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ORIGINAL RESEARCH

Application of rock phosphate enriched composts increases nodulation, growth and yield of chickpea

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Abstract

Purpose Phosphorus (P) deficiency in agricultural land is one of the main factors which reduce the crop production and yield. To increase the crop growth, the availability of P using the rock phosphate (RP) can be enhanced using organic waste with the addition of phosphate solubilizing microorganisms (PSMs). Moreover, the combination along with time and dose application of RP and compost can also affect the P-availability through mineralization and/immobilization.

Methods To investigate the effect of different combinations of RP and compost (0:100, 25:75, 50:50, 75:25 and 100:0) and time of application (30, 15, 7, 3 and 0 days before sowing), each was conducted in two consecutive pot experiments while, the rate of application (100–1000 kg ha^{-1}) was investigated under field conditions, in comparison to control (recommended P fertilizer).

Results Rock phosphate enriched compost (RP-EC) with a combination ratio of 50:50; RP and compost applied before 7 days of sowing in pot experiments resulted in the maximum nodulation, growth and productivity of chickpea. Under field conditions, the maximum increase of 35.3% in no. nodules $plant^{-1}$, 26.7% in dry wt. of nodules $plant^{-1}$ and 20.8% in grain yield (t ha^{-1}) compared to control was obtained by RP-EC @ 1000 kg ha^{-1}. The same treatment indicated an increase of 12.9 and 4.3% in P contents in straw and grains, respectively, compared to control. However, most results were non-significant when RP-EC applied at the rate of 1000 kg ha^{-1}.

Conclusion Application of RP-EC, with the ratio of 50:50 (RP:Compost) and application rate of 800 kg ha^{-1} before 7 days of sowing, exhibited maximum growth and development, and can be highly recommended for optimum production of chickpea.

Keywords Optimum combination ratio · Rock phosphate · Time and rate of application · Compost · Chickpea · Phosphorus

Introduction

Globally, the agricultural soils are getting phosphorus (P) deficient after nitrogen (Vance et al. 2003) and hence, impairs the various physiological and biochemical processes within plants (Wu et al. 2005). Generally, on dry weight basis, it constitutes ~ 0.2% of the plant biomass (Schachtman et al. 1998). Phosphorus, being an immobile nutrient in soil necessitates the application of chemical phosphatic fertilizers as its available sources for optimum production of crop plants. However, nutrient availability from chemical fertilizers is not more than 20% and has forced the poor farmers to add two times more than the optimum application rate of P-fertilizers. The addition of extra P in the soil led to consume more resources for the crop production, and hence, the costs of production of crop plants per unit area increase (Aziz et al. 2006). Moreover, there is expected depletion of high quality rock phosphate (RP) which is the major sources of P-fertilizers by the year 2050 (Vance et al. 2003). These circumstances necessitate to find out an economical and eco-friendly way to increase the availability of P, and at the same time, reduce the losses of P, and RP enriched with compost and phosphate solubilizing microorganisms (PSMs) can be a good solution.

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Rock phosphate (RP) is an important natural source of P and is used as raw material for the production of chemical phosphatic fertilizers (Reddy et al. 2002). The direct application of RP has been found suitable for acidic soils as low pH helps to solubilize the RP and increases available form of P to the plants. However, this approach does not work for alkaline/or calcareous soils due to high pH (Caravaca et al. 2004). The application of enriched-RP with compost to alkaline/or calcareous soils could be a wise approach for the solubilization of RP. Furthermore, addition of organic fertilizers also improves the physico-chemical as well as biological properties of soil (Adhami et al. 2014; Lim et al. 2015). This approach also had positive effects on crop because organic fertilizers contained plenty of macro and micro-nutrients (Gaur 1997; Kalaivanan and Hattab 2016). Typically, most of the organic fertilizers are produced from biodegradable solid wastes using compost or/and vermicompost (Wu et al. 2014; Lim et al. 2016).

Besides, some rhizobacteria have also been used to improve the P-bank in the soil such as with P-solubilizing and ACC-deaminase activities. Ultimately, these approaches also help to increase P availability to the crop plants and alleviate the stress induced by ethylene (Glick et al. 1998). Ethylene, a gaseous phytohormones, is produced under biotic and abiotic stresses (Arshad and Frakenberger 2002). Its higher concentration ($\geq 25\ \mu g\ L^{-1}$) inhibits root growth and nodulation in legumes (Mattoo and Suttle 1991; Arshad and Frakenberger 2002). Inoculation of rhizobacteria with ACC-deaminase activity significantly improved growth parameters of maize and mung bean (Shaharoona et al. 2006, 2007; Davari et al. 2012), root proliferation (Dey et al. 2004), and transformed soil P (Chen et al. 2006). So, the use of rhizobacteria with both of the above-mentioned activities could be a good strategy to decrease ethylene production during nodulation and also improve P availability especially from RP.

Most of the organic P is mineralized and certain organic acids are produced during composting. These organic acids lower the pH of microclimate and hence, increase the solubility of RP, ultimately the bioavailability of P. On the other hand, combined application of rhizobacteria carrying P-solubilizing as well as ACC-deaminase activities with RP-EC can reduce the ecological issues due to overuse of fertilizers and enhance the nutrient use efficiency. In literature, there are few reports of combined use of RP, compost and/PSM (Biswas and Narayanasamy 2006; Saleem et al. 2013). Moreover, no research work reports about the optimum combination ratio of RP and compost, its time and rate of application except on lentil (Ditta et al. 2015; Ditta and Khalid, 2016). Here in this study, we have investigated the effects of the optimum ratio of combination between RP and compost in RP-EC, its time and rate of application with PSM strain (*Bacillus* spp.) on nodulation, growth and productivity of chickpea.

Materials and methods

Pot experiments

Effect of different combinations of RP and compost, i.e., 0:100, 25:75, 50:50, 75:25 and 100:0 (W/W) on nodulation, growth and yield parameters of chickpea was investigated in the first pot experiment under wire house conditions in comparison to control (recommended NPK). The different combination ratios of RP-EC were applied at 600 kg ha^{-1} (0.3 g kg^{-1} soil), thoroughly mixed with soil and the pots were arranged in completely randomized design (CRD) with six replications. Remaining N and P were applied through urea and diammonium phosphate (DAP) after analysis and calculations for available N and P in each combination. RP used in the studies was chemically analyzed for P using standard methods and it contained 22% P_2O_5 as total P and 0.022% P_2O_5 as Olson P. The *Bacillus strain* (PSM) had high ACC-deaminase and P-solubilizing activities, 1.53 μmol mL^{-1}, 753.0 μg P mL^{-1}, respectively (Baig et al. 2012) was taken from the Laboratory of Environmental Sciences. The inoculum was prepared separately for PSM and rhizobia using National Botanical Research Institute's Phosphate (Nautiyal 1999) and N-free medium, respectively, in Erlenmeyer flasks (250 ml) which were incubated for 48 h in orbital shaking incubator (Model OSI-503 LD; Firstek Scientific, Japan), at 28 ± 1 °C and 100 rev min^{-1}. For surface sterilization, chickpea seeds (var. Noor-2009) were soaked in ethanol (70% v/v) for 2 min and then in NaClO (5% v/v) for 5 min. The seeds were thoroughly washed 3 times using sterile distilled water. The inoculum was mixed with sugar solution (15% *w*/*v*) and sterilized peat + clay (1:1 w/w) and surface sterilized seeds were dipped. Seeds treated with sterilized broth, sugar solution and peat plus clay were used as control.

After finding out optimum combination ratio of RP and compost, another pot study was conducted under wire house conditions to investigate the effect of different application times (30, 15, 7, 3 and 0 days before sowing) of RP-EC on nodulation, growth and yield contributing parameters comparison to control (60 kg P ha^{-1} using DAP). Chickpea (var. Noor-2009) was used as test crop in the experiment. RP-EC with an optimum combination ratio of RP and compost, i.e., 50:50, applied at the rate of 600 kg ha^{-1} as described in the earlier pot experiment. The inoculum preparation and seed inoculation were performed using standard methods as described earlier in the above paragraph.

In both pot experiments, inoculated seeds were sown in plastic pots with 25 cm diameter and 23 cm of height. Each pot contained 8 kg dried and sieved (2 mm) soil collected from the University research area. Respective treatment of RP-EC in both the trials was thoroughly mixed in the soil manually before sowing of inoculated chickpea seeds. Remaining N and P were applied through urea and diammonium phosphate (DAP) after analysis and calculations for available N and P in each combination. Physicochemical properties of soil used in the experiment were determined using standard methods (Ryan et al. 2001). The soil was sandy clay loam in texture with alkaline pH 7.6 and $EC_{extract}$ 3.4 dS m^{-1}, low in organic matter (0.67%). The nutrient contents of the soil were as follows: total N = 0.056%, available P = 8.6 mg kg^{-1} and extractable K = 110 mg kg^{-1}. The pots were arranged in the CRD with six replications. Each pot contained two plants in the beginning while after proper germination, thinning was done to select one uniform germinated plant/pot. Standard procedures were adopted for the estimation of growth and yield parameters such as root dry weight, fresh biomass and grain yield at maturity. The roots were excised from the shoot part and were dried in oven at 105 °C for 24 h till constant dry weight was obtained using a digital balance. P contents in grain and straw samples were also determined (Olsen et al. 1954; Ryan et al. 2001). At the flowering stage, three replicates were randomly selected from each treatment for nodulation parameters, washed to remove soil; nodules were excised manually, placed on filter paper and dried. Their number was counted manually and electrical balance was used for dry weight of nodules.

Field experiment

Under field conditions, the effect of different application rates (100–1000 kg ha^{-1}) of RP-EC with PSM and with a combination ratio of RP and compost (50:50 W/W), applied 7 days before sowing, on nodulation, growth and productivity of chickpea compared to control (60 kg P ha^{-1} using DAP) was investigated at the University research farm. The treatments were arranged using randomized complete block design (RCBD) in triplicate. For sowing, hand drill was used to maintain row to row distance of 40 cm. After a week, plant to plant distance (30 cm) was maintained by thinning. The recommended rate of N and K (25 and 25 kg ha^{-1}) were applied in control using urea and sulfate of potash (SOP). Remaining N and P were applied through urea and diammonium phosphate (DAP) after analysis and calculations for available N and P in treatments where RP-EC was applied. Rhizobia and PSM inoculum were prepared using standard methods as described above and were applied in all the treatments. The inoculated seeds were sown in respective plots (1.5 × 1.5 m^2). Similar standard methods as described in pot experiments were adopted for the estimation of agronomic and yield parameters at maturity and P contents from grain and straw samples (Olsen et al. 1954; Ryan et al. 2001). Each treatment in triplicate was randomly selected using a square meter ring and plants were harvested at the flowering stage for nodulation parameters. Number of nodules $plant^{-1}$ were counted manually and their dry wt. using digital balance.

Preparation of RP-EC

RP-EC was prepared following the procedures reported in our previous paper (Ditta et al. 2015). Briefly, fruit peels and vegetable wastes (mainly consisted of green peas waste) were collected during January–March, 2013, from the local market, oven dried (70 °C) overnight, ground, sieved (< 2.0 mm) and was mixed with RP in different combinations as described earlier (0:100, 25:75, 50:50, 75:25 and 100:0), respectively. After mixing, the mixture was composted for 7 days with moisture contents (40% *v*/*w*) maintained manually in a locally manufactured composter with a load capacity of 500 kg. For the preparation of each RP-EC with specific ratio, the composter was thoroughly cleaned each time to remove the previous one. Simple compost without RP was also prepared using similar methods as described earlier.

Chemical analysis of compost, RP-EC

For chemical analysis of simple compost and RP-EC with specific combinations of RP and compost, standard methods were used with four replications. Loss-on-ignition method was employed for carbon contents (Nelson and Sommers 1996). The available N ($NH_4 + NO_3$) was determined by the MgO Devarda alloy method (Ryan et al. 2001). Sodium bicarbonate ($NaHCO_3$) method was used for available P determination (Olsen et al. 1954) while total P was determined through vanadomolybdophosphoric yellow color method (Jackson 1973). The results of chemical analysis are given in Table 1.

Statistical analysis

Data collected in each treatment were subjected to statistical scrutiny through analysis of variance (ANOVA) using Statistix 8.1 and to compare each treatment mean, least significant difference (LSD) test at $\alpha = 0.05$ was applied (Steel et al. 1997).

Table 1 The chemical analysis of the compost and the RP- enriched composts

Parameters	Raw organic material	Combination ratios of RP and compost				
		0:100	25:75	50:50	75:25	100:0
Carbon (g kg^{-1})	345 ± 3.2†	255 ± 6.6	237 ± 4.4	215 ± 5.5	174 ± 3.3	–
Nitrogen (g kg^{-1})	13.8 ± 0.1	22.1 ± 0.3	17.1 ± 0.2	15.3 ± 0.3	12.4 ± 0.2	–
Total P (g kg^{-1})	3.5 ± 0.06	3.7 ± 0.9	59.7 ± 2.1	123.0 ± 4.4	175.0 ± 2.1	224 ± 2.6
Olson P (mg kg^{-1})	340 ± 10	450 ± 20	2070 ± 20	2380 ± 30	2150 ± 20	220 ± 10
C:N	25.00 ± 0.34	11.53 ± 0.18	13.85 ± 0.28	14.05 ± 0.63	14.03 ± 0.45	–
C:P	98.57 ± 1.63	54.26 ± 0.96	12.03 ± 0.12	9.19 ± 0.18	7.73 ± 0.07	–

† Shows the standard error of means (SEM) where $n = 4$

Results

Effects of RP-EC with different ratios of combination on nodulation parameters, growth and yield parameters and P contents (g kg^{-1})

The formation of nodules in leguminous crops is very important because it helps to increase the uptake of nitrogen to the plants and in this process, availability of P is very critical. As clear from Table 1, the availability of P was increased with different ratios of RP and compost, and the maximum availability was observed with 50:50 ratio of combination between RP and compost. The same ratio produced maximum no. of nodules plant^{-1} and dry wt. compared to other combination ratios (Table 2). The maximum no. of nodules plant^{-1} were 86.1% more than that treated with 0:100 combination ratio of RP and compost, respectively.

The obtained results show that the application of different combination ratios of RP and compost exhibited a significant increase in grain yield and fresh biomass (g pot^{-1}) as clear from the data presented in Table 2. The results also show that about 82.1% more grain yield was obtained when plants treated with 50:50 as compared to 0:100 ratio of RP and compost. The same treatment resulted in the maximum fresh biomass (43.8 g pot^{-1}).

Moreover, the straw and grain of chickpea accumulated higher P contents about 2.8 and 5.0 g kg^{-1}, respectively, when treated 50:50 ratio of RP and compost (Table 2).

Effects of Application time of RP-EC on nodulation parameters, growth and yield parameters and P contents (g kg^{-1})

Application time of an organic amendment is critical with respect to the availability of nutrients through mineralization/immobilization and it has an indirect impact on nodulation, growth and yield in plants. The results indicated that the application of RP-EC before 7 days of sowing enhanced the production of nodules plant^{-1} as well as their dry biomass. (Table 3). This application time exhibited 57 nodules plant^{-1} which were 119.2% more as compared to that applied before 30 days of sowing. The same treatment resulted in the maximum dry wt. of nodules (0.74 g plant^{-1}).

The dry weight of root, grain yield and fresh biomass were also increased with the application of RP-EC before 7 days. The results show that chickpea exhibited about 2.47 , 43.7 g pot^{-1}, and 80% more dry weight, fresh biomass and

Table 2 Impact of RP-EC with different ratios of combination on nodule, growth, yield and P uptake in chickpea under soil pot culture conditions

Combination ratios of RP and compost	Nodules (No. plant^{-1})	Dry wt. of nodules (g plant^{-1})	Root dry wt. (g plant^{-1})	Grain yield (g pot^{-1})	Fresh biomass (g pot^{-1})	P in straw (g kg^{-1})	P in grains (g kg^{-1})
0:100	36 c†	0.46 c	1.34 d	6.23 b	27.27 d	1.4 d	3.8 b
25:75	45 bc	0.57 b	2.25 b	11.07 a	37.58 c	2.4 ab	4.5 ab
50:50	67 a	0.79 a	2.47 a	11.37 a	43.83 a	2.8 a	5.0 a
75:25	47 b	0.58 b	1.78 c	10.23 a	38.61 b	2.0 bc	4.2 ab
100:0	38 bc	0.48 bc	1.03 e	7.40 b	27.04 d	1.5 cd	3.7 b
LSD	9.77***	0.11***	0.30***	2.10***	1.79***	0.51***	0.99***

*** Significant at $p \leq 0.001$

† Means sharing the same letter, for a parameter, do not differ significantly at $p \leq 0.05$ using least significance difference (LSD) test

Table 3 Impact of application time of RP-EC with optimum combination ratio (50:50) on nodule, growth, yield and P uptake in chickpea under soil pot culture conditions

Application time (Days before sowing)	Nodules (No. plant^{-1})	Dry wt. of nodules (g plant^{-1})	Root dry wt. (g plant^{-1})	Grain yield (g pot^{-1})	Fresh biomass (g pot^{-1})	P in straw (g kg^{-1})	P in grains (g kg^{-1})
30	26 c†	0.41 c	1.34 d	6.40 d	27.2 d	1.5 c	3.6 b
15	35 b	0.52 b	2.25 b	11.24 ab	35.8 c	2.6 ab	4.3 ab
7	57 a	0.74 a	2.47 a	11.52 a	43.7 a	3.1 a	4.8 a
3	37 b	0.53 b	1.78 c	10.40 b	38.5 b	2.3 b	4.1 ab
0	28 c	0.43 c	1.03 e	7.56 c	26.9 d	1.7 c	3.5 b
LSD value	4.74**	0.05**	0.14**	1.02**	0.87**	0.25**	0.47**

*** Significant at $p \leq 0.001$

†Means sharing the same letter, for a parameter, do not differ significantly at *p ≤ 0.05* using least significance difference (LSD) test

grain yield, respectively, than the application of RP-EC before 30 days of sowing.

The accumulation of P contents in the straw and grains of chickpea was also increased when RP-EC was applied before 7 days of sowing. With the application of RP-EC before 7 days of sowing, chickpea accumulated P contents about 3.1 and 4.8 g kg^{-1} in straw and grains, respectively, and this P accumulation was higher than other application times of RP-EC (Table 3).

Effect of field application of RP-EC on nodulation parameters, growth and yield parameters and P contents (g kg^{-1})

Under the field conditions, application of RP-EC at the rate of 1000 kg ha^{-1} with phosphate solubilizing microorganisms (PSMs) resulted in the maximum number of nodules plant^{-1} (about 69 nodules) (Table 4). A similar trend was observed for the dry weight of nodules (g). However, the results about nodulation parameters: number of nodules plant^{-1} and dry weight of nodules showed non-significant difference when exposed to RP-EC at the rate of 800 and 1000 kg ha^{-1}.

The obtained results indicated that chickpea plants treated with the application of RP-EC at the rate of 1000 kg ha^{-1} with PSM exhibited more grain yield and fresh biomass, which were about 3.66 and 13.59 t ha^{-1}, respectively, as compared to control where recommended NPK was applied (Table 4).

Under field conditions, the P accumulated more in straw and grains was about 3.5 and 4.8 g kg^{-1}, respectively, when RP-EC applied at the rate of 1000 kg ha^{-1} with PSM. Furthermore, the application of RP-EC at the rate of 800 and 1000 kg ha^{-1} showed statistically non-significant differences in P accumulation in chickpea plants (Table 4).

Table 4 Impact of field application of RP-EC with optimum combination ratio (50:50) on nodule, growth, yield and P uptake in chickpea

Rate of application (kg ha^{-1})	Nodules (No. plant^{-1})	Dry wt. of nodules (g plant^{-1})	Root dry wt. (g plant^{-1})	Grain yield (t ha^{-1})	Fresh biomass (t ha^{-1})	P in straw (g kg^{-1})	P in grains (g kg^{-1})
100	29 e†	0.52 d	1.35 e	1.87 f	6.93 e	1.7 f	3.7 c
200	31 de	0.54 d	1.57 d	2.44 e	8.93 d	2.0 e	3.9 bc
300	39 d	0.63 c	1.88 c	2.63 de	10.62 c	2.3 d	4.1 b
400	58 bc	0.72 b	2.13 b	2.93 cd	10.73 bc	2.7 c	4.6 a
500	63 ab	0.85 a	2.44 a	3.23 bc	11.86 bc	3.2 b	4.8 a
800	68 a	0.89 a	2.55 a	3.35 ab	11.97 b	3.4 a	4.8 a
1000	69 a	0.90 a	2.57 a	3.66 a	13.59 a	3.5 a	4.8 a
NPK (recommended)	51 c	0.71 bc	2.44 a	3.03 bc	11.70 bc	3.1 b	4.6 a
LSD value	9.49***	0.07***	0.21***	0.35***	1.33***	0.23***	0.32***

*** Significant at $p \leq 0.001$

† Means sharing the same letter, for a parameter, do not differ significantly at *p ≤ 0.05* using least significance difference (LSD) test

Discussion

Chemical analysis of the composted finished product, i.e., RP-EC with different combination ratios of RP and compost revealed that the maximum improvement in the P availability (2380 mg kg^{-1}) was exhibited with 50:50 combination ratio between RP and compost (Table 1). The C:N is an important indicator of compost maturity as it indicates the extent of decomposition of biological wastes being used during composting and its stabilization, ranges from 15 to 25 of matured compost materials (Watson 2003). The production of organic acids such as acetate, lactate, oxalate, tartrate, succinate, citrate, gluconate, ketogluconate, glycolate, etc., during the composting process by the microbes might have resulted in increasing the availability of nutrients especially P as observed the chemical analysis after composting (Table 1). Due to mineralization of nutrients present, availability of carbon and other nutrients is increased during composting, which increases the microbial population and ultimately the production of organic acids (Rashid et al. 2004; Biswas and Narayanasamy 2006; Chakraborty et al. 2011). The presence of various organic acids in the composted materials helps to accelerate the break down the RP by pushing the dissolution reaction to the right. The increase in production of CO_2 during the composting process occurred due to low pH. This CO_2 helps to produce carbonic acids in the presence of water and have been reported to increase the available P in the soil and from RP (Chien 1979). Previous studies indicated that production of microbial extracellular products such as enzymes and organic acids can increase the mineralization of nutrients (Chien 1979; Jansson et al. 1988).

Another factor that influences the nodulation in legumes is the source of carbon and energy which increases the population of N-fixing bacteria (Hill and Patriquin 1996). In our studies, fruit and vegetable compost was used as it is easily mineralized thereby, increasing the availability of C and energy to diazotrophic bacteria. Similarly, any biotic or abiotic stress also induces ethylene production (Shaharoona et al. 2006), including rhizobial infection during nodulation (Suganuma et al. 1995), which may ultimately reduce root growth (van Workum et al. 1995). The application of microbes with ACC-deaminase activity in growth medium help in reducing this ethylene stress. In the present study, addition of phosphate solubilizing microorganisms (PSMs) contained both ACC- and P-solubilizing activities; the former activity might have caused a reduction in ethylene levels and the P-solubilizing activity increased P availability which helped to increase nodulation (Table 2, 3 and 4). Moreover, the compost material used in the present study supplied micro- as well as macro nutrients which promoted better root growth and nodulation (Cheuk et al. 2003; Ahmad et al. 2008a, b). Other researchers have also reported similar results (Shaharoona et al. 2006, 2007; Ditta et al. 2015).

The results about to find the optimum ratio and then its time of application to release the nutrients from RP-EC are presented in Table 1. Moreover, the effect was more pronounced when microbial strain with high P-solubilization and ACC-deaminase activity was applied. The addition of P-solubilization in RP-EC maximally increased the available P while, ACC-deaminase activity enhanced the root growth by reducing ethylene stress. The Tables 2, 3 and 4 contained the results about releasing of nutrients and availability of nutrients, which revealed that growth and yield parameters were increased using applied treatments. Furthermore, the improvement in growth and production of chickpea was more pronounced with the inoculation of bacterial strain with ACC-deaminase and P-solubilizing activities. The application of organic fertilizers alone may not help to attain the standard yield of crops due to their low and slow nutrient availability (Fageria et al. 2010). According to Roy et al. (2001), organic inputs are beneficial; however, the inclusion of additional P with phosphate solubilizing microorganisms may produce yields at par with inorganic fertilizers. The obtained results show an agreement with the results of previous studies (Mattoo and Suttle 1991; Surange et al. 1995; Chang and Janzen 1996; Nevens and Reheul 2003; Verma et al. 2013).

With the application of RP-EC and PSM, an increase in P contents was observed in straw and grain samples which might be due to the higher P-solubilizing activity of PSM strain, the better root growth via alleviating ethylene stress through ACC-deaminase activity, and/or better solubilization of P in RP during the composting process. The addition organic matter increases the dissolution of RP by complexing Ca^{2+} ions in the soil solution (Sanyal and De Datta 1991) and ultimately increases the available P for the crop plants grown in calcareous soils. Singh and Amberger (1995) found that amount of loosely bound P in the soil increases while fraction held as Ca–P decreases with the addition of phosphor-compost as compared to RP application only. Other researchers have also reported an increase in P availability which ultimately resulted in higher growth, productivity and nutrient contents of various crops (Belimov et al. 2002; Vassilev et al. 2006; Glick et al. 2007; Salimpour et al. 2010).

Conclusions

In conclusion, RP-EC with a combination ratio of 50:50 (RP:Compost), applied before 7 days of sowing under pot culture conditions and at the rate of 800 kg ha^{-1} with PSM under field conditions produced maximum nodulation, growth and yield parameters of chickpea in comparison to conventional chemical phosphatic fertilizers was observed with the application of. Therefore, RP-EC can be used as an alternate source of P for maximum production of leguminous crops. In future, there is need to evaluate and ensure conditions.

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