and cheapest source of proteins and oils and it is called "Poor man's meat". (Pawar *et al*. 2018) [11] It is referred as a "wonder crop" because it is the richest, cheapest, and easiest source of the highest quality proteins and fats, as well as having a massive multitude of purposes in both food and industry. Soybean roots like those of most legume, contain microorganisms that fix nitrogen from the atmosphere allowing the plant to grow in restricted areas or in soil that cannot support most other crops. Besides this, soybeans can leave 35-40 kg ha^{-1} of residual nitrogen for the succeeding crop. These qualities have made soybean to fit well in sustainable agriculture. Soybean due to many uses rightly called "GoldenBean" of twentieth century. It has a high nutritional value and contains other essential amino acids as well as vitamins A, B, D, and E. Soybean is an excellent food available at the most affordable rate. It is recommended in heart, stomach, diabetes and kidney diseases.

Globally soybean is cultivated over an area of 132.42 million hectares with a production of 363.27 million metric tons and productivity 2.74 t ha^{-1}, while in India, it is cultivated on 12.70 million hectares with 10.45 million t ha-1 production and 0.82 t ha^{-1} productivity (USDA, 2020) [8].

Bio-fertilizers are microbial formulations that contain beneficial microbial strains which have been immobilized or trapped on inert carrier materials and can be used to improve plant development and soil fertility. According to research biofertilizers have been shown to boost crop yields by around 25% and reduce the usage of inorganic N and P fertilizers by about 25% and 25%, respectively (Aloo *et al*. 2020) [4].

It supply nutrients for plant needs, minimizing leaching, therefore improves fertilizer use efficiency. By supplying natural nutrients and sufficient organic matter, bio-fertilizers improve the physicochemical features of soil, such as structure, texture, water holding capacity, cation exchange capacity, and pH. Chemical fertilizers do not improve basic soil health, but they do degrade the structure of the soil. The production and use of bio-fertilizer is proposed, to improve yield of crops by using root nodule bacteria (rhizobia), mycorrhizal fungi and other microorganisms that are able to increase availability of plant nutrients from the soils.

Materials and method

The field experiment took place at the Instructional Cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, during the kharif season of 2021, Raipur (Chhattisgarh). The experiment was laid out in randomized block design (RBD) with three replications and seven different treatments. The treatment comprised T_1: Control (No nutrients), T_2: 100% RDN, T_3: 75% RDN, T_4: 75% RDN + Bio Zn, T_5: 75% RDN + Bio NPK, T6: 75% RDN + Bio Zn + Bio NPK, T_7: 75% RDN + *Rhizobium* + MDSR 14 + MDSR 34. The soil of the experimental field was Clay loam and reaction of the soil was alkaline with low available nitrogen (N), low available phosphorus (P) and high available potassium (K) content.

Results and discussion

Number of nodules plant^{-1}

Number of nodules plant-1 was counted at 25 and at 50 DAS because maximum nodules formation occurred during these two intervals (Table 1). Number of nodules plant-1 was found non- significant at 25 DAS and at 50 DAS, number of nodules plant-1 was recorded significantly higher in treatment 75% RDN + Bio Zn + Bio NPK (T_6) where *Azotobacter spp.* (Asymbiotic N fixer) positively affect the nodule number and phosphate solubilizing bacteria increased availability of P to the plants which promote nodulation, root elongation and zinc solubilizing bacteria promote healthy and abundant plant root that significantly increase the leghaemoglobin in root nodules and number of effective nodules in soybean roots and lowest was recorded under control (No nutrients) (T_1), which was un-inoculated from bio-fertilizer. This similar observation was found by Ahsan *et al.* (2012) [1] and Kumar *et al.* (2016) [3, 10].

Dry weight of nodules (mg plant^{-1})

The maximum dry weight of nodules plant-1 was observed in T6 treatment (Table 1). The increase in number of root nodules plant-1 leads to increase in dry weight of nodules plant-1 and greater effect of *Azotobacter* in root growth and minimum dry weight of nodules plant-1 obtained in T1 treatment (No nutrients). Bio-fertilizer influence dry weight of nodule reported by Ahsan *et al.* (2012) [1] and Kumar *et al.* (2016) [3, 10].

Dry matter accumulation (g plant^{-1})

Highest dry matter accumulation increased in T_6 treatment possible to identify that PSB at these fertilizer doses influenced plant growth and enhanced plant dry weight favourably (Table1). This may be due to the bacteria's production of growth hormones and their impact on plant development being stimulated (Zarei *et al*., 2012) [9]. The Zn solubilizing bacteria and PSB provide available form of zinc and phosphorus, which increases the growth parameters such as number of leaves and leaf area, which might be enhanced the photosynthesis activity and they positively affect the plant dry matter accumulation. The dry matter increased progressively at succeeding observations because increase in vegetative and reproductive growth and minimum dry matter found in control treatment (T_1). The similar result reported by Kant *et al.* (2016) [3].

Table 1: Effect of bio-fertilizer formulations on growth attributes of soybean

Treatment	Number of nodules plant^{-1}		Dry weight nodules (mg plant^{-1})		Dry matter accumulation(g)
	25 DAS	50 DAS	25 DAS	50 DAS	At harvest
T_1: Control (No nutrients)	6.63	22.83	17.37	136.9	33.22
T_2: 100% RDN	8.16	29.60	28.53	163.3	42.55
T_3: 75% RDN	6.93	26.53	23.20	139.2	35.33
T_4: 75% RDN + Bio Zn	7.60	28.43	23.70	143.2	37.99
T_5: 75% RDN + Bio NPK	8.06	28.63	25.73	159.4	41.03
T_6: 75% RDN + Bio Zn + Bio NPK	8.73	32.10	36.20	179.8	46.49
T_7: 75% RDN + *Rhizobium* + MDSR 14 + MDSR 34	8.53	30.40	30.50	168.6	45.02
S.E.M ±	0.81	1.52	5.04	9.03	1.73
CD (p = 0.05)	NS	4.72	NS	27.82	5.33

*RDN- Recommended dose of nutrients

Number of pods plant^{-1}

The Maximum number of pods plant-1 (Table 2) was recorded in T6 treatment might be affected by combine application of bio Zn and bio NPK due to the balanced nutrient intake in the root environment, the positive impacts of these microorganisms on enzymes and hormones and their effects on plant growth. Similar result was corroborated by Kant *et al.* (2016) [3].

Number of seeds pod^{-1}

The maximum number of seeds pod-1 (Table 2) was showed in treatment T6 where combined inoculation of nitrogen fixing bacteria, PSB, KSM and bio Zn with 75% RDN fertilizer due to the phosphate solubilizing bacteria's hormonal effects and a consistent and stable supply of P to the plants during the growth and flowering periods increase seeds pod-1. The similar result found by Shete *et al.* (2021) [7].

100-seeds weight (g)

The maximum 100-seed weight (Table 2) was reported in T6 treatment where different bio-fertilizers were applied and these microorganisms create better rooting system and better nutrient absorption and improved photosynthesis which

might be positively increase hundred seeds weight and bio Zn used as activator for soil microorganisms and enzyme which participate in yield enhancement. The similar result reported by Prajapat *et al*. (2015) [6]

Seed yield (q ha^{-1})

Observed data of seed yield are presented in Table 2. The data revealed that the maximum seed yield obtained in treatment T6 might be increase seed yield by providing macro and micronutrients for plant growth, production of enhancing material, development of the rooting system and anti-pathogenic effects. Similarly observation was reported by Kumar *et al.* (2016) [3, 10].

Stover yield (q ha^{-1}): Higher stover yield (Table 2) was reported in T6 this might be due to the cumulative effect of different microorganism which was applied in treatment and they supply of plant nutrients which resulted in higher Stover yield. Higher Stover yield would have resulted from the excessive vegetative development, even at the expanse of seed production. Similar result have also reported by Kumar *et al.* (2016) [3, 10] and Prajapat*et al*. (2015) [6].

Table 2: Effect of bio-fertilizer formulations on yield attributes and yields of soybean

Treatment	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	100-seed weight (g)	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})
T1: Control (No nutrients)	51.67	1.53	8.79	10.73	29.18
T2: 100% RDN	59.53	1.83	10.29	18.08	46.25
T3: 75% RDN	54.8	1.70	9.29	16.68	37.49
T4: 75% RDN + Bio Zn	55.87	1.73	9.34	17.07	41.66
T5: 75% RDN + Bio NPK	56.33	1.80	9.47	17.07	43.28
T6: 75% RDN + Bio Zn + Bio NPK	68.47	2.06	10.99	20.2	48.07
T7: 75% RDN + *Rhizobium* + MDSR 14 + MDSR 34	65.67	2.03	10.66	20.0	47.14
S.E.M±	2.80	0.06	0.14	0.69	1.95
CD (p = 0.05)	8.64	0.19	0.43	2.12	6.01

Conclusion

According to the results of the aforementioned study, the combination application of bio-fertilizers was determined to be superior then the single application and control treatment. The application of 75% RDN+ Bio NPK+ Bio Zn produced the highest levels of growth, yield attributes, seed yield, and Stover yield; this treatment was on par with 75% RDN + *Rhizobium* + MDSR 14 + MDSR 34 and 100% RDN treatment, which were found to be superior to the other treatments, while the lowest levels were observed in the control treatment. Using bio-fertilizers and 75% RDN rather than 100% RDN resulted in a 25% reduction in the amount of inorganic nutrients used. Comparing the treatment with the control, the seed production increased by 48.66%.

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