

Effect of Rhizobium and Phosphate Solubilizing Bacteria Inoculation on Growth and Yield Performance of *Lathyrus* (*Lathyrus sativus* L.) in Chhattisgarh Plains

Balram Sahu^{1*}, Anup Kumar Singh¹, Anand Kumar Chaubey²
and Ravindra Soni¹

¹Department of Agricultural Microbiology, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh), India.

²Department of Soil Science and Agricultural Chemistry, Banda University of Agriculture and Technology, Banda (Uttar Pradesh), India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors BS, AKC and AKS designed the study and analyzed the data. Authors AKS, AKC and RS finalized the draft and review the final draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The study was conducted at the College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidyalaya, Janjgir- Champa (Chhattisgarh), during the year 2017-18 Rabi Season to Study the Influence of *Rhizobium* and phosphate solubilizing bacteria on the performance of field-grown *Lathyrus* (*Lathyrus sativus* L.) under climatic conditions of Chhattisgarh plains. In the present investigation total of 8 treatments T₁.Control (No inoculum no fertilizer), T₂. Recommended Dose of Fertilizer RDF(N:P: K::20:40:20), T₃- Rhi.HG-25 (Std.) + PSB-H-27 (Std.), T₄ Rhi.HG-25 + Korba PSB-118, T₅. Rhi.L-3 *Lathyrus* + PSB-H-27, T₆ Rhi.L-3 *Lathyrus* + Korba PSB-118, T₇.Rhi.L-

*Corresponding author: E-mail: balramsahu919@gmail.com;

11 *Lathyrus* + PSB-H-27 , T₈ Rhi.L-11 *Lathyrus* + Korba PSB-118. Recommended Dose of Fertilizer (RDF) T₂ recorded maximum and significantly higher value of plant height over rest of the treatments at 45, 60 DAS and at maturity except T₇ (Rhi.L-11 *Lathyrus* + PSB-H-27) treatment which was statistically similar at maturity. A general perusal of the data of the fresh plant reveals that T₂ (Recommended Dose of Fertilizer, RDF) recorded the maximum and significantly higher value of fresh weight over the rest of the treatments at a later stage of crop growth i.e 60 DAS and at harvest. A critical perusal of the nodule count data revealed that treatment T₈ (Rhi.L-11 *Lathyrus*+ KorbaPSB-118) was found superior over all the treatments showing the superiority of combined use of local strains over other strains and RDF. In case of grain yield the maximum grain yield were observed in 1451.39 kg/ha due to application of T₈ (Rhi.L-11 *Lathyrus*+ KorbaPSB-118) followed by T₂ RDF 1415.28 kg/ha, T₄ (Rhi.HG-25 +KorbaPSB-118)1388.89 kg/ha, T₇ (Rhi.L-11 *Lathyrus*+ PSB-H-27)1344.44 kg/ha, T₆ (Rhi.L-3 *Lathyrus* , PSB-H-27)706.94 kg/ha, 12.77 kg/ha, T5 (Rhi.L-3 *Lathyrus*+ PSB-H-27) 1216.67 kg/ha, T3 (Rhi.HG-25 + PSB-H-27) 1219.94kg/ha. Maximum grain yield was observed due to the application of effective local strains of rhizobia and PSB which also enhanced the nodulation activity due to an increase in the available soil phosphorus. The maximum and significantly higher value of grain yield straw yield (1118.06 kg/ha) was observed due to treatment T8 (Rhi.L-11 *Lathyrus*+ Korba-PSB-118) which was statistically superior over all the treatments except T₂ RDF.

Keywords: *Lathyrus*; inoculation; rhizobium; RDF (Recommended Dose of Fertilizer); PSB (Phosphate Solubilizing Bacteria).

1. INTRODUCTION

The newly formed Chhattisgarh state is bigger than many states of the country. Their economy is mainly based on agriculture and Soil property are very rich in natural resources, despite the fact, people of the Chhattisgarh region has been under constant threat of poverty, unemployment, and hunger that often forced rural poor people, in particular, to leave their home to find a job elsewhere especially after every *Khari frice*.

Out of 135.00 lakh ha (1.35 lakh sq. km) area of Chhattisgarh, about 46.02 lakh hectares is under *Kharif* mostly with rice crop while about 18.00 lakh ha only under *rabi* crops. About 28.02 lakh ha area remains fallow during *rabi*. *Lathyrus* crop (*Lathyrus sativus* L.) is an important pulse provide bonus crop in rice belts of Central and Eastern part of India. The cultivated area of *Lathyrus* crop is more than 0.89 m ha out of this; nearly 0.61 m ha is situated in Chhattisgarh during *rabi* season representing the major *Lathyrus* belt in the country under rice-based relay cropping system. The main *Lathyrus* growing Districts of this region are Mungeli, Bilaspur, Durg, Rajnandgaon, and Raipur. This is a traditional crop known for its ability to little tolerate moisture stress and other production constraints. The annual production of *Lathyrus* 224.8 thousand tonnes with low productivity of 0.38 t ha⁻¹.

The proposed study aimed to increase *Lathyrus* productivity in Chhattisgarh. Hence, keeping in

view, the present investigation was planned with the following objectives to select effective of above combinations of acidity tolerant *Rhizobium* and PSB isolates for better biological nitrogen fixation and P solubilizing, respectively under low input and Eco-friendly technology for sustainable *Lathyrus* production. The soil temperature makes the adverse effect for at the time of summer season of Chhattisgarh region during 60 °C (air temperature reached up to 48 °C and air humidity drops up to 3 to 4 percent) destroying rhizobial population hence produce poor nodule and microbial population on the plant [1] and [2]. Raipur showed that 67.54 percent area of Raipur, Durg, Rajnandgaon, Bilaspur, and Raigarh districts of Chhattisgarh state do not have native *Rhizobium* of one or more than one legume crop [3].

Some studies have indicated an increase in the growth of plant and phosphorus uptake due to the use of PSB. Some bacteria belonging to genera *Bacillus*, *Serratia*, *Pseudomonas*, *Enterobacter*, etc., are reported to help of solubilizing the insoluble phosphatic compounds and plant easily uptake for our growth phase [4,5].

Nitrogen is the most important element to all life, although it's present in nearly 80% of the atmosphere. Nitrogen is one of the major elements in the soil that promote the growth and productivity of plants in many ecosystems. This is a result of the inability of the plant to directly utilize atmospheric nitrogen to meet their

biological requirement for this element. Biological nitrogen-fixing (BNF) root nodule bacterium i.e. *Rhizobium* is highly beneficial for enhancing the productivity of various legumes including pulses and oilseeds. The symbiotic relationships between specific soil micro-organisms and plants are the most significant contributor of BNF in most terrestrial ecosystems [6].

Peoples et al. [7] reported that symbiotic relationship with rhizobia is responsible for fixing, on average on a whole plant basis (shoots and nodulated roots), the equivalent of 30-40 kg of nitrogen (N). Consequently, factors that directly influence legume growth (e.g. water and nutrient availability, disease incidence, and pests) tend to be the main determinants of the amounts of N₂ fixed.

Phosphate Solubilizing Microorganisms (PSM) play a significant role for the plant they making phosphorus available to plants by favorable changes in soil reaction in the soil micro-environment leading to solubilization of inorganic phosphate sources. Some microorganisms associated with different plant rhizosphere can solubilize inorganic insoluble P salts. *Bacillus* and *Pseudomonas* are two important genera of soil microbes that promising activity of the phosphate solubilization process. [8].

James et al. [9] studied that the legume in the genera of some microbes associated with host-specific plants like *Pisum* and *Vicia* and *Lathyrus*. In the present study, the seedling of native rare and/or scarce species of *Lathyrus* and *Vicia* ("vetches") were grown in soil from their native environment (coastal, woodlands or high land) in other of the induced nodulation by "trapping" the indigenous Rlv *rhizobium*.

2. MATERIALS AND METHODS

Geographically, Janjgir-Champa district is situated in the north Mahanadi region and the center of Chhattisgarh and show location between 21°06 to 22°04 North latitude and 82°03 to 83°02 East longitude with an altitude of 294.4 meters above the mean sea level. The experiment was conducted at the College of Agriculture & Research Station, Janjgir-Champa, (C.G.). The experimental site's good facility was available for irrigation and drainage to grow the *Lathyrus* crop. The district experiences a hot and semi-humid climate. The annual temperature of the district varies between 8°C and 46°C.

Lathyrus cultivar Mahateowda (RLS 4595), developed through the pedigree method from a cross Ratan x JRL-II, was used for sowing after seed treatment with Bio-fertilizer (*Rhizobium* and PSB) @ 5g/kg of seed before sowing at the spacing of 30 x 10 cm and the treated seed was carefully covered by the soil. The required amount of N, P, and K was applied as basal dose at the time of sowing of the crop in the specific plot.

In the present investigation total of 8 treatments T₁ - (Control (No inoculum no fertilizer), T₂- Recommended Dose of Fertilizer RDF (N:P:K::20:40:20), T₃- Rhi.HG-25 (Std.) + PSB-H-27 (Std.), T₄ Rhi.HG-25 + Korba PSB-118, T₅ - Rhi.L-3 *Lathyrus* + PSB-H-27, T₆ Rhi.L-3 *Lathyrus* + Korba PSB-118, T₇- Rhi.L-11 *Lathyrus* + PSB-H-27 , T₈ Rhi.L-11 *Lathyrus* + Korba PSB-118. The observation of plant height was recorded randomly selected plant in each plot at an interval of 30, 60, and 90 days after sowing. At maturity, it is measured up to the tip of the panicle of the maternity shoot of the plants. To get dry matter production g plant⁻¹, five plants in each plot were carefully uprooted and fresh and dry weights were recorded after oven drying. The value of average dry weight g plant⁻¹ was worked out. Grain and straw yield was recorded on kg plot⁻¹ of the net plot after threshing, winnowing, and drying, which was converted into q ha⁻¹ by multiplying with the appropriate multiplication factor.

2.1 Statistical Analysis

The experiment was laid out in Randomized Block Design (RBD). The data obtained from various characters under study were analyzed by the method of analysis of variance as described by Gomez and Gomez (1984). The level of significance used in "F" test was given at 5 per cent. Critical difference (CD) values are given in the table at 5 percent level of significance, wherever the "F" test was significant at 5 percent level (Steel and Torrie, 1980).

$$(a) SEm = \sqrt{\frac{2EMS}{r}}$$

EMS= Mean square of error

$$(b) C.D. = SEm \times t_{0.05}(\text{error } df)$$

$$(c) C.V. (\%) = \frac{\sqrt{EMS}}{GM} \times 100$$

GM= General mean

3. RESULTS AND DISCUSSION

3.1 Plant Height

Data of plant height observed at four different growth stages of 30, 45, 60 DAS and harvest varied from 12.80 to 18.67, 18.63 to 30.77, 20.53 to 34.80, and 22.57 to 40.89 cm plant⁻¹, respectively (Table 1). At 30 DAS T₂ recorded the maximum and significantly higher value of plant height not only over control but also over T₃ and T₈ however, it was statically similar with rest treatments. Recommended Dose of Fertilizer (RDF) T₂ recorded maximum and significantly higher value of plant height over rest of the treatments at 45, 60 DAS and at maturity except T₇ (*Rhi.L-11 Lathyrus* ** + PSB-H-27*) treatment which was statistically similar at maturity. An overall Perusal of the plant height observation showed that Recommended Dose of Fertilizer (RDF) T₂ performed well as compared to other treatments.

3.1.1 Shoot biomass accumulation study

Inoculation of the Rhizobium and phosphate solubilizing bacteria significantly increased the fresh and dry weight of the plant at 45, 60 DAS and harvest. A general perusal of the data of the fresh plant reveals that T₂ (Recommended Dose of Fertilizer, RDF) recorded the maximum and significantly higher value of fresh weight not only over control but also over the rest of the treatments at a later stage of crop growth i.e. 60 DAS and harvest. T₂ also recorded the maximum and significantly higher value of fresh weight not only over control but also over the rest of the treatments at early crop growth stages but it was statically similar with T₄ and T₇ treatments at 30 DAS and with T₆, T₇ & T₈ at 45 DAS. As for as dry weight is concerned T₂ recorded the maximum and significantly higher value of fresh weight not only over control but also over the rest of the treatments at all the stages of crop growth i.e. 30, 45, 60 DAS and at harvest except T₇ treatment at 30 DAS. This finding was supported by the Bhuiyan et al. [10] of *Lathyrus* dry matter was increased due to inoculation of *Rhizobium* strain bearing the root strain was over-powerful to the atmospheric nitrogen as compared to the national check.

3.1.2 Number of nodules at different stages of crop growth

The data pertaining to the number of nodules per plant (Table 3) varied from 2.33 to 7.67, 4.67 to

12.67, and 5.0 to 13.0 at 30, 45, and 60 days after sowing, respectively. All the treatments were capable to enhance the nodule count over control in a significant fashion. A critical perusal of the nodule count data revealed that treatment T₈ (*Rhi.L-11 Lathyrus*+ KorbaPSB-118) was found superior over all the treatments showing the superiority of combined use of local strains over other strains and RDF. Maximum nodulation was observed due to the application of effective local strains and PSB which also enhanced the nodulation activity due to an increase in the available soil phosphorus and secretion of organic acids. A similar finding was observed by Mallik et al. [11] and Bhuiyan et al. [10] The *Rhizobium* bacteria are play important role in the symbiotic nodulation process and enhance the capacity to fix atmospheric N₂ for the present as well as future crop Shubhojit Das et al. [12].

3.1.3 Nodulation

The data pertaining to a number of the pod, grain yield, and straw yield (kg/ha) of *Lathyrus* crop under field condition varied from 5.47 to 11.60, 706.94 to 1451.39, and 522.22 to 1118.06, respectively (Table 4). The number of Pod per plant increased significantly as compared to all treatments. The number of Pod plant was increased significantly from 5.47 per plant (control) to 11.60, 11.50, 11.47, 11.00, 10.87, 8.60, and 8.53 per plant due to treatment T₈, T₂, T₄, T₃, T₇, T₆, and T₅, respectively.

3.2 Grain and Straw Yield

In case of grain yield the maximum grain yield were observed in 1451.39 kg/ha due to application of T₈ (*Rhi.L-11 Lathyrus*** + KorbaPSB-118**) followed by T₂ RDF 1415.28 kg/ha, T₄ (*Rhi.HG-25**+KorbaPSB-118**) 1388.89, T₇ (*Rhi.L-11 Lathyrus*** + PSB-H-27*) 1344.44 kg/ha, T₆ (*Rhi.L-3 Lathyrus*** + PSB-H-27**) 706.94 kg/ha, 12.77 kg/ha, T₅ (*Rhi.L-3 Lathyrus*** + PSB-H-27*) 1216.67 kg/ha, T₃ (*Rhi.HG-25** + PSB-H-27*) 1219.94 kg/ha. Maximum grain yield was observed due to the application of effective local strains of rhizobia and PSB which also enhanced the nodulation activity due to an increase in the available soil phosphorus. A similar finding was observed by Mallik et al. [11] and Bhuiyan et al. [10].

The maximum and significantly higher value of straw yield (1118.06 kg/ha) was observed due to treatment T₈ (*Rhi.L-11 Lathyrus***+ Korba-PSB-118**) which was statistically superior over all the treatments except T₂ RDF. Hoque and Sattar

[13] showed yield increments in their trials by using *Rhizobium spp.*, Phosphate Solubilizing Microorganism, and VAM in pulse crops including *Lathyrus* Anil et al. [14].

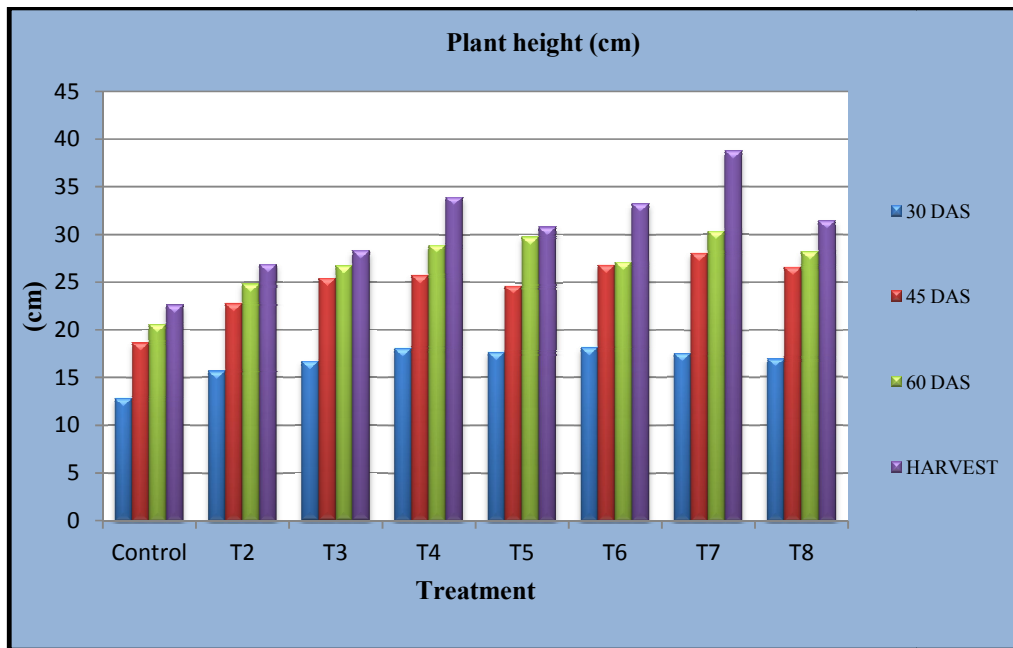


Fig. 1. Plant height at different stages of *Lathyrus*

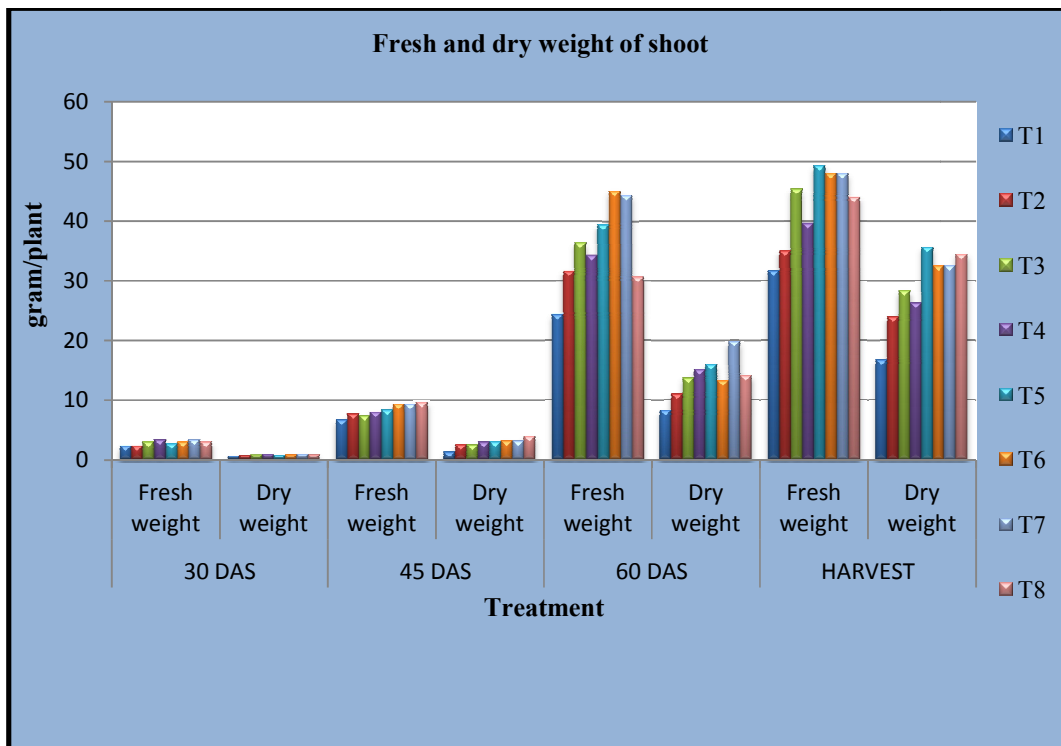


Fig. 2. Fresh and Dry weight of *Lathyrus*

Table 1. Response of *Rhizobium* and PSB inoculants in plant height (cm plant⁻¹) at different stages of crop growth of *Lathyrus* under field condition

Treatments	Plant height (cm plant ⁻¹) at different crop growth stages			
	30 DAS	45 DAS	60 DAS	HARVEST
T ₁ : Control	12.80	18.63	20.53	22.57
T ₂ : Recommended Dose of Fertilizer (RDF)	18.67	30.77	34.80	40.89
T ₃ : Rhi.HG-25* +PSB-H-27 *	16.67	25.40	26.70	28.33
T ₄ : Rhi.HG-25* +Korba PSB-118**	18.03	25.67	28.87	33.89
T ₅ : Rhi.L-3 <i>Lathyrus</i> ** + PSB-H-27 *	17.63	24.57	29.73	30.78
T ₆ : Rhi.L-3 <i>Lathyrus</i> ** + Korba PSB-118**	18.13	26.80	27.10	33.22
T ₇ : Rhi.L-11 <i>Lathyrus</i> ** + PSB-H-27*	17.50	28.03	30.33	38.78
T ₈ : Rhi.L-11 <i>Lathyrus</i> **+ KorbaPSB-118 **	16.97	26.57	28.17	31.45
C.D.	1.44	2.18	2.35	2.78
C.V.	9.71	9.88	9.74	10.15

*Standard strain **Local strain

Table 2. Response of *Rhizobium* and PSB inoculants in fresh and dry weight in a gram of plant at different stages of crop growth of *Lathyrus* under field condition

Treatments	30 DAS (g plant ⁻¹)		45 DAS (g plant ⁻¹)		60 DAS (g plant ⁻¹)		HARVEST (g plant ⁻¹)	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
T ₁ : Control	2.33	0.64	6.67	1.28	24.33	8.28	31.67	16.73
T ₂ : Recommended Dose of Fertilizer (RDF)	3.43	0.95	10.17	4.24	51.67	23.99	65.00	42.94
T ₃ : Rhi.HG-25* +PSB-H-27 *	3.00	0.82	7.33	2.47	36.33	13.70	45.33	28.32
T ₄ : Rhi.HG-25* + Korba PSB-118**	3.33	0.88	8.00	2.94	34.33	15.09	39.67	26.26
T ₅ :Rhi.L-3 <i>Lathyrus</i> ** + PSB-H-27 *	2.67	0.73	8.33	3.00	39.33	15.98	44.00	34.49
T ₆ :Rhi.L-3 <i>Lathyrus</i> ** + Korba PSB-118**	3.00	0.84	9.33	3.16	45.00	13.25	48.00	32.48
T ₇ :Rhi.L-11 <i>Lathyrus</i> ** + PSB-H-27*	3.33	0.91	9.67	3.13	44.33	19.83	48.00	32.50
T ₈ :Rhi.L-11 <i>Lathyrus</i> ** + KorbaPSB-118 **	3.00	0.84	9.67	3.93	30.67	14.10	49.00	35.26
C.D.	0.40	0.068	0.56	0.24	3.08	1.39	4.51	3.12
C.V.	15.59	9.65	7.61	9.90	9.68	11.23	11.87	12.17

*Standard strain, **Local strain

Table 3. Response of *Rhizobium* and PSB inoculants in number of nodules plant⁻¹ at different stages of crop growth of *Lathyrus* under field condition

No. Of nodule per plant at	30 DAS	45 DAS	60 DAS
Treatment			
T ₁ : Control	2.33	4.67	5.00
T ₂ : Recommended Dose of Fertilizer (RDF)	4.67	6.33	7.33
T ₃ : Rhi.HG-25* +PSB-H-27 *	6.33	7.67	10.67
T ₄ : Rhi.HG-25* +Korba PSB-118**	6.67	8.67	11.33
T ₅ : Rhi.L-3 <i>Lathyrus</i> ** + PSB-H-27 *	5.00	10.33	11.33
T ₆ : Rhi.L-3 <i>Lathyrus</i> ** + Korba PSB-118**	5.67	8.00	10.33
T ₇ : Rhi.L-11 <i>Lathyrus</i> ** + PSB-H-27*	5.00	11.67	11.33
T ₈ : Rhi.L-11 <i>Lathyrus</i> **+ KorbaPSB-118 **	7.67	12.67	13.00
C.D.	0.69	0.71	1.12
C.V.	14.31	9.12	12.60

*Standard strain, **Local strain

Table 4. Response of *Rhizobium* and PSB inoculants in number of the pod, grain yield and straw yield of *Lathyrus* crops under field condition

Treatment	No. of pod plant ⁻¹	Grain yield kg/ ha	Straw yield kg / ha
T ₁ : Control	5.47	706.94	522.22
T ₂ : Recommended Dose of Fertilizer (RDF)	8.27	1415.28	1087.50
T ₃ : Rhi.HG-25* +PSB-H-27 *	11.00	1219.44	951.39
T ₄ : Rhi.HG-25* +Korba PSB-118**	11.47	1388.89	884.72
T ₅ : Rhi.L-3 <i>Lathyrus</i> ** + PSB-H-27 *	8.53	1266.67	825.00
T ₆ : Rhi.L-3 <i>Lathyrus</i> ** + Korba PSB-118**	8.60	1277.78	861.11
T ₇ : Rhi.L-11 <i>Lathyrus</i> ** + PSB-H-27*	10.87	1344.44	1062.50
T ₈ : Rhi.L-11 <i>Lathyrus</i> **+ KorbaPSB-118 **	11.60	1451.39	1118.06
C.D.	1.45	153.42	74.28
C.V.	17.26	13.68	9.31

*Standard strain, **Local strain

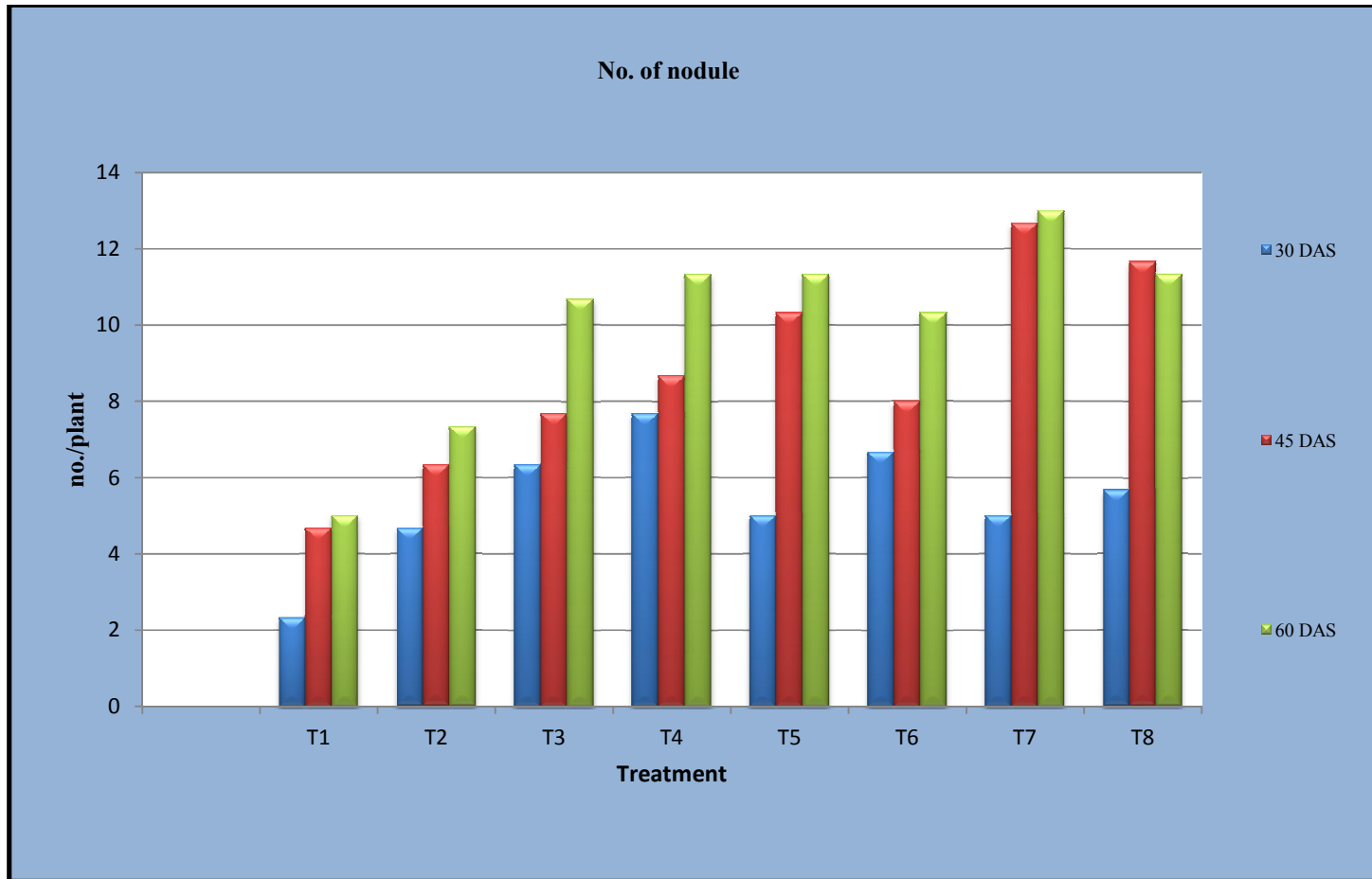


Fig. 3. No. of nodule at difference stage of *Lathyrus*

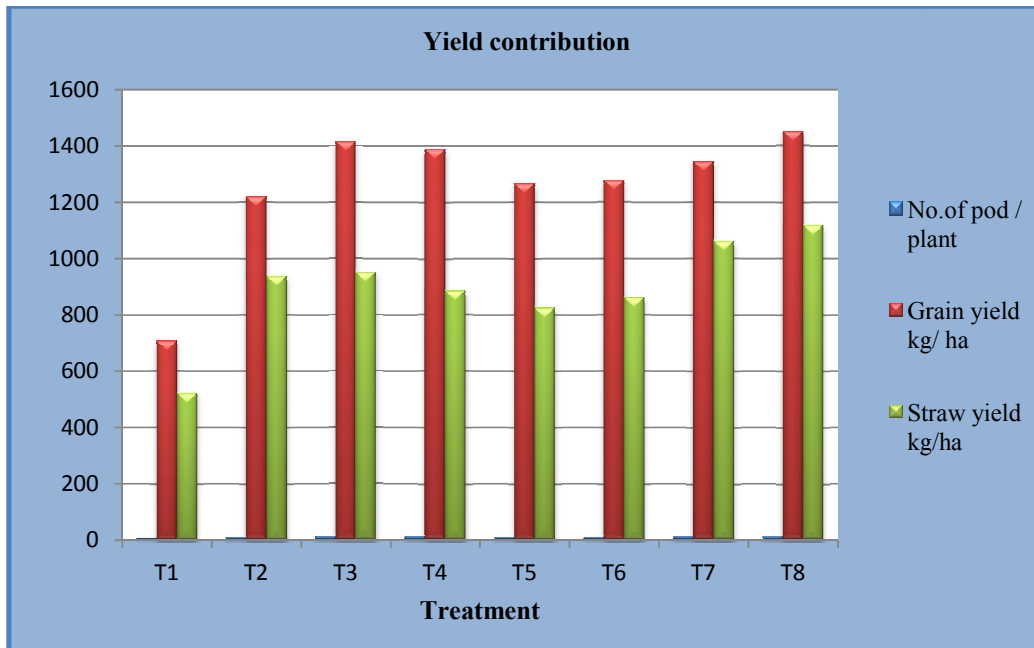


Fig. 4. No. of pod, grain yield and straw yield of *Lathyrus*

4. CONCLUSION

Recommended Dose of Fertilizer (RDF) T₂ recorded maximum and significantly higher value of plant height over rest of the treatments at 45, 60 DAS and at maturity except T₇ (*Rhi.L-11 Lathyrus* + PSB-H-27) treatment which was statistically similar at maturity. Inoculation of the Rhizobium and phosphate solubilizing bacteria significantly increased the fresh and dry weight of the plant at 45, 60 DAS and harvest. A general perusal of the data of the fresh of the plant reveals that T₂ (Recommended Dose of Fertilizer, RDF) recorded the maximum and significantly higher value of fresh weight over the rest of the treatments at a later stage of crop growth i.e. 60 DAS and at harvest, however, T₂ was statically similar with T₄ and T₇ treatments at 30 DAS and with T₆, T₇ & T₈ at 45 DAS. As for as dry weight is concerned T₂ recorded the maximum and significantly higher value of fresh weight not only over control but also over the rest of the treatments at all the stages of crop growth i.e. 30, 45, 60 DAS and at harvest except T₇ treatment at 30 DAS. The data about the number of nodules per plant varied from 2.33 to 7.67, 4.67 to 12.67, and 5.0 to 13.0 at 30, 45, and 60 days after sowing, respectively. A critical perusal of the nodule count data revealed that treatment T₈ was found superior over all the treatments showing the superiority of combined use of local strains over other strains and RDF. The

maximum grain yield was observed in 1451.39 kg/ha due to the application of T₈ followed by T₂ RDF 1415.28kg/ha, Maximum grain yield was observed due to the application of effective local strains of rhizobia and PSB which also enhanced the nodulation activity due to an increase in the available soil phosphorus. The maximum and significantly higher value of grain yield straw yield (1118.06 kg/ha) was observed due to treatment T₈ (*Rhi.L-11 Lathyrus* + Korba-PSB-118) which was statistically superior over all the treatments except T₂ RDF.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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