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Effect of rhizobium inoculation and nitrogen fertilizer on growth and productivity of soybean (*Glycine max* L. Merrill)

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Abstract
A field experiment entitled "Effect of rhizobium and nitrogen fertilizer on the growth and productivity of soybean (*Glycine Max* L.) in South-west Punjab" was conducted during the kharif season of 2019 at Research Farm of Guru Kashi University, Talwandi Sabo, Bathinda (Punjab). The trail was laid out in split plot design with two levels of rhizobium *viz.*, 0 and 350 g ha^{-1} in main plot and five levels of nitrogen 0 kg ha^{-1}, 20 kg ha^{-1}, 30 kg ha^{-1}, 40 kg ha^{-1} and 50 kg ha^{-1} in sub plot. The results showed that the rhizobium 350 g ha^{-1} resulted in higher plant height (128.2cm), dry matter accumulation (40 q ha^{-1}), number of primary branches per plant (15.3), leaf area index (8.28), test weight, (9.8 g), number of grains per pod (3.34), pod length (3.22 cm) and pod weight (4.1). The percent increase in grain yield at 350 g rhizobium ha^{-1} was 65.6 application and control, respectively. Similarly, nitrogen recorded higher growth and yield attributes than other nitrogen levels. The grain yields of 50 kg N ha^{-1} (71.5 q ha^{-1}) and, 40 kg N ha^{-1} (68.3 q ha^{-1}) was statistically similar. Rhizobium @ 350 g ha^{-1} with nitrogen 50 kg N ha^{-1} gave highest grain yield (72.3q ha^{-1}).

Keywords: Grain yield, growth, nitrogen, rhizobium and soybean

Introduction
Soybean (*Glycine max* L.) are a diploid species with chromosome number (2n=2x=40) belongs to the family of Leguminoseae or Fabaceae and one of the most important source of protein and oil in the world. It is also known as a "wonder crop", and "Golden Bean" crop. The soybean plant used for animal feed is also healthy and useful addition to the human diet (Singhal, 2003) [13]. In recent years, because of health benefit claims of soybean diet, its importance is gradually increased and gave rise to soymilk, candies, ice-cream, breads biscuits and baby food industries (Jain and Jain 1987) [2]. Soybean are excellent sources of different dietary fiber components of alpha- galactosides, beta-carotene, cellulose, isoflavones pectines. The neutral cell wall of polysaccharide beta-glucan has outstanding functional and nutritional properties. It rich in protein, fat, carbohydrate and calories, having average contain of carbohydrates (25- 30%) and almost no starch (useful to diabetic patients), protein content (40%), oil content (20%) and lipid (18.3%). It is also rich source of Ca (277 mg), and Fe (15.7 mg), Zinc (4.9 mg) and it is regarded as a nutrient storage.
Nitrogen use efficiency for oilseed production is approximately 40% in the world. Nitrogen fertilizer loss is caused mainly by gaseous soil denitrification, plant emission, surface runoff and volatilization and leaching. Therefore, determination of optimum nitrogen fertilization level for soybean production is also very important because of its role in lodging and higher grain or biomass yield. Presence of various elements such as , P,K Ca, Mg, S, Zn, MN, Fe and micronutrients in the Rhizobium make it a good source of plant nutrients (Takkar, 1996) [16]. The increase yields of different crops due to application of Rhizobium was observed by (Singh Patel and Ramani, 2003) [14]. Soybean is an important oilseed crop and which needs not only macronutrients but secondary as well as micronutrients to produce higher yields. Use of manures, organic and inorganic wastes and biofertlizersis gaining wider acceptance to reduce input cost and to sustain soil fertility. Therefore, this research work was aimed to determine the response of soybean cultivars to different doses of Rhizobium and nitrogen fertilizers on yield components. Choosing an optimum dose and timing of fertilizer application could also be a compromise between maximizing yield potential and minimizing disease levels. Keeping in view, the present investigation was undertaken to study the effect of rhizobium and nitrogen levels on the performance of soybean.

Materials and Methods

The field experiment study entitled, "Effect of rhizobium inoculation and nitrogen Fertilizer on the growth and yield of soybean (*Glycine max* L.)" was conducted at research farm of Guru Kashi University, Talwandi Sabo (Bathinda) during *kharif* season 2019-20. The farm is located at 29.9875^{0}N latitude and 75.0903^{0}E longitude with an altitude of 252 meters above the mean sea level as per are extreme. The mean maximum and mean minimum temperature ranged 45.8 ^{0}C and 13 ^{0}C respectively recorded during May, 2019 to October, 2020. The field experiment was conducted at experimental area of agriculture research farm of Guru Kashi University, Talwandi Sabo (Bathinda) during *rabi* 2018-19. The farm is located at 29^{o}57 N latitude and 75^{o}7 E longitude and altitude of 213 meters above the sea level as per are extreme. The maximum temperature of about 45 ^{o}C is achieved during month of May and June during the year, while freezing temperature accompanied by frost occurrence may be recorded in the months of December and January in this region. The monsoon generally starts in the first week of July.). The trail was laid out in split plot design with two levels of rhizobium *viz.*, 0 and 350 g ha^{-1} in main plot and five levels of nitrogen 0 kg ha^{-1}, 20 kg ha^{-1}, 30 kg ha^{-1}, 40 kg ha^{-1} and 50 kg ha^{-1} in sub plot.

The collected data were statistically analyzed by using Fisher's ANOVA technique and least significant difference (LSD) test at 5% probability level was used to compare differences among treatment means.

Results and Discussion

Growth parameters of soybean

The maximum plant height (133.2 cm) was recorded with rhizobium (350g/ha) application which was significantly higher than control (Table 1). Application of nitrogen resultant in increased the plant height. The maximum plant height (134.4 cm) was recorded with 50 kg N/ha application which was significantly higher as compared to other nitrogen levels. Similar results were also reported by Singh *et al.* (2009) [11] and Shrivastava (2001) [15].

Similarly, application of rhizobium showed significant effect on other growth parameters of plant. The maximum number of primary branches/plant (15.3) and leaf area index (8.28) were recorded with rhizobium (350g/ha) application (Table 1). However, the nitrogen and the interaction effect between rhizobium and nitrogen levels on number of primary branches/plant and leaf area index was significant. Similar results were also reported by Vyas *et al.* (2005) [18].

The maximum dry matter accumulation (40 q/ha) was recorded with rhizobium (350g/ha) application which was significantly higher than control (Table 1). Application of nitrogen increased the dry matter accumulation of plant and maximum dry matter accumulation (51.9 q/ha) was observed with 50kg N/ha application which was significantly higher as compared to other nitrogen levels. Similar results were also reported by Mitchell and Russell *et al.* (1998) [6] and Babu (2009) [10].

Table 1: Effect of rhizobium and nitrogen levels on plant height, number of branches, dry matter and leaf area index in soybean.

Treatment	Plant height (cm)	Number of branches/plant	Dry matter accumulation (q/ha)	Leaf area index
Rhizobium levels (g/ha)				
Control	126.8	13.6	36.2	8.02
350 g/ha	128.2	15.3	40.0	8.28
LSD (0.05%)	0.3	0.8	1.2	0.5
Nitrogen levels (kg/ha)				
0	121.4	12.0	23.0	3.71
20	124.1	16.1	32.4	9.10
30	126.6	13.4	37.3	7.96
40	131.2	16.1	43.2	8.53
50	134.4	15	51.9	11.6
LSD (0.05%)	0.5	0.6	NS	0.3

Table 2: Effect of rhizobium and nitrogen levels on yield attributing characters in soybean.

Treatment	1000-grain weight (g)	Number of grains/pod	Number of pods/ plant
Rhizobium levels (g/ha)			
Control	9.60	3.11	99.2
350g/ha	9.80	3.34	103.1
LSD (0.05%)	1.2	0.25	1.59
Nitrogen levels (kg/ha)			
0	3.40	2.69	90.5
20	3.90	3.53	96
30	10.8	3.16	104.5
40	9.70	3.1	106
50	9.75	3.66	110
LSD (0.05%)	1.3	0.24	0.82

Yield attributes of soybean

The rhizobium application also showed significant effect on various yield attributes of soybean (Table 2). The increase test weight, number of grains per seed and number of pods per plant was recorded and was 9.80 g, 3.34 and 103.1, respectively with rhizobium (350g/ha) application. Similarly, the nitrogen application significantly increased the yield attributing parameters and application of 50 kg N/ha resulted as increase test weight (9.75 g), number of grains per pod (3.66) and number of pos per plant (110) as compared to other nitrogen levels. However, the interaction effect between rhizobium and nitrogen levels on 1000-grain weight, was non-significant. Similar results were also reported by *Paikara et al.* (1988) [8] Singh *et al.* (2007) [9] and Vyas *et al. (*2006) [17].

Table 3: Effect of rhizobium and nitrogen levels on pod length and pod weight in soybean.

Treatment	Pod length (cm)	Pod weight (g)
Rhizobium levels (g/ha)		
Control	3.2	3.9
350 g/ha	3.22	4.1
LSD (0.05%)	0.1	0.21
Nitrogen levels (kg/ha)		
0	3.05	3.45
20	3.22	4
30	3.18	4.1
40	3.21	4.1
50	3.40	4.6
LSD (0.05%)	0.04	0.16

The rhizobium application also showed significant effect on various yield attributes of soybean (Table 3). The pod length and pod weight was recorded and was 3.22 cm and 3.2 g, respectively with rhizobium (350g/ha) application. Similarly, the nitrogen application significantly increased the yield attributing parameters and application of 50 kg N/ha resulted as increase pod pength (3.40), pod weight (4.6) a as compared to other nitrogen levels. However, the interaction effect between rhizobium and nitrogen levels was non-significant. Similar results were also reported by Lorenc-Kozik and Pisulewska (2003) [3].

Productivity of soybean

The rhizobium increased the grain yield of Soybean and maximum grain yield (65.6 kg/ha) was obtained with rhizobium (350g/ha) application which was 63.4 percent over control (Table 4). In case of nitrogen, significantly higher grain yield (71.5 kg/ha) was recorded at 50 kg P_2O_5/ha applications compared to other nitrogen levels. The percent increase in grain yield with 50 kg P_2O_5/ha application was 56.3, 62, 63.9 and 68.3 percent over control, 20, 30 and 40 kg N/ha respectively. The interaction effect between rhizobium and nitrogen levels was significant and maximum grain yield (72.3 kg/ha) was obtained with fly ash (350g/ha) in combination with 50 kg P_2O_5/ha application as compared to other treatment combinations. Similar trend was observed

Table 4: Effect of rhizobium and nitrogen levels on grain yield in soybean.

Rhizobium levels (g/ha)	Grain yield (g/ha)					
	Nitrogen levels (kg/ha)					
	0	20	30	40	50	Mean
Control	55.1	61.6	63.1	66.6	70.7	63.4
350 g/ha	57.6	62.4	64.7	70	72.3	65.6
Mean	56.3	62	63.9	68.3	71.5	-
LSD (P=0.05)	Rhizobium		Nitrogen			Interaction
	0.79		0.56			0.80

Table 5: Effect of rhizobium and nitrogen levels on straw yield and harvest index in soybean.

Treatment	Straw yield (kg/ha)	Harvest index (%)
Rhizobium levels (g/ha)		
Control	111.4	44.9
10 g/ha	114.1	48.5
LSD (0.05%)	2.05	1.32
Nitrogen levels (kg/ha)		
0	99.4	39.9
20	109.3	42.9
30	112.8	48.4
40	119.3	50.1
50	123	52.3
LSD (P=0.05)	1.26	0.85

in straw yield (Table 5). The straw yield (114.1 kg/ha) was significantly increased with application of rhizobium @ 350 g/ha. Application of nitrogen resulted in higher straw yield and the maximum straw yield (123 kg/ha) was recorded at 50 kg N/ha application. There was significant interaction between rhizobium and mitrogen levels on straw yield and the maximum straw yield (124 kg/ha) was obtained with rhizobium (350 g/ha) in combination with 50kg N/ha application as compared to other treatment combinations. However, application of nitrogen alone and in combination with rhizobium showed non-significant effect on percent harvest index. Similar results were also reported by Mayaki *et al.* (1976) [5] Vessey (2004), Powder *et al.* (1999) [7], Bhuiyan *et al.* (1998) [1] and Solaiman (1999) [12].

In conclusion, application of rhizobium @ 350 g/ha significantly increased the growth and yield attributes of soybean and gave 65.6 % higher grain yield over control. The nitrogen application significantly increased the growth and yield attributes resulting percent increase in grain yield to the extent of 56.3, 62 and 63.9, 68.3% over control, 20, 30, and 40 kg N/ha, respectively. It is concluded that application of 350g/ha rhizobium in combination with 50 kg N/ha gave maximum grain yield of soybean. These findings can be useful for improving the production of soybean in south-west Punjab.

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