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Growth and Yield of Soybean (*Glycine max* (L.) Merill) as Influenced by Carrier Based and Liquid Bio-inoculants

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Abstract: *A field experiment was conducted at Department of Agronomy,Parbhani in Maharashtra during the rainy (kharif) season of 2014-15 to study the comparative performance of carrier based and liquid bio-inoculants in soybean. Results revealed that the application of liquid based Rhizobium + PSB (100+100 ml each 10 kg^{-1} seed) + 100% RDF significantly increased the plant growth, seed and straw yield. Application of liquid based Rhizobium + PSB (100+100 ml each 10 kg^{-1} seed) with 100% RDF the gave the highest seed and straw yield, but it was at par with application of liquid based Rhizobium + PSB (50+50 ml each 10 kg^{-1} seed) + 100% RDF and carrier based Rhizobium + PSB (250 g 10 kg^{-1} seed) + 100% RDF.*

Key words: *Soybean, Carrier based inoculants (CB), Liquid based inoculants (LB) and Seed yield.*

INTRODUCTION

Soybean is one of the most important crop worldwide and soybean seeds are important as protein meal and vegetable oil. It is known as the Golden bean of the 21st century. It has been established as an industrially vital and economically viable oilseed crop in many areas of India. It is emerging as a leading oilseed crop in India due to its higher yield potential and as a substitute for low yielding crops in *Kharif*.

Now days, there is vast scope for soybean production due to high nutritional quality, more production and short duration (90-110 days), tolerance to long dry spell and being leguminous crop helps in improving the soil fertility and productivity of the soil. Hence, it is known as "Gold of soil."

Recent data reveals that India ranks fifth in area and production of soybean. Soybean is grown on area of 12.03 million ha in India with total production of 12.98 million tonnes and average productivity 1079 kg ha^{-1} (Anonymous, 2013). Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka, Chhattisgarh and Gujarat are the leading states of India in soybean production.

The most prominent and contributing function of biofertilizer is sustainable reduction in environmental pollution and improvement in agro-ecological soundness. Biofertilizers are affordable to farmers because of low costs and they are very significant in making available nutrients like nitrogen and phosphorus to the crop plants. (Pandy and Pandey, 1995).

Liquid biofertilizer formulation is the promising and updated technology of the conventional carrier based production technology which inspite of many advantages over the agrochemicals. However, the administration of liquid bio-fertilizers in the fields is comparatively easier than carrier-based bio-fertilizers. The other disadvantages of carrier-based bio-fertilizers like poor cell protection, labor intensity, and dosage controversy, limited scope of export, expensive package and transport, very slow adaptation by the farmer community are some of the strongest problems which are being solved by the liquid biofertilizers very effectively. Therefore, liquid biofertilizers are believed to be the best alternative for the conventional carrier based biofertilizers in the modern agriculture research community witnessing the enhanced crop yields,

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Table 1
Effect of treatments on Growth attributes of soybean.

Treatment	*Mean plant height plant^{-1} at harvest*	*Mean number of branches (cm) plant^{-1} at harvest*	*Mean dry matter accumulation (g) plant^{-1} at harvest*
T_1–RDF alone	35.60	4.80	20.00
T_2–*Rhizobium* inoculation (CB) (250g 10kg^{-1} seed) + T_1	41.50	5.20	22.00
T_3–PSB inoculation (CB) (250g 10kg^{-1} seed) + T_1	41.00	4.80	21.30
T_4–*Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1	44.50	5.80	25.20
T_5–*Rhizobium* (LB) (50 ml 10 kg^{-1} seed) + T_1	42.90	5.30	23.50
T_6–*Rhizobium* (LB) (100 ml 10 kg^{-1} seed) + T_1	43.20	5.40	24.00
T_7–PSB (LB) (50 ml 10 kg^{-1} seed) + T_1	42.10	5.10	22.0
T_8–PSB (LB) (100 ml 10 kg^{-1} seed) + T_1	42.60	5.20	23.10
T_9 –*Rhizobium* + PSB (LB) (50 + 50 ml each 10 kg^{-1} seed) + T_1	47.20	6.10	26.60
T_{10}–*Rhizobium* + PSB (LB) (100 + 100ml each 10 kg^{-1} seed) + T_1	47.80	6.40	28.10
SE ±	1.47	0.26	1.31
CD at 5%	4.37	0.78	3.91

regaining soil health and sustainable global food production (Pindi and Satyanarayana, 2012).

MATERIALS AND METHODS

A field experiment on soybean (*Glycine max (L) Merill)* was conducted during *kharif* season of 2014-15 at Department of Agronomy, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experiment was laid out in randomized block design consisted of ten treatments replicated in three times. The treatments were as T_1-RDF alone, T_2-*Rhizobium* inoculation (CB) (250g 10kg^{-1} seed) +T_1, T_3-PSB inoculation (CB) (250g 10kg^{-1} seed) +T_1, T_4-*Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1, T_5-*Rhizobium* (LB) (50 ml 10 kg^{-1} seed) + T_1, T_6-*Rhizobium* (LB) (100 ml 10 kg^{-1} seed) + T_1, T_7-PSB (LB) (50 ml 10 kg^{-1} seed) + T_1, T_8-PSB (LB) (100 ml 10 kg^{-1} seed) + T_1, T_9-*Rhizobium* + PSB (LB) (50 + 50 ml each 10 kg^{-1} seed) + T_1, T_{10}-*Rhizobium* + PSB (LB) (100 + 100 ml each 10 kg^{-1} seed) + T_1.

Seeds were inoculated with carrier based inoculants such as *Bradyrhizobium japonicum* and PSB 250 g each 10 kg^{-1} seed and with liquid based inoculants such as *Bradyrhizobium japonicum* and PSB 50 and 100 ml each 10 kg^{-1} seed as seed treatment before sowing. The recommended dose of chemical fertilizers was applied @ 30:60:30 N, P_2O_5 and K_2O kg ha^{-1} through urea, single super phosphate and muriate of potash. The crop was sown on 14 July 2014 and harvested on 17 July 2014. Recommended plant protection measures were followed for control of pests and diseases.

RESULTS AND DISCUSSION

Growth Attributes

There was a progressive increase in plant height, number of functional leaves plant^{-1}, leaf area, number of branches plant^{-1} and dry matter accumulation plant^{-1} with the application of *Rhizobium* + PSB (liquid based) (100+100 ml each 10 kg^{-1} seed) +T_1(T_{10}), but it was found at par with the application of *Rhizobium* + PSB (liquid based) (50+50 ml each 10 kg^{-1}seed)+T_1 (T_9) and *Rhizobium* + PSB (carrier based) (250g each 10kg^{-1} seed) +T_1 (T_4).

Application of *Rhizobium* + PSB (LB) (100 + 100 ml each 10 kg^{-1} seed) + T_1 (T_{10}) recorded the highest plant height as 47.80 cm plant^{-1}, but it was at par with the application of *Rhizobium* + PSB (LB) (50 + 50 ml each 10 kg^{-1} seed) + T_1 (T_9) and *Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1 (T_4). The result was in confirmation with Singh *et al.* (2007), Singaravel *et al.* (2008), Singh *et al.* (2009) and Gupta *et al.* (2012).

Table 2
Effect of treatments on Yield attributes of soybean.

Treatment plant^{-1}	*No. of pods plant^{1}*	*Pod weight plant^{-1} (g)*	*No. of seeds plant^{-1}*	*Seed yield (g)*	*Test weight (kg ha^{1})*	*Seed yield (kg ha^{1})*	*Straw yield*
T_1– RDF alone	29.10	6.00	77.60	3.60	85.00	1236	2093
T_2–*Rhizobium* inoculation (CB) (250g 10kg^{-1} seed) + T_1	30.30	6.40	78.20	3.90	86.20	1343	2150
T_3-PSB inoculation (CB) (250g 10kg^{-1} seed) + T_1	29.70	6.20	78.00	3.70	85.80	1318	2121
T_4-*Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1	33.50	7.20	81.80	4.80	89.80	1533	2283
T_5-*Rhizobium* (LB) (50 ml 10 kg^{-1} seed) + T_1	30.90	6.80	79.30	4.10	88.30	1468	2216
T_6-*Rhizobium* (LB) (100 ml 10 kg^{-1} seed) + T_1	31.30	6.90	79.40	4.20	88.50	1488	2220
T_7-PSB (LB) (50 ml 10 kg^{-1} seed) + T_1	30.40	6.60	78.70	3.90	87.10	1430	2206
T_8-PSB (LB) (100 ml 10 kg^{-1} seed) + T_1	30.70	6.70	78.90	4.00	87.50	1442	2213
T_9-*Rhizobium* + PSB (LB) (50+50 ml each 10 kg^{-1} seed) + T_1	34.90	7.40	82.50	5.00	90.40	1590	2341
T_{10}-*Rhizobium* + PSB (LB) (100+100ml each 10 kg^{-1} seed) + T_1	35.20	7.70	83.20	5.10	90.70	1640	2413
SE±	1.26	0.22	1.17	0.27	2.65	49.09	62.38
CD at 5%	3.76	0.65	3.49	0.82	NS	145.87	185.35

Application of *Rhizobium* + PSB (LB) (100 + 100 ml each 10 kg^{-1} seed) + T_1 (T_{10}) treatment recorded higher dry matter accumulation as 28.10 g plant^{-1}. However, *Rhizobium* + PSB (LB) (50 + 50 ml each 10 kg^{-1} seed) + T_1 (T_9) and *Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1 (T_4) treatments recorded on par result with *Rhizobium* + PSB (LB) (100 + 100 ml each 10 kg^{-1} seed) + T_1 (T_{10}), recorded dry matter accumulation as 26.60 and 25.20 g plant^{-1} except at 30 DAS. This was mainly because of dry matter contributing plant character towards increasing dry matter like plant height, number of functional leaves, number of branches, number of pods. Similar results were found by Gupta (2005) and Pratibha Sahai and Ramesh Chandra (2011).

Yield Attributes and Yield

The magnitude of the expression of yield attributes like number of pods, weight of pods, weight of seeds and number of seeds plant^{-1} were influenced significantly due to various treatments of application of bioinoculants.

Significantly more number of pods plant^{-1} was recorded with application of *Rhizobium* + PSB (LB) (100+100 ml each 10 kg^{-1} seed) + T_1 (T_{10}) but it was at par with application of *Rhizobium* + PSB (LB) (50 + 50 ml each 10 kg^{-1} seed) + T_1 (T_9) and *Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1 (T_4) treatments. These results were in line with the results of Tran Thi Ngoc Son *et al*. (2007) and Waghmare *et al*. (2011).

Pod weight, number of seeds plant^{-1} and seed yield plant^{-1} were found significantly improved with the application of *Rhizobium* + PSB (LB) (100+100 ml each 10 kg^{-1} seed) + T_1 (T_{10}) than rest of the treatments. However, it was found at par with the treatments *Rhizobium* + PSB (LB) (50 + 50 ml each 10 kg^{-1} seed) + T_1 (T_9) and *Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1 (T_4). The results were in agreement with Tran Thi Ngoc Son *et al*. (2007) and Rajesh *et al*. (2013).

Application of *Rhizobium* + PSB (LB) (100 + 100 ml each 10 kg^{-1} seed) + T_1 (T_{10}) produced significantly higher seed yield over rest of the treatments except with application of *Rhizobium* + PSB (LB) (50 + 50 ml each 10 kg^{-1} seed) + T_1 (T_9) and *Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1 (T_4) treatments. Increase in seed yield may be contributed due to enhanced growth and yield attributes with the application of two bio inoculants *i.e. Bradyrhizobium japonicum* and PSB (*Bacillus megaterium*) + RDF. Similar finding reported by Tran Thi Ngoc Son *et al*. (2007) and Singaravel *et al*. (2008). Similar results were recorded in respect of straw yield of soybean.

Significantly more straw yield was recorded by application of *Rhizobium* + PSB (LB) (100 + 100 ml each 10 kg^{-1} seed) + T_1 (T_{10}) and which was at par

with *Rhizobium*+PSB (LB) (50+50 ml each 10 kg^{-1} seed) + T_1 (T_9) and *Rhizobium* + PSB (CB) (250g each 10kg^{-1} seed) + T_1 (T_4) treatments. This might be due to plant contributing characters. The results were in confirmation with Pratibha Sahai and Ramesh Chandra (2011) and Gupta (2005). Similar trend was found in case of biological yield also.

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