Role of Phosphorous Solubilizing Microorganisms to Eradicate P- Deficiency in Plants: A Review

K. Nisha., Padma Devi, S.N., Vasandha.S and Sunitha kumari, K

Department of Botany, PSGR Krishnammal College for Women, Peelamedu, Coimbatore-641 004.

Abstract- Phosphorus is the second most important macro nutrient required by the plants for its optimum growth and yield. But it is considered to be a most limiting factor of many crop production systems, due to its unavailability of soluble forms in the soils. About 80% of applied P fertilizers are immobilized due to the formation of complex with Al or Fe in acidic soils or Ca in calcareous soils. An alternative way to circumvent P deficiency in soil and to improve crop production is through the utilization of microorganisms as biofertilizer. Rhizospheric microorganisms play a vital role in the transformation of unavailable form of P into available form which will be a boon to the agrarian communities to remove P deficiency in plants.

Index Terms- Phosphorous, deficiency, solubilization, microorganisms, organic acid.

I. Introduction

Phosphorus (P) is one of the major essential macro-nutrients required for maximizing crop growth and production. It plays a significant role in plant metabolism and is important for the functioning of key enzymes that regulate the metabolic pathways (Theodorou and plaxton, 1993). Therefore, P deficiency is considered to be the most important chemical factor that restricts plant growth because of its vital role in physiological and biochemical functions of the plant.

In India, P content in an average soil is 0.05%. Only 0.1% from the total P forms is available to plant, rest of the P forms become insoluble salt (Bhattacharya and Jain, 1996). The use of chemical fertilizers to circumvent the P deficiency in soil also becomes unavailable to the plants due to the rapid immobilization of P soon after application (Dey, K.B., 1988; Sanyal, S.K & De Datta, S. K., 1991; Yadav, K. S & Dadarwal, K. R., 1997). This immobilization is due to the high reactivity of phosphate anions through precipitation with cations such as Fe^{3+} and Al^{3+} in acidic soils (Norrish and Rosser, 1983) or Ca^{2+} in calcareous soils (Sample *et al*., 1980). In these forms P is highly insoluble and unavailable to plants (Rdresh *et al*., 2004).

In Tamil Nadu most of the agricultural soils are calcareous in nature. P mineral present in the calcareous soil become unavailable to plants due to the immobilization of phosphate anions by forming a complex with Ca (Sample *et al*., 1980). Thus P deficiency in soil always remains as a major challenge to agriculturist.

Application of microorganisms solubilizing phosphate will be a promising approach to increase P availability in agricultural soil. The major mechanism involved in the P solubilization is the production of organic acids and chelating oxo-acids from sugars (Antoun and Kloepper, 2001; Peix *et al*., 2001).

II. PHOSPHORUS IN SOIL

Phosphorus is a vital nutrient available to plant roots only in soluble forms that are in short supply in the soil (Malviya *et al*., 2011). It is estimated that about 98% of Indian soil contains insufficient amount of available phosphorus, which is necessary to support maximum plant growth (Padmavathi and Usha, 2012). There are two types of phosphorus present in soil, that are organic and inorganic (Rasoolkhatibi, 2011). Organic form of phosphorus is available as soil humus, which is taken up by plants from soil and utilized by animals that consume plants. They are returned to soil as organic residues which will get decayed in soil. These organic phosphates will slowly release inorganic phosphate. The release of inorganic phosphate from organic phosphate is called "mineralization" which is caused by micro organism by the breakdown of organic compounds (McGrath *et al*., 1995). The level of inorganic phosphorus is very low in the soil (Adarsh *et al*., 2011), which is either adsorbed to soil mineral surfaces or occur as sparingly available precipitate form (Richardson *et al*., 2011).

The greater part of soil phosphorus, approximately 95-99 % is present in the form of insoluble phosphates (Vessileva *et al*., 1993). It means that soil contain high amount of total phosphorus, but it's availability to plant is very low and it is often a limiting factor for the plant growth (Mikanova and Novakova, 2002).

III. ROLE OF PHOSPHORUS IN PLANT DEVELOPMENT

Phosphorus is the "King Pin" in Indian agriculture and occupies a unique position both in conventional as well as in alternative agriculture (Karunaiselvi *et al*., 2011). It is one of the essential mineral macronutrients, which are required for maximum yield of agriculturally important crops (Islam *et al*., 2007) and also it helps for plant growth and reproduction (Mahantesh and Patil, 2011). Without adequate phosphorus supply the yield of the crops cannot reach the economic level (Balamurugan *et al*., 2010).

An adequate supply of phosphorus in the early stages of plant helps to promotes growth and productivity of the crops. It plays a vital role in many physiological activities such as cell division, photosynthesis and development of good root system and utilization of carbohydrates (Mahantesh and Patil, 2011). It plays an indispensible biochemical role in respiration, cell enlargement and several other processes in living plant (Sagervanshi *et al*., 2012). The most essential function of phosphorus in plant is energy storage and transfer of Adenosine di and tri phosphate (ADP and ATP) which act as energy currency in the plants (Kaviyarasi *et al*., 2011). Phosphorus also helps in development of meristamatic tissue, in stimulation of early root growth (Sonam Sharma *et al*., 2011).

Phosphorus is an important constituents of nucleic acid, phytin and phospholipids (Sagervanshi *et al*., 2012). Phosphorus helps plant to survive winter rigors and also improve the quality of many fruits, vegetables and grain crops (Sagervanshi *et al*., 2012). Ahmanalikhan *et al*., (2009) reported that phosphorus occupies major factor in stalk and stem strength, flower and seed formation, crop maturity and production, nitrogen fixation in legumes, crop quality and resistance to plant disease. But due to the unavailability of phosphorus in soil, its deficiency is major constraints for crop production (Aadarsh *et al*., 2011) and it can severely limit plant growth and productivity (Alikani *et al*., 2006).

IV. PHOSPHORUS DEFICIENCY IN PLANTS

Phosphorus deficiency in plants leads to chlorosis, weak stem and slow growth (Mahantesh and Patil, 2011).

A mild P deficiency results in stunted crop growth, which will be insignificant visibly. In severe cases of P deficiency, symptoms include characteristic stunting, purpling or browning, appearing first on the lower leaves and base of the stem and working upward on the plant, particularly on cereal crops. The effect is first evident on leaf tips, and then progresses toward the base. Eventually, the leaf tip dies. However, visual diagnosis of P deficiency is very difficult and must be confirmed with soil tests and possibly with the aid of plant tissue analysis. Symptoms are most pronounced in young plants because their more rapid growth makes greater demands on the available supply (Ross H. McKenzie, 2003).

V. AVAILABILITY OF PHOSPHORUS IN SOIL

Phosphorus is a major growth limiting nutrient and unlike the case of nitrogen, there is no large atmospheric source that can be made biologically available (Ezawa *et al*., 2002). In soil phosphorus is sequestered by adsorption of surface soil particles and through precipitation with soil cations, particularly iron, aluminium, and calcium (Harries *et al*., 2006) and these phosphate anions are extremely reactive and immobilized through precipitation (Keneni *et al*., 2010). Rodriguez and Fraga, 1999; Fernandez *et al*., 2007 also reported that both phosphorus fixation and precipitation occurs in soil, because of the large reactivity of phosphate ions with numerous soil constituents and these phosphorus ions adsorbed as Fe – oxides, Al- oxides, Al-silicates and Ca–carbonates depending on the particular properties of soil (Karunaiselvi *et al*., 2011). These forms of phosphorus are highly insoluble and unavailable to plants.

Mostly phosphate is predominantly present in the form of Inorganic phosphate (IP) which belongs to two groups; (i.e.) of calcium and those of iron and aluminium (Selvi *et al*., 2011). In acidic soil phosphorus is fixed by free oxides and hydroxides of aluminium and iron, while in alkaline soils, phosphorus fixed by calcium (Goldstein, 1994; Jones *et al*., 1991).

A recent estimation revealed that 49.3% of cultivated lands are deficient in available phosphorus (Patil *et al*., 2012). The uptake of phosphorus by the plants is only a small fraction, which is actually added as phosphate fertilizer (Vassilev and Vassileva, 2003). The remaining phosphorus from total phosphorus content is converted into insoluble form of phosphates and lost in the soil due to the adsorption, precipitation or conversion of organic phosphates (Holford, 1997).

VI. FACTORS AFFECTING THE AVAILABILITY OF PHOSPHORUS IN THE SOIL

Different parameters such as soil pH, calcium concentration, proportion of organic matter and its type, soil moisture, soil texture, root density and exudates can affect the availability of soil phosphorus to the plants (Tisdale *et al*., 1993; Barber, 1995). In case of acidic soil, free oxides and hydroxides of Al and Fe play a key role in fixing phosphorus, while alkaline soil it is fixed by Ca (Toro, 2007). Regular applications of phosphorus fertilizer also decrease the high total phosphorus content in soil (Borling *et al*., 2001; Hao *et al*., 2002).

The availability of soil phosphorus is also influenced by nature and content of clay, active sesquioxides, lime content and organic matters (Karunaiselvi *et al*., 2011).

VII. IMPACT OF CHEMICAL FERTILIZERS ON SOIL

Due to the unavailability of phosphorus in soil, plants cannot meet their requirement which lead to the large utilization of phosphorus chemical fertilizers by farmers (Islam *et al*., 2007).

Using phosphorus fertilizer, especially superphosphate, as very common method of providing plant phosphorus requirement, is not very efficient in calcareous and alkaline soil. The amounts of phosphorus applied were turned into insoluble products and becomes unavailable to the plants and only about 20% of the fertilizers is soluble in the first year of use (Tisdale *et al*., 1993). To rectify the effect of chemical fertilizer and to maintain the soil fertility status, solubilization of insoluble phosphorus in the soil is made available to crops by sustainable agricultural methods (Rodriguez and Fraga, 1999; Vessey, 2003; Thakurai *et al*., 2004).

VIII. BIOFERTILIZERS

Use of biological alternatives (Biofertilizer) radically been increased due to the increasing prices of synthetic fertilizers and concurrently threat of agro chemicals to the environment (Socolno, 1999; Vance, 2001).

IX. ROLE OF MICROORGANISMS IN PHOSPHORUS SOLUBILIZATION

Microbial inoculants have provided their worth as biological alternative to compensate agro chemicals and to sustain environment friendly crop production (Dobbelaere *et al*., 2003).

Phosphorus solubilizing microorganisms was more effective approach for providing balanced nutrition (Gupta *et al*., 1998; Martins *et al*., 2004) and recently, these phosphorus solubilizing microorganisms have attracted the attention of agriculturalists as soil inoculums to improve the plant growth and yield (Yung, 1994; Yung *et al*., 1998; Goldstein *et al*., 1999; Fasim *et al*., 2002).

X. RHIZOSPHERE MICROORGANISMS

Microorganisms are integral to the soil phosphorus cycle and as such play an important role in mediating the availability of phosphorus to plants (Richardson *et al*., 2011). The role of microorganism in solubilization of inorganic phosphates in soil and making them available to plants is the well known mechanism (Bhattacharya and Jain, 2000) and such organisms are called as phosphate solubilizers. High proportion of phosphate solubilizing microorganisms is concentrated in the rhizosphere, and they are metabolically more active than other sources (Vazquez *et al*., 2000).

Both the group of microorganisms such as phosphate solubilizing bacteria and phosphorus solubilizing fungi are equally important to enhance plant growth by means of solubilization mechanism and their acquisition to plant production through the synthesis of organic acid and plant growth promoting substance (Yadav *et al*., 2011).

XI. PHOSPHORUS SOLUBILIZING BACTERIA

Among the soil bacterial community's ectorhizospheric strains such as *Pseudomonas, Bacillus* and endosymbiotic rhizobia have been served as effective phosphate solubilizers (Igual *et al*., 2001). Whitelaw, (2000) also reported that *Pseudomonas, Bacillius, Rhizobium* and *Enterobacter* are the most powerful solubilizers.

Villegas and Fortin, (2002) identified that bacteria belonging to *Mesorhizobium, Rhizobium, Klebsiella, Acinetobacter, Enterobacter, Erwinia, Achrobacter, Micrococcus, Pseudomonas* and *Bacillus* isolated from different soils were the efficient P solubilizing strains.

XII. PHOSPHORUS SOLUBILIZING FUNGI

Most of the fungi were non-solubilizer of phosphorus but species of *Aspergillus* and *Penicillium* were identified to have more phosphate solubilizing capabilities (Sagervanshi *et al*., 2012).

XIII. MECHANISM INVOLVED IN PHOSPHORUS SOLUBILIZATION

Major mechanism of mineral phosphate solubilizatiion is the action of organic acid synthesized by soil micro organisms. Production of these organic acid results in acidification of the microbial cell and its surroundings (Halder *et al*., 1990; Duff and Webley, 1959; Salih *et al*., 1989).

In particular soil microorganisms are effective in releasing phosphorus from organic pools of total soil phosphorus by mineralization (Abd-Alla, 1994; Bishop *et al*., 1994) and from inorganic complexes through solubilization (Kucey *et al*., 1989; Richardson, 1994). Such, beneficial microorganisms in the soil convert insoluble phosphorus into soluble form for plant growth (Rodriguez and Fraga, 1999) by acidification, chelation and exchange reactions (Gerke, 1992). During the solubilization, microorganisms secrete different types of organic acids, thus lowering the pH in the rhizosphere (He and Zhu, 1988) and consequently dissociate the bond form of phosphates like $Ca_3(PO_4)_2$ (Tri Calcium Phosphate) in calcareous soil.

Organic acid such as acetic, citric, lactic, propoionic, glycolic, oxalic, melonic, succinic acid, fumaric, tartaric etc. have also been involved in phosphorus solubilization (Ahmad and Shahab, 2011) but GLUCONIC acid was reported as the principal organic acid in the solubilization of inorganic phosphate compound *Pseudomonas* sp, *Erwinia herbicola*, *Pseudomonas cepacia* and *Burkholderia cepacia* are phosphorus solubilizing bacteria, which produce more amount of gluconic acid (Goldstein *et al*., 1993).

XIV. CONCLUSION

By employing microbial inoculants to the soil, P can be made available to plants that shall improve the crop production. Such use of microbial inoculants as a biofertilizer will reduce the use of chemical fertilizers which in turn shall reduce the cost but enhance soil fertility.

REFERENCES

[1] Aadarsh Prasanna, D., V. Deepa., M. Balakrishna Murthy., R. Deecaraman., Sridhar and P. Danndapani. 2011. Insoluble phosphate solubilization by bacterial strains isolated from rice rhizosphere soils from southern India. Int. J. Soil. Sci., 6(2):134-141.

[2] Abd-alla, M. H. 1994. Phosphatases and the utilization of organic P by Rhizobium leguminosarum. Biovar viceae. Lett. Appl. Microbiol., 18: 294-296.

[3] Ahmad ali khan G. J., M. SaleemAkhtar, S. M. Saqlannaqvi and M. Rasheed. 2009. Phosphorus solubilizing bacteria: occurrence, Mechanisms and their role in crop production.

[4] Ahmad, N., and S. Shahab. 2011. Phosphate solubilization: Their mechanism genetics and application. Int. J. Microbiol., 9: 4408-4412.

[5] Alikhani, H.A., N. Saleh-Rastin and H. Antoun. 2006. Phosphate solubilization activity of rhizobia native to Iranian soils. Plant and soil., 287: 35-41.

[6] Balamurugan, A., T. Princy, P. Vidhya pallavi, P. Nepolean, R. Jayanthi and R. Premakumar. 2010. Isolation and characterization of phosphate solubilizing bacteria in tea (Camellia sinansis). J.Biosci. Res., 1(4): 285-293.

[7] Barber, S.A. 1995. Soil nutrient bioavailability. John Wiley and Sons Inc., 23-28.

[8] Bhattacharya, P and R. K. Jain. 2000. Phosphorus solubilizing biofertilizers in the whirlpool of rock phosphate challenges and opportunities. Fert. News., 45: 45-49.

[9] Bishop, M. L., A. C. Chang and R.W. K. Lee. 1994. Enzymatic mineralization of organic phosphorus in a volcanic soil in Chile. Soil sciences., 157: 238-243.

[10] Borling, K., E. Otabbong and E. Barberis. 2001. Phosphorus sorption in relation to soil properties in some cultivated Swedish soils. Nutrient Cycling in Agroecosystem., 59: 39-46.

[11] Dey, K.B. 1988. Phosphate solubilizing organisms in improving fertility status. In: Sen SP, Palit P, editors. Biofertilizers : Potentialities and Problems. Calcutta: Plant Physiology Forum, Naya Prokash. 237-48.

[12] Dobbelaere, S., Vanderleyden and Y. Okon. 2003. Plant growth-promoting effects of diazotrophs in the rhizosphere. Crit. Rev. Plant Sci., 22: 107-149.

[13] Ezawa, T., S. E. Smith and F. A. Smith.2002. P metabolism and transport in AM fungi. Plant Soil., 244: 221-230.

[14] Fasim, F., N. Ahmed, R. Parson, G.M. Gadd. 2002. Solubilization of zinc salts by a bacterium isolated from air environment of a tannery. FEMS Microbiol. Lett 213: 1-6.

[15] Fernandez, L.A., P. Zalba, M.A. Gomez and M.A. Sagardoy. 2007. Phosphate solubul.ization activity of bacterial strains in soil and their effect on soybean growth under green house conditions. Bio. Fert. Soil., 43: 805-809.

[16] Gerke, J., 1992. Phosphate, aluminium and iron in the soil solution of three different soils in relation to voarying concentration of citric acid. Zeitschrift Pflanzenernhr Bodenkunde, 155: 339-343.

[17] Goldstein, A.H. 1994. Involvement of the quinoprotein glucose dehydrogenase in the solubilization of exogenous phosphates by gram-negative bacteria. Torriani-Gorini A,

[18] Yagil E, Silver, S, editors. Phosphate in micro organisms: Cellular and Molecular Biology. Washington, DC: ASM Press.197-203.

[19] Goldstein, A.H., K. Braverman, and N. Osorio. 1999. Evidence for mutualism between a plant growing in a phosphate-limited desert environment and a mineral phosphate solubilizing (MPS) bacterium. FEMS Microbiol. Ecol., 3: 295-300.

[20] Gupta, A., A.K. Saxena, M. Gopal and K.V. B. R. Tilak. 1998. Effect of plant growth promoting rhizobacteria on competitive ability of introduced Bradyrhizobium sp.(Vigna) for nodulation. Microbiol. Res., 153: 113-117.

[21] Halder, A.K., A.K. Mishra, P. Bhattacharya and P.K. Chakrabarthy. 1990. Solubilization of rock phosphate by Rhizobium and Bradyrhizobium. J.Gen. Appl. Microbiol., 36: 81-92.

[22] Hao, X., C.M. Cho, G.J. Racz and C. Chang. 2002. Chemical retardation of phosphate diffusion in an acid soil as affected by liming. Nutr. Cycl. Agroecosys., 64: 213-224.

[23] Harris, D. L. and B. G. Lottermoser. 2006. Evaluation of phosphate fertilizers for ameliorating acid mine waste. Applied Geochemistry., 21: 1216-1225.

[24] He, Z. L. and J. Zhu. 1988. Microbial utilization and transformation of phosphate adsorbed by variable charged minerals. Soil Biol. Biochem., 30: 917-923.

[25] Holford, I. C. R.. 1997. Soil phosphorus: its measurement and its uptake by plants. Aust. J. Soil Res., 35: 227-239.

[26] Igual, J. M., A. Valverde, E. Cervantes and E. Velazquez. 2001. Phosphate-solubilizing bacteria as inoculants for agriculture: use of updated molecular techniques in their study. Agronomie., 21: 561-568.

[27] Jones, D.A., B.F.L. Smith, M.J. Wilson and B.A. Goodman. 1991. Solubilizator fungi of phosphate in rice soil. Mycol Res., 95: 1090-3.

[28] Karunai Selvi, B., J.A. John Paul, A.D. Ravindran and V. Vijaya. 2011. Quantitative estimation of insoluble inorganic phosphate solubilization. I.J.S.N., 2(2): 292-295.

[29] Kucey, R. M. N., H. H. Janzen and M. E. Legett. 1989. Microbial mediated increases in plants available phosphorus. Adv. Agro., 42: 199-228.

[30] Malviya J., K. singh and V. Joshi. 2011. Effect of phosphate solubilizing fungi on growth and nutrient uptake of Ground nut (Arachishypogaea)plants. Adv. Biores. 2(2): 110-113.

[31] Martins, A., O. Kimura, S. R. Goi and J. I. Baldani. 2004. Effect of co-inoculation of plant growth promoting rhizobacteria and rhizobia on development of common bean plants (Phaseolus vulgaris, L.). Floresta e Ambiente., 11: 33-39.

[32] McGrath J.W., G.B. Wisdom, G. McMullan, M.J. Lrakin and J.P. Quinn. 1995. The purification and properties of phosphonoacetate hydrolase, a novel carbon-phosphorus bond-cleaving enzyme from Pseudomonas fluorescens 23 F. Eur J Biochem., 30: 225- 234.

[33] Patil, A. S., S. V. Mahamuni, P. V. Wani. 2012. Isolation of phosphate solubilizing fungi from rhizosphere of sugarcane and sugar beet using TCP and RP solubilization. Asian journal of biochemical and pharmaceutical reaserch., (2): 2231-2560.

[34] Patil, C.S and P. Mahantesh, . 2011. Isolation and screening of efficiency of phosphate solubilizing microbes. Int. J. Microbiol. Res., 3(1): 56-58.

[35] Rasool, K. 2011. Using sulfur oxidizing bacteria and P solubilizing for enhancing phosphorus availability to Raphanus sativus. African journal of Plant Science., 5(8): 430-435.

[36] Rdresh, D. L., M. D. Shivprakash, and R. D. Prasad. 2004. Effect of Combined Application of Rhizobium, Phosphate Solubilizing Bacterium and Trichoderma spp. On Growth, Nutrient Uptake and Yield of Chickpea (Cicer aritenium L.). Appl. Soil Ecol., 28: 139-146.

[37] Richardson, A. E. and R. J. Simpson. 2011. Soil microorganisms mediating phosphorus availability. Plant Physiol., 156: 989-996.

[38] Mikanova, O. and J. Novakova. 2002. Evaluation of the P solubilizing activity of soil microorganisms and its sensitivity to soluble phosphate. Rostlinna vyroba., 48: 397-400.

[39] Rodriguez, H. and R. Fraga. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. Biotechnol. Adv., 17: 319-339.

[40] Sagervanshi, A., P. Kumara, A. Nagee and A. Kumar. 2012. Isolation and charactrizatio of phosphate solubilizing bacteria from anand agriculture soil. International journal of life science and pharma research., 2: 256-266.

[41] Sample, E. C., R. J. Soper and G.J. Raez. 1980. Reactions of phosphate fertilizers in soils.In: The role of phosphate in agriculture, 263-310.

[42] Sharma, S., V. Kumar and R. B. Tripathi. 2011. Isolation of phosphate solubilizing microorganism (PSMs) from soil. J. Microbiol. Biotech. Res., 1(2): 90-95.

[43] Theodorou, M.E., and W. C. Plaxton. 1993. Metabolic adaptation of plant respiration to nutritional phosphate deprivation. Plant Physiol., 101: 339-344.

[44] Tisdale, S.L., W.L. Nelson, J.D. Beaton and J.L. Havlin. 1993. Soil fertility and fertilizers. 5th ed., Mcmillon Publishing Co., New York, 561-576.

[45] Vassilev, N., Vassileva, and D. Spassova. 1993. Production of gluconic acid by Aspergillus niger immobilized on polyurethane foam. Appl. Microbiol. Biotechnol., 39: 285-288.

[46] Vazquez, P., G. Holguin, M. E. Puente, A. Lopez-Cortez and Y. Bashan. 2000. Phosphate- solubilizing microorganisms associated with the rhizosphere of mangroves in a semiarid coastal lagoon. Biol. Fertil. Soils., 30: 460-468

[47] Vessey, J.K., 2003. Plant growth promoting rhizobacteria as biofertilizers. Plant Soil., 255: 571-586.

[48] Vessilev, N. and M. Vessilev. 2003. Biotechnological solubilization of rock phosphate on media containing agro-industrial wastes. Appl. Microbiol. Biotechnol., 61: 435-440.

[49] Villegas, J. and J.A. Fortin. 2002. Phosphorus solubilization and pH changes as a result of the interactions between soil bacteria and arbuscular mycorrhizal fungi on a medium containing NO3 as nitrogen source. Can. J. Bot., 80: 571-576.

[50] Whitelaw, M.A. 2000. Growth promotion of plants inoculated with phosphate solubilizing fungi. Adv. Agron., 69: 99-151.

[51] Yadav, B. K. and J. C. Tarafdar. 2011. Penicillium purpurogenum, unique P mobilizers in arid agro-ecosystems. Arid Land Res. Manag., 25(1): 87-99.

[52] Young, C. C. 1994. Selection and application of biofretilizer in Taiwan. Food and Fertilizer Technology Centre. Tech. Bull., 141: 1-9.

[53] Young, C. C., C. H. Chang, L. F. Chen and C. C. Chao. 1998. Characterization of the nitrogen fixing ferric phosphate solubilizing bacteria isolated from Taiwan soil. J. Chin. Agricult. Chem. Soc., 36: 201-210.

AUTHORS

First author: K. Nisha M.Sc., M.Phil, Department of Botany, PSGR Krishnammal college for women, Peelamedu, Coimbatore-641 004. E-mail: sunitha239kk@gmail.com.

Second author: Dr.S.N.Padma Devi, Associate professor, Department of Botany, PSGR Krishnammal college for women, Peelamedu, Coimbatore-641 004.
Third author: Mrs. S. Vasandha, Dean-student affairs, PSGR Krishnammal college for women, Peelamedu, Coimbatore-641 004.

Fourth author: K.Sunitha kumari M.Sc., Ph.D scholar, Department of Botany, PSGR Krishnammal college for women, Peelamedu, Coimbatore-641 004.

Correspondence author: K. Nisha M.Sc., M.Phil, Department of Botany, PSGR Krishnammal college for women, Peelamedu, Coimbatore-641 004. E-mail: sunitha239kk@gmail.com.