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Effect of phosphate solubilizing bacteria on growth and yield of chickpea in calcareous soil

SD Gaikwad, PA Bhosale and Dr. SS Chandanshive

Abstract
A field experiment was conducted during the winter (*Rabi*) seasons of 2019 at field of Plant Pathology section, College of Agriculture, Pune to study the **"**Effect of Phosphate solubilizing bacteria on growth and yield of chickpea in calcareous soil." (*Cicer arietinum*). The experiment was laid out in randomized block design with eight treatments and three replications. Results revealed that the treatment T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium* was statistically superior among all other treatments with respect to growth and yield parameters such as germination %, plant height, no. of effective nodules per plant, dry matter weight (g), no. of pods/plant, 1000 seed weight, yield/plot (g) and (qt/ha) of chickpea over control. The uptake of N and P by chickpea improved significantly with seed treatment with MPKV PSB + MPKV *Rhizobium*. Inoculations with *Pseudomonas fluorescence* alone also improved the growth and yield of chickpea over control.

Keywords: PSB, *Rhizobium, Pseudomonas fluorescence,* Nutrient uptake, Calcareous soil, Chickpea

Introduction
Chickpea (*Cicer arietinum* L.) occupies an important position among the leguminous crop, due to its nutritive values (17-23% protein) in large vegetarian population of the country (Ali and Kumar, 2006) [2]. Grown principally for its protein rich edible seeds, this crop can be used for both seeds and forage production. It is an excellent animal feed and its straw has good forage value (Prasad 2012) [10]. In addition to proteins, it is a good source of carbohydrates (52-70%), Fat (4-10%), minerals (calcium, phosphorus, iron etc.) vitamins and trace elements. It is an important cool season pulse crop and it is also called Bengal gram.
In terms of pulse production, India contributes about 25% to the total global pulses production. In India, per capita net availability of pulses is 56 g /day (Anonymous 2019) although the World Health Organization (WHO) recommends at least 80 g/capita. The productivity of chickpea depends on the availability of nutrients for the crop of the major essential macro nutrients phosphorous occupies the second place, which is required for the growth and development of plants. It has been renowned fact that legume require more phosphorus as compared to non legume as they have characteristic property to fix atmospheric nitrogen up to 140 kg N /ha from air.
Phosphorus is the main limiting input for chickpea (*Cicer arietinum* L.,) without which higher production is impossible. Phosphate fertilization of chickpea has been known to promote growth and increase yield (Prasad and Sonoria, 1981) [9]. But after application, a considerable amount of P is rapidly transformed into less available forms by forming a complex with Fe and Al in acid soils or Ca in calcareous soils before plant roots have a chance to absorb it (Alam and Ladha, 2004) [1].
In calcareous soil, the solubility of phosphorus is depressed which results in the decrease of P availability. Phosphorus is often lacking in calcareous soil. Under such a situation phosphate solubilizing microorganisms play an important role in making P available to the plants which increase the yield of crop plants. The approach/hypothesis of using microbes for better plant growth in calcareous soil was tested on Chickpea plant which is very sensitive to calcareous soil.

Materials and Methods
The present field experiment was carried out at Plant Pathology Research Farm, College of Agriculture, Pune. The experiment was laid out in randomized block design with three replications and eight treatments.

Experiment design

1. Season : *Rabi*, 2019
2. Crop : Chickpea
3. Variety : *Digvijay*
4. Spacing : 30 cm X 10 cm
5. RDF : 25: 50: 30 kg NPK/ha

Treatment Details

The chickpea seeds were treated before sowing as follows:
T1: Seed treatments with PSB isolate 1 (*Pseudomonas fluorescence*)
T2: Seed treatments with PSB isolate 2 (*Bacillus subtilis*)
T3: Seed treatments with PSB isolate 3 (*Bacillus thuringienesis*)
T4: Seed treatments with PSB isolate 4 (*Pseudomonas aeruginosa*)
T5: Seed treatment with MPKV PSB strain.
T6: Seed treatment with MPKV *Rhizobium* strain.
T7: Seed treatment with MPKV PSB strain + MPKV *Rhizobium* strain.
T8: Absolute control

Observations

The observations on growth parameters like germination (%), plant height (cm), dry weight of plant(g), number of effective nodules and yield parameters like number of pods per plant, 1000 seed weight(g), seed yield per plot (g) and seed yield (q ha-1). N and P uptake (kg ha-1) of chickpea were recorded. Nitrogen and Phosphorus uptake of plant was estimated by following Modified Kjeldahl's process and Colorimetric method respectively suggested by Jackson (1973) [6]. Initial microbial count for total PSB and *Rhizobium* was estimated from soil before sowing and after harvest of crop as per the irrespective of each treatment suggested by Skinner *et al*., 1952 [13].

Results and Discussion

The results obtained in the investigations are presented below.

Effect of Phosphate solubilizing bacteria on growth parameters of chickpea in calcareous soil.

Germination (%) of chickpea

The results in respect of germination of chickpea as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 1. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium*, recorded significantly highest germination (94.73%), followed by T_1 *i:e* Seed treatment with PSB isolate 1 (91.05%). The minimum germination percentage was noticed in T_8 *i:e* absolute control plot. (78.66%) Among other treatments, T_1 *i:e* Seed treatment with PSB isolate 1 (91.05%) followed by T_5 *i:e* seed treatment with MPKV PSB strain (87.45%), T_6 *i:e* seed treatment with MPKV *Rhizobium* strain (84.47 %). T_4 *i:e* seed treatment with PSB isolate 4 (82.65%) and T_2 *i:e* seed treatment with PSB isolate 2 (82.37 %) was found statistically at par and T_2 *i:e* seed treatment with PSB isolate 2 (82.37 %) and T_3 *i:e* seed treatment with PSB isolate 3 (80.78%) was found statistically at par with each other. Results of the present investigations are in agreement with results of Rudresh (2004) [11] who obtained increased germination of chickpea due to seed inoculation with *Rhizobium* and phosphate solubilizing *Bacillus megatherium* in comparison with control under glasshouse and field conditions.

Table 1: Effect of phosphate solubilizing bacteria on germination (%) of chickpea in calcareous soil.

Sr. No.	Treatment details	Germination%
T1	Seed treatment with PSB isolate 1	91.05
T2	Seed treatment with PSB isolate 2	82.37
T3	Seed treatment with PSB isolate 3	80.78
T4	Seed treatment with PSB isolate 4	82.65
T5	Seed treatment with MPKV PSB strain	87.45
T6	Seed treatment with MPKV *Rhizobium* strain	84.47
T7	Seed treatment with MPKV PSB + MPKV *Rhizobium* strain	94.73
T8	Absolute control	78.66
	SE±	0.581
	CD at 5%	1.77

Plant height (cm) of chickpea at 30, 45 and 60 DAS

The results in respect of plant height (cm) of chickpea as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 2.

Table 2: Effect of phosphate solubilizing bacteria on plant height (cm) of chickpea at 30, 45 and 60 DAS in calcareous soil.

Sr. No.	Treatment Details	Plant height (cm)		
		30 DAS	45 DAS	60 DAS
T1	Seed treatment with PSB isolate 1	38.23	42.27	53.07
T2	Seed treatment with PSB isolate 2	26.78	33.1	44.61
T3	Seed treatment with PSB isolate 3	24.33	32.54	44.03
T4	Seed treatment with PSB isolate 4	27.87	34.7	46.36
T5	Seed treatment with MPKV PSB strain	34.67	39.42	50.9
T6	Seed treatment with MPKV *Rhizobium* strain	30.97	37	48.82
T7	Seed treatment with MPKV PSB strain + MPKV *Rhizobium* strain	41.88	45.29	55.39
T8	Absolute control	21.82	30.55	41.07
	SE±	0.808	0.638	0.666
	CD at 5%	2.47	1.95	2.03

Plant height at 30DAS

Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium*, was found to be the most effective as it recorded significantly highest plant height at 30 DAS (41.88cm), followed by T_1 *i:e* seed treatment with PSB isolate 1 recorded height at 30 DAS (38.23cm). The lowest plant height recorded in T_8 *i:e* absolute control plot (21.82cm). Among other treatments, T_1 *i:e* Seed treatment with PSB isolate 1 (38.23cm), followed by T_5 *i:e* seed treatment with MPKV PSB strain (34.67cm), T6 *i:e* seed treatment with MPKV *Rhizobium* strain (30.97cm). T_4 *i:e* seed treatment with PSB isolate 4 (27.87cm) and T_2 *i:e* seed treatment with PSB isolate 2 (26.78cm) are statistically at par and significant to T_3 *i:e* seed treatment with PSB isolate 3 (24.33cm).

Plant height at 45 DAS

Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium*, was found to be the most effective as it recorded significantly highest plant height at 45 DAS (45.29 cm), followed by T_1 *i:e* seed treatment with PSB isolate 1 (42.27cm). The lowest plant height recorded in T_8 *i:e* absolute control plot (30.55 cm). Among other treatments, T_1 *i:e* Seed treatment with PSB isolate 1 (42.27cm), followed by T_5 *i:e* seed treatment with MPKV PSB strain (39.42cm), T_6 *i:e* seed treatment with MPKV *Rhizobium* strain (37cm). T_4 *i:e* seed treatment with PSB isolate 4 (34.7cm) and T_2 *i:e* seed treatment with PSB isolate 2 (33.1cm) are statistically at par with each other. T_2 *i:e* seed treatment with PSB isolate 2 (33.1cm) and T_3 *i:e* seed treatment with PSB isolate 3 (32.54cm) was found at par with each other.

Plant height at 60 DAS

Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium*, was found to be the most effective as it recorded significantly highest plant height at 60 DAS (55.39cm), followed by T_1 i.e. *i:e* seed treatment with PSB isolate 1 (53.07cm). The lowest plant height recorded in T_8 *i:e* absolute control plot. (41.07 cm). Among other treatments, T_1 *i:e* Seed treatment with PSB isolate 1 (53.07cm), followed by T_5 *i:e* seed treatment with MPKV PSB strain (50.9cm), T_6 *i:e* seed treatment with MPKV *Rhizobium* strain (48.82cm). T_4 *i:e* seed treatment with PSB isolate 4 (46.36cm) and T_2 *i:e* seed treatment with PSB isolate 2 (44.61cm) are statistically at par with each other. T_2 *i:e* seed treatment with PSB isolate 2 (44.61cm) and T_3 *i:e* seed treatment with PSB isolate 3 (44.03cm) was found at par with each other.

Results of the present investigations are in conformity with those of Dakshsyini *et al.*, (2016) who reported increase the plant height in chickpea due to inoculation with efficient PSB isolates. Moreover, Shete *et al.* (2019) [12] who reported increased plant height in different legume crops due to seed inoculation of *Rhizobium*, PGPR and PSB alone or in combination.

Number of effective nodules/plant

The results in respect of number of effective nodules/plant of chickpea as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 3. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium*, was found to be the most effective as it recorded significantly highest number of nodules (34.53 plant^{-1}), followed by T_6 *i:e* seed treatment with MPKV *Rhizobium* (30.90 plant^{-1}), T1 *i:e* PSB isolate 1 (27.17 plant^{-1}). The lowest no. of effective nodule observed in T_8 *i:e* absolute control plot (14.20 plant^{-1}) Among other treatment T_5 *i:e* seed treatment with MPKV PSB strain (23.57 plant^{-1}) and T_4 *i:e* seed treatment with PSB isolate 4 (20.13 plant^{-1}) are statistically at par with each other. T_2 i.e. seed treatment with PSB isolate 2 (18.93 plant^{-1}) and T_3 *i:e* seed treatment with PSB isolate 3 (17.87 plant^{-1}) are at par with each other.

These results are in agreement with Shete *et al.* (2019) [12] reported that seed inoculation of green gram with consortia of MPKV *Rhizobium*, PSB and KMB + 75% RDF significantly increase the number of nodules/plant (41.50) and found at par with 100% RDF.

Table 3: Effect of phosphate solubilizing bacteria on number of effective nodules/plant of chickpea in calcareous soil.

Sr. No.	Treatment details	No. of effective nodules / Plant
T1	Seed treatment with PSB isolate 1	27.17
T2	Seed treatment with PSB isolate 2	18.93
T3	Seed treatment with PSB isolate 3	17.87
T4	Seed treatment with PSB isolate 4	20.13
T5	Seed treatment with MPKV PSB strain	23.57
T6	Seed treatment with MPKV *Rhizobium* strain	30.90
T7	Seed treatment with MPKV PSB + MPKV *Rhizobium* strain	34.53
T8	Absolute control	14.20
	SE±	3.62
	CD at 5%	1.18

Dry weight of chickpea plant

The results in respect of number of effective nodules/plant of chickpea as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 4. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium*, was found to be the most effective as it recorded significantly highest dry weight of plant after harvest (36.55 gm plant^{-1}) of the crop, followed by T_1 *i:e* seed treatment with PSB isolate 1 (32.9 gm plant^{-1}). The lowest dry weight of plant after harvest (11.77gm plant^{-1}) was noticed in T_8 *i:e* absolute control plot. However T_6 *i:e* seed treatment with MPKV *Rhizobium* strain (29.59 gm plant^{-1}) was found at par with T_1 *i:e* seed treatment with PSB isolate 1 (32.29 gm plant^{-1}). T_2 *i:e* seed treatment with PSB isolate 2 (16.13 gm plant^{-1}) and T_3 *i:e* seed treatment with PSB isolate 3 (16.03 gm plant^{-1}) are statistically at par with each other. These results are in agreement with Dakshayini *et al.*, (2016) [5] reported that significantly increase in dry matter weight of chickpea plant due to inoculation of *Rhizobium* and efficient PSB isolates over uninoculated control.

Table 4: Effect of phosphate solubilizing bacteria on dry matter weight (g) of chickpea plant in calcareous soil.

Sr. No.	Treatment details	Dry matter weight (g)/ plant
T1	Seed treatment with PSB isolate 1	32.29
T2	Seed treatment with PSB isolate 2	16.13
T3	Seed treatment with PSB isolate 3	16.03
T4	Seed treatment with PSB isolate 4	20.00
T5	Seed treatment with MPKV PSB strain	28.13
T6	Seed treatment with MPKV *Rhizobium* strain	29.59
T7	Seed treatment with MPKV PSB + MPKV *Rhizobium* strain	36.55
T8	Absolute control	11.77
	SE±	3.59
	CD at 5%	1.17

Effect of Phosphate solubilizing bacteria on yield parameters of chickpea in calcareous soil

Number of pods/plant

The results in respect of number of pods/plant of chickpea as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 5. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium* was found to be the most effective as it recorded significantly highest number of pods (91.46 plant^{-1}), followed by T_1 *i:e* seed treatment with PSB isolate 1 recorded number of pods (88. 02 plant^{-1}). The lowest number of pods (71.14 plant^{-1}) was noticed in T_8 *i:e* absolute control plot. Among other treatments, T_5 *i:e* seed treatment with MPKV PSB strain (84.20 plant^{-1}) followed by T_6 *i:e* seed treatment with MPKV *Rhizobium* strain (80.88 plant^{-1}). T_4 *i:e* seed treatment with PSB isolate 4 (77.97 plant^{-1}) and T_2 *i:e* seed treatment with PSB isolate 2 (77.09 plant^{-1}) are statistically at par with each other, and T_2 *i:e* seed treatment with PSB isolate 2 (77.09 plant^{-1}) and T_3 *i:e* seed treatment with PSB isolate 3 (75.10 plant^{-1}) was found statistically at par. These results are in agreement with Dakshayani *et al.*, (2016) [5] reported that inoculation with *Rhizobium* and PSB significantly increases no. of pod per plant, and biomass in chickpea over uninoculated control.

Table 5: Effect of phosphate solubilizing bacteria on number of pods/plant of chickpea in calcareous soil.

Sr. No.	Treatment details	No. of pods plant $^{-1}$
T1	Seed treatment with PSB isolate 1	88.02
T2	Seed treatment with PSB isolate 2	77.09
T3	Seed treatment with PSB isolate 3	75.10
T4	Seed treatment with PSB isolate 4	77.97
T5	Seed treatment with MPKV PSB strain	84.20
T6	Seed treatment with MPKV *Rhizobium* strain	80.88
T7	Seed treatment with MPKV PSB + MPKV *Rhizobium* strain	91.46
T8	Absolute control	71.14
	SE$\pm$	2.39
	CD at 5%	0.78

1000 seed weight

The results in respect of 1000 seed weight (g) of chickpea as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 6. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium* was found to be the most effective as it recorded significantly highest 1000 seed weight (242.98 g), followed by T_1 *i:e* seed treatment with PSB isolate 1 (225.81 g). The lowest 1000 seed weight (149.39 g) was noticed in T_8 *i:e* absolute control plot. Among other treatments, T_5 *i:e* seed treatment with MPKV PSB strain (208.64 g) followed by T_6 *i:e* seed treatment with MPKV *Rhizobium* (192.21 g). T_4 *i:e* seed treatment with PSB isolate 4 (175.03 g) and T_2 *i:e* seed treatment with PSB isolate 2 (163.77 g) are statistically at par and T_2 *i:e* seed treatment with PSB isolate 2 (163.77g) and T_3 *i:e* seed treatment with PSB isolate 3 (161.16 g) are at par with each other. These results are in agreement Shete *et al.* (2019) [12] reported that seed inoculation of green gram with consortia of MPKV *Rhizobium*, PSB and KMB + 75% RDF significantly increase the 1000 seed weight and found at par with 100% RDF.

Table 6: Effect of phosphate solubilizing bacteria on 1000 seed weight (g) of chickpea in calcareous soil.

Sr. No.	Treatment details	1000 seed weight (g)
T1	Seed treatment with PSB isolate 1	225.81
T2	Seed treatment with PSB isolate 2	163.77
T3	Seed treatment with PSB isolate 3	161.16
T4	Seed treatment with PSB isolate 4	175.03
T5	Seed treatment with MPKV PSB strain	208.64
T6	Seed treatment with MPKV *Rhizobium* strain	192.21
T7	Seed treatment with MPKV PSB + MPKV *Rhizobium* strain	242.98
T8	Absolute control	149.39
	SE$\pm$	3.86
	CD at 5%	11.82

Seed yield (g/plot) and yield (qt/ha)

The results in respect of seed yield (g/plot) and yield (qt/ha) of chickpea as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 7. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium* was found to be the most effective as it recorded significantly highest seed yield (725.52 g plot^{-1}), as converted to per ha basis recorded yield obtained (20.09 qt ha^{-1}), followed by T_1 *i:e* seed treatment with PSB isolate 1 recorded seed yield (686.23 g plot^{-1}), (19.01 qt ha^{-1}). The lowest seed yield was noticed in T_8 *i:e* absolute control plot. (490.75 g plot^{-1}) (13.59 qt ha^{-1}) Among other treatments, T_5 *i:e* seed treatment with MPKV PSB strain (635.27 g plot^{-1}), (17.59 qt ha^{-1}) followed by T_6 *i:e* seed treatment with MPKV *Rhizobium* strain (587.04 g plot^{-1}), (16.23 qt ha^{-1}). T_4 *i:e* seed treatment with PSB isolate 4 (542.50 g plot^{-1}), (15.02 qt ha^{-1}), T_2 *i:e* seed treatment with PSB isolate 2 (522.15 g plot^{-1}), (14.45 qt ha^{-1}) and T_3 *i:e* seed treatment with PSB isolate 3 (530.34 g plot^{-1}), (14.69 qt ha^{-1}) are statistically at par with each other. These results are in agreement with Yadav and Singh (2014) [15] reported that combined inoculation of *Rhizobium* and PSB significantly increases yield in late sown chickpea over absolute control.

Table 7: Effect of phosphate solubilizing bacteria on seed yield (g/plot) and yield (qt/ ha) of chickpea in calcareous soil.

Sr. No.	Treatment details	Yield/plot (g)	Yield /ha (q)
T1	Seed treatment with PSB isolate	686.23	19.01
T2	Seed treatment with PSB isolate 2	522.15	14.45
T3	Seed treatment with PSB isolate 3	530.34	14.69
T4	Seed treatment with PSB isolate 4	542.50	15.02
T5	Seed treatment with MPKV PSB strain	635.27	17.59
T6	Seed treatment with MPKV *Rhizobium* strain	587.04	16.23
T7	Seed treatment with MPKV PSB + MPKV *Rhizobium* strain	725.52	20.09
T8	Absolute control	490.75	13.59
	SE$\pm$	10.15	0.86
	CD at 5%	31.10	0.28

Effect of Phosphate solubilizing bacteria on N and P uptake by chickpea in calcareous soil

N uptake by plant

The results in respect of N uptake by chickpea plant as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 8. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium* was found to be the most effective as it recorded significantly highest N uptake by plant (56.38 kg ha^{-1}), followed by T_6 *i:e* seed treatment with MPKV *Rhizobium* (53.33 kg ha^{-1}), however T_6 statistically at par with T_1 *i:e* seed treatment with PSB isolate 1 (50.44 kg ha^{-1}) in soil. The lowest N uptake in soil was noticed in T_8 *i:e* absolute control plot (36.33 kg ha^{-1}). Among other treatments, T_1 *i:e* seed treatment with PSB isolate 1 (50.44 kg ha^{-1}), followed by T_5 *i:e* seed treatment with MPKV PSB strain (45.01 kg ha^{-1}). T_4 *i:e* seed treatment with PSB isolate 4, T_2 *i:e* seed treatment with PSB isolate and 2 and T_3 *i:e* seed treatment with PSB isolate 3 was found statistically at par with each other for recorded N uptake by plant (41.15 kg ha^{1}), (40.48 kg ha^{1}), (40.13 Kg ha^{1}) respectively.

P uptake by plant

The results in respect of P uptake by chickpea plant as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 8. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium* was found to be the most effective as it recorded significantly highest P uptake by plant (18.68 kg ha^{1}), followed by T_1 *i:e* seed treatment with PSB isolate 1 (15.42 kg ha^{1}) in soil. The lowest P uptake by plant in soil was noticed in T_8 *i:e* absolute control plot (4.34 kg ha^{1}). Among other treatments, T_1 *i:e* seed treatment with PSB isolate 1 (15.42 kg ha^{1}) followed by T_5 *i:e* seed treatment with MPKV PSB strain (12.16 kg ha^{1}). T_4 *i:e* seed treatment with PSB isolate 4, T_2 *i:e* seed treatment with PSB isolate 2, T_3 *i:e* seed treatment of PSB isolate 3 and T_6 *i:e* seed treatment with MPKV *Rhizobium* strain are statistically at par with each other for recorded P uptake by plant (9.72 kg ha^{1}), (9.56 kg ha^{1}), (9.44kg ha^{1}) and (9.14 kg ha^{1}) respectively. These results are in agreement with Tagore *et al*., (2014) [14] who reported that significantly increased N and P uptake in chickpea due to inoculation with *Rhizobium* and PSB.

Table 8: Effect of Phosphate solubilizing bacteria on N and P uptake (kg/ha) by chickpea in calcareous soil.

Sr. No.	Treatment details	N uptake (kgha^{-1})	P uptake (kgha^{-1})
T1	Seed treatment with PSB isolate 1	50.44	15.42
T2	Seed treatment with PSB isolate 2	40.48	9.56
T3	Seed treatment with PSB isolate 3	40.13	9.44
T4	Seed treatment with PSB isolate 4	41.15	9.72
T5	Seed treatment with MPKV PSB strain	45.01	12.16
T6	Seed treatment with MPKV *Rhizobium* strain	53.33	9.14
T7	Seed treatment with MPKV PSB + MPKV *Rhizobium* strain	56.38	18.68
T8	Absolute control	36.33	4.34
	SE±	0.98	0.78
	CD at 5%	1.38	1.11

Effect of Phosphate solubilizing bacteria on Microbial Population of *Rhizobium* and PSB after harvest of chickpea in calcareous soil

PSB population

The results in respect of PSB population in soil as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 9. Among different seed treatments, T_7 *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium* recorded significantly highest population of PSB (50.33 x 10^6 cfu g^{-1} soil), followed by T_1 *i:e* seed treatment with PSB isolate 1 recorded PSB population (47.22 x10^6 cfu g^{-1} soil), in soil. The lowest microbial population of PSB in soil after harvest of chickpea was noticed in T_8 *i:e* absolute control plot (27 x 10^6 cfu g^{-1}soil). Among other treatments, T_1 *i:e* seed treatment with PSB isolate 1 (47.22 x 10^6 cfu g^{-1} soil), followed by T_5 *i:e* seed treatment with MPKV PSB strain (44 x 10^6 cfu g^{-1}soil). T_4 *i:e* seed treatment with PSB isolate 4 (41x 10^6 cfu g^{-1} soil) and T_6 *i:e* seed treatment with MPKV *Rhizobium* (38.22 x 10^6 cfu g^{-1}soil) are at par. T_6 *i:e* seed treatment with MPKV *Rhizobium* , T_2 *i:e* seed treatment with PSB isolate 2 and T_3 *i:e* seed treatment with PSB isolate 3 are statistically at par with each other recorded PSB population (38.22 x 10^6 cfu g^{-1} soil), (35.56 x 10^6 cfu g^{-1}soil), (33.89 x 10^6 cfu g^{-1} soil) respectively.

***Rhizobium* population**

The results in respect of PSB population in soil as influenced by seed treatment with phosphate solubilizing bacteria are presented in Table 9. Among different seed treatments, T_7, *i:e* seed treatment with MPKV PSB + MPKV *Rhizobium* recorded significantly highest population of *Rhizobium* (40.44 x 10^6 cfu g^{-1}soil), followed by T6 *i:e* seed treatment with MPKV *Rhizobium* (34.78 x 10^6 cfu g^{-1}soil) however T_6 was found at par with T_1 *i:e* seed treatment with PSB isolate 1 (33.33 x 10^6 cfu g^{-1}soil). The lowest *Rhizobium* population in soil after harvest of chickpea was noticed in T_8 *i:e* absolute control plot (18.33 x 10^6 cfu g^{-1}soil). Among other treatments, T_1 *i:e* seed treatment with PSB isolate 1 (33.33 x 10^6 cfu g^{-1}soil) followed by T_5 *i:e* seed treatment with MPKV PSB strain (30 x 10^6 cfu g^{-1}soil), T4 *i:e* seed treatment with PSB isolate 4 (27.22 x 10^6 cfu g^{-1}soil). T2 *i:e* seed treatment with PSB isolate 2 and T_3 *i:e* seed treatment with PSB isolate 3 was found statistically at par with each other recorded *Rhizobium* population (23.44 x 10^6 cfu g^{-1} soil) and (21.56 x 10^6 cfu g^{-1}soil) respectively. These results are in agreement with the results of Cao *et al*. (2016) [4] who reported that the application of *Rhizobium* inoculant and/or PSB inoculation to soybean significantly increased the population of *Rhizobium* and PSB in soybean.

Table 9: Effect of PSB on microbial population of PSB and *Rhizobium* (10^6) after harvest of chickpea in calcareous soil.

Sr. No.	Treatment details	PSB (10^6cfu g^{-1} soil)	***Rhizobium*** (10^6cfu g^{-1} soil)
T1	Seed treatment with PSB isolate 1	47.22	33.33
T2	Seed treatment with PSB isolate 2	35.56	23.44
T3	Seed treatment with PSB isolate 3	33.89	21.56
T4	Seed treatment with PSB isolate 4	41.00	27.22
T5	Seed treatment with MPKV PSB strain	44.00	30
T6	Seed treatment with MPKV *Rhizobium* strain	38.22	34.78
T7	Seed treatment with MPKV PSB + MPKV *Rhizobium* strain	50.33	40.44
T8	Absolute control	27.00	18.33
	SE±	0.94	0.87
	CD at 5%	2.88	2.68

Effect of Phosphate solubilizing bacteria on No. of nodules/plant of chickpea in Calcareous soil.

General view of field experiment plot

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