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Studies on Carrier and Liquid Based Bio-Fertilizer on Performance of Lentil (*Lens esculenta*) in Alluvial Soil of West Bengal

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ABSTRACT

Lentil (*Lens culinaris*) is an important crop of sustainable agriculture system having good nutritional value. Liquid biofertiliser formulations are known to have better result at field level. A field experiment was conducted in the gangetic alluvial soil belt of West Bengal to study the performance of lentil cv WBL 77 (Moitree) at farmer's field in Krishnaganj block, Nadia, WB in the *rabi* season 2020-21. The experiment was conducted in randomised Block Design having ten treatments replicated thrice. Carrier and liquid based formulations of rhizobium and phosphorus solubilising biofertilisers were used. The results revealed that growth and yield parameters responded positively when lentil were grown with different combinations of biofertilizer and inorganic fertilizers. Recommended dose of fertilizers (RDF) + liquid based rhizobium and PSB and was found to be better in respect to growth, nodulation and yield attributes. However, was statistically at par with treatment RDF + Carrier based Rhizobium & PSB. Plots where 75% RDF + liquid or carrier based biofertilisers were applied were observed to be at par with treatments where RDF and any one biofertilier were applied. Based on the study, we may infer that liquid biofertiliser formulations can have better effect on lentil growth, nodulation and yield.

Keywords Biofertiliser, Lentil, PSB, Rhizobium, Sustainability.

INTRODUCTION

India produced 25.58 million MT pulses during 2020-21 (Gaur 2021). Our country being the largest producer of pulses in the world (25%) is also the largest consumer of pulses (Shukla and Mishra 2020). Hence, to meet the domestic requirement India imported pulses worth over 119.38 billion Indian rupees in the year 2021 (Statista 2022a). Leguminous crops are one of the most important component of the sustainable agriculture system, which play vital role in the economy and sustainability of the environment. The net per capita availability of pulses has come down over

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years from 60.7 grams per day per person in 1951 to 45 grams per day per person in 2021 (Anonymous 2014 and Statista 2022b). Lentil is an important cool season crop with a relatively shallow root system and is moderately resistant to high temperature and drought and more cold tolerant than chickpea and pea (Materne *et al.* 2007). It is also cover crop to check soil erosion in problem areas and has 25% protein content in seeds (Mahmood *et al*. 2010).

Organic inputs like bio-fertilisers have multiple benefits adding nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth-promoting substances (Vessey 2003). Rhizobium enhances nitrogen fixation but their population in the soil depends on cultivation of legume crops in the field. Phosphorus solubilizing bacteria helps in increasing crop productivity by solubilization of insoluble phosphorus, stimulating growth by providing hormones, vitamins and other growth factors (Singh *et al.* 2013). Inoculation with bio-fertilisers can increase pulse production, provide environmental protection and reduce production cost incurred through application of mineral fertilisers.

Based on the physical nature, bio-fertilisers are marketed as carrier based and liquid based bio-fertilisers. Carrier based bio-fertilisers, though widely used, have some disadvantages like low temperature tolerance, low shelf life and less viability in soil. Liquid based formulations are best alternative for the carrier-based bio-fertilisers.

Considering the negative impacts of inorganic fertilization in ecosystem, increasing cost of fertilisers and the positive effects of liquid based formulations of biofertilisers, the present study was conducted to evaluate the effect of carrier and liquid based bio-fertilisers (Rhizobium and PSB) on growth, nodulation, yield and economics of lentil (*Lens esculenta* Moench).

MATERIALS AND METHODS

The field experiment was conducted during rabi season of 2020-2021 in a farmer's field at Joyghata Gram Panchayat, Krishnaganj Block, Nadia 741506, West Bengal. The field is situated at 23˚41'67" N latitude and 88˚40'2" E longitude under humid, lower gangetic plain zone of West Bengal. The experiment was conducted on a medium land, well-drained gangetic alluvial soil, which was sandy loam soil and moderately alkaline (pH 8.35 before sowing) reaction.

The experiment consisted of carrier based and liquid based formulations of two bio-fertilisers rhizobium and phosphorus solubilizing bacteria (PSB) having ten treatment combinations. Lentil variety, Moitree (WBL 77) was grown. Seeds were treated with fungicide, Captan 70% + Hexaconazole 5% WP @ 2 g per kg of seed, 10 days prior to seed inoculation. Carrier based biofertilisers were applied @ 250 g per 10 kg seeds and liquid based formulations @ 10 ml/kg seeds. Seeds were mixed with jaggery @ 250g/10 kg seeds for good adherence and initial growth of biofertilisers. Recommended agronomic practices of lentil (Singh and Singh, 1983) was followed and the sowing was done on November 11, 2020.

The experiment was laid out in a randomized block design with ten treatments, T_1: Recommended doses of fertilisers (RDF), T_2: RDF + Carrier based Rhizobium; T_3: RDF + Carrier based Phosphorus solubilizing bacteria (PSB); T_4: RDF + Carrier based Rhizobium + PSB; T_5: RDF + Liquid based Rhizobium; T_6: RDF + Liquid based PSB; T_7: RDF + Liquid based Rhizobium + PSB; T_8: 75% RDF + Carrier based Rhizobium + PSB; T_9: 75% RDF + Liquid based Rhizobium + PSB; T_{10}: Absolute Control (No fertiliser and bio-fertilisers). The RDF followed was @ 25 Kg N/ha, 50 Kg P_2O_5/ha and 25 Kg K_2O/ha using urea, single super phosphate and muriate of potash as basal dose (Singh and Singh 1983).

The observations for the growth attributes and yield components were taken at different stages of crop growth at 30, 60, 90 DAS and at harvest. Before harvesting the whole plot, 10 plants were randomly selected from each plot for obtaining data on yield.

The experimental data related to each character of crop and weed were analysed statistically by the technique of "Analysis of variance" and significance was tested by variance ratio i.e. value at 5% level of significance as described by Gomez and Gomez (1984).

Table I. Effect of carrier and liquid based bio-fertilizer on plant height (cm) and dry matter accumulation (g/m2) of lentil at different growth stages.

Treatment	Plant height (cm)		Dry matter accumulation (g/m^2)	
	60 DAS	90 DAS	60 DAS	90 DAS
T_1: Recommended doses of fertilizer	19.36	31.50	91.19	487.02
T_2: RDF + Carrier based Rhizobium	22.52	34.20	96.33	491.25
T_3: RDF + Carrier based PSB	21.67	35.24	94.68	490.99
T_4: RDF + Carrier based Rhizobium & PSB	24.60	36.27	107.24	580.29
T_5: RDF + Liquid based Rhizobium	22.27	31.97	94.09	489.14
T_6: RDF + Liquid based PSB	21.81	34.50	96.06	504.07
T_7: RDF + Liquid based Rhizobium & PSB	24.39	38.89	128.78	602.28
T_8: 75% RDF + Carrier based Rhizobium & PSB	19.23	30.73	93.14	488.81
T_9: 75% RDF + Liquid based Rhizobium & PSB	19.45	32.13	91.84	490.18
T_{10}: Absolute Control	18.68	27.77	84.63	440.69
SEm±	0.88	1.24	7.82	12.64
CD at 5%	2.63	3.68	23.23	37.54

RESULTS AND DISCUSSION

Plant Growth parameters

The treatments brought significant effect on different growth parameters, viz. plant height, dry matter accumulation, and number of nodules per plant, leaf area index (LAI) and crop growth rate (CGR) at different growth stages.

Table 2. Effect of carrier and liquid based bio-fertilizer on number of nodule per plant and root length (cm) of lentil at different growth stages.

Treatment	No. of nodule per plant	
	75 DAS	90 DAS
T_1: Recommended doses of fertilizer	18.00	16.87
T_2: RDF + Carrier based Rhizobium	27.67	23.33
T_3: RDF + Carrier based PSB	28.67	21.83
T_4: RDF + Carrier based Rhizobium & PSB	32.33	28.50
T_5: RDF + Liquid based Rhizobium	28.33	24.77
T_6: RDF + Liquid based PSB	29.33	22.00
T_7: RDF + Liquid based Rhizobium & PSB	39.00	35.00
T_8: 75% RDF + Carrier based Rhizobium & PSB	29.67	21.00
T_9: 75% RDF + Liquid based Rhizobium & PSB	27.00	22.13
T_{10}: Absolute Control	13.00	11.33
S.Em±	1.66	1.82
CD at 5%	4.93	5.40

At 60 DAS the highest plant height was recorded in T_4, which was at par with T_7 treated plots, but in 90 DAS the highest plant height was recorded in T_7, which was at par with T_4 and T_3 (Table 1). Kannapiran and Ramkumar (2011) also observed that application of biofertiliser in black gram significantly influenced plant height in green gram.

At 60 DAS and 90 DAS the highest dry matter accumulation was recorded (128.78 g/m^2 and 602.28 g/m^2 respectively) in T_7 which was significantly higher than all other treatments and at par with T_4. Khatkar *et al.* 2007 in blackgram also observed that dry matter accumulation is significantly influenced due to synergistic effect of biofertilisers like rhizobium and PSB.

Number of nodules of lentil during 75 DAS and 90 DAS showed significant influence due to different biofertiliser treatments under this study (Table 2). Treatment T_7 recorded highest number of nodules per plant at 75 DAS and 90 DAS, which was significantly higher than all other treatments. Tagore *et al.* (2013) in chick pea also noted that rhizobium and PSB inoculation increased the root nodulation through better root development and more nutrient availability, resulting in better absorption and utilization of all plant nutrients. Nodulation was lower in plots where only inorganic nutrients were applied (T_1) but lowest

Table 3. Effect of carrier and liquid based bio-fertilizer on Leaf Area Index of CGR (g/m^2/day) lentil at different growth stages.

Treatment	LAI		CGR (g/g/day)	
	60 DAS	75 DAS	30-60 DAS	60-90 DAS
T_1: Recommended doses of fertilizer	0.90	1.61	2.72	12.28
T_2: RDF + Carrier based Rhizobium	1.17	1.89	2.70	13.16
T_3: RDF + Carrier based PSB	1.18	2.10	2.68	13.21
T_4: RDF + Carrier based Rhizobium & PSB	1.31	2.24	3.04	15.34
T_5: RDF + Liquid based Rhizobium	1.14	1.84	2.59	13.17
T_6: RDF + Liquid based PSB	1.17	1.94	2.70	13.38
T_7: RDF + Liquid based Rhizobium & PSB	1.36	2.22	3.52	17.06
T_8: 75% RDF + Carrier based Rhizobium & PSB	1.02	2.02	2.80	12.86
T_9 : 75% RDF + Liquid based Rhizobium & PSB	0.89	1.68	2.71	13.06
$T_{10:}$ Absolute Control	0.87	1.24	2.54	10.81
SEm±	0.07	0.17	0.16	0.49
CD at 5%	0.20	0.51	0.46	1.45

nodulation was in absolute control (T10) plots.

Observations on leaf area index at 60 and 75 DAS depicted highest leaf area index (1.36 and 2.22) in T_7 treated plots, which was significantly higher than all other treatments (Table 3). At 75 DAS, LAI of T_7 treatment was statistically at par with T_2, T_3, T_4, T_5, T_6 and T_8. Increased leaf area in biofertiliser treated plots was effect of better growth due to better nutrient availability by improved physiological and metabolic processed in plant (Khatkar *et al.* 2007).

Crop growth rate at 30-60 DAS and 60-90 DAS was highest (3.52 and 17.06 g/m^2/day) T_7 which was significantly higher than all other treatments. The lowest CGR was in absolute control (2.54 and 10.81 g/m^2/day) at both the durations studied. Improved growth rate in the treated plots was mainly due to synergistic effect of rhizobium and PSB leading to better nodulation and growth (Amit *et al.* 2010).

Yield parameters

Influence of application of biofertiliser was positively

Table 4. Effect of carrier and liquid based bio-fertilizer on no of pods per plant, no of seeds per plant at harvesting and test weight (g) of seed after harvesting of lentil.

Treatment	No. of pods per plant after	No. of seed per plant after harvest	Test weight (g) of seeds after harvest
T_1: Recommended doses of fertilizer	105.0	208.3	16.4
T_2: RDF + Carrier based Rhizobium	109.7	219.3	17.9
T_3: RDF + Carrier based PSB	123.3	246.7	17.2
T_4: RDF + Carrier based Rhizobium & PSB	134.7	269.3	20.8
T_5: RDF + Liquid based Rhizobium	120.0	240.0	18.4
T_6: RDF + Liquid based PSB	122.3	244.7	18.4
T_7: RDF + Liquid based Rhizobium & PSB	136.0	272.0	21.8
T_8: 75% RDF + Carrier based Rhizobium & PSB	119.7	239.3	16.4
T_9: 75% RDF + Liquid based Rhizobium & PSB	118.7	237.3	17.5
T_{10}: Absolute Control	93.3	186.7	14.9
SEm±	3.6	7.5	1.1
CD at 5%	10.8	21.5	3.3

Table 5. Effect of carrier and liquid based bio-fertilizer on seed yield (kg/ha), stover yield (kg/ha), biological yield (kg/ha) & harvest index of lentil.

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index
T_1: Recommended doses of fertilizer	1371.8	3494.7	4866.4	28.18
T_2: RDF + Carrier based Rhizobium	1393	3598	4991	27.92
T_3: RDF + Carrier based PSB	1402.2	3569.3	4971.5	28.20
T_4: RDF + Carrier based Rhizobium & PSB	1781.7	3914	5695.7	31.27
T_5: RDF + Liquid based Rhizobium	1460.6	3616.7	5077.3	28.76
T_6: RDF + Liquid based PSB	1486.3	3640.7	5127	28.94
T_7: RDF + Liquid based Rhizobium & PSB	1856.6	3949.3	5805.9	31.84
T_8: 75% RDF + Carrier based Rhizobium & PSB	1382.2	3578.7	4960.9	27.86
T_9: 75% RDF + Liquid based Rhizobium & PSB	1337.4	3590.7	4928	27.13
T_{10}: Absolute Control	1080.9	3186.3	4267.3	25.32
SEm±	72.4	63.3	111.8	0.87
CD at 5%	215	188.2	332.1	2.60

observed in treated plots as compared to the plots where only inorganic fertilisers (T_1) were applied (Table 4 and Table 5). The number of pods per plant, the number of seeds per plant and test weight influenced significantly due to use of bio-fertilisers during seed treatment over that of the control plots (T_{10}). Treatment T_7 produced the maximum number of pods per plant (136) and the maximum number of seeds per plant (272). Number of pods per plant in T_7 was at par to T_4 and was 22.79% more as compared to T_1 plots. Plots where only recommended dose of fertilisers (T_1) was used gave 63.7% less number of plots as compared to T_7 plots. Test weight of T_7 treated plots were at par to T_4 plots. This might be due to rhizobium and PSB inoculation, which increased the root nodulation through better root development and more nutrient availability, resulting in better absorption and utilization of all plant nutrients, which ultimately resulted in more number of pods and seeds per plant (Ghosh and Joseph 2008).

The plots with treatment T_7 recorded highest seed yield (1856.6 kg/ha), stover yield (3949.3 kg/ha) which was significantly higher than other treatments but was statistically at par with T_4. Seed yield, stover yield and biological yield of plots where recommended doses of fertilisers were applied (T_1) was observed at par with T_2, T_3, T_5, T_6, T_8 and T_9. The seed yield of treatment T_7 was 26.11% more than T_1. Moreover, just single application of carrier based bio-fertiliser in T_2 (RDF + Carrier based Rhizobium) and T_3 (RDF + Carrier based PSB) yielded 22.40 % and 22.91 % increase over T_{10} (Absolute control) respectively. Liquid based bio-fertiliser application in T_5 (RDF + Liquid based Rhizobium) showed 4.62 % increase over that in T_2 (RDF + Carrier based Rhizobium) and T_6 (RDF + Liquid based PSB) showed 5.66 % increase over T_3 (RDF + Carrier based PSB). Kannapiran and Ramkumar (2011) observed the positive effect of biofertiliser innoculation on seed, stover yield of black gram.

Significantly highest harvest index of 31.84% was observed in T_7 (RDF + Liquid based Rhizobium + PSB) which was statistically at par with T_4 (RDF + Carrier based Rhizobium + PSB). The lowest harvest index of 25.32 % was observed in absolute control (T_{10}) among the treatments.

CONCLUSION

Use of bio-fertilisers either as solid carrier or liquid based along with different inorganic nutrients was found better than using only inorganic fertilisers for nutrition. Bio-fertilisers improved the yield of lentil when combined with recommended doses of fertilisers. Also, application of 75% of inorganic fertilisers and bio fertilisers gave yield at par to that of treatments where recommended doses of fertilisers

and bio-fertilisers were applied.Application of bio-fertilisers (Rhizobium and PSB) has the potential to reduce the application of inorganic fertilisers on lentil crop without compromising output yield.

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