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Effect of *rhizobium* inoculation and nitrogen levels on performance of green gram [*Vigna radiate* L. Wilczek]

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Abstract
A field experiment was conducted during *kharif* 2019 at Research Farm, Guru Kashi University, Talwandi Sabo, Bathinda (Punjab) to check the effect of rhizobium inoculation in relation with nitrogen levels on the performance of green gram. The trial was laid in split plot design with two rhizobium levels *viz.*, 0 and 350 g ha-1 in main plot and four nitrogen levels 0 kg ha -1, 6 kg ha-1, 12 kg ha-1, and 18 kg ha-1 in sub plot. *Rhizobium* seed inoculation significantly increased the plant growth parameters *viz.*, plant height, dry matter accumulation, number of branches and number of nodules/plant and yield attributing characters *viz.*, number of pods/plants, number of seeds/pod and test weight in green gram. *Rhizobium* seed inoculation recorded highest seed yield (1435 kg/ha) which was significantly higher than control (1293 kg/ha). *Rhizobium* seed inoculation results in 10.9% higher seed yield than control. Application of 18 kg N/ha recorded higher plant growth parameters *viz.*, plant height, dry matter accumulation, number of branches and number of nodules/plant and yield attributing characters *viz.*, pod length and number of seeds/pods in green gram. Application of 12 kg N/ha (1523 kg/ha) and 18 kg N/ha (1469 kg/ha) gave the statistically similar seed yields which were significantly higher than control (1083 kg/ha) and 6 kg N/ha (1382 kg/ha). Nitrogen @ 12 kg N/ha recorded 40.6, 10.2 and 3.69% higher seed yield than control, 6 and 18 kg N/ha, respectively.

Keywords: grain yield, green gram, nitrogen and rhizobium

Introduction
Green gram [*Vigna radiate* (L.) Wilczek] has been grown in India since ancient times. It is an important pulse crop in South and East Asia (Keatinge *et al*. 2011) [6]. At global level pulses are the third most important group of crops after cereals and oil grains. India ranks first in the world in area as well as production of green gram. It is the third important pulse crop of India in terms of area cultivated and production, next to chickpea and pigeon pea. India is the largest producer of pulses in the world with 35.7 per cent share in global production (FAOSTAT 2013) [5]. Green gram contributed 9.4 per cent to the total production of pulses in the country during 2018-19. In India, area and production of green gram in 2019-20 was 3.55 million hectares and 1.82 million tons, respectively and average yield was 512 kg/ha (Anonymous 2020a) [1]. In Punjab, during *kharif* season area and production of green gram in 2019-20 was 3.5 thousand hectares and 3.2 thousand tons, respectively and average yield was 845 kg/ha (Anonymous 2020b) [2].

Pulses are one of the important segments of Indian agriculture after cereals in production. It is considered to be the hardiest of all pulse crops. It requires a hot climate and can tolerate drought also. It is also suitable as a summer crop. The *kharif* season is the most prevalent and traditional green gram growing period in India. The pulses have the ability to fix atmospheric nitrogen (N_2) in their root nodules in association with specific Rhizobium/Bradyrhizobium species. In green gram, nitrogen derived from N_2 fixation (P_{fix}) is 15-17% and total nitrogen fixed is 9-137 kg/ha (Singh and Sekhon 2005) [11]. The residual effects of preceding pulse crops in cereals observed in terms of fertilizer-N equivalent, may be 68 kg/ha in case of moong (Wani *et al*. 1995) [14]. When green gram is sown in green gram-rice rotation it not only increases nitrogen uptake in rice due to N-fixation as well as also incorporated the plant residues, but also improves rice grain yield (Rahman *et al*. 2012) [8]. Incorporation of green gram residue increases the biological activity in soil as measured by dehydrogenase activity and carbon dioxide (CO_2) evolution (Singh and Sekhon 2005) [11]. Therefore, this research experiment was aimed to record the response of green gram to different rhizobium and nitrogen levels on its growth and yield components.

Material and Methods

The investigation was carried out in the research farm of Guru Kashi University, Talwandi Sabo (Bathinda) during *kharif* season of 2019. The location of farm is at 29.98 75 ^{0}N latitude and 75.09 03 ^{0}E longitude. The altitude of the farm is 252 meters above the sea level. The soil texture was loamy sand and slightly alkaline in soil pH. The soil was poor in organic carbon, low in available nitrogen and medium in phosphorus but high in available potassium. The mean maximum and mean minimum temperature ranged 41.6 ^{0}C and 9.4 ^{0}C, respectively recorded during June 2019 to Nov. 2019. The mean evaporation ranged from 57.20 mm (Nov. 2019) to 329.70 mm (April 2019) during the period under study. The mean monthly rainfall varied from 2 mm (Nov. 20119) to 117 mm (July. 2019). The trial was laid in split plot design with two rhizobium levels *viz*., 0 and 350 g ha-1 in main plot and four nitrogen levels 0 kg ha -1, 6 kg ha-1, 12 kg ha-1, and 18 kg ha-1 in sub plot with three replications.

The data recorded were analysed statistically using split plot design described by Cochran and Cox (1957) [3] using statistical package CPCS-1 by Cheema and Singh (1991) [4]. All the comparisons were made at 5 per cent level of significance.

Results and Discussion

Growth parameters of green gram

The maximum plant height (45.2 cm) was recorded in *rhizobium* seed inoculation which was significantly higher over the control (Table 1). The highest plant height(52.1 cm) was recorded from nitrogen @ 18 kg/ha, which was significantly higher than control and nitrogen @ 6 kg/ha and it was statistically at par with nitrogen @ 12 kg/ha. Similar results were also reported by Pramanik and Singh (2003) [7].

Table 1: Effect of rhizobium and nitrogen levels on plant height in green gram

Seed inoculation	Plant height (cm)				
	Nitrogen (kg N/ha)				Mean
	Control	6	12	18	
Control	43.0	47.3	51.6	52.1	48.5
Rhizobium seed inoculation	45.2	49.2	53.5	54.8	50.7
Mean	44.1	48.3	52.6	53.5	49.6
CD (p=0.05) Seed inoculation (S): 0.8 Nitrogen levels (N): 1.2 Interaction (M×S): NS					

Similarly, the *rhizobium* seed inoculation increased branches per plant and recorded a greater number of branches (67.0) as compared with control (Table 2). The interaction effect between *rhizobium* seed inoculation and nitrogen levels on number of branches per plant was non-significant. Similar results were also reported by Pramanik and Singh (2003) [7].

Table 2: Effect of rhizobium and nitrogen levels on number of branches in green gram

Seed inoculation	Number of branches/plant				
	Nitrogen (kg N/ha)				Mean
	Control	6	12	18	
Control	64.4	70.2	73.3	74.5	70.6
Rhizobium seed inoculation	67.0	72.4	75.0	76.3	72.7
Mean	65.7	71.3	74.2	75.4	71.6
CD (p=0.05) Seed inoculation (S): 0.5 Nitrogen levels (N): 1.5 Interaction (M×S): NS					

The data showed that *rhizobium* seed inoculation recorded more dry matter accumulation (55.5 q/ha) which was significantly higher than control (Table 3). Rhizobium inoculation in conjunction with nitrogen might have helped in increased cell size and vegetative growth resulted in increased dry matter accumulation of green gram. Similar results were also reported by Pramanik and Singh (2003) [7]. Dry matter accumulation was significantly influenced by different nitrogen levels. Nitrogen @ 18 kg/ha recorded highest dry matter accumulation (66.1 q/ha), which was significantly higher than control and nitrogen @ 6 kg/ha but it was statistically at par (65.9 q/ha) with nitrogen @ 12 kg/ha. Similar results were also reported by Takankhar *et al.* (1998) [12].

Table 3: Effect of rhizobium and nitrogen levels on dry matter in green gram

Seed inoculation	Dry matter accumulation (q/ha)				
	Nitrogen (kg N/ha)				Mean
	Control	6	12	18	
Control	50.1	55.1	65.9	66.1	59.3
Rhizobium seed inoculation	55.5	59.1	68.9	70.1	63.4
Mean	52.8	57.1	67.4	68.1	61.4
CD (p=0.05) Seed inoculation (S): 1.8 Nitrogen levels (N): 1.9 Interaction (M×S): NS					

Yield attributes of green gram

The number of pods per plant, number of grains per seed, and test weight was recorded 26, 10.7 and 35.1 g, respectively with rhizobium (350g/ha) application, which was significantly higher than control (Table 4,5). Similarly, the nitrogen increased the yield attributes at different levels, and application of 12 kg N/ha increased test weight (39.4 g) and number of pods per plant (39.3) than other nitrogen levels (Table 4). However, the interaction effect between rhizobium and nitrogen levels was non-significant. These results collaborate the reports of Korwar (1975) and Pramanik and Singh (2003) [7].

Table 4: Effect of rhizobium and nitrogen levels on number of pods per plant in green gram

Seed inoculation	Number of pods /plant				
	Nitrogen (kg N/ha)				Mean
	Control	6	12	18	
Control	20.7	32.7	39.3	37.1	32.5
Rhizobium seed inoculation	26.0	37.0	46.6	44.3	38.5
Mean	23.4	34.9	43.0	40.7	35.5
CD (p=0.05) Seed inoculation (S): 2.3 Nitrogen levels (N): 3.8 Interaction (M×S): NS					

Table 5: Effect of rhizobium and nitrogen levels on number of pods per plant in green gram

Seed inoculation	Number of seeds/pod				
	Nitrogen (kg N/ha)				Mean
	Control	6	12	18	
Control	8.5	11.8	13.2	13.6	11.8
Rhizobium seed inoculation	10.7	12.9	13.8	14.0	12.9
Mean	9.6	12.4	13.5	13.8	12.3
CD (p=0.05) Seed inoculation (S): 0.4 Nitrogen levels (N): 0.5 Interaction (M×S): NS					

Productivity of green gram

The rhizobium inoculation increased the seed yield (1152kg/ha) of green gram with rhizobium @ 350g/ha application, which was significantly higher than control (Table 6). Also, nitrogen @ 12kg/ha along with rhizobium inoculation gave the highest seed yield (1598 kg/ha), which was higher than all other treatments (Table 6). However, the interaction of rhizobium and nitrogen showed non-significant effect on seed yield. Similar results were also reported by Pramanik and Singh (2003) [7] and Korwar (1975).

Table 6: Seed yield (kg/ha) of green gram as influenced by *rhizobium* seed inoculation and nitrogen levels

Seed inoculation	**Seed yield (kg/ha)**				
	Nitrogen (kg N/ha)				
	Control	6	12	18	**Mean**
Control	1014	1312	1447	1397	1293
Rhizobium seed inoculation	1152	1451	1598	1540	1435
Mean	1083	1382	1523	1469	1364
CD (p=0.05) Seed inoculation (S): 58 Nitrogen levels (N): 69 Interaction (M×S): NS					

In conclusion, the yield and growth attributes of green gram were significantly increased by rhizobium inoculation @ 350 g/ha over control. The interaction of both nitrogen @12kg/ha and rhizobium increased the seed yield of green gram over other treatments. So, it is found that rhizobium inoculation @ 350gm/ha and nitrogen @ 12kg/ha can increase the yield of green gram. These findings can be recommended for increasing the yield of green gram in South west Punjab region.

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