established in 2016

MAS JOURNAL of Applied Sciences

ISSN 2757-5675

DOI: http://dx.doi.org/10.52520/masjaps.9

Derleme Makalesi

Phosphorus Solubilising Bacteria Applications in Chickpea: A Review

Sipan SOYSAL[1*], Murat ERMAN[2]

[1] Siirt University, Kurtalan Vocational High School, Siirt

[2]Siirt University, Faculty of Agricultural, Department of Field Crops, Siirt

*Corresponding author: sipansoysal@siirt.edu.tr

Geliş Tarihi: 23.01.2021 **Kabul Tarihi**: 28.02.2021

Abstract

Chickpea (*Cicer arietinum* L.) is an ancient legume consumed all over the world as a good source of carbohydrates and protein. Fertiliser usage in intensive farming practices has a big environmental cost. Significant amount of phosphorus is immediately fixed by soils after applications to soils where only a small fraction of it becomes available during crop season. An interest in biofertilizers is fresh again where many beneficial microorganisms are available on market. Here in this review, we searched, extracted and analysed electrnically published articles related to Phosphorus solubilising bacteria applications in chickpea. Our general comments related to the subject is also given to assist new researches on chickpea with beneficial phosphorus solubilising bacterias.

Keywords: Chickpea, solubilizing, PSB, solubilising, mobilizing

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an ancient legume believed to be originated from South-Eastern Anatolia of Turkey and the adjoining part of Syria (Singh, 1997). It is the third most important food grain legume in the World after common bean (*Phaseolus vulgaris* L.) and field pea (*Pisum sativum* L.) (Ahmad et al., 2005). Chickpea is consumed all over the world as a good source of carbohydrates and protein. Its protein quality is considered to be better than other pulses which has significant amounts of all essential amino acids except sulphur-containing amino acids (Jukanti et al., 2012).

Problems related to intensive farming practices and environmental costs of nitrogen and phosphorus fertilizers have renewed interest in biofertilizers (Elkoca et al., 2017). Fertilizer phosphorus tends to be fixed soon after application (Ravikumar et al., 2014). Phosphorus in soil reacts readily to form insoluble compounds, which are not available for plant utilisation (Harris et al., 2006). This is why, soils contain significant amount of phosphorus which is not immediately available to crops where only a small fraction of it becomes available during crop season (Pinochet and Valenzuela, 2008). Microbial solubilisation of insoluble mineral phosphate in soil is an important natural ecosystem process in agricultural soils. Many microorganisms in soils solubilize insoluble inorganic phosphates which are referred as phosphorus solubilising microorganisms in general (Marhual et al., 2011). The use of Phosphorus solubilising bacteria (PSB) as seed or soil inoculant may enhance phosphorus uptake by the plant and thereby improve crops yields (Edalatjo et al., 2017). Biological fertilisers as an alternative to chemical fertilisers in agriculture may improve the grain yield and quality of crops (Yousefi et al., 2018). Classical, soluble fertilisers create environmental and economic problems (Han et al., 2006). Root exudation of carboxylates into the rhizosphere are important strategies for plant phosphorus acquisition (Pang et al., 2018).

Plant phosphorus status were found low effective on the concentration of phosphorus-mobilising carboxylates in the rhizosphere of chickpea in pots in sand culture at two experiments conducted by Wouterlood et al. (2005). Malonate was the main carboxylate in the roots. Whereas citrate and malate were the main carboxylate in shoots. Carboxylate concentrations in the rhizosphere decreased only slightly at high P supply. In split-root sand culture the rhizosphere of both root halves released similar concentrations of carboxylates at different P supply. Results indicate that carboxylate exudation is determined by internal P rather than external factors.

100 chickpea (*Cicer arietinum*) genotypes were grown by (Pang et al., 2018) in pots in a low-P sterilized river sand supplied $FePO_4$, a poorly soluble form of P. There was a large genotypic variation based on root morphology (total root length, root surface area, mean root diameter, specific root length and root hair length), and root physiology (rhizosheath pH, carboxylates and acid phosphatase activity). Shoot P content was correlated with total root length, root surface area and total carboxylates per plant, particularly malonate. A positive correlation was found between mature leaf manganese concentration and carboxylate amount in rhizosheath relative to root dry weight. Mature leaf manganese concentration found effective fort he assessment of belowground carboxylate-releasing processes in a wide range of chickpea genotypes grown under low-P.

To evaluate Phosphorus solubilizing bacterias with different fertilizer sources, a field experiment was carried out in Pakistan by Zafar et al., (2020). Five fertilizer treatments were 1) Recommended NP at 32:85 kg ha^{-1} (F1); 2) Seed treatment of PSB + recommended NP (F2); 3) Farmyard manure at 3.5 t ha^{-1} (F3), 4) Seed treatment of Phosphorus solubilizing bacterias with + Farmyard manure at 3.5 t ha^{-1} (F4); 5) Farmyard manure at 3.5 t ha^{-1} + Remaining P from Single Super Phosphate (F5). Seed inoculation with Phosphorus solubilizing bacterias + Recommended NP (application F2) resulted with maximum grain yield (1.8 t ha^{-1}), plant height (53 cm), branches per plant (4 piece), grains per pod (1.6 piece) and 100 seed weight (18.5 g).

A field experiment was conducted in India in the Rabi season to study the influence of sulphur, phosphorus fertilization and PSB inoculation on growth and yield of chickpea. Combinations of three sulphur application (S0: 0 kg S ha^{-1}, S1: 20 kg S ha^{-1} and S2: 40 kg S ha^{-1}) and four phosphorus applications (P0: No phosphorus, no PSB, P1: PSB alone, P2: 25 kg P_2O_5 ha^{-1} and P3: 25 kg P_2O_5 ha^{-1} + PSB) were conbined. Standart 25 kg N ha^{-1} was applied to all treatments as starter nitrogen. Increased vegetative growth due to sulphur application were improved yield and yield components. Maximum yield was obtained by 20 kg S ha^{-1}. Highest postharvest available nitrogen and available sulphur in soil was observed under 40 kg S ha^{-1}. However, available phosphorus was optimum at 20 kg S ha^{-1}. Adequate supply of phosphorus either through P2 or P3 resulted with significantly higher grain and straw yields and better harvest index. The nitrogen and protein content in grain were also improved significantly by P3 fertilization. As a result, chickpea variety GC-2 produced highest grain yield as well as net returns when it was fertilized with 20 kg S ha^{-1} + 25 kg P_2O_5 ha^{-1} (Patel, 2004).

The effects of phosphate solubilizing microorganisms *Aspergillus awamori*, *Pseudomonas aeruginosa* (isolate Pa28) and *Glomus intraradices* were evaluated for interaction with root-rot disease complex of chickpea caused by *Meloidogyne incognita* and *Macrophomina phaseolina*. Application of phosphate solubilizing microorganisms alone and in combination increased plant growth, pod number, and chlorophyll, nitrogen, phosphorus and potassium contents and also reduced galling, nematode multiplication and root-rot index of chickpea. *Pseudomonas aeruginosa* was most effective in reducing galling and nematode multiplication followed by *A. awamori* and *G. intraradices*. Combined inoculation of these microorganisms caused the greatest increase in plant growth and reduced the root-rot index more than individual inoculations (Siddiqui and Akhtar, 2007).

Shahid and Khan (2018) isolated Strain PSBB1 from *Vicia faba* rhizosphere was identified as *Burkholderia cepacia* by 16S rDNA sequence analysis. Strain was tolerated glyphosate and secreted exopolysaccharides; mitigated toxicity and enhanced the size, dry matter, symbiosis and nutritional contents of chickpea. Further, *B. cepacia* declined the levels of stress related chemicals contents under glyphosate in soil.

A field experiment was conducted during the winter (Rabi) seasons in 2012-13 and 2013-14 in India by Chauhan and Raghav, (2017) to study the effects of phosphorus and phosphate solubilizing bacteria on growth, yield and quality of chickpea. Application of 60 kg P_2O_5 ha^{-1} + PSB inoculation significantly increased yield, pods plant^{-1}, 1000 seed weight, plant height, branches plant^{-1}, number and dry weight of root nodule and root and shoot dry weight plants^{-1}. The maximum seed (1.2 t ha^{-1}) and straw (3.2 t ha^{-1}) yields were obtained with 60 kg P_2O_5 ha^{-1} + PSB inoculation. The maximum protein content (22.5%) in grain and straw (8.0%) and protein yield (534 kg ha^{-1}) were also obtained with 90 kg P_2O_5 ha^{-1}.

Thirty nine efficient PSB isolates were selected from Erbil soils in Iraq by Khudhur (2020). PSB strains belonged to Pseudomonas putida strains screened for their solubilization efficiency on both solid and liquid medium. Bh36 strain of P. putida was the most efficient isolate in P solubilization (94.92%, 117.78mg ml^{-1}). Pot experiment showed that seed inoculation with P. Putida significantly enhanced chickpea growth. Local *P. putida* strains found to be used as biofertilizer source.

The effect of phosphate solubilizing bacterias and fungi were evaluated with chickpea in field conditions for three years during Kharif season by Rajani and Rakholiya (2010). Nine different cultures were compared to control. The seed treatment of bacteria *Bacillus coagulans* (PBA-13) was found most effective in increasing seed yield (1.8 t ha^{-1}) followed by fungus *Aspergillus* spp (PBA-20). Maximum net return was also obtained by seed treatment of bacteria *Bacillus coagulans*.

Total 17 isolates from chickpea rhizosphere were screened for various phosphate solubilizing plant growth promoting activities by Shilpa (2019). On “NBRİP and Pikovskaya’s media” (PVK), maximum P solubilization was obtained with isolate RB-1 and RB-3 with Phosphate Solubilizing İndex (PSI) 2.28 and 1.88, respectively. Total of 39% and 61% of isolates were found positive for organic acid production for RB-1 and RB-3, respectively. Isolates RB-1 and RB-4 were found resistant to ampicillin and tetracycline.

A field experiment was carried out during Rabi season in India in a study of Waghmode (2020) who tested four levels of seed inoculation with phosphate solubilizing microorganisms (T0-control, T1-*Bacillus megaterium* (bacteria) at 10 ml kg^{-1} seeds, T2-*Aspergillus niger* (fungus) at 10 ml kg^{-1} seeds and T3-*Aspergillus awamori* (fungus) at 10 ml kg^{-1} seeds) and four levels of phosphorus (P0-control, P1- at 45 kg P_2O_5 ha^{-1}, P2- at 60 P_2O_5 ha^{-1}, P4- at 75 P_2O_5 ha^{-1}). Inoculation with *Aspergillus awamori* along with 75 kg P_2O_5 ha^{-1} showed significant increase in N, P and K availability. The seed and straw yield were maximum with inoculation with *Aspergillus awamori* + 75 kg P_2O_5 ha^{-1} compared to other treatments. It was concluded that balanced inoculation of Aspergillus awamori and 75 kg P_2O_5 ha^{-1} showed superiority over all other applications.

Total 76 isolates of phosphate solubilizing bacteria from rhizosphere of chickpea were evaluated by Kundu, (2005) for solubilization of tricalcium phosphate (TCP) and rock phosphate (RP). Total 69 isolates showed $<$ 50% solubilization efficiency and only two isolates showed solubilization efficiency greater than 100%. Total 15 isolates showed antibiotic resistance to *E. coli*. Morphological and biochemical characteristics of selected isolates with good P solubilization efficiency (18 ^{0}C, 42 ^{0}C, 43 ^{0}C and 76 ^{0}C) indicated genus Pseudomonas. The PSB increased dry shoot weight and nutrients uptake in chickpeas. Dry matter yield of 61.8; 82.9 and 110.7 g pot^{-1} was recorded by the application of 30 kg Single Super Phosphate with PSB at 60, 90 and 120 DAS respectively.

Gull (2002) isolated phosphate solubilizing bacteria from rhizosphere, roots and nodules of chickpeas. Then isolates were grown and purified in petri plates containing pikovskaia medium. All strains were Gram negative, rod shaped, motile, fast growing and varied in IAA production. In pot trials, PSB strains enhanced seedling emergence, promoted plant growth chickpea plants and phosphate availability to plants. Favourable effect of PSB inoculation on iron accumulation was an important feature which effected growth and yield of plants significantly. PSB inoculation caused an extensive increase in concentration of total nitrogen, nitrogenase activity, total phosphorus and Na+, K+ and Ca+2.

Goud et al. (2012) conducted a field experiment was conducted during Rabi season in India to study the effect of farmyard manure, seed inoculation with phosphate solubilizing bacteria and different phosphorus levels on Kabuli chickpea. Seed inoculation with phosphate solubilizing bacteria significantly increased the grain yield over control, however, did not influence the net return significantly. Application of 60 kg P_2O_5 ha^{-1} resulted with higher grain yield, growth and yield attributes, gross and net monetary return compared to lower phosphorous level like 30 kg P_2O_5 ha^{-1}.

Singh et al. (2014) was conducted a field experiment for two winter (Rabi) seasons in India to study the effect of diammonium phosphate fertilizer and phosphate solubilizing bacteria application to a salt affected soil under rainfed conditions. The split application of 100 kg DAP/ha (½ through soil+½ through foliage in two splits at 45 and 60 days after sowing, DAS) in conjunction with PSB significantly improved plant height, leaf area/plant, number and dry weight of nodules $plant^{-1}$, root and shoot dry weight/plant, leaf area index, crop growth rate, net assimilation rate, days to 50% flowering, days to pod formation and days to maturity), seed weight/plant, yield. Maximum seed yield (1.48 t ha^{-1}) and protein yield (336 kg ha^{-1}) were obtained with the application of 100 kg DAP/ha (½ as basal+½ as foliar in two splits at 45 and 60 DAS)+PSB.

CONCLUSIONS

Response of chickpea to phosphorus solubilising bacteria applications is positive based on yield and related growth parameters when published articles analysed.

Microelement studies in relation to PSBs are limited in number. Manure applications from different animal origin is needed to be tested. Ultrafine grinded phospate rocks may be used to conduct studies to improve yields more. More PSBs studies are needed in combination with foliar agrochemical applications on chickpea. More diseases research are also needed, especially root diseases. Studies conducted on sand are problematic due to deficiency of micros in soil if not supplied during trials.

Bacterias from Indian market and research structures can be obtained especially from “Anand Agricultural University”via contacting to researcher “Patil, S. V”. Bacterias obtained from roots of different legumes than chickpea may also be tested on chickpea.

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