Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(6): 1859-1865
Received: 07-09-2019
Accepted: 09-10-2019

Kamlesh Kumar Mohle
Department of Plant Pathology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

RKS Tiwari
BTCARS, Bilaspur, Chhattisgarh, India

Manisha Tondey
Department of Agricultural Microbiology, PAU, Punjab, India

Kovid Kumar
Department of Plant Pathology, SHIATS, Allahabad, Uttar Parades, India

Corresponding Author:
Kamlesh Kumar Mohle
Department of Plant Pathology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Rhizosphere competence and plant growth promoting activities of *Pseudomonas fluorescens* in rice crop

Kamlesh Kumar Mohle, RKS Tiwari, Manisha Tondey and Kovid Kumar

Abstract
Rhizosphere competence and plant growth promoting rhizobacteria (PGPR) of *Pseudomonas fluorescens* beneficial effects on plant growth and health of rice crop. *P. fluorescens* from different origins for their ability to colonize the rhizosphere of rice plants grown in natural soil. PGPR are known to influence plant growth by various direct or indirect mechanisms, *P. fluorescens* identified as important organisms with ability for plant growth promotion and effective disease management properties, root colonization by *Pseudomonas fluorescens,* biotic and abiotic factors affecting colonization and mechanisms of pathogen suppression. Role in biological suppression and growth promotion, promoting biotic resistance to pests, increased herbicide tolerance, enhanced, and effective control against abiotic and environmental stresses. The production of secondary metabolites siderophore, volatile compounds, HCN, enzymes, phytohormones and antibiotics, *Pseudomonas fluorescens* the production of antibiotics such as 2,4-diacetylphloroglucinol (DAPG), phenazine, pyrrolnitrin, pyoluteorin and biosurfactant antibiotics to enhance the disease resistance quality of plants. Rhizosphere competence of *Pseudomonas fluorescens* and their influence on growth and yield of rice, analysis of biological properties, growth and yield parameters. The vermicompost based formulation was used for sandy clay loamsoil and seedling treatments. The application of vermi-based formulation of *Pseudomonas fluorescens in combination with Trichoderma viridae* and *Trichoderma harzianum*at the three different dosages (@ 10g litre^{-1} of water 50 and 500 kg per ha). Untreated control was kept for making comparison with treated.

Keywords: *Pseudomonas fluorescens, Trichoderma viridae, Trichoderma harzianum,* PGPR, biological properties, rice crop

Introduction
Pseudomonads are straight to curved rods, 0.5-1.0 by1.5-4.0 µm, motile by means of one or many polar flagella, Gram negative and Chemo-organotrophs. Several species of genus *Pseudomonas* are phytopathogenic, while some are non-phytophathogenic. Most bacteria genera the *Pseudomonas* last common ancestor lived hundreds of millions of years ago. They were initially classified at the end of the 19th century when first identified by Walter Migula. The etymology of the name was not specified at the time and first appeared in the7th edition of Bergey's manual (themain authorityin bacterial nomeclature) as Greek pseudes means "false"and -monas means "asingleunit", which can mean false unit; however, it is also possible that Migula intended it as false Monas, a nano flagellate protist (Palleroni and Moore., 2004) [10].
Pseudomonas fluorescens have been identified for their role in biological suppression and growth promotion, promoting biotic resistance to pests, increased herbicide tolerance, enhanced disease resistance, and effective control against abiotic and environmental stresses (Khan *et al*., 2016) [7]. The synthesis of yellow-green, *fluorescen*s, water-soluble pigments is a characteristic property of some *Pseudomonas* spp. (Dewangan *et al.,* 2014) [5]. Plant Growth Promoting rhizobacteria (PGP) activity of *P. fluorescens* in rice crop was observed in this study. Selected *P. fluorescens* PW-5, *P. fluorescens* PW-104 were resistant against heavy metal such as Cu, Cr, Ni, Cd. These strains effectively showed four major PGPR activities such as Indole AceticAcid (IAA), Hydrogen cyanide (HCN), Siderophore and Phosphorous solubilization, (Deshwal and Kumar., 2013) [4].
Plant growth promoting rhizobacteria consisting of primarily *P. fluorescens* and *P. putida* identified as important organisms with ability for plant growth promotion and effective disease management properties, (Belkar and Gade., 2012) [2]. Rhizosphere competence of *Pseudomonads fluorescens* beneficial effects on plant growth and health. A collection of 23 *Pseudomonas* species and strains from different origins for their ability to colonize the rhizosphere of tomato plants grown in natural soil (Ghirardi *et al.*, 2012) [6]. Improved method for seed treatment with biocontrol agent a seed bio priming method was developed for the

application of *Pseudomonas* This method enhances efficacy of biocontrol agents against root and seed borne diseases. It has been found useful in a number of crops like rice, wheat, pulses, vegetables, soybean etc. (Kumar and Pundhir., 2009) [8]. Tremendous progress has been made in characterizing the process of root colonization by *Pseudomonas*, biotic and abiotic factors affecting colonization one mechanisms of pathogen suppression (Weller., 2007) [14]. The biocontrol mechanism to suppress fungal pathogens by *Pseudomonas* spp. normally involves the production of antibiotics such as 2,4-diacetylphloroglucinol (DAPG), phenazine, pyrrolnitrin, pyoluteorin and biosurfactant antibiotics (Angayarkanni *et al*., 2005) [1]. Biological control using PGPR strains especially from the genus *Pseudomonas* is an effective substitute for chemical pesticides to suppress plant diseases (Compant *et al.*, 2005) [3]. Bacterial antagonists have the twin advantage of faster multiplication and higher rhizosphere competence hence *P. fluorescens* have been successfully used for biological control of plant pathogens (Ramamoorthy *et al.*, 2002) [11].

Materials and Methods

Rhizosphere competence of*Pseudomonas fluorescens* and their influence on growth and yield of rice.

Effect of *Pseudomonas fluorescens* on growth and yield of rice as seedling and soil treatment,
Seedling treatment @ 10g litre^{-1} of water,
Soil treatment@ 50 kg ha^{-1}& 500 kg ha^{-1} and
Total number of treatments- 8
Design: RBD
Replication: 3
Variety: Rajeshwari
Plot size: 4 x 5 mts
Observations to be recorded - plant^{-1}

Growth parameters: Observations on growth parameters i.e. plant height; number of tillers plant^{-1}, root length (cm), shoot length (cm), fresh weight (g) and dry weight (g) of root and shoot were recorded 47 days after transplanting.

Growthand yield parameters: Observations on growth and yield parameters i.e. plant height (109 days after transplanting), number of effective tillers, height of spike (cm), unfilled grains, filled grains, test weight (500 seed), and Yield (q ha^{-1}) were recorded at the time of harvesting.

Methodology: The experiment was conducted in rice field having sandy clay loam soil (Sand: 22% clay: 42% Silt: 36%) under transplanted condition. The land was well prepared by ploughing two times followed by puddling. Talc based formulations of *Pseudomonas fluorescens* were developed and used as seedling treatment. Untreated control was kept for making comparison. Rice seedlings were transplanted in each plot under randomized block design with three replications. The soil samples were collected from all the experimental plots after harvesting of crop for analysis of biological properties. Whereas, rhizosphere competence of *Pseudomonas fluorescens* was studied at State Biocontrol laboratory, Sesal farm Chorbhhatti BTC CARS Bilaspur using serial dilution method.

Serial dilution method was performed adopting following procedure

- The collected soil samples were prepared for analysis by drying under shade condition followed by grinding and sieving.
- One gram of soil sample was taken from each soil sample into separate test tubes containing 10 ml of sterilized water and dissolved properly by mixing thoroughly.
- One ml of solution was taken out from previous one and added in second test tube containing nine ml of sterilized water and dissolved by mixing thoroughly.

One ml of solution was taken from each test tube and inoculated in three Petriplates containing nutrient agar medium followed by spread with the help of spreader. The inoculated plates were incubated in BOD incubator at 29 ± 2 ℃ for a period of 1 to 2 days. Total microbial population and population of *Pseudomonas fluorescens*were recorded at 48 hours after inoculation. Unless otherwise mentioned for each set of treatment, three replications were used for all the *in vitro* studies. In general, Petri dishes were poured with 15-20 ml sterilized melted and cooled nutrient agar media.

Result and Discussion

Effect of *Pseudomonas fluorescens*on rhizosphere competence and influence on growth and yield of rice as seedling and soil treatments

Experiments on rhizosphere competence of *P. fluorescens* were giving seedling and soil treatments conducted insandy clay loam

Under transplanted condition, Results indicate that *P. fluorescens* not only significantly influenced the growth, plant height (47 days after transplanting), number of tillers, root length, shoot length, fresh and dry weight of root and shoot and yield Parameters plant height (109 days after transplanting), number of effective tillers, spike length, numberof filled grain, number of unfilled grains, weight of 500 seeds, grain yield (q ha^{-1}) of rice but also established in the rhizosphere.

Growth Parameters: Data on growth promoting parameters plant height (47 days after transplanting), number of tillers, root length, shoot length, fresh and dry weight of root and shoot were recorded and presented in Table 1 and Fig. 1

Plant Height: All treatments were significantly superior over control. Plant height (116.77cm) was the highest in T_1 - (Farmer practice NPK@ 80:60:40 kg ha^{-1}) which was at par with plant height of 113.77 in T_7 -*(T. viride* + *P. fluorescens* soil application @500 kg ha^{-1}), plant height (112.66 cm) T_6 - *(T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1}).Whereas, the lowest plant height (106.77cm) was recorded in control. Other treatments *i.e.* T_4 -(*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1}-112.33cm) and T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} - 111.33cm) were at par with each other.

Number of Tillers: Maximum number of tillers (14.86) were recorded from T_1 (Farmer practice NPK @ 80:60:40 kg ha^{-1}) followed by T_7- (*T. viride* + *P. fluorescens* so application @500 kg ha^{-1}), T_6 - (*T. harzianum* + *P. fluorescen*)application @500 kg ha^{-1}) and T_3 -(*P. fluorescens* soil application @50kg ha^{-1}) having 14.20, 13.80 and 13.53 with respectively, whereas, T1, T2 and T5 were at par with each other in respect to control. Minimum number of tillers (10.46) were recorded from control.

Root Length: All the treatments exhibited significantly higher root length in compression to control (23.00cm), the highest root length (26.50cm) was observed in T_2 - (*P.*

fluorescens seedling dip) closely followed by T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1}**)** and T_3 - (*P. fluorescens* soil application @50kg ha^{-1}) treatments. However, T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1} – 25.16cm), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} – 24.83cm), T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} – 24.66cm) and T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} – 24.50cm) were at par with each other.

Fresh Weight of Root: The maximum fresh weight of root (49.18g) was recorded in T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1}) followed by T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1} – 40.14g), whereas, minimum fresh weight of root (25.20g) was recorded in control. Other treatments *i.e.* T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} – 36.85g), T_2 - (*P. fluorescens* seedling dip -33.78g), T_3 - (*P. fluorescens* soil application @50kg ha^{-1} – 33.20g) and T_4 -(*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} – 25.98g) were at par with each other.

Dry Weight of Root: The maximum dry weight of root (9.36g) was recorded in T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1}) closely followed by T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} – 8.75g), T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} - 8.03g), T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1} -7.81g),T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} – 7.33g), T_3 - (*P. fluorescens* soil application @50kg ha^{-1} -7.01) and T_2 - (*P. fluorescens* seedling dip – 6.46g) were at par with each other, whereas lowest dry weight of root (5.51g) was recorded in control.

Height of Shoot: Highest shoot height (91.11cm) was recorded in T_1 -(Farmer practice NPK @ 80:60:40 kg ha^{-1}), whereas lowest shoot height (82.77cm) was recorded in control. Other treatments *i.e.* T_6 - *(T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} -88.00cm), T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} - 78.83cm), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} -86.50cm) were at par with each other and significantly superior over control T_3 - (*P. fluorescens* soil application @50kg ha^{-1} - 83.89cm).

Fresh Weight of Shoot: Maximum shoot fresh weight (119.72g) was recorded from T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1}), whereas, minimum fresh weight of shoot (96.00g) was recorded in control. Other treatments *i.e.* T_7 - *(T. viride* + *P. fluorescens* soil application @500 kg ha^{-1} - 119.00g), T_6 - *(T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} -1118.82g), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1}(118.39g), T_3 - (*P. fluorescens* soil application @50kg ha^{-1} -116.81cm), T_2 - (*P. fluorescens* seedling dip -116.31cm) were at par with each other.

Dry Weight of Shoot: Maximum dry weight of shoot (32.99g) was recorded in T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1}), whereas, minimum dry weight of shoot (25.26g) was recorded in control. Treatments T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1}– 32.93g), T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} - 32.16g), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} - 32.04g), T_3 - (*P. fluorescens* soil application @50kg ha^{-1} - 31.71g), T_2 - (*P. fluorescens* seedling dip - 31.64g) and T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1}– 30.00g) were found to be non-significant with each other.

Growth and Yield Parameters: Data on growth and yield parameters i.e. plant height (109 days after transplanting), number of effective tillers, spike length, numberof filled grain, number of unfilled grains, weight of 500 seeds grain, yield q ha^{-1} were recorded and presented in table: 2 and fig. 2.

Plant height: All the treatments were significantly superior over control. The maximum plant height (108.11cm) was observed in T_3 - (*P. fluorescens* soil application @50kg ha^{-1}) and were at par with treatment T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} - 107.91cm), T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1} -107.81cm), T_2 - (*P. fluorescens* seedling dip -107.81 cm), T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} -107.74 cm), T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} - 107.42 cm) whereas T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1} -106.71cm) showed significant different. The Lowest (97.62cm) plant height was observed in control.

Number of Effective Tillers: The maximum number of effective tillers (10.53) were observed in T_2 - (*P. fluorescens* seedling dip) andwere at par with treatment T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1}-10.46), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1}-10.20), T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1} -10.00), T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1}-10.00) whereas T_3 - (*P. fluorescens* soil application @50kg ha^{-1}-9.80) and T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1}-9.66 showed significant difference. The minimum numbers of effective tillers (8.33) were observed in control.

Spike Length: The spike length in all the treatments were superior over control. Highest spike length (24.94cm) was recorded in T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1}) andwere at par with other treatments (T_6 - *T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} - 24.81cm), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} -24.72cm), T1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1} - 24.71cm), T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} - 24.62cm), T_2 - (*P. fluorescens* seedling deep - 24.51cm) and T_3 - *(P. fluorescens* soil application @50kg ha^{-1} - 24.41cm), whereas the lowest spike length (21.22cm) was recorded in control.

Number of Unfilled Grains: The minimum number of unfilled grains (14.13) were recorded in T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1}), followed by T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1}) and T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1}) 16.60 and 17.27 respectively, whereas, maximum number of unfilled grains (27.33) were recorded in control.

Number of Filled Grain: The maximum number of filled grain (144.91) were recorded from T_2 - (*P. fluorescens* seedling dip) and rest treatments *i.e.* T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} - 144.45), T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1} - 144.15), T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1}- 144.12), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} - 143.94), T_3 - *(P. fluorescens* soil application @50kg

ha^{-1} - 142.61) and T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} - 147.97) were statistically at par with each other, whereas, minimum number of filled grains (131.22) recorded in control.

Test Weight: The highest test weight 500 seed was recorded (18.77g) in T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1}) was at par with other treatments T_1 - (Farmer practice NPK @ 80:60:40 kg ha^{-1} - 18.16g), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} - 17.80g), T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1} - 17.25), T_3 - (*P. fluorescens* soil application @50kg ha^{-1} - 16.43g), T_2 - (*P. fluorescens* seedling dip - 16.30g) and T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1} - 16.07g), whereas, lowest test weight (15.65g) was recorded in control.

Yield: The highest grain yield (58.90q ha^{-1}) was recorded in T_1 which was significantly superior over all other treatments. Treatments T_2 - (*P. fluorescens* seedling dip) and T_7 - (*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1}) show at par with each other, whereas T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1}), T_4 - (*T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1}), T_5 - (*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1}) and T_3 - (*P. fluorescens* soil application @50kg ha^{-1}) were at par with each other and significantly superior over control.

It may be concluded from present findings that various growth parameters like plant height (47 days after transplanting), number of tillers, root length, shoot length, fresh and dry weight of root and shoot and yield Parameters plant height (109 days after transplanting), number of effective tillers, spike length, numberof filled grain, number of unfilled grains, weight of 500 seeds, grain yield (q ha^{-1}) to study the effect of bacterial application on the growth of rice plants in increase other treatments comparison to the control plants.

Biocontrol using *P. fluorescens* have shown to be very effective in promoting growth, resistance, and competency through chemical, biological, and physical stimulation of various growth factors, systemic signaling moieties, and intercommunal interactions. Nutrients or exudates and electrons acquired through feedback mechanisms between the host plant and *P. fluorescens*, mutual or synergistic in nature, promote nitrogen fixation and phosphate solubilization, releasing secondary metabolites, such as flavonoids, phytohormones, and ACC and IAA compounds, reflecting their role as plant growth regulators. Other important characteristics of *Pseudomonas fluorescens* include ecological inhibition of phytopathogens through the production and secretion of antimetabolites, site-specific recombinase enzymes, siderophores, antibiotics, and a signaling cascade for induced systemic resistance (Khan *et al*., 2016) [7].

Sharma *et al*.,(2014) also foundand concluded that application of PGPR potential to be used as agricultural crop inoculants as they promote plant growth as well as improve the health and yield of the plants.

Sakthivel and Gnanamanickam (1987) [13] also found and concluded that *Pseudomonas fluorescens* were evaluated in greenhouse and field tests for enhancement of grain yields of rice.

Similar result Sharma *et al.,* (2014) [12] and Sakthivel and Gnanamanickam (1987) [13] recorded the enhance plant height, number of tillers, and grain yields from 3 to 16%.

Effect of *Pseudomonas fluorescens* applied as seedling and soil treatmenton biological properties of soil

Data presented in table: 3, figure: 3, indicate that the total microbial population and *P. fluorescens* population of soil were significantly higher in all treatments over control. Significantly higher number of total microbialpopulation (28.58×10^{-1}) was recorded in T_6 - (*T. harzianum* + *P. fluorescens* soil application @500 kg ha^{-1}). Treatments *i.e.*T_7 - *T. viride* + *P. fluorescens* soil application @500 kg ha^{-1} (28.22×10^{-1}), T_5-*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1} (27.97×10-1), T_4- *T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1}(28.22×10^{-1}), T_3-*P. fluorescens* soil application @50kg ha^{-1} (27.70×10^{-1}) and T_2 - *P. fluorescens* seedling dip (27.56×10^{-1}) were statistically at par with each other and significantly differ with treatment T_1-(Farmer practiceNPK @ 80:60:40 kg ha^{-1}) (26.37×10^{-1}). The minimum total microbial population (22.66×10^{-1}) was observed in control.

The populations of *P. fluorescens* in soil were significantly higher in all treatments and farmers practiceNPK @ 80:60:40 kg ha^{-1}. Significantly higher number of *P. fluorescens* population (9.40×10^{-1}) was recorded in T_6- (*T. harzianum* + *P. fluorescens* soil application @ 500 kg ha^{-1}), followed by T_7 -*T. viride* + *P. fluorescens* soil application @500 kg ha^{-1} (8.50×10^{-1}), T_5 -*T. viride* + *P. fluorescens* soil application @50 kg ha^{-1}(7.50×10^{-1}), T_4- *T. harzianum* + *P. fluorescens* soil application @50 kg ha^{-1}(4.30×10^{-1}) and T_3 - *P. fluorescens* soil application @50kg ha^{-1}(5.20×10^{-1}), and T_2 - *P. fluorescens* seedling dip(26.37×10^{-1}), whereas, the minimum *P. fluorescens*population (0.00×10^{-1}) was observed in T_1- (Farmer practice NPK @ 80:60:40 kg ha^{-1}) andcontrol.

Pseudomonas fluorescens are used in agriculture as plant growth-promoting rhizobacteria (PGPR), soil treatment with *P. fluorescens* on biological properties of soil, increase in microbial biomass and activity, non-target effects and large-scale use,microbial communities of *P. fluorescens* with a greater diversity should be less susceptible and disturbance to other microorganisms. Based on this principle, we laid out a pot experiment with field soil different in their microbial biomass and activity due to long-term management (Mader *et al*., 2009) [9].

Table 1: Effect of *Pseudomonas fluorescens* on growth parameters of rice

Treatment details	Plant height 47DAT (cm)	Number of tillers	Length of root (cm)	Fresh weight of root (g)	Dry weight of root (g)	Height of shoot (cm)	Fresh weight of shoot (g)	Dry weight of shoot (g)
T_1 Farmer practice (NPK @ 80:60:40 kg ha^{-1})	116.77	14.86	25.66	49.18	7.81	91.11	119.72	30.00
T_2*P. fluorescens* seedling dip	109.66	13.46	26.50	33.78	6.46	83.16	116.31	31.64
T_3*P. fluorescens* soil application @ 50kg ha^{-1}	109.55	13.53	25.66	33.20	7.01	83.89	116.81	31.71
T_4 *T. harzianum* + *P. fluorescens* soil application @ 50 kg ha^{-1}	112.33	12.60	24.50	25.98	8.03	87.83	116.75	32.16
T_5 *T. viride* + *P. fluorescens*	111.33	13.33	24.83	25.71	7.33	86.50	118.39	32.04

soil application @ 50 kg ha^{-1}								
T$_6$ *T. harzianum* + *P. fluorescens* soil application @ 500 kg ha^{-1}	112.66	13.80	24.66	36.85	8.75	88.00	118.82	32.93
T$_7$ *T. viride* + *P. fluorescens* soil application @ 500 kg ha^{-1}	113.77	14.20	25.16	40.14	9.36	88.61	119.00	32.99
T$_8$ Control	106.77	10.46	23.00	25.20	5.51	82.77	96.00	25.26
S E m (±)	1.09	0.38	0.30	2.48	0.18	0.79	2.03	0.77
CD 5%	3.32	1.16	0.91	7.53	0.57	2.41	6.17	2.36

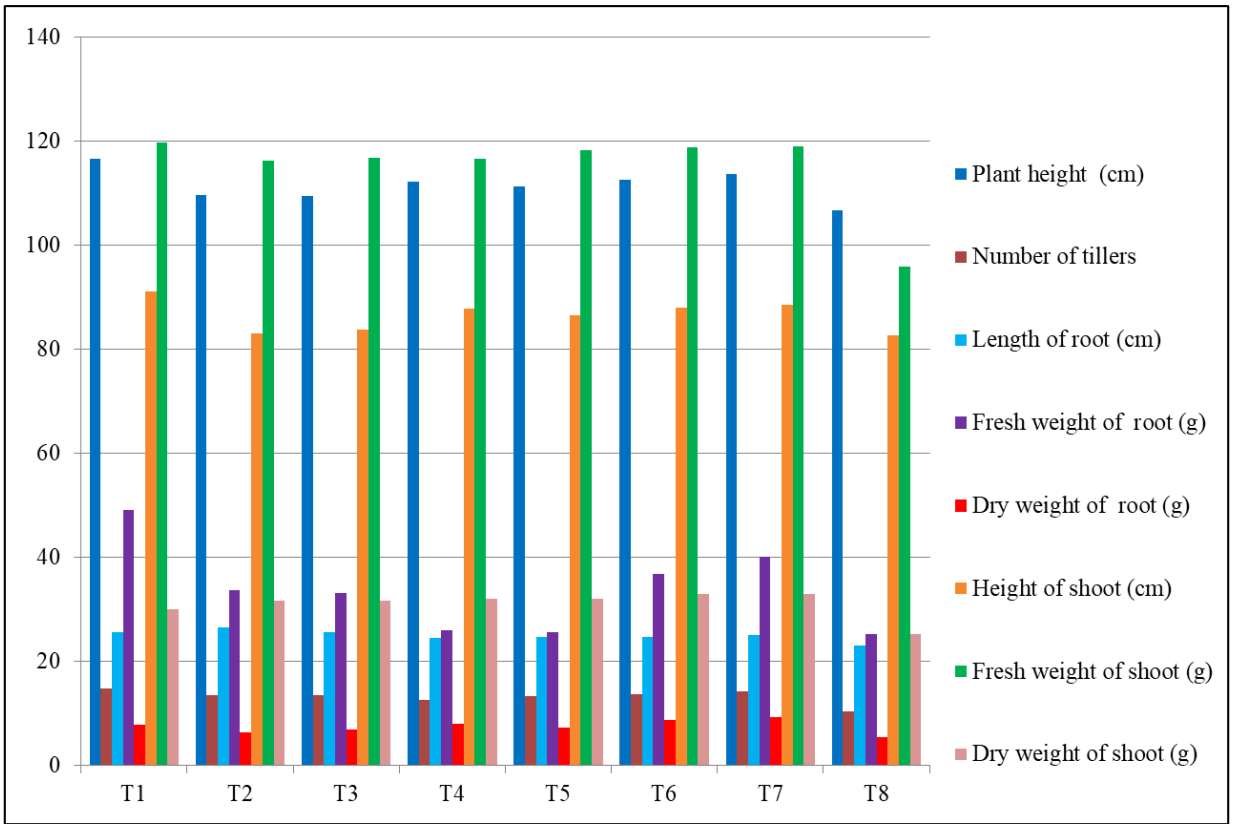

Fig 1: Effect of *Pseudomonas fluorescens* on growth parameters of rice

Table 2: Effect of *Pseudomonas fluorescens* on growth and yield parameters of rice

Treatment details	Plant height 109 DAT (cm)	Number of effective tillers	Spike Length (cm)	Unfilled Grains	Filled Grains	weight of 500 seeds in (g)	Yield (q ha^{-1})
T1 Farmer practice (NPK 80:60:40 kg ha^{-1})	106.71	10.00	24.71	23.80	144.12	18.16	58.90
T2 *P. fluorescens* seedling dip	107.81	10.53	24.51	19.20	144.91	16.30	48.65
T3 *P. fluorescens* soil application @ 50kg ha^{-1}	108.11	9.80	24.41	19.07	142.61	16.43	45.40
T4 *T. harzianum* + *P. fluorescens* soil application @ 50 kg ha^{-1}	107.42	9.66	24.62	18.47	141.32	16.07	46.70
T5 *T. viride* + *P. fluorescens* soil application @ 50 kg ha^{-1}	107.91	10.20	24.72	16.60	143.94	17.80	45.95
T6 *T. harzianum* + *P. fluorescens* soil application @ 500 kg ha^{-1}	107.74	10.00	24.81	17.27	144.45	17.25	47.50
T7 *T. viride* + *P. fluorescens* soil application @ 500 kg ha^{-1}	107.81	10.46	24.94	14.13	144.15	18.77	48.50
T8 Control	97.62	8.33	21.22	27.33	131.22	15.65	43.60
S E m (±)	0.41	0.18	0.35	2.49	0.35	0.93	0.55
CD 5%	1.26	0.56	1.06	7.56	1.97	2.83	1.67

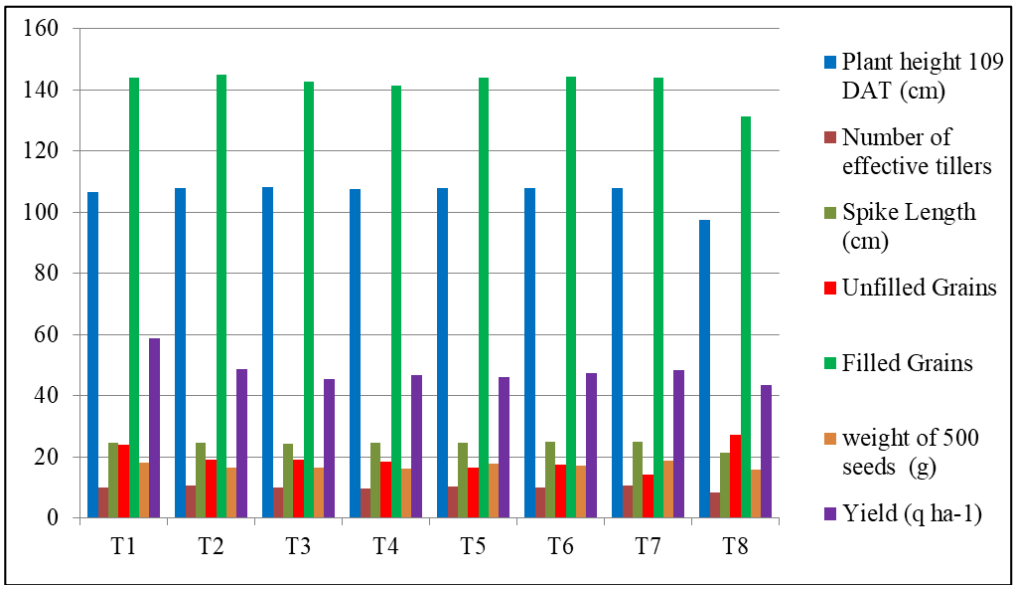

Fig 2: Effect of *Pseudomonas fluorescens* on growth and yield parameters of rice

Table 3: Effect of *Pseudomonas fluorescens* on biological properties of soil

Treatment details	Total microbial population in soil x10^{-1}	*Pseudomonas fluorescens* Population in soil x10^{-1}
T_1 Farmer practice NPK @ 80:60:40 kg ha^{-1}	26.37	0.00
T_2*P. fluorescens* seedling dip	27.56	4.30
T_3*P. fluorescens* soil application @ 50kg ha^{-1}	27.70	5.20
T_4 *T. harzianum* + *P. fluorescens* soil application @ 50 kg ha^{-1}	27.78	6.03
T_5 *T. viride* + *P. fluorescens* soil application @ 50 kg ha^{-1}	27.97	7.50
T_6 *T. harzianum* + *P. fluorescens* soil application @ 500 kg ha^{-1}	28.58	9.40
T_7 *T. viride* + *P. fluorescens* soil application @ 500 kg ha^{-1}	28.22	8.50
T_8 Control	22.66	0.00
SEm (±)	0.37	0.07
CD 5%	1.14	0.22

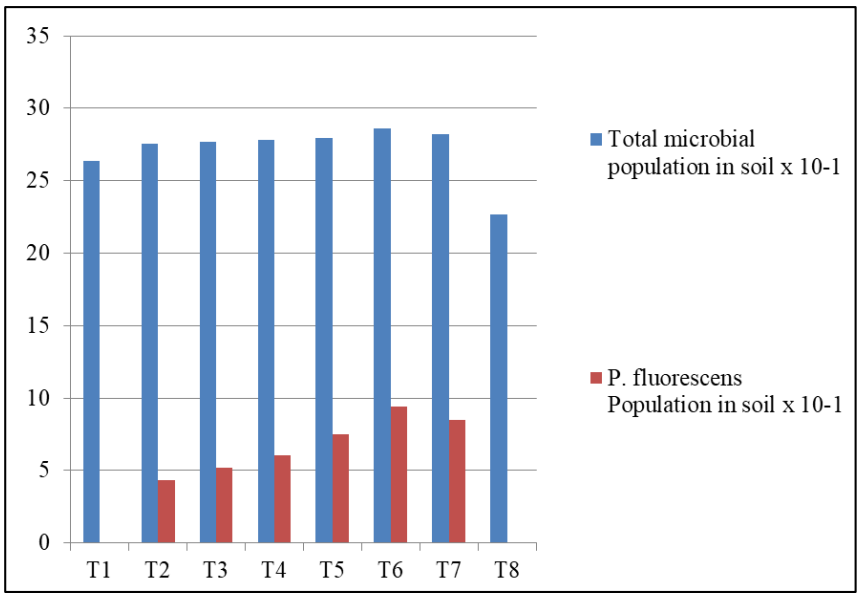

Fig 3: Effect of *Pseudomonas fluorescens* on biological properties of soil

References

1. Angayarkanni T, Kamalaknnan A, Santhini E, Predeepa D. Identification of biochemical markers for the selection of *Pseudomonas fluorescens* against *Pythium sp*. in Asian conference on Emerging. Trends in plant-microbial Interactions. University of Madras, Chenniai, 2005, 295-303.
2. Belkar YK, Gade RM. Biochemical characterization and growth promotion activities of *Pseudomonas fluorescens.* J Pl. Dis. Sci., 2012; 7(2):170.
3. Compant S, Duffy B, Nowak J, Clement Ch, Barka EA. Use of Plant Growth-Promoting Bacteria for Biocontrol of Plant Diseases: Principles, Mechanisms of Action, and Future Prospects. Appl. and Environ. Microb. 2005; 71(9):4951-4959.

4. Deshwal VK, Kumar P. Plant growth promoting activity of Pseudomonads in Rice crop, Int. J Curr. Microbiol. App. Sci. 2013; 2(11):152-157.
5. Dewangan PK, Koma B, Baghel S, Khare N, Singh HK. Characterization of *Pseudomonas fluorescens* indifferent media and its antagonistic effect on phytopathogenic fungi. The Biol., 2014; 9(1):317-321.
6. Ghirardi S, Dessaint F, Mazurier S, Corberand T, Raaijmakers JM, Meyer JM *et al*. Identification of traits shared by rhizosphere-competence strains of Fluorescent Pseudomonads. Microb. Ecol., 2012; 64:725-73.
7. Khan H, Parmar N, Kahlon RS. *Pseudomonas*-Plant Interactions I: Plant Growth Promotion and Defense-Mediated Mechanisms. Mol. and Appl. Biol., 2016, 419-468.
8. Kumar J, Pundhir VS. Proceedings of the 22nd Training *Pseudomonas fluorescens* in different media and its antagonistic effect on phytopathogenic fungi. *In. Rec*. Advan. in Biol. Con. of Pl. Dis. Coun. Agri. Res., 2009; 9(1):317-321.
9. Mäder P, Lutz MP, Oberholzer HR, Winkler M. Soil amendment with *Pseudomonas fluorescens* CHA0: lasting effects on soil biological properties in soils low in microbial biomass and activity. Microb. Ecol., 2009; 57:611-623.
10. Palleroni NJ, Moore ERB. Taxonomic of *Pseudomonas* experimental approaches. Edited by Juan-Luis Ramos Kluwer Academic Plenum Publishers, New York, 2004, 1.
11. Ramamoorthy V, Raguchander T, Samiyappan R. Enhancing resistance of tomato and hot pepper to Pythium diseases by seed treatment with *Fluorescent pseudomonads*. Euro. J. Pl. Pathol. 2002; 108:429-441.
12. Sharma A, Shankhdhar D, Sharma A, Shankhdhar SC. Growth promotion of the rice genotypes by pgprs isolated from rice rhizosphere. J Soil Sci. Pl. Nutri. 2014; 14(2):505-517.
13. Sakthivel N, Gnanamanickam SS. Evaluation of *Pseudomonas fluorescens* for suppression of sheath rot disease and for enhancement of grain yields in rice (*Oryza sativa* L.). Appl. Environ. Microb. 1987; 53(9):2056-2059.
14. Weller DM. *Pseudomonas* biocontrol agents of soil borne pathogens. Phytopathol. 2007; 97:250-256.