Available Online at http://www.recentscientific.com

CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 10, Issue, 06(F), pp. 33102-33106, June, 2019

ISSN: 0976-3031

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

A REVIEW ON PLANT GROWTH PROMOTORY PROPERTIES OF FLUORESCENT PSEUDOMONADS

Preeti Chandurkar

Department of Biotechnology, Barkatullah University, Bhopal

DOI: http://dx.doi.org/10.24327/ijrsr.2019.1006.3606

ARTICLE INFO

Article History:
Received 10th March, 2019
Received in revised form 2nd April, 2019
Accepted 26th April, 2019
Published online 28th June, 2019

Key Words:

Rhizobacteria, Bioinoculant, Fluorescent Pseudomonads, Siderophore

ABSTRACT

The modern agriculture system emphasizes on wide use of chemical based fertilizers, herbicides and pesticides which have dramatically polluted the environment. By employing eco-friendly methods like the application of bioinoculant and biopesticides, agricultural sustainability, environmental safety and increased crop production can be achieved. The useful effects of microbial inoculants, mostly plant growth promoting rhizobacteria (PGPR) necessitates the demand for increased research and their utility in modern agriculture. Fluorescent pseudomonads are well known potential plant growth promoting bacteria which are common inhabitants of agricultural field soil and plant rhizosphere. They play a crucial role in agriculture by enhancing the growth of plants by showing various properties like phosphate solubilization, phytoharmones and siderophore production also it helps in suppression of phytopathogens which cause diseases to plants by producing antimicrobial compounds.

INTRODUCTION

In twenty first century increased use of pesticides, synthetic fertilizers, drought, salinity, loss of soil fertility, fluctuating climatic conditions and increase in attack by phytopathogens on crops etc (Abboud, 2014) are the current challenges that are been faced by agriculture sector. The international need to enhance agricultural production from rapidly declining land resources had placed considerable strain on the fragile agriculture ecosystem (Gomiero *et al*., 2011). The use of plant growth promotory rhizobacteria as bioinoculants in agriculture system will greatly helps in solving the above mentioned problems. Since long there had been a practice of using PGPR for enhancing crop production, plant and soil health. Further more understanding of the basic mechanism of plant-bacteria interactions and their beneficial relationship is likely to accelerate the acceptance efficiency of these microorganisms as appropriate and effective addition in agriculture practices. The rhizospheric soil is directly influenced by plant root exudates and considered as a sink of nutrients compared to bulk soil. Fatty acids, amino acids, nucleotides, phenols, organic acids, plant growth promoters/regulators, sterols, sugars and vitamins are the nutrients mainly present in rhizospheric soil. The nutrients availability in roots consequently increased the microbial population among which fungi and bacteria influenced the plant growth significantly (Uren, 2001).

Plant Growth Promoting Rhizobacteria

Rhizosphere is the confined area where root activity significantly influences biological properties (Manthey *et al*., 1994). In the rhizosphere, a large number of microorganisms ranging from algae, bacteria, fungi and nematodes coexist with each other. Bacteria plays a major role in this mixed population and is the most abundant. Plant Growth Promoting Rhizobacteria are class of bacteria that are positive promotor of soil quality and dwell with the plant symbiotically at their rhizosphere or as an endophyte that invades the tissue of host plants. PGPR can aid in stimulating plant growth by increasing the plant nutrition by several mechanisms like the production of plant growth hormones, nitrogen fixation and phosphate solubilization, siderophore production (Glick, 1995; Ahmad *et al*., 2008a; Bhattacharyya and Jha, 2012). The major task which is to be dealt in modern agriculture is to increase crop production, maintain environmental safety and soil fertility.

Depending on their presence rhizobacteria were categorized as (i) Rhizosphere, bacteria living in soil that are strongly adhered to the roots (ii) Rhizoplane, bacteria that are adhered to root surface (iii) Endophytes, bacteria residing inside root tissues and occupies spaces between cortical cells (iv) Symbiotic, bacteria residing inside root nodules of legumes and woody plants (Glick, 1995). Microorganisms belonging to any of these categories can directly improve plant growth either by increasing nutrient uptake of nitrogen, phosphorus and other

Corresponding author:* **Preeti Chandurkar
Department of Biotechnology, Barkatullah University, Bhopal

important minerals and indirectly by suppressing the harmful effects of various plant pathogens in the form of biocontrol (Kloepper *et al*, 1989). Vessey et al. (2003) categorized the bacteria belonging to the first three groups mentioned above have been categorized as extracellular PGPR (ePGPR) namely *Bacillus, Caulobacter, Pseudomonas, Arthrobacter, Erwinia, Micrococcus, Hyphomycrobium, Flavobacterium, Chromobacterium, Serratia, Agrobacterium* and the fourth group has been categorized as intracellular PGPR (iPGPR) includes the genera *Rhizobium, Bradyrhizobium, Sinorhizobium, Azorhizobium, Mesorhizobium* and *Allorhizobium.*

For minimizing the dependence of farmers on chemical fertilizers without declining the productivity of crops, the application of different PGPRs in the form bioinoculants single or mixed is presently the main thrust area of research to increase the crop yield (Trivedi *et al*., 2012). The discovery of different PGPRs is gaining momentum and emphasis on development of bioinoculants for various economically important crops are undergoing till date (Saharan and Nehra, 2011; Glick, 2014; Zahid *et al*., 2015).

Genus Pseudomonas

Pseudomonas are gram negative, motile, oxidase positive, extremely diverse genus of Y-Proteobacteria (Galli *et al*. 1992). Members of this genus have very minimal nutritional requirement for survival and growth under simple conditions when grown with other microbial system (Foster, 1988). A pseudomonas strain was phenotypically characterized by Den in 1926, the basis being their nutritional utilizing characteristics. Stanier *et al*. (1966) conducted an extensive analysis on *Pseudomonas* based on phenotypic characterization that resulted in subdivision of genus into species and grouping these species. It is widely distributed in nature. *Pseudomonas* is ideal and the most studied Plant growth promoting rhizobacteria till date. Pseudomonads have diverse plant growth promoting activities (Glick, 1995; Podile and Kishore, 2006; Goswami *et al*., 2016). The positive influence of these bacteria is due its capability to improve plant growth and suppression of plant diseases. Most of the strains of fluorescent pseudomonad species such as *P. putida, P. aeruginosa, P. chlororaphis, P. monteilli, P. fluorescens,* etc. are known to be the most powerful plant growth promoting bacteria (Baavno and Musarrat 2003; Kumar *et al*. 2005; Naik *et al*. 2008; Jha *et al*. 2009).

Mechanisms of plant growth promotion by Fluorescent pseudomonads

Phosphate Solubilisation

Phosphorus is an important nutrient that is required for plants development. Soil contains a diversified range of organic phosphorus substrates, but to make this form accessible to the plant it requires to be hydrolyzed into inorganic form (Glass 1989). Also a large portion of soluble inorganic phosphate applied to soil as chemical fertilizer is rapidly immobilized soon after application and becomes unavailable to plants (Dey 1998). The principal mechanism for the mineralization of organic phosphorus is the production of organic acids and acid phosphatases. To solve the problem of phosphorus deficiency, the application of microbial inoculants having phosphate solubilizing ability could be considered as an eco-friendly and cost effective alternative to reduce dependence on chemical phosphate based fertilizers (Khan *et al*., 2014).

Phytohormones

In the various stages of plant development like cell elongation, cell division, apical dominance and tissue differentiation phytohormones plays an important role. Fluorescent pseudomonads produce variety of phytohormones such as gibberellins, abscisic acid, cytokinins and auxins (Streit *et al*. 1996; Patten and Glick 2002). Indole-3-acetic acid (IAA) a type of auxin is a pivotal phytohormone as it stimulates the mass and longitudinal increase of root hairs thereby resulting in improvement in plant uptake capacity to absorb nutrients and water from soil, thus stimulating plant growth. Fluorescent pseudomonads yield a significant amount of IAA and are also capable of producing hormones like cytokinins and gibberellins (Kumar *et al*. 2005). Cytokinins are believed to act as a signal involved in mediating ecological stress from roots to shoots (Jackson 1993). Ethylene causes inhibition of root growth is a phytohormone of gaseous nature and is commonly induced by cutting plants.

Siderophore Production

Iron is relatively insoluble in soil yet an essential nutrient for development of plants. Plant roots can readily absorb ferrous ions (Fe^{2+}), but ferric ions (Fe^{3+}) is the most common form available in the soil. Production of siderophore is an important trait, expressed by rhizobacteria to improve plant growth. Siderophores are small high affinity iron chelating compounds which increases plant growth by direct and indirect mechanisms. The direct mechanism provides iron to plants and in indirect mechanism by suppressing plant diseases by binding with iron strongly making them unavailable to plant pathogens (Glick, 2012). Under iron limiting situations, most of the species of Fluorescent pseudomonads yields fluorescent yellow siderophores such as called as pyochelin (Cox *et al*. 1981), pyoverdines (Budzikiewicz 1993, 1997), quinolobactin (Matthijs *et al*. 2007), ornicorrugatin (Matthijs *et al*. 2008) and pseudomonine (Lewis *et al*. 2000; Mossialos *et al*. 2000; Mercado-Blanco *et al*. 2001). Siderophores production has been linked to the resistance to disease by suppressing the causative agent and is produced by fluorescent pseudomonads (Loper 1988). Production of siderophore by fluorescent pseudomonads is influenced by factors such as, nature concentration of carbon and nitrogen sources (Park *et al*. 1988), phosphate level (Barbhaiya and Rao 1985); iron concentration (Kloepper *et al*. 1980a, b); presence or absence of trace elements such as magnesium (Georgia and Poe 1931); zinc (Chakrabarty and Roy 1964) or molybdenum (Lenhoff *et al*. 1956); temperature conditions (Weisbeek *et al*. 1986) and extent of aeration (Lenhoff 1963).

Antimicrobial Metabolites

Fluorescent pseudomonads are known to synthesize a wide range of secondary metabolites along with certain cell wall degrading enzymes. They produce secondary metabolite having well-characterized biocontrol properties which includes phenazines, pyoluteorin, phloroglucinols, lipopeptides, pyrolnitrin, and hydrogen cyanide. These metabolites exhibit lethal activity against a wide range of pathogenic fungi and bacteria.

Response of Crops to inoculation of Pseudomonas sp

Members of the genus *Pseudomonas* are most important as well as dominant genus of gram negative bacteria in soil community that influences plant growth because of its direct as well as indirect mechanisms (Lucy *et al*., 2004). Chemicals that are used to control diseases are hazardous to animals, humans, beneficial organisms and stays in natural ecosystems. The inoculation of soil with *Pseudomonas sp.* has enhanced yield in two cultivars of rice (Mirza *et al*., 2006) and tomato (Minorsky, 2008). Inoculation of *Pseudomonas sp*. significantly increased the growth parameters of Tomato plant (**Luis** *et al*., 2017). Plant vigour index and Asparagus productivity was enhanced due to inoculation with *Pseudomonas sp.* under greenhouse conditions (Liddycoat *et al*., 2009). *Pseudomonas aeruginosa* RRALC3 strain showed to increased biomass and nutrients of *Pongamia sp.* seedlings in forest soil (Parthasarathy Radhapriya, 2015). Patten and Glick (2002) reported the role of indole acetic acid in increasing 50% root length as compared to mutant deficient in IAA. 1-amino cyclo propane 1- carboxylic acid (ACC) deaminase activity is also found in *Pseudomonas sp.* G12-2. *Pseudomonas sp.* CHAO a well-studied biocontrol agent, known for the production of siderophore, hydrogen cyanide and different antibiotics. Sharma *et al*. (2003) reported that when *Vigna radiata* plant, inoculated with siderophore producing *Pseudomonas* strain GRP3 and grown in iron limiting conditions, results in reduced chlorotic symptoms and increased chlorophyll content compared to uninoculated plants. Similarly, Vansuyt *et al*. (2007) reported that Fe-pyoverdine complex synthesized by *Pseudomonas sp.* C7 absorbed and assimilated by *Arabidopsis thaliana*, thus increasing the iron level within the plant cells and resulted in improvement in plant growth.

Fluorescent Pseudomonads suppress disease severities caused by phytopathogens and enhance growth of a variety of crops like wheat (Weller and Cook 1983), rice (Mew and Rosales 1986; Sakthivel and Gnanamanickaln 1987), sugar beet (Suslow and Schroth 1982), potato (Kloepper *et al*. 1980), cassava (Hernandez *et al*. 1986) radish (Kloepper and Schroth 1978), cotton (Howell and Stipanovic 1980). A number of different fluorescent pseudomonad species such as *P. aeruginosa* (Bano and Musalat 2003; Sunish kumar *et al*. 2005), *P. putida* (Scher and Baker 1980), *P. chlororaphis* (Chin-A-Woeng *et al*. 1998); *P. cepacia* (Cattelan *et al*. 1999) has been reported as a biocontrol against fungal pathogen as well as plant growth promotor (de Salmone *et al*. 2001).

References

Abboud M.A.A., (2014) Bioimpact of application of pesticides with plant growth hormone (gibberellic acid) on target and non-target microorganisms. J Saudi Chem Soc 18: 1005-1010.

Ahmad F., Ahmad I., Khan M.S., (2008a) Screening of free-living rhizospheric bacteria for their multiple plant growth promoting activities. Microbiol Res 163: 173-181.

Alexandre Cattelan P. G. Hartel Jeffry J. Fuhrmann 1999 Screening for plant growth-promoting rhizobacteria to promote early soybean growth Soil Science Society of America Journal 63(6):1670-1680.

Bano J. and Musarrat J. (2003), Characterization of a new *Pseudomonas aeruginosa* strain NJ-15 as a potential biocontrol agent, Curr. Microbial. 46(5):324-8.

Barbhaiya H.B., and Rao K.K., (1985) Production of pyoverdine, the fluorescent pigment of *Pseudomonas aeruginosa* PAO1, FEMS Microbiology, 27(2):233-235.

Bhattacharyya P.N., Jha D.K., (2012) Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. World J Microbiol Biotechnol 28: 1327-1350.

Budzikiewicz H., (1993) Secondary metabolites from fluorescent pseudomonads, FEMS Microbiol Rev 104:209–228.

Chakrabarty, A.M. and Roy, SC., (1964). Nature of endogenous reserve material in a strain of *Pseudomonas fluorescens-putida*, Biochemical Journal 92(1):105-112.

Chin-A-Woeng TFC, Bloemberg GV, van der Bij AJ, *et al*. 1998. Biocontrol by phenazine-1-carboxamide-producing *Pseudomonas chlororaphis* PCL 1391 of tomato root rot caused by *Fusarium oxysporum* f. sp. *radicis-lycopersici*. *Molecular Plant-Microbe Interactions*11, 1069–1077.

Cox C.D., Rinehart K.L. Jr., Moore M.L., Cook J.C Jr., (1981) Pyochelin: novel structure of an iron-chelating growth promotor for *Pseudomonas. aeruginosa*. Proc Natl Acad Sci USA78, 4256-4260.

den Dooren de Jong L.E., (1926) Bijdrage tot de kennis van het mineralization process. Dissertation. Technische Hogeschool, Delft. Nijgh and van Ditmar, Rotterdam, the Netherlands.

Dey K.B., (1998) Phosphate solubilizing organisms in improving fertility status. Biofertilizers: potentialities and problems. Plant Physiology Forum, Naya Prokash, Calcutta, pp 237–248.

Foster R.C., (1988) Microenvironments of soil microorganisms. Biol Fertil Soils 6:189–203.

Galli E., Barbieri P., Bestetti G., (1992) Potential of pseudomonads in the degradation of methylbenzenes. In: Galli E, Silver S, Witholt B (eds) Pseudomonas: molecular biology and biotechnology. American Society for Microbiology, Washington, DC, pp 268–276.

Georgia FR, Poe CF. (1931) Study of Bacterial Fluorescence in Various Media: I. Inorganic Substances Necessary for Bacterial Fluorescence. J Bacteriol. 22(5):349–361.

Glass A.D.M., (1989) Plant nutrition: an introduction to current concepts. Jones and Bartlett, Boston, MA, p 234.

Glick B.R. (2012), Plant growth-promoting bacteria: Mechanisms and applications, Scientifica 2012:15.

Glick B.R., (1995) The enhancement of plant growth by free-living bacteria. Can J Microbiol 41(2): 109-117.

Glick B.R., (2014) Bacteria with ACC deaminase can promote plant growth and help to feed the world. Microbiol Res 169:30-39.

Gomiero T., Pimentel D., Paoletti M.G, (2011) Environmental impact of different agricultural management practices: conventional vs. organic agriculture, Crit Rev Plant Sci, 30:95-124.

Goswami D., Thakker J.N., Dhandhukia P.C., (2016) Portraying mechanics of plant growth promoting rhizobacteria (PGPR): A review. Cogent Food Agri 2:1127500.

Hernandez J.M., Laberry R., Lozano J.C. (1986), Observations on the effect of inoculating cassava (Manihot esculenta) plantlets with flouorescent pseudomonads, Phytopathol. 117(1):17-25.

Howell, C. R., and R. D. Stipanovic. 1979. Control of Rhizoctonia solani on cotton seedlings with Pseudomonas fluorescens and with an antibiotic produced by the bacterium. Phytopathology 69:480-482.

Ines E García de Salamone, , Russell K Hynes, and , Louise M Nelson (2001), Cytokinin production by plant growth promoting rhizobacteria and selected mutants Canadian Journal of Microbiology, 47(5): 404-411

Jackson MB. (1993). Are plant hormones involved in root to shoot communication? Advances in Botanical Research 19:103–187.

Jha BK, Pragash MG, Cletus J, Raman G, Sakthivel N. (2009) Simultaneous phosphate solubilization potential and antifungal activity of new fluorescent pseudomonad strains, *Pseudomonas aeruginosa, P. plecoglossicida* and *P. mosselii.* World J Microbiol Biotechnol. 25:573–581.

Khan M. S., Zaidi A., Ahmad E. (2014). Mechanism of phosphate solubilisation and physiological functions of phosphate-solubilizing microorganisms, in Phosphate Solubilizing Microorganisms, eds Khan M. S., Zaidi A., Mussarrat J., editors., Springer International Publishing , 34–35.

Kloepper J.W. and Schroth L.N., (1978) Association of in-vitro antibiosis with inducibility of increased plant growth by *Pseudomonas spp*. Phytopathol. News. 12: 136.

Kloepper J.W., Leong J., Teintze M., Schroth M.N., (1980a.) Enhanced plant growth by siderophores produced by plant growth promoting rhizobacteria. Nature 286:885–886.

Kloepper J.W., Schroth M.N., Miller T.D. (1980b.), Effects of rhizosphere colonization by plant growth- promoting rhizobacteria on potato plant development and yield, Phytopathology 70:1078-1082.

Lenhoff HM (1963) An inverse relationship of the effects of oxygen and iron on the production of fluorescein and cytochrome C by *Pseudomonas fluorescens*. Nature 199:601–602.

Lenhoff HM, Nicholas DJD, Kaplan NO (1956) Effects of oxygen, iron and molybdenum on routes of electron transfer in *Pseudomonas fluorescens*. J Biol Chem 220:983–995.

Leonard K. J. and Szabo, L. J. (2005) Stem rust of small grains and grasses caused by *Puccinia graminis*. Mol. Plant Pathol. 6, 99–111.

Lewis TA, Cortese MS, Sebat JL, Green TL, Crawford RL, Lee CH (2000) A *Pseudomonas stutzeri* gene cluster encoding biosynthesis of the CCl4-dechlorination agent pyridine-2, 6-bis (thiocarboxylic acid). Environ Microbiol 2:407–416.

Liddycoat S.M., Greenberg B.M., Wolyn D.J., (2009) The effect of plant growth-promoting rhizobacteria on asparagus seedlings and germinating seeds subjected to water stress under greenhouse conditions Canadian Journal of Microbiology 55(4):388-94.

Loper, J.E, (1988) Role of Fluorescent Siderophore Production in Biological Control of *Pythium ultimum* by a *Pseudomonas fluorescens* Strain, Phytopathology 78;166-172.

Lucy M., Reed E., Glick B.R., (2004) Applications of free living plant growth-promoting rhizobacteria. Antonie Van Leeuwenhoek. 86 (1):1-25.

Luis G. Hernández-Montiel, César J. Chiquito-Contreras , Bernardo Murillo-Amador , Librado Vidal-Hernández , Evangelina E. Quiñones-Aguilar , and Roberto G. Chiquito Contreras. (2017) Efficiency of two inoculation methods of *Pseudomonas putida* on growth and yield of tomato plants, Journal of Soil Science and Plant Nutrition, 17 (4): 1003-1012.

Manthey JA , Crowley DE , Luster DG (eds) Biochemistry of metal micronutrients in the rhizosphere. Lewis Publishers, Boca Raton, FL, 81-92.

Matthijs S., Budzikiewicz H., Schafer M., Wathelet B., Cornelis P. (2008), Ornicorrugatin, a new siderophore from *Pseudomonas fluorescens* AF76. Z Naturforsch C 63:8–12.

Matthijs, S., Tehrani, K. A., Laus, G., Jackson, R. W., Cooper, R. M., and Cornelis P. (2007), Thioquinolobactin, a *Pseudomonas* siderophore with antifungal and anti-Pythium activity. Environ. Microbiol. 9:425–434.

Mercado-Blanco J.1, van der Drift K.M., Olsson P.E., Thomas-Oates J.E., van Loon L.C., Bakker P.A., (2001) Analysis of the pmsCEAB gene cluster involved in biosynthesis of salicylic acid and the siderophore pseudomonine in the biocontrol strain *Pseudomonas fluorescens* WCS374. J Bacteriol. 183(6):1909-20.

Mew, T.W. and Rosales A.M. (1986) Bacterization of rice plants for control of sheath blight caused by *Rhizoctonia solani*. Phytopatholgy, 76: 1260-1264.

Minorsky P.V., (2008) On the inside. Plant Physiol 146:323–324

Mirza, M.S., Mehnaz, S., Normand, P., Prigent-Combaret, C., Moënne-Loccoz, Y., Bally, R.,Malik, K.A., (2006) Molecular characterization and PCR detection of a nitrogen-fixing Pseudomonas strain promoting rice growth. Biology and Fertility of Soils 43, 163-170.

Mossialos D, Meyer JM, Budzikiewicz H, Wolff U, Koedam N, Baysse C, Anjaiah V, Cornelis P. (2000) Quinolobactin, a new siderophore of *Pseudomonas fluorescens* ATCC 17400, the production of which is repressed by the cognate pyoverdine. *Appl Environ Microbiol*. 66(2):487-92.

Naik P.R, Raman G., Badrinarayanan K., Sakthivel N., (2008) Assessment of genetic and functional diversity of phosphate solubilizing fluorescent pseudomonads isolated from rhizospheric soil, BMC Microbiol, 8:230.

Park, C.S., Paulitz, T.C., and Baker, R. (1988). Biocontrol of *Fusarium wilt* of cucumber resulting from interactions between Pseudomonas putida and nonpathogenic isolates of *Fusarium oxysporum*. Phytopathology 78, 190–194.

Patten C., Glick B., (2002) Role of *Pseudomonas putida* indoleacetic acid in development of the host plant root system. Appl Environ Microbio 68:3795-3801.

Podile A.R., and Kishore G.K., (2006) Plant growth-promoting rhizobacteria. In: Gnanamanickam SS (ed) Plant-Associated Bacteria. Springer, Netherlands, pp. 195-230.

Radhapriya P, Ramachandran A, Anandham R, Mahalingam S (2015) *Pseudomonas aeruginosa* RRALC3 Enhances the Biomass, Nutrient and Carbon Contents of *Pongamia pinnata* Seedlings in Degraded Forest Soil. PLOS ONE 10(10).

Saharan B.S., Nehra V., (2011) Plant growth promoting rhizobacteria: a critical review. Life Sci Med Res 21: 1-30.

Sakthivel N. and Gnanamanickam, S. (1987). Evaluation of *Pseudomonas fluorescens* for Suppression of Sheath Rot Disease and for Enhancement of Grain Yields in Rice (*Oryza sativa L.).* Applied and environmental microbiology. 53. 2056-9.

Scher F.M. and Barker R. (1980), Mechanism of biological control in a Fusarium- suppressive soil, Phytopathology 70:412-417.

Schroth, M. N., Hildebrand, D. C., Panopoulos, N. (1992). Phytopathogenic pseudomonads and related plant-associated pseudomonads. In The Prokaryotes, Springer. 3104–3131.

Sharma A., Johri B.N., Sharma A.K., Glick B.R. (2003) Plant growth-promoting bacterium *Pseudomonas* sp. strain GRP3 influences iron acquisition in mung bean (*Vigna radiata* L. Wilzeck) Soil Biol. Biochem., 38:887-894.

Stanier R.Y., Palleroni N.J., Doudoroff M., (1966) The aerobic pseudomonads: a taxonomic study. J Gen Microbiol 43:159–271.

Streit, W.R., Joseph, C.M. & Phillips, D.A. (1996). Biotin and other water-soluble vitamins are key growth factors for alfalfa root colonization by Rhizobium meliloti 1021. Mol. Plant-Microbe Interac, 5: 330-338.

Sunish Kumar R., Ayyadurai N., Pandiaraja P., Reddy A.V., Venkateswarlu Y., Prakash O., Sakthivel N., (2005) Characterization of antifungal metabolite produced by a new strain Pseudomonas aeruginosa PUPa3 that exhibits broad-spectrum antifungal activity and biofertilizing traits. J Appl Microbiol 98:145–154.

Suslow T.V., Schroth M.N., (1982) Rhizobacteria of sugar beets: effects of seed application and root colonization on yield. Phytopathology 72:199–206.

Trivedi P., Pandey A., Palni L.M.S., (2012) Bacterial inoculants for field applications under mountain ecosystem: present initiatives and future prospects. In: Maheshwari DK (ed). Bacteria in Agrobiology: Plant Probiotics, Springer, Heidelberg, pp. 15-44.

Uren N.C., (2001) Types, amounts and possible functions of compounds released into the rhizosphere by soil-grown plants. In: Pinto RZ, Varanini PN (eds) The Rhizosphere: Biochemistry and organic substances at the soil-plant interface. CRC Press, Boca Raton, Florida, USA, pp. 1-21.

Vansuyt G., Robin A., Briat J.F., Curie C., Lemanceau P., (2007) Iron acquisition from Fe-pyoverdine by *Arabidopsis thaliana*. Mol Plant Microbe Interact 20:441-447.

Varma A. and Chincholkar S., (2007) Microbial siderophore. Berlin-Heidelberg: Springer-Verlag Berlin Heidelberg.

Vessey J.K., (2003) Plant growth promoting rhizobacteria as biofertilizers. Plant Soil 255: 571-586.

Weisbeek PJ, van der Hofstad GAJM, Schippers B, Marugg JD (1986) Genetic analysis of the iron uptake system of two plant growth promoting *Pseudomonas* strains. NATO ASI Ser A 117:299–313.

Weller D.M., and Cook R.J., (1983) Suppression of Take-All of Wheat by Seed Treatments with Fluorescent Pseudomonads. Disease Control and Pest Management. Vol. 73(3):463-469.

Zahid M., Abbasi M.K., Hameed S., Rahim N., (2015) Isolation and identification of indigenous plant growth promoting rhizobacteria from Himalayan region of Kashmir and their effect on improving growth and nutrient contents of maize (*Zeamays* L.). Front Microbiol 6:207.

How to cite this article:

Preeti Chandurkar., 2019, A Review on Plant Growth Promotory Properties of Fluorescent Pseudomonads. *Int J Recent Sci Res.* 10(06), pp. 33102-33106. DOI: http://dx.doi.org/10.24327/ijrsr.2019.1006.3606

****