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Response of *Rhizobium* strains on Horse gram (*Dolichos biflorus* L.) in Northern hills region of Chhattisgarh

Bholeshankar Paikara, Dr. AK Paliwal, Dr. RN Singh and Dr. DK Gupta

Abstract
This experiment was conducted at the research farm of Raj Mohini Devi College of Agriculture and Research station, Ambikapur (Chhattisgarh) to study the response of *Rhizobium* strains on Horse gram (*Dolichos biflorus* L.) in Northern hills region of Chhattisgarh during *kharif* 2017. The variety Chhattisgarh kulthi-2 was used as the test crop. The trial was carried out in Randomized Block Design (RBD) with three replications, using eight treatments comprised of four levels of Nitrogen (0, 50, 75 and 100% of GRD @ 20 kg ha^{-1}) and full dose of phosphorus and potassium followed all treatments. Three strain of *Rhizobium* (*Rhizobium* strain-1, *Rhizobium* strain-2 and *Rhizobium* strain-3) combined with two level of N (50 and 75%) except 100% GRD and control. Result revealed that growth parameters i.e. plant height (cm), number of branches plant^{-1}, number of nodules plant^{-1}, fresh and dry weight plant^{-1} at 30, 45 and 60 days after sowing, yield attributing characters-number of pods plant^{-1} and number of seeds pod^{-1}, nitrogen content in grain (4.23%) and straw (0.88%), uptake by grain (34.47 kg ha^{-1}) and straw (9.55 kg ha^{-1}), protein content (26.43%) under the treatment 75% N of GRD (15 kg ha^{-1}) and full dose of P_2O_5 (40 kg ha^{-1}), K_2O (30 kg ha^{-1}) + *Rhizobium* strain-2 (T_7) which finally showed the highest grain production and straw yield of horse gram (8.15 and 10.86 q ha^{-1}, respectively). While, the highest agronomical nitrogen use efficiency (25.1 kg grain yield kg^{-1} applied N) was registered under the treatment 50% N of GRD and full dose of P, K + *Rhizobium* strain-2 (T_3).

Keywords: Horse gram, rhizobium, NPK fertilizer, biofertilizer, legume, growth and yield

Introduction
Horse gram [*Macrotyloma uniflorum* (Lam.) Verdc., previously *Dolichos biflorus* (L.)] is one of the important grain legume crops of India. It is an underutilized (Aiyer, 1990) [5] and unexplored (Reddy *et al.*, 2008) [34] food legume. Horse gram is most extensively grown in the various country *viz*., Africa, Australia, Burma, India, Malaysia, Mauritius, and West Indies (Jeswani and Baldev, 1990) [22] in low fertile soils with low inputs (Witcombe *et al.*,2008) [47]. It is adapted to wide range temperature regimes (Smartt, 1985) [41] where other crops unable to survive. It is widely cultivated in Andhra Pradesh, Karnataka and Tamilnadu states of India. Horse gram is an excellent source of protein, minerals and vitamins. It contains 25% protein, 60% carbohydrates, essential amino acids, energy and 0.58% lipid, iron and molybdenum (Bravo *et al*., 1999) [10].

Chhattisgarh is a landlocked state in east central India. It is the 9th largest state of the country with a total geographical area of 137.90 lakh hectare. It ranks as the 16th most-populated state of the country with a population of 25.5 million (Galhotra *et al*., 2014) [17]. Chhattisgarh state is located between 17°46' to 23°15' North latitude and 80°30' to 84°23' East longitude. Chhattisgarh state is divided into three distinct Agro-climatic zones namely Northern hills, Chhattisgarh plains and Baster plateau. Climate of Chhattisgarh is mainly tropical, humid and sub humid. Each Agro-climatic zone is having a different type of soil. In general red soil, sandy loam soil, loamy sand soil and black soil are found in all the districts.

Horse gram (locally known as *kulthi* in Chhattisgarh) is one of the under-exploited legumes of the tropics and subtropics zone, mostly grown in upland soils with marginal care (Sreerama *et al*., 2008) [42]. It is generally grown in Northern hill zone and Baster plateau of Chhattisgarh which are dominated by tribal farmers. Total cultivated area, crop production and productivity of horse gram in Chhattisgarh are 47.62 thousand ha, 16.37 thousand ton and 344 kg ha^{-1}, respectively (Anonymous, 2018) [7]. As regards to area Kanker ranks 1st (6.58 Thousand ha) followed by Korba (5.15), Kondagaon (4.68) and Jagdalpur (4.09). Overall Baster plateau comprising 42.10 per cent followed by Northern hills 31.16 per cent and plain area 26.73 per cent, out of total cultivated area of 47.62 thousand hectare under horse gram.

Materials and Methods

Experimental details

A field experiment was conducted at Raj Mohini Devi College of Agriculture and Research station, Ambikapur, District-Surguja, Chhattisgarh to study the response of *Rhizobium* strains on Horse gram (*Dolichos biflorus* L.) in Northern Hills region of Chhattisgarh during *kharif* 2017.

Experimental site

The soil of experimental site was sandy loam and belonged to the order Inceptisol, which was low in nitrogen.

Geographical situation: Ambikapur comes under northern hill zone of Chhattisgarh which is situated at $23^0$10' North latitude and $83^0$15' East longitude with an altitude of 623 meters above the mean sea level. It is the head quarter of district Surguja of Chhattisgarh state.

Climate and weather conditions

The climate of Ambikapur is sub-humid and subtropical having a temperature range of 23^0 to 41 ^{0}C and 4^0 to 26 ^{0}C in summer and winter seasons, respectively. The average annual rainfall varies from 1200 to 1400 mm.

Treatments details

Eight treatments comprised of four levels of Nitrogen (0, 50, 75 and 100% of GRD) and full dose of phosphorus and potassium followed all treatments. Three strains of *Rhizobium* (*Rhizobium* strain-1, *Rhizobium* strain-2 and *Rhizobium* strain-3) combined with two level of N (50 and 75%) except 100% GRD and control.

The field experiment was replicated thrice in randomized block design comprising eight treatments, namely control (No application of N and full dose of P, K) (T_1), 50% N of GRD and full dose of P, K + *Rhizobium* strain-1 (T_2), 50% N of GRD and full dose of P, K + *Rhizobium* strain-2 (T_3), 50% N of GRD and full dose of P, K + *Rhizobium* strain-3 (T_4), 100% GRD (20:40:30 NPK kg ha^{-1}) (T_5), 75% N of GRD and full dose of P, K + *Rhizobium* strain-1 (T_6), 75% N of GRD and full dose of P, K + *Rhizobium* strain-2 (T_7), 75% N of GRD and full dose of P, K + *Rhizobium* strain-3 (T_8). Recommended dose of fertilizer 20:40:30 N:P_2O_5:K_2O kg ha^{-1} was applied under 100% GRD treatment through urea, single super phosphate and murate of potash, respectively.

T_1	-	Control (No application of N and full dose of P, K)
T_2	-	50% N of GRD and full dose of P, K + *Rhizobium* strain-1
T_3	-	50% N of GRD and full dose of P, K + *Rhizobium* strain-2
T_4	-	50% N of GRD and full dose of P, K + *Rhizobium* strain-3
T_5	-	100% GRD (20:40:30 NPK kg ha^{-1})
T_6	-	75% N of GRD and full dose of P, K + *Rhizobium* strain-1
T_7	-	75% N of GRD and full dose of P, K + *Rhizobium* strain-2
T_8	-	75% N of GRD and full dose of P, K + *Rhizobium* strain-3

Seed sowing

The variety Chhattisgarh kulthi-2 was used as the test crop. The seeds were collected from BTC College of Agriculture and Research station, Bilaspur (Chhattisgarh). The land was prepared by ploughing and harrowing. The stubble and weeds were removed. The size of each unit plot was 5.0m x 3.9m (19.5 m^2).

Inoculated seeds @ 20 kg ha^{-1} were sown on 05 September 2017 in rows having a depth of 2-3 cm. Row to row distance was 30 cm and plant to plant 10 cm. Irrigation was done as per requirement. Protection measure was taken as and when required. Harvesting was done when 90% of the pods become brown to black in color. Five plants from each plot were randomly sampled to study the plant height, number of branches, number of nodules, fresh weight and dry weight at 30, 45 and 60 days after sowing. Number of pods plant^{-1} and number of seeds pod^{-1} at harvest stages.

Seed inoculation

The seeds of horse gram (Kulthi) were treated with three *Rhizobium* strains i.e. *Rhizobium* strain-1, *Rhizobium* strain-2 and *Rhizobium* strain-3 @ 20 g kg^{-1} seeds on outer layer of seeds using jaggery as a sticky material. These *Rhizobium* strains were collected from Department of Agricultural Microbiology, IGKV Raipur (C.G.).

Soil studies

Collection of soil sampling

A composite soil sample from the experimental field was taken before sowing and other soil samples were collected from each plot after harvest of the crop up to the depth of 0-15 cm with the help of soil auger. These soil samples were air-dried, crushed with pestle and mortar and passed through 2.0 mm sieve for subsequent physico-chemical analysis. The physico-chemical properties of the soil are presented in Table 1.

Soil analysis

The initial soil sample analyzed for pH, EC, Organic carbon and available N, P and K by using standard methods presented in Table 1.

Table 1: Important chemical properties of experimental soil (0-15 cm) at initiation

Properties of initial soil sample			Methods
pH (1:2.5 Soil:water)	5.7	Moderately acidic	Glass electrode pH meter (Piper, 1967)
EC (dS m^{-1})	0.10	Normal	Solubridge conductivity method (Black,1965)
Organic carbon (%)	0.33	Low	Walkley and Black's rapid titration method (Black, 1965)
Available N (kg ha^{-1})	202.96	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	34.20	Medium	By the method No. 1 of Bray and Kurtz (1945)
Available K (kg ha^{-1})	278.16	Medium	Flame photometeric method as described by Hanway and Heidal (1952)

Agronomical nitrogen use efficiency (kg grain yield kg^{-1} applied N)

Agronomical nitrogen use efficiency was calculated by using the following formula.

$$AE_N \text{ (kg grain yield kg}^{-1} \text{ applied N)} = \frac{\text{Grain yield from treated plot (kg ha}^{-1}) - \text{Grain yield from control plot (kg ha}^{-1})}{\text{Amount of applied N (kg ha}^{-1})}$$

N-content

$$\text{N\% in grain or straw} = \frac{\text{(S-B) x normality of acid x atomic wt. of N x 100}}{\text{weight of sample (g) x 1000}}$$

Where

S= Sample titer value

B= Blank titer value

N uptake

Nitrogen uptake in grain and straw was calculated using the following formula.

$$\text{Nitrogen uptake (kg ha}^{-1}) = \frac{\text{N-content (\%) x yield (kg ha}^{-1})}{100}$$

Protein content

The treatment wise protein content (%) of horse gram seeds was calculated by multiplying the N-content value (%) of seeds with the conversion factor 6.25 (Humphries, 1956).

Protein content (%) = N-content value (%) x 6.25

Results and Discussion

Growth parameters: The data on growth parameters of horse gram as affected by different *Rhizobium* strains were recorded at the interval of 30, 45 and 60 days of sowing. However, the growth parameters *viz*. plant height, number of branches, number of nodules, fresh weight and dry weight were the highest under the treatment T_7-75% N of GRD (15 kg ha^{-1}) and full dose of P_2O_5 (40 kg ha^{-1}), K_2O (30 kg ha^{-1}) + *Rhizobium* strain-2. At 30 DAS, the highest plant height 24.00 cm plant^{-1} were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 23.37 cm plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 22.55 and 21.98 cm plant^{-1}, respectively. Similarly, at 45 DAS, the highest plant height 45.05 cm plant^{-1} were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 44.25 cm plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 43.55 and 42.97 cm plant^{-1}, respectively. At 60 DAS, the highest plant height 67.45 cm plant^{-1} were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 66.50 cm plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 65.85 and 65.35 cm plant^{-1}, respectively. It is clear from the study that plant height increased successively from 30 to 60 days due to combined effect of nitrogen levels and *rhizobium* inoculation with different strains. This may be because of greater rate of nutrient utilization up to reproductive phase i.e. 60 days after sowing. The integrated approach of nitrogen fertilizer increased plant height as it increase the internodal length (Dutta *et al*., 2011) [12].

At 30 DAS, number of branches plant^{-1} increased from 2.92 to 4.67. Maximum number of branches 4.67 were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 4.57 plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 4.41 and 4.32 plant^{-1}, respectively.

At 45 DAS, number of branches plant^{-1} increased from 4.39 to 7.02. Maximum number of branches 7.02 were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 6.90 plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 6.63 and 6.52 plant^{-1}, respectively.

Similarly, at 60 DAS, number of branches plant^{-1} increased from 5.87 to 9.41. Maximum number of branches 9.41 were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 9.20 plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 8.87 and 8.74 plant^{-1}, respectively. Significant increase in number of branches per plant of horse gram with *rhizobium* inoculation and nitrogen level was earlier reported by Nayak (1983) [32]. Biswas *et al*. (2009) [8] also reported significant increase in number of branches plant^{-1} of urdbean due to influence of *rhizobium* inoculation over the uninoculated control.

At 30 DAS, the highest number of effective nodules 7.89 were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 7.40 plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 6.62 and 6.42 plant^{-1}, respectively. Similarly, at 45 and 60 DAS, the highest number of effective nodules 13.76 and 17.41 respectively were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N and full dose of P, K + *Rhz*-3 (T_8). These results were similar with the findings of Ahmed *et al*. (2006) [4] who reported an increase in number of nodules per plant due to application of *rhizobium* inoculation in combination with nitrogen fertilizer in mung bean.

Above findings have the resemblance with the results of Tahir *et al*. (2009) [46] who found maximum nodulation in soybean when *rhizobium* inoculation was combined with 25 kg N ha^{-1} in the presence of phosphorus. Increased nodulation resulted in N_2-fixation that leads to increased yield components. Singh *et al.* (2017) [40], Prasad and Ram (1988) [33] and Alagawadi *et al*. (1993) [6] also reported that number of nodules can be increased by inoculation with effective rhizobial strains.

At 30 DAS, fresh weight plant^{-1} increased from 2.35 to 3.80 g plant^{-1}. The highest fresh weight 3.80 g was recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 3.65 g plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8)

3.54 and 3.43 g plant^{-1}, respectively. Similarly at 45 and 60 DAS, fresh weight plant^{-1} increased from 11.55 to 16.22 g plant^{-1} and 23.21 to 35.61 g plant^{-1} respectively. The highest fresh weight 16.22 and 35.61 g plant^{-1} at 45 and 60 DAS respectively were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which were at par with 100% GRD (T_5) followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8).

These are in accordance with those of Ishaq (2002) [21] who reported that inoculation of pea seeds with biofertilizers and N application attained the best results on fresh weight per plant. Elkhatib (2009) [15] also reported that *rhizobium* inoculation with nitrogen application had significant positive effect on fresh weight of common bean. Similar significant enhancement on fresh weight of horse gram plant with *rhizobium* inoculation over uninoculated control was reported by Murthy (1989) [30] and Kala *et al*. (2011) [23].

At 30 DAS, dry weight plant^{-1} increased from 0.61 to 0.98 g plant^{-1}. The highest dry weight 0.98 was recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) 0.94 g plant^{-1} followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 0.92 and 0.89 g plant^{-1}, respectively. Similarly at 45 and 60 DAS, the highest dry weight 5.03 and 9.56 g plant^{-1} respectively were recorded due to influence of 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8). These findings were clearly supported by Elkhatib (2009) [15] who mentioned that *rhizobium* inoculation with nitrogen application had significant positive effect on dry weight of common bean.

Yield and yield attributes

The performance of yield attributing characters i.e. number of pods per plant, number of seeds per pod, grain and straw yield of horse gram. Revealed that the number of pods plant^{-1} at harvest, increased from 10.87 to 21.15. The maximum number of pods plant^{-1} 21.15 were recorded due to influence of 75% N of GRD and full dose of P, K+ *Rhz*-2 (T_7) followed by 100% GRD (T_5), 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 20.35, 18.13 and 16.80, respectively. These results are in line with the findings of Ahmed (2013) [3] who revealed that the *rhizobium* inoculation with low dose of nitrogen application significantly enhanced number of pods per plant in soybean. Mrkovacki *et al*. (2008) [29] reported maximum results for number of pods per plant by applying 30 kg N ha^{-1} to inoculated soybean instead of higher rates of N.

Number of seeds pod^{-1} at harvest increased from 2.83 to 5.37. The maximum number of seeds pod^{-1} 5.37 were recorded due to influence of 75% N of GRD and full dose of P, K+ *Rhz*-2 (T_7) followed by 100% GRD (T_5), 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 4.97, 4.25 and 4.04 seeds pod^{-1}, respectively. These results corroborative with results reported by Agha *et al*. (2004) [2]. Supporting evidence was also reported by Ahmed (2013) [3] who attributed the significant higher number of seeds per pod in soybean by *rhizobium* inoculation with low dose of nitrogen application.

The highest grain yield 8.15 q ha^{-1} was recorded with the treatment T_7-75% N of GRD and full dose of P, K+ *Rhz*-2 followed by 100% GRD (T_5), 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 7.81, 7.64 and 7.28 q ha^{-1}, respectively. The lowest grain yield 4.67 q ha^{-1} was obtained with control-N_0 P_{40} K_{30} (T_1). These results were in close conformity with the results of Sharma *et al.* (2000) [37] who noticed increased yield of black gram to a great extent by the combined application of N_{20} kg ha^{-1} and *rhizobium* inoculation.

These results might be explained on the basis that the promoting effects of biofertilizer and nitrogen together on growth of horse gram plants were reflected on the increased of yield and its components. Many investigators, working on different crops, emphasized the beneficial effects of the interaction between inoculation with biofertilizers and mineral nitrogen application on yield and its components as El-Araby *et al*. (2003) [14] on peas, Abd EL-Mouty (2000) [1] on cowpea, Shiboob (2000) [37] on common bean and Elkhatib *et al*. (2004) [4] on onion.

The maximum straw yield (10.86 q ha^{-1}) was recorded with the treatment T_7-75% N of GRD and full dose of P, K+ *Rhz*-2 followed by 100% GRD (T_5) and 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) 10.69 and 10.31 q ha^{-1}, respectively. The lowest straw yield (6.63 q ha^{-1}) was obtained with control-N_0 P_{40} K_{30} (T_1). Similar observation was reported by Rao (1982) who obtained highest straw yield of horse gram with the application of 12.5 kg N ha^{-1} (652.77 kg ha^{-1}) as compared to no nitrogen (600 kg ha^{-1}) and 25 kg N ha^{-1} (530.55 kg ha^{-1}) under *rhizobium* inoculated condition. Singh *et al*. (2017) [41] clearly mentioned that seed inoculation with *rhizobium* strains significantly increased the straw yield of horse gram over control.

Agronomical nitrogen use efficiency (kg grain yield kg^{-1} applied N)

The agronomical nitrogen use efficiency due to use of *rhizobium* biofertilizer in concerned treatments. The highest agronomical nitrogen use efficiency (25.1) registered under the treatment T_3-50% N of GRD and full dose of P, K + *Rhizobium* strain-2 followed by Treatment T_7 -75% N of GRD and full dose of P, K + *Rhizobium* strain-2 due to increasing N levels from 50 to 75% of recommended dose. The treatment 100% GRD gave relatively lower nitrogen use efficiency due to higher N dose. However, in pursuance of the law of diminishing returns (Voisin, 1962), it decreased as the N levels increased, with every additional increment of N. The above information is in agreement with the findings of Kumar *et al*. (2019) [27] in chickpea and Kanzaria *et al*. (2021) [24] in groundnut.

Nitrogen content (%)

The highest N-content in grain (4.23%) was recorded with 75% N of GRD and full dose of P, K+ *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 4.21, 4.18 and 4.17%, respectively. The similar synergistic effect of *rhizobium* inoculation with small dose of N fertilizer on nitrogen content in grain of pigeonpea was reported by Kaushik *et al*. (1993) [25].

The highest N-content (0.88%) in straw was recorded with 75% N of GRD and full dose of P, K+ *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full

dose of P, K + *Rhz*-3 (T_8) 0.85, 0.84 and 0.83%, respectively. The result is in agreement with the work of Talaat and Abdallah (2008) [46] who revealed that the *rhizobium* inoculation along with 75% of the recommended dose of N fertilizer positively enhanced N-content in the straw of faba bean.

Nitrogen uptake by grain and straw (kg ha^{-1})

The highest nitrogen uptake by grain 34.47 kg ha^{-1} was recorded with 75% N of GRD and full dose of P, K+ *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 32.88, 31.93 and 30.35 kg ha^{-1}, respectively. These results agreed with those of Tahir *et al*. (2009) [46], who mentioned the maximum increase in N uptake in seed of soybean due to combined effect of *rhizobium* inoculation and reduced level of N fertilizer.

The highest nitrogen uptake by straw (9.55 kg ha^{-1}) was recorded with 75% N of GRD and full dose of P, K+ *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 9.08, 8.66 and 8.21 kg ha^{-1}, respectively. Mondal *et al*. (2020) [28] demonstrated that the addition of *rhizobium* as a seed inoculation combined with nitrogen fertilizer resulted in higher N-uptake by straw of peanut. Similar findings were also reported by Sultana *et al*. (2014) [44] in soybean. Who stated that rhizobial strains along with 15 kg N ha^{-1} remarkably increased N uptake in straw of soybean.

Seed quality

Protein content (%)

The highest protein content (26.43%) in grain of horse gram was recorded with 75% N of GRD and full dose of P, K + *Rhz*-2 (T_7) which was at par with 100% GRD (T_5) followed by 75% N of GRD and full dose of P, K + *Rhz*-1 (T_6) and 75% N of GRD and full dose of P, K + *Rhz*-3 (T_8) 26.31, 26.12 and 26.06%, respectively. Similar findings were also reported by Talaat and Abdallah (2008) [46] and Singh *et al*. (2007) [38]. They reported appreciable increase in protein content of faba bean and cowpea due to the combined application of *rhizobium* inoculation and small N-fertilizer, respectively.

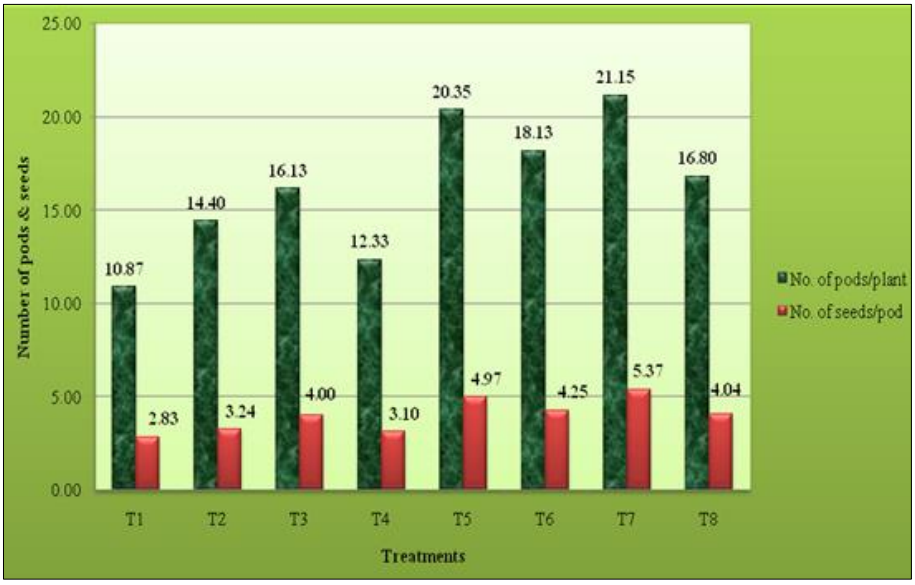

Fig 1: Influence of *Rhizobium* inoculation with various strains and nitrogen levels on number of pods plant^{-1} and seed pod^{-1} at harvest stage

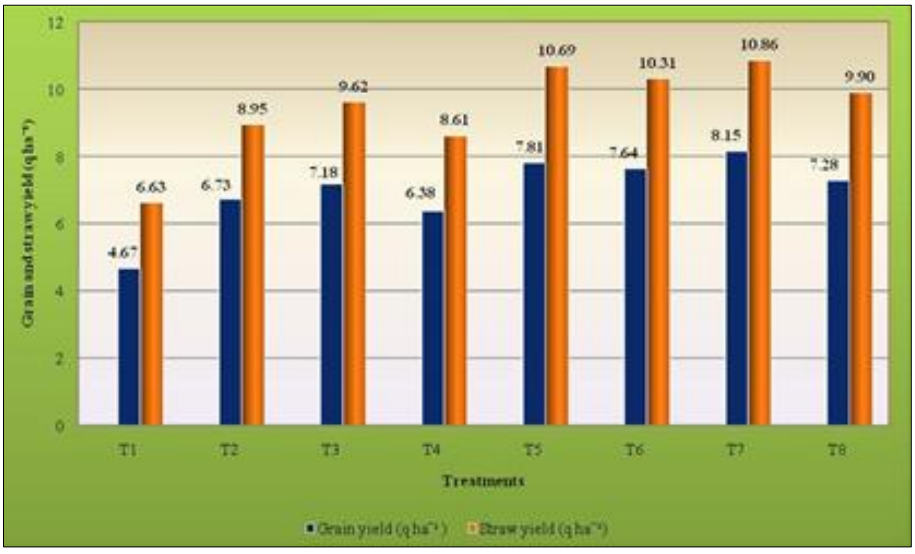

Fig 2: Influence of *Rhizobium* inoculation with various strains and nitrogen levels on grain and straw yield (q ha^{-1})

Table 2: Growth parameters per plant at 30, 45 and 60 days after sowing of horse gram

Treatments		Plant height (cm)			No. of branches (no.)			No. of nodules (no.)			Fresh wt. (g)			Dry wt. (g)		
		30	45	60	30	45	60	30	45	60	30	45	60	30	45	60
T_1	Control (No application of N and full dose of P, K)	16.87	37.85	58.35	2.92	4.39	5.87	4.04	7.63	9.57	2.35	11.55	23.21	0.61	2.74	5.34
T_2	50%N of GRD and full dose of P, K + *Rhizobium* strain-1	19.48	40.49	62.27	3.70	5.57	7.45	5.44	10.38	13.94	2.90	13.51	27.36	0.75	3.76	7.15
T_3	50%N of GRD and full dose of P, K + *Rhizobium* strain-2	20.68	41.74	63.54	3.91	5.89	7.88	6.12	11.00	14.68	3.10	14.38	29.45	0.80	4.17	7.95
T_4	50%N of GRD and full dose of P, K + *Rhizobium* strain-3	18.96	39.96	61.74	3.59	5.39	7.22	5.24	10.19	13.71	2.78	12.96	26.58	0.72	3.63	6.99
T_5	100% GRD (20:40:30 NPK kg ha^{-1})	23.37	44.25	66.50	4.57	6.90	9.20	7.40	13.11	16.69	3.65	15.63	34.41	0.94	4.72	9.02
T_6	75%N of GRD and full dose of P, K + *Rhizobium* strain-1	22.55	43.55	65.85	4.41	6.63	8.87	6.62	12.69	16.35	3.54	15.16	33.07	0.92	4.55	8.60
T_7	75% N of GRD and full dose of P, K + *Rhizobium* strain-2	24.00	45.05	67.45	4.67	7.02	9.41	7.89	13.76	17.41	3.80	16.22	35.61	0.98	5.03	9.56
T_8	75%N of GRD and full dose of P, K + *Rhizobium* strain-3	21.98	42.97	65.35	4.32	6.52	8.74	6.42	12.45	15.98	3.43	14.79	32.25	0.89	4.42	8.37
S.Em±		0.33	0.43	0.38	0.08	0.11	0.10	0.17	0.27	0.25	0.07	0.27	0.45	0.01	0.15	0.21
SE(d)		0.45	0.59	0.52	0.11	0.15	0.15	0.24	0.38	0.35	0.09	0.38	0.61	0.02	0.21	0.29
CD @ 5%		0.96	1.26	1.12	0.24	0.32	0.31	0.51	0.80	0.74	0.20	0.81	1.31	0.05	0.45	0.62

Table 3: Yield and yield attributes at harvest stage of horse gram

Treatments		At harvest			
		No. of pods $plant^{-1}$	No. of seeds pod^{-1}	Grain yield (q/ha)	Straw yield (q/ha)
T_1	Control (No application of N and full dose of P, K)	10.87	2.83	4.67	6.63
T_2	50%N of GRD and full dose of P, K + *Rhizobium* strain-1	14.40	3.24	6.73	8.95
T_3	50%N of GRD and full dose of P, K + *Rhizobium* strain-2	16.13	4.00	7.18	9.62
T_4	50%N of GRD and full dose of P, K + *Rhizobium* strain-3	12.33	3.10	6.38	8.61
T_5	100% GRD (20:40:30 NPK kg ha^{-1})	20.35	4.97	7.81	10.69
T_6	75%N of GRD and full dose of P, K + *Rhizobium* strain-1	18.13	4.25	7.64	10.31
T_7	75% N of GRD and full dose of P, K + *Rhizobium* strain-2	21.15	5.37	8.15	10.86
T_8	75%N of GRD and full dose of P, K + *Rhizobium* strain-3	16.80	4.04	7.28	9.90
S.Em±		0.73	0.26	0.15	0.17
SE(d)		1.00	0.37	0.21	0.24
CD @ 5%		2.15	0.78	0.44	0.52

Table 4: Nitrogen content, uptake, agronomical nitrogen use efficiency and protein content parameters of horse gram

Treatments		Garin		Straw		Total N uptake grain + straw (Kg/ha)	Agronomical nitrogen use efficiency (kg grain yield kg^{-1} applied N)	Protein content in grain (%)
		% N Content	N uptake (Kg/ha)	% N Content	N uptake (Kg/ha)			
T_1	Control (No application of N and full dose of P, K)	4.10	19.14	0.81	5.30	24.44	-	25.62
T_2	50%N of GRD and full dose of P, K + *Rhizobium* strain-1	4.14	27.86	0.82	7.33	35.19	20.6	25.87
T_3	50%N of GRD and full dose of P, K + *Rhizobium* strain-2	4.16	29.86	0.83	7.98	37.84	25.1	26
T_4	50%N of GRD and full dose of P, K + *Rhizobium* strain-3	4.12	26.28	0.81	6.97	33.25	17.1	25.75
T_5	100% GRD (20:40:30 NPK kg ha^{-1})	4.21	32.88	0.85	9.08	41.96	15.7	26.31
T_6	75%N of GRD and full dose of P, K + *Rhizobium* strain-1	4.18	31.93	0.84	8.66	40.59	19.8	26.12
T_7	75% N of GRD and full dose of P, K + *Rhizobium* strain-2	4.23	34.47	0.88	9.55	44.02	23.2	26.43
T_8	75%N of GRD and full dose of P, K + *Rhizobium* strain-3	4.17	30.35	0.83	8.21	38.56	17.4	26.06
S.Em±		0.11	0.58	0.02	0.21			0.11
SE(d)		0.16	1.12	0.04	0.29			0.15
CD @ 5%		0.34	1.69	0.08	0.63			0.33

Conclusion

1. Performance of horse gram in terms of plant height, number of branchs/plant, number of nodules/plant, fresh weight and dry weight at three growth stages i.e. at 30, 45 and 60 days after sowing indicated significantly better with treatment T_7 that received 75% N of GRD and full dose of P and K+ *Rhizobium* strain-2.
2. No. of pods/plant, no. of seeds/pod, grain and straw yields of horse gram per hectare responded better with treatment T_7 which received 75% N of GRD and full dose of P and K+ *Rhizobium* strain-2.
3. The N content and total N uptake by horse gram was significantly highest with T_7. Similarly, agronomic N use efficiency was highest where 50% N of GRD and full dose of P and K+ *Rhizobium* strain-2 was applied followed by 75% N of GRD and full dose of P and K+ *Rhizobium* strain-2.

Hence, it is concluded that combination of 75% N (15 kg ha^{-1}) and full dose of P_2O_5 (40 kg ha^{-1}), K_2O (30 kg ha^{-1}) + *rhizobium* strain-2 is the most effective for horse gram cultivation under field conditions of Northern hills zone of Chhattisgarh.

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