Plant Archives Vol. 24, Special Issue (GABELS), 2024 pp.1-6 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.SP-GABELS.001

EFFECT OF LIQUID BIOFERTILIZER AND INORGANIC NUTRIENTS APPLICATION ON GROWTH, PHYSIOLOGY AND PRODUCTIVITY OF SOYBEAN (*GLYCINE MAX* L. MERRILL)

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ABSTRACT

A field experiment entitled "Effect of Liquid Biofertilizer and Inorganic Nutrients Application on Growth, Physiology and productivity of Soybean (*Glycine Max* L. Merrill)" was conducted during Kharif season of 2021 at Research farm of R.A.K. College of Agriculture, Sehore (M.P.) to study the effect of Bio-NPK and Bio-Zn with chemical fertilizers on soybean growth, physiological parameters and yield in *Black soil* of Madhya Pradesh. The experiment was evaluated to use a randomized block design (RBD) with three replications and seven distinct treatments. The experiment results revealed that application of 100% RDF significantly gave the highest values of plant height plant^{-1}, number of branches plant^{-1}, dry weight plant^{-1}, number of nodules plant^{-1}, dry weight of nodules plant^{-1},leaf area index, crop growth rate, relative growth rate, net assimilation rate and number of pods plant^{-1} number of seeds pod^{-1}, seed yield (1008 kg ha^{-1}), stover yield (869 kg ha^{-1}) as compare to control.

Keywords : Bio-NPK, Bio-Zn, productivity, Balck soil, root nodules and seed yield .

Introduction

Soybean is also known as "Golden Bean" of the 21st century because of its nutritive value and regarded a substitute or compliment of protein (Imliwati *et al.*, 2016). It has great potential as a kharif oilseed and has emerged as an important commercial oilseed crop in Madhya Pradesh. Soybean is mainly grown for their seeds and it is the second largest oil seed after groundnut in India. Soybean seeds contain 43.2% protein, 19.5% fat, 20.9% carbohydrate and a good amount of other nutrients like calcium, phosphorus, iron and vitamins (Gupta *et al.,* 2003).

The state of Madhya Pradesh is referred to as the "soybean state". During kharif 2018, Madhya Pradesh's total area under soybean crop was 5.41 million hectares, with production of 6.67 million tonnes and a productivity of 1231 kg/ha, the total area under soybean crop in India was 11.13 million hectares, with production of 13.26 million tonnes and a productivity of 1192 kg/ha (Anonymous, 2021).

Nutrient supply plays an important role in the crop production but under intensive cultivation, use of chemical fertilizers alone for a longer period would result in deterioration of soil fertility and quality of produce (Prakash *et al.*, 2019). The application of biofertilizer into the soil leads to increase soil fertility and crop productivity (Yadav and Sarkar, 2019). Biofertilizers are the most useful technology necessary to support developing organic, sustainable, green and non-polluted agriculture. Addition of biofertilizers not only helps to proliferate beneficial microbes in soil but also provide residual effect for subsequent crops.

Liquid biofertilizer formulation is the promising, updated and one of the best modern tools for agriculture. It positively influence nodulation, helps in symbiotic nitrogen fixation, growth, yield & quality of groundnut, reduce the use of chemical fertilizers by 15-40%, have longer shelf life, easy to produce and apply compared to dry formulations of biofertilizers. They are tolerant to high temperature and contamination free.

Bio source mediums such as Bio-NPK Liquid Microbial Consortium contain mixed populations of N-fixing bacteria (*Azotobacter crococum*), P-solubilizing bacteria (*Paenibacillus tylopilii*), K-solubilizing bacteria (*Bacillus decoloration*), and Bio-ZN Liquid contains a single population of Z-solubilizing bacteria (*Bacillus endophyticus*). *Rhizobium* is one of the dominant symbiotic nitrogen-fixation bacteria. As most of our soils are poor in organic matter, response to fertilizer has not been higher due to the rapid fixation of nutrients (Rabiul *et al.*, 2020). *Rhizobium* and PSB inoculants as liquid biofertilizers helps to increase yield of legume crop by fixing atmospheric nitrogen in root nodules and by converting the insoluble phosphate in to soluble form respectively. *Rhizobium* inoculant is recommended to ensure adequate nodulation and nitrogen fixation offers an economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of internal resource of nitrogen. In mungbean, nitrogen fixation takes place through symbiotic association between the bacteria of genus *Bradyrhizobium* and mungbean crop (Raja and Takankhar, 2017). The use of growth promoters has been gaining more importance in the recent years for improvement of crop yield potential and quality of produce (Ramesh and Ramprasad 2013).

Materials and Methods

The research trial was laid out in field of R.A.K. college of Agriculture, Sehore (M.P.), during kharif 2021 on the soybean variety JS 95-60. The global position of the site was situated in the Eastern part of Vindhyan Plateau in subtropical zone at the latitude of 27□15’ North and longitude of 77□05’ East at an altitude of 498.77 m from mean sea level (MSL) in Madhya Pradesh. The average annual rainfall varies from 1000 to 1200 mm concentrated mostly from June to September. The mean annual maximum and minimum temperatures are 33.3°C and 20.2°C, respectively. Soils of the experimental site were medium black which belongs to the order Vertisol that was popularly known as “black cotton soil”. The status of organic carbon (0.56%) was medium whereas the soil has low initial N (220 kg ha^{-1}), medium P (11.5 kg ha^{-1}) and high K (442 kg ha^{-1}) contents. The experiment had 21 treatments combinations, set in a Randomized Block design with three replications in fixed plots. The experiment consisting of 7 treatments T1: Control; T2: 100% Recommended dose of fertilizers (RDF*); T3: 75%RDF; T4: 75%RDF + Bio-Zn; T5: 75% RDF + Bio-NPK; T6: 75% RDF + Bio-Zn + Bio-NPK; T7: 75%RDF + *Rhizobium japonicum*. The dose of RDF were 20:60:20:20 (N: P_2O_5:K_2O:S kg ha^{-1}) at basal dose urea, single super phosphate and murate of potash, respectively and Seed treatment with Bio-NPK and Bio-Zn @ 250 ml and *Rhizobium japonium* @ 200 ml for the seed of one hectare. Parameters of observation carried out consisted of three components namely physiological observation, growth observation and observation of yield. Physiological observations consist of Leaf area index, crop growth rate, relative growth rate and net assimilation rate. Growth observation consisted of the number of effective root nodules, number of branches and plant height and dry weight $plant^{-1}$. For taking dry weight samples were oven dried at 65ºC for 48 hours that previously packed in envelops and then oven dry weight was taken. Five plants in each plot were selected randomly for observations on quality and physiological parameters. Observations were made on leaf area index, crop growth rate (g $m^{-2}day^{-1}$), relative growth rate (g $g^{-1}day^{-1}$) and net assimilation rate (g cm^{-2} day^{-1}) at 30, 60 and 90 DAS.

Result and Discussions

Effect of Liquid Biofertilizer and Inorganic Nutrients Application on Growth

The results presented in Table-1 indicated that the plant height was significantly affected by application of chemical fertilizer with liquid bio-inoculants at 45 and 60 DAS and at harvest stage, however, it was observed that at initial stage of crop (30 DAS) found not significant. Significantly higher values of plant height (35.22, 39.89 and 40.11 cm) were observed at 45 and 60 DAS and at harvest, respectively with the treatment 100% RDF, but remained statistically at par with the treatment 75% RDF+ Bio-Zn + Bio-NPK. The control treatment produced shortest plant height at 45, 60 DAS and at harvest (32.11, 34.44 and 35.22 cm). The increase in plant height might be due to the increased metabolic activities, stimulation of root growth resulting in enhanced uptake of nutrients the findings are in close conformity with those reported by Singh *et al.* (2018) and Islam *et al.* (2021).

Data in respect of number of branches $plant^{-1}$ recorded at different intervals of growth stages and it was found significantly influenced by different treatments are presented in Table 1. At 90 DAS and harvest similar result was recorded, the highest number of branches plant^{-1} observed under the application of 100% RDF (3.11) and found at par treatments 75%RDF+ Bio-Zn, 75% RDF+ Bio-NPK, 75% RDF+ Bio-Zn + Bio- NPK and 75% RDF + *Rhizobium japonicum* and lowest number of branches plant^{-1} was recorded under control (2.37). The Similar findings were also observed by Singh *et al*. (2018) and Kanwar *et al*. (2022).

The data on dry matter accumulation plant^{-1} as influenced by different treatments recorded periodically are presented in Table 1. Dry matter was significantly influenced mainly due to application of chemical fertilizers with liquid bio-inoculants. Maximum dry matter accumulation plant^{-1} was found with the application of 100% RDF (2.50, 6.89, 12.33 and 12.35g, respectively) and at par to the application of 75% RDF+ Bio-Zn + Bio- NPK over the rest of treatments. Minimum dry matter accumulation plant^{-1} was recorded under the control (1.39, 4.67, 8.94 and 10.59 g, respectively). It might be due to balance dose of fertilizers and tendency of bio-inoculants to enhance the availability of nutrients to plants. Under this treatment, crop plants avail the nutrition for longer period therefore; it promotes more growth and development of soybean crop. The application of Bio-inoculants might have enhanced microbial activities at root zone of soybean crop, which may help for nutrient transformation. The findings are in close conformity with those reported by Fitriatin *et al*. (2020) and Singh *et al.* (2018).

The number of nodules plant^{-1} and their dry weight were influenced significantly different combination of organic and inorganic fertilizers at 30 and 45 DAS. Maximum nodules plant^{-1} and nodule dry weight plant^{-1} at 30 DAS (40.87 and 199 mg) was found in the integration of 75% RDF with *Rhizobium* which was significantly higher than other treatments (Table 1). Similarly at 60 DAS maximum number of nodules and their dry weight plant^{-1} (26.55 and 125mg) was also found in treatment 75% RDF with *Rhizobium* (Table 1). The increase in nodule dry weight might be due to more number of nodules plant^{-1}. Nodulation might be due to effective symbiosis between legume and *Rhizobium*. Thus, the findings of this experiment is in agreement with Slattery *et al.,* (2004) who reported that *Rhizobium leguminosarum bv viciae* is responsible for effective nodulation of faba bean, lentils and field pea. Icgen (2002) conducted a field experiment with five local and seven standard strains of *Rhizobium* and the maximum increase in nodule dry weight was found in *rhizobial* infection compared to control in soybean. Egamberdiyeva *et al.* (2004) investigated the effect of inoculation with *Bradyrhizobium japonicum* on soybean nodulation.

Effect of Liquid Biofertilizer and Inorganic Nutrients Application on Physiological Parameters

The effect of biofertilizer treatments on various physiological traits is shown in Table 2. The results revealed that LAI was significantly influenced with the application of chemical fertilizers with bio formulations at 30, 45 and 60 DAS. The maximum values for all the LAI was recorded with the application of 100 % RDF (30.11, 35.22 and 39.89) at all growth stages however, it remained statistically at par with 75% RDF+ Bio-NPK, 75% RDF+ Bio-Zn + Bio- NPK and 75% RDF + *Rhizobium japonicum.* The leaf area index is an essential factor determining the dry matter production of a crop and, subsequently, the yield. The reason being the leaf area index depends on the number of leaves and leaf area of a plant which was recorded maximum in the treatment and directly reflected on the leaf area index. The findings are in close conformity with those reported by Singh *et al.* (2018)

The values of CGR, RGR and NAR were recorded at 30-45 and 45-60 days interval. The results presented in Table-2 indicated that the CGR was significantly affected by application of chemical fertilizer with liquid bio-inoculants at both the intervals, however RGR and NAR were not significantly influenced by different treatments. The maximum values of CGR were recorded with the application of 100 % RDF (16.49 and 24.22) and found at par to 75%RDF+ Bio-NPK, 75%RDF+ Bio-Zn + Bio- NPK and 75%RDF + *Rhizobium japonicum, a*nd maximum value of RGR (0.0809) and 0.0434) and NAR (0.000459 and 0.000762) found in 100% RDF and minimum value found in control. This might be due to application of fertilizers and biofertilizers stimulated light interception by the crop which contributed towards the vegetative growth of crop plants leading to enhanced physiological growth. These results closely conform with the findings of Jat *et al*. (2016) and Yadav and Meena (2014).

Table 1 : Effect of different treatments on growth attributes of soybean at successive stages of crop.

Treatments		Plant height plant^{-1}				Branches plant^{-1}				Dry weight plant^{-1}				Nodules number		Dry weight of nodules	
		30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	30 DAS	45 DAS
T1	Control	28.22	32.11	34.44	35.22	2.11	2.33	2.37	2.37	1.39	4.67	8.94	10.59	33.89	18.78	145.00	107.00
T2	100% Recommen-ded dose of fertilizers (RDF)	30.11	35.22	39.89	40.11	2.89	3.04	3.11	3.11	2.50	6.89	12.33	12.35	37.33	24.22	183.33	121.33
T3	75%RDF	28.77	31.44	34.78	35.44	2.20	2.44	2.55	2.55	2.05	5.77	10.94	11.09	35.44	20.22	158.67	115.33
T4	75%RDF+ Bio-Zn	28.55	32.00	37.77	38.33	2.44	2.60	2.73	2.73	2.18	6.11	11.16	12.03	36.00	21.66	169.33	119.67
T5	75%RDF+ Bio-NPK	29.77	34.32	39.22	40.00	2.46	2.85	2.89	2.89	2.22	6.33	11.55	12.48	38.33	23.44	186.67	122.00
T6	75%RDF+ Bio-Zn + Bio- NPK	29.33	33.77	38.89	39.33	2.66	2.96	3.00	3.00	2.48	6.50	11.58	11.92	39.22	24.00	192.67	123.67
T7	75%RDF + *Rhizobium japonicum*	28.33	32.66	37.78	38.00	2.55	2.92	2.97	2.97	2.18	5.89	10.65	11.65	40.87	26.55	199.00	125.00
	S.Em (±)	**0.57**	**0.49**	**0.45**	**0.27**	**0.14**	**0.16**	**0.14**	**0.14**	**0.10**	**0.17**	**0.27**	**0.09**	**1.36**	**1.31**	**9.47**	**2.93**
	CD at 5%	**NS**	**1.50**	**1.39**	**0.84**	**0.42**	**0.48**	**0.44**	**0.44**	**0.31**	**0.53**	**0.82**	**0.27**	**4.19**	**4.05**	**29.18**	**9.02**

Table 2 : Effect of different treatments on physiological parameters of soybean crop

Treatments		Leaf area index			Crop growth rate		Relative growth rate		Net assimilation rate	
		30 DAS	45 DAS	60 DAS	30-45 Days interval	45-60 Days interval	30-45 Days interval	45-60 Days interval	30-45 Days interval	45-60 Days interval
T1	Control	1.76	3.11	9.94	12.96	18.78	0.0643	0.0386	0.000392	0.000654
T2	100% Recommended dose of fertilizers (RDF)	2.18	3.63	13.30	16.49	24.22	0.0809	0.0434	0.000459	0.000762
T3	75%RDF	2.00	3.40	11.27	15.66	20.22	0.0689	0.0426	0.000417	0.000699
T4	75%RDF+ Bio-Zn	2.05	3.44	11.24	15.31	21.66	0.0689	0.0402	0.000429	0.000699
T5	75%RDF+ Bio-NPK	2.07	3.50	12.45	15.82	23.44	0.0701	0.0401	0.000449	0.000737
T6	75%RDF+ Bio-Zn + Bio-NPK	2.17	3.58	12.19	15.40	24.00	0.0689	0.0388	0.000419	0.000701
T7	75%RDF + *Rhizobium japonicum*	2.12	3.60	11.92	14.44	26.55	0.0664	0.0395	0.000409	0.000683
	S.Em (±)	**0.03**	**0.05**	**0.58**	**0.53**	**1.31**	**0.0033**	**0.0014**	**0.00000001**	**0.00000001**
	CD at 5%	**0.11**	**0.14**	**1.78**	**1.63**	**4.05**	**NS**	**NS**	**NS**	**NS**

Table 3 : Effect of different treatments on yield and yield attributes of soybean.

Treatments		pods plant^{-1}	seeds pods^{-1}	yield plant^{-1}(g)	Seed index (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T1	Control	17.22	1.93	3.05	9.17	648	594	52.18
T2	100% Recommended dose of fertilizers (RDF)	25.33	2.53	6.79	10.67	1008	869	53.75
T3	75%RDF	21.33	2.00	4.48	10.50	840	747	53.21
T4	75%RDF+ Bio-Zn	22.00	2.10	4.93	10.67	889	728	54.94
T5	75%RDF+ Bio-NPK	24.22	2.20	5.75	10.83	941	773	54.90
T6	75%RDF+ Bio-Zn + Bio- NPK	25.00	2.40	6.47	10.83	949	810	53.95
T7	75%RDF + *Rhizobium japonicum*	23.55	2.13	5.59	11.17	914	738	55.88
	S.Em (±)	**1.33**	**0.07**	**0.33**	**0.23**	**57.98**	**78.90**	**0.23**
	CD at 5%	**4.09**	**0.21**	**1.03**	**0.70**	**178.64**	**NS**	**NS**

Effect of Liquid Biofertilizer and Inorganic Nutrients Application on Productivity

The number of pods plant[1] was counted under each treatment and data was analysed using statistical tool which is presented in Table 3. Among all the different treatments, significantly maximum number of pods plant^{-1} (25.3) was found in 100% RDF which was at par with all remaining treatments except control. Highest seeds pod^{-1} (32.53) and Yield plant^{-1} **(**6.79 g) were found in 100 % RDF which was at par with 75% RDF+ Bio-Zn + Bio-NPK. However, minimum number of pods plant^{-1}, seeds pod^{-1} and yield plant^{-1} was recorded under control. According to Nyakpa *et al.*, 1988 physiological potassium functions as one of the ingredients used for carbohydrate metabolism namely the formation, breakdown, and translocation of starch in plant tissues and nitrogen metabolism and protein synthesis. Carbohydrates that are formed is translocated throughout the plant mainly pods and form seeds. These findings are in agreement with those of Tomar and Khajanji (2009) and Singh Guriqbal (2009)

However, the highest value of seed index recorded in 75%RDF + *Rhizobium japonicum* (11.17 g) which is at par with all the remaining treatments except control. It is suspected that RDF has sufficient K and N in order to enhance seed weight plant^{-1} in soybean.

Observed data of yield parameters are presented in Table 3. The data revealed that maximum seed yield obtained in treatment 100% RDF (1008 kgha^{-1}). Straw yield and harvest index were found non significant and highest straw was recorded under 100% RDF (869 kgha^{-1}) and harvest index under 75%RDF + *Rhizobium japonicum (55.88).* Yield might be increase by providing macro and micronutrients to plant growth, production of enhancing material and development of the rooting system. Similar observation was reported by Kumar *et al.* (2016), Imade *et al*. (2010) and Tomar and Khajanji (2009)

Conclusion

Based on the foregoing results and discussion above it can be concluded that that 100% recommended dose of fertilizer brought significant improvement in growth, physiological traits as well as productivity of soybean crop.

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