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Effect of Different Rhizobial Strains on Growth and Yield of Soybean [*Glycine max* (L.) Merrill]

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A B S T R A C T

A field experiment was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) in *kharif* 2016 to assess the effect of different *rhizobial* strains on growth, yield and net returns of soybean. The experiment was laid out in randomized block design with four replications. The experiment comprised with nine treatments of different rhizobial strains to the soybean and one treatment should be uninoculated. The results revealed that inoculation with different Rhizobial isolates have significant influence on growth parameters, yield & yield attributes and net returns of soybean.

Introduction

Soybean (*Glycine max* L.) is one of the major grain legume crops, whose production is getting popularized and adopted in the region of Southern Rajasthan. The governmental and non-governmental bodies also undertaken for the purpose of making to aware of the importance of soybean to small land holding farmers not only as a crop for improving their economic status but also as an important high protein food. India ranks fifth in soybean production in the world. Soybean production is mainly confined to Madhya Pradesh (also known as bowl of soybean in India), Maharashtra, Rajasthan, Andhra Pradesh, Karnataka, Uttar Pradesh and Chhattisgarh (Pawar *et. al*, 2011). In Rajasthan, soybean is mainly cultivated in the south eastern part of the state covering Kota, Bundi, Baran and Jhalawar districts which are known as Haroti region while it is grown in patches in some other districts like Sawai Madhopur, Bhilwara, Chittorgarh, Rajsamand, Dungarpur, Banswara and Udaipur (SOPA, 2001). Total area of soybean in Rajasthan in the year 2015-16 was 11.04 lakh ha with production of 7.86 lakh MT (Anonymous, 2015-16).

It is a source of edible oil having 20-25 percent and protein 42-45 percent content (Alam *et al.*, 2009). Soybean is a promising pulse crop proposed for the alleviation of the acute shortage of protein and oil worldwide (Mahamood *et al.*, 2009). It used as a good

source of unsaturated fatty acids, minerals (Ca and P) and vitamins A, B, C and D (Alam *et al.,* 2009). Soybean protein contributes all eight amino acids in the amount needed for human health; hence it is called meal of the field (Rathore, 2000). It is therefore, highly desirable in human diet and animal (Haq *et al.,* 2002).

Soybean has a unique importance in the Indian agricultural economy due to great shortage of edible oil in the country. Since, past few years, the consumption of oil has been increasing steadily as a result of rise in population and living standard of people, the basic question before the scientist is to develop a concrete strategy that permits self-reliance in edible oils (Meghvansi *et al.,* 2006). Soybean oil is the world most widely used edible oil, as it is low in cholesterol, with a natural taste and nearly imperceptible odour, which makes it the ultimate choice of vegetable oil for domestic and industrial food processing units (Mpepereki *et al.,* 2000).

Nitrogen is a limiting nutrient for growth and yield of soybean, *rhizobia* have a direct role to play in its supply to the growing plants (Kanimozhi and Panneerselvam 2010). *Bradyrhizobium japonicum* capable of forming root nodules on soybean. The ability to form nodules has been found to be highly host specific for different species of *rhizobia* (Jordan, 1982).

Better N_2 fixation can be achieved by selecting superior *Rhizobia*. However, selection of these *Rhizobia* would need to take into consideration not only their N_2-fixing capacity, but also competitive ability against native *Rhizobia* which are frequently ineffective in N_2 fixation have to out compete with native *Rhizobia* and occupy a significant proportion of the nodules. The subject of symbiotic effectiveness and competitiveness of *Rhizobia* in Indian context assumes more significance and has attracted a lot of Indian workers (Shivananda *et al.,* 2000; Appunu and Dhar 2006 and Appunu *et al.,* 2008). However, in Rajasthan, most of the *Rhizobial* research has been confined to the tree legumes (Srivastava and Prabhakaran, 1999) while little attention has been paid to the studies on *Rhizobia* of soybean despite being an important oil yielding crop. As a consequence, symbiotic potential of the *Rhizobia* autochthonous to different soybean growing regions of Rajasthan is still unexploited.

Materials and Methods

The experiment was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) in *kharif 2016* on sandy clay loam soil which is slightly alkaline in nature consisted of 9 treatments of different rhizobial strains, *viz*., SB-22 (T_2), SB-272 (T_3), SB-31 (T_4), SB-431 (T_5), SB-401 (T_6), SB-441 (T_7), SB-442 (T_8), SB-481 (T_9) and SB-402 (T_{10}), respectively and control (T_1). These treatments were evaluated under randomized block design (RBD) with four replications. Soybean cultivar (JS - 9560) was taken as test crop.

Results and Discussion

Effect of inoculation on plant growth

Data presented in Table 1 revealed that inoculation of seed with different *Rhizobium* strains significantly increased in different growth parameter, *viz*. plant height, shoot dry weight, dry matter accumulation, fresh root weight, dry root weight, number of nodule at 60 DAS and nodule dry weight was increased when seed was inoculated with different *Rhizobial* strains. The highest plant height was observed in inoculation with SB - 401 (110.50 cm), maximum shoot dry weight (21.60 g plant^{-1}) was observed with

inoculation of SB-401, maximum dry matter accumulation (10.65 g plant^{-1}) was observed of the plants which were inoculated with SB-401 strain (T_6) which was followed by SB-402 (T_{10}), highest fresh root weight (18.24 g plant^{-1}) was recorded with SB- 401 isolate, inoculation with SB- 401 (T_6) produced highest root dry weight (9.45 g plant^{-1}), highest number of nodule (37.88) was observed with plants raised from seed inoculated with the soybean isolate SB- 401 (T_6) however, it was found statistically at par with SB-272(T_3), SB-31(T_4), SB-431(T_5), SB-441(T_7), SB-442(T_8), SB-481(T_9) and SB-402 (T_{10}) number of nodules per plants was increased 35.28 and 32.14 percent per plant under the seed inoculated with SB- 401 (T_6) and SB-402 (T_{10}), highest nodule weight (1.69 g plant^{-1}) was recorded with SB- 401 (T_6) respectively over uninoculated treatment. The results of the present study that inoculation of different *Rhizobial* strains has been found to be providing higher growth of plant with those reported by Seed inoculation with different *Rhizobium* strains significantly increased growth attributes *viz*., plant height, shoot dry weight, fresh root weight, root dry weight and number of nodules plant^{-1}. The significantly higher growth parameters were associated with Rhizobium isolate SB-401.

The variation in plant height might be due to the inoculation of effective *Rhizobial* strain. These results are in agreement with the findings of Solaiman (1999). Gupta *et al.*, (2005), they mentioned that plant height can also be increased significantly by inoculation of effective soybean rhizobial strains. These findings are confirming the observations of earlier workers Khan *et al.*, (2014), Nyoki and Ndakidemi (2014). Seeds inoculated by different *Rhizobium strains* showed significantly higher nodulation, fresh root weight and root dry weight over control. Nodulation might be due to the effective symbiosis between soybean plants and rhizobial strains. Higher number of nodules may be increased by inoculation with effective rhizobial strains. Similar findings were also reported by Alagawadi *et al.*, (1993) and Devi and Gupta (1996).

Effect of Inoculation on yield & yield attributes

As evident from the results (Table 2) inoculation of different *rhizobial* strains showed significant difference in number of pod plant^{-1} and number of seed pod^{-1}. The maximum number of pod plant^{-1} and number of seed pod^{-1} was 41.25 and 3.26 obtained from the plant inoculated with strain SB-401. The minimum number of pod plant^{-1} and number of seed pod^{-1} was 30.50 and 1.50 counted from control.

Similar trendes was found in test weight (1000 grains weight) and harvest index. Highest test weight and harvest index was found in SB-401 133.50gm and 36.70% due to inoculation of seed with different *Rhizobial* strains but harvest index is statistically found non-significant.

Different rhizobial strains inoculation significantly influenced the seed, straw and biological yield of soybean. The highest seed, straw and biological yield was 1776.25, 3110.98 and 4887.23 kg/ha recorded from the plant inoculated with strain SB-401. The lowest seed, straw and biological yield was 1280, 2295 and 3575 kg/ha recorded from uninoculated treatment respectively (Figure 1).

Similar results also obtained due to the fact that *Rhizobium* inoculation increased the root nodulation, better root development and more nutrient availability, resulting in vigorous plant growth and dry matter production which resulted in better flowering, fruiting and pod formation and ultimately seed yield.

Table.1 Effect of different *Rhizobial* strains on different growth parameters

Treatments	Plant height (cm)	Shoot dry weight (g plant^{-1})	Dry matter accumulation (g plant^{-1})	Fresh root weight (g plant^{-1})	Dry root weight (g plant^{-1})	Number of nodule at 60 DAS	Nodule weight (g plant^{-1})
T1- Control	83.11	12.50	5.98	9.75	5.06	28.00	1.09
T2- SB- 22	96.75	16.75	7.58	14.25	7.75	33.75	1.21
T3- SB- 272	99.25	16.75	7.68	15.00	7.75	34.75	1.25
T4- SB- 31	100.50	19.50	7.48	15.25	7.83	36.00	1.29
T5- SB- 431	102.50	14.50	7.98	17.50	9.05	36.75	1.33
T6- SB- 401	110.50	21.60	10.65	18.24	9.45	37.88	1.69
T7- SB- 441	106.75	18.00	8.15	17.01	8.50	36.75	1.32
T8- SB- 442	101.75	18.75	8.99	16.50	8.25	35.25	1.44
T9- SB- 481	98.25	20.25	9.00	15.00	7.75	36.75	1.52
T10- SB- 402	103.25	18.50	9.53	16.00	8.75	37.00	1.48
SEm±	3.63	0.29	0.17	0.33	0.15	1.22	0.02
CD (P= 0.05)	10.525	0.845	0.492	0.950	0.437	3.539	0.071

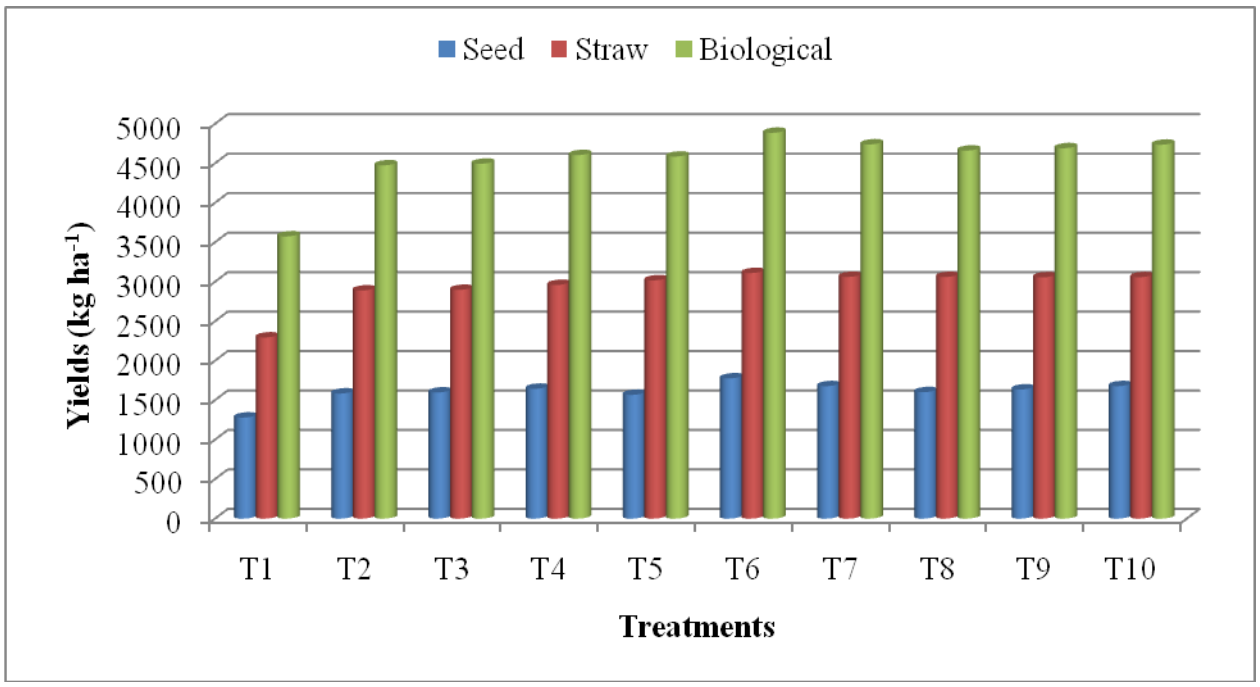
Table.2 Effect of different Rhizobial strains on yield attributes

Treatments	Number of pod plant^{-1}	Number of seed pod^{-1}	Test weight (gm)	Harvest index (%)
T1- Control	30.50	1.50	104.50	35.80
T2- SB- 22	36.50	2.50	121.00	35.42
T3- SB- 272	38.50	2.25	125.75	35.54
T4- SB- 31	38.25	2.75	130.00	35.72
T5- SB- 431	39.75	2.25	127.75	34.36
T6- SB- 401	41.25	3.26	133.50	36.47
T7- SB- 441	40.75	2.50	126.75	35.41
T8- SB- 442	39.00	2.00	128.50	34.24
T9- SB- 481	37.55	2.75	129.00	34.86
T10- SB- 402	37.25	2.75	130.25	35.41
SEm±	1.49	0.08	1.83	0.81
CD (P= 0.05)	4.33	0.24	5.29	NS

Table.3 Effect of different Rhizobial strains on gross returns and net returns

Treatments	Gross return (` ha^{-1})	Net return (` ha^{-1})
T1- Control	52832.50	41312.50
T2- SB- 22	65590.00	51690.00
T3- SB- 272	66073.00	52173.00
T4- SB- 31	67935.00	54035.00
T5- SB- 431	65441.78	51541.78
T6- SB- 401	73057.18	59157.18
T7- SB- 441	69447.76	55547.76
T8- SB- 442	66779.48	52879.48
T9- SB- 481	67950.00	54050.00
T10- SB- 402	69434.49	55534.49
SEm±	2371.04	2371.04
CD (P= 0.05)	6880.11	6880.11

Fig.1 Effect of different *rhizobial* strains on yield of crop



The substantial increase in yield observed in the *Rhizobium* inoculated seeds may be due to the nitrogen fixation potential of soybean. Similar results were reported by Kumawat, *et al.,* (2000) and Patra *et al.,* (2012).

These results could be explained by the reported symbiosis efficiency between soybean and *Bradyrhizobium japonicum* (Abbasi *et al.,* 2008). Increased nodulation and subsequent N2 fixation due to inoculation might have resulted in the measured increases in yield and yield components of soybean. In addition, increased NPK uptake may also be due to better availability of nutrients by *Rhizobium* inoculation may also contributed to increase soybean yield and yield components as significant positive correlations existed between these components. Increased soybean yields due to inoculation have also been reported by earlier many researchers. Egamberdiyeva *et al.,* (2004) reported 48% increase in soybean yield after inoculation in Uzbekistan while Okereke *et al.,* (2001) in Nigeria found a significant increase in soybean seed yields after *Bradyrhizobium* inoculation varied between 14–108% compared to the non-inoculated treatment. Zhang *et al.,* (2002) suggested that *Bradyrhizobium japonicum* improved seed yield of soybean largely due to increase in pod and seed number as observed in this study. Comparative assessment of the results of the field experiment indicated a significant improvement in nodulation, vegetative growth and seed yield of three soybean genotypes grown in Rajasthan, India (Meghvansi *et al.,* 2010). The findings of this investigation confirm the observations of earlier workers, Tanwar (2003), Malik *et al.,* (2006) and Abdalgani *et al.,* (2014).

Effect of Inoculation on net returns of soybean

The data presented in Table 3 showed that seed inoculation of different *Rhizobial* strains give highest net returns. Highest net returns and gross returns was found with isolate SB-401 (Rs. 59157.18 and 73057.18 ha^{-1}) as

compared to control (Rs. 41312.50 and 52832.50 ha^{-1}) and other treatments. It is obvious that net returns and gross returns increased with increased in seed and straw yield in soybean crop.

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