***Pak. J. Bot.*, 53(1): 293-300, 2021.** **DOI: http://dx.doi.org/10.30848/PJB2021-1(3)**

INFLUENCE OF PHOSPHATIC FERTILIZER ON GROWTH, YIELD AND BACTERIAL ABUNDANCE IN RICE (*ORYZA SATIVA* L.) GENOTYPES

QURBAN ALI PANHWAR*, AMANAT ALI, NIZAMUDDIN DEPAR AND MUHAMMAD YOUSUF MEMON

Soil & Environmental Sciences Division, Nuclear Institute of Agriculture (NIA), Tandojam 70060, Sindh, Pakistan
**Corresponding author's email: pawhar107@yahoo.com*

Abstract

Rice is one of the most important cereal crops in the world and has high nutritional food value. A field study was laid to assess the effect of phosphatic fertilizer on microbial root colonization and yield of different rice genotypes. The soil of field experiment was moderately saline, low in OM and nitrogen, and inadequate in phosphorus. Three rice genotypes MR219-9, Shandar and DR-92 were transplanted at three different rates of phosphate (30, 60 and 90 kg P_2O_5 ha^{-1}). The experiment was conducted in split plot design with three replications. The abundance of general bacteria, nitrogen fixing and phosphate solubilizing bacteria (PSB) was assessed in rhizosphere of rice plants. The maximum general bacterial abundance (7.54 log cfu g^{-1} soil) and PSB abundance (6.97 log cfu g^{-1} soil) was recorded in soil under plants of Shandar genotype while the most N_2 fixing bacterial abundance (6.26 log cfu g^{-1} soil) prevailed in soil under rice genotype MR219-9 at 30 kg P_2O_5 ha^{-1}. Among rice genotypes, Shandar showed excellent enhancement in growth and yield at the 90 kg P_2O_5 ha^{-1}. The maximum plant height (87.26 cm), root length (9.25 cm), number of tillers per plant (16.60 plant^{-1}), number of panicles per plant (15.76), panicle length (25.20 cm) and 1000 grain weight (22.16 g) were observed in Shandar genotype at 90 kg P_2O_5. The highest grain (5.53 t ha^{-1}) and straw yield (12.23 t ha^{-1}) was also recorded in Shandar at 90 kg P_2O_5. The abundant microbial population prevailed in rhizosphere of all rice genotypes at low levels of phosphatic fertilizer application. However, the microbial populations varied among rice genotypes at different P levels that indicated the root colonization of rice that may enhance rice growth and productivity with low input of chemical fertilizers.

Key words: Phosphatic fertilizer, Microbial population, Levels, Rice growth, Nutrient uptake.

Introduction

Rice (*Oryza sativa* L.) is one of the major food crops of world and one of the important staple foods for majority of the world population. About 90% of the world rice is grown and consumed in Asia (Santos *et al*., 2017). After wheat and cotton, rice is third major crop of Pakistan, being cultivated on 11% of Pakistan's total agricultural land. Pakistan is a one of the prominent producer and exporter of rice (Basmati and IRRI white long & grain rice). Moreover, the rice positions second in the staple food grain crops of the country and contribute much in foreign exchange earnings (Agrochart, 2015). Furthermore, the rice pays 2.7% of the value addition in the agriculture sector and 0.6% of GDP. Rice is being cultivated mainly in two provinces of and Sindh, contributing about 88% of total rice production of the country. The recent year's rice production Pakistan i.e. Punjab was remained about 6.9 million tons and area was not changed from the revised official estimates (Agrochart, 2015). Rice is a monsoon crop in Pakistan but with the introduction of hybrid rice prejudiced the time of sowing and transplanting.

The world population is growing rapidly and to fulfill world's rice requirements, the addition of fertilizers has become necessary to enhance the proper growth and productivity (Shen *et al.*, 2010). Among the three major nutrients phosphorous (P) is critical for plant growth and productivity as it is essential for several plant physiological and morphological processes such as cell division, reproduction, and plant metabolism etc. Furthermore, P performs a vital part in lateral root morphology and root branching and effects not only development of roots, but also for the nutrient availability of nutrients (Epstein and Bloom, 2004). Therefore, plants have established different approaches to obtain optimum P from the soils, including increase in plant root length, root surface area and root-shoot ratio (Xu *et al.*, 2012). The plant growth and root morphology are significant parameters for assessing the effects of supplied nutrients (Razaq *et al.*, 2017). Phosphorus is reflected as a main element for the plant growth and is required to endure optimal production and quality of many crops (Zapata and Zaharah, 2002).

However, non-judicious use of P fertilizer may result in eutrophication and other environmental issues. Therefore, scientists are emphasizing to explore alternatives of chemical fertilizer for food security in an efficient manner. The soil microorganisms perform significant role in agriculture sector while remaining in close contact with plants and improve the soil health and plant development (Kim *et al.*, 2011). Bacteria living in soil have close interaction with plant roots and play role in increasing nutrient availability via fixing atmospheric nitrogen and phosphorus through solubilization of soil inorganic P (Pieterse *et al.*, 2014) and improve plant growth by phytohormones production (Panhwar *et al.*, 2012), suppressing phytopathogens and helping in tolerating abiotic stress like heat, high salt, or drought (Haney *et al.*, 2015). Moreover, microbial community is also accountable for organic matter decomposition in soil (Kuzyakov, 2002).

The population and rhizosphere abundance of soil microorganisms can be affected by various chemical, physical and biological soil properties. The unavailability of essential nutrients can reduce the microbial growth in a specific soil system as these elements are prerequisite for the growth and activity of microorganisms. The presence or absence of plants in soil affects specific microbial association because plant root exudates make proper growth environment for microorganisms. The release of such type of simple or low molecular weight carbon compounds with the root exudates that are major energy source of soil microorganisms (Naher *et al*., 2009). Soil beneficial microbes perform an important role in supplying soil nutrients particularly N and P. The N_2 fixing and P-solubilizer soil microbes have simultaneously enhanced the uptake of N and P in plants and grain yields of many crops (Panhwar *et al*., 2011). The soil microbial species in the rhizosphere environment is dire for the health of soil and plants as well as for improving soil organic matter. Much work for microbial activity in rice has been reported but the microbial dynamics in agro-climatic conditions of Tandojam, Sindh is lacking. Therefore, the study aimed to determine microbial abundance in soil rhizosphere of rice crop and their impact for the improving growth and productivity of the rice genotypes in combination with different P levels.

Material and Methods

Study site and experimental design: This experiment was conducted at NIA farm, Tandojam, Sindh, Pakistan. The site was 5m above the sea level, located at the latitude of 25°25′35.68″N and longitude of 68°32′22.31″E. In this study three rice genotypes V1 = MR219-9, V2= Shandar, and V3 = DR-92 were used as test crop. Three levels of phosphatic fertilizer (Dia Ammonium Phosphate) were used 30, 60 and 90 kg P_2O_5 ha^{-1} as Recommended dose of nitrogen (Urea) was applied in three split doses 1/3 @ the time transplanting, 1/3 after 40 days of transplanting and 1/3 at 60 days after transplanting. Five kg ha^{-1} of zinc (Zinc sulphate) was applied at the time of first irrigation after transplantation. The plot size was 4×4 m and treatments were randomized in split plot design with the genotype being main plot and P levels in subplot replicated thrice.

Experimental soil properties: The experimental soil was non-alkaline (pH 7.2) and moderately saline (EC (1:2.5) = 6.65 dS m^{-1}) in nature. The soil organic matter contents (<0.86%) were very low. The soil was deficient in available nitrogen, while AB-DTPA extractable P was inadequate and K was sufficient in the experimental soil (Table 1).

Climatic conditions of experimental site: The climatic conditions during July-October 2016 are presented in table 2. Light rain falls occurred in month of June (0.3 mm) and again in August (5.2 mm). However, the temperature remained warm during the experimental time. The average minimum temperature 24.1°C and average maximum temperature 37.38°C temperatures were recorded during the experimental period. The average relative humidity was 61.8%, and average sunshine remained 8.9 hrs. However, the average wind speed was 11.7 km hr^{-1} with SW directions and evaporation was 6.1 mm/day during the experimental period.

Rice seedlings and transplanting: Nursery of three coarse rice genotypes MR219-9, Shandar and DR-92 seedlings was grown. After, 25days old rice plants were transplanted (20×20 cm) into experimental plots. The irrigation was given as per requirement till crop maturity.

Soil analysis: The soil samples were collected from the experimental area before experiment and after harvest for soil physico-chemical properties, soil organic matter and nutrient concentration of soil. The soil texture was determined by Bouyoucos hydrometer method (Gee & Bauder, 1986), organic matter contents were determined following the procedure described by Walkley & Black (1934), soil organic carbon was assessed by using the formula (SOC% = SOM/1.724 × 100), electrical conductivity was measured through Digital Electrical Conductivity Meter using 1:2.5 soil water ratio (Benton, 2001), soil pH was measured in soil to water (1:2.5) ratio (Benton, 2001) by means of Standard pH meter (PHM210), the total N was determined by Kjeldahl digestion method (Bremner and Mulvaney, 1982) and AB-DTPA extractable phosphorus and potash was determined following by the method given by Soultanpur & Schwab (1977).

Table 1. Soil physico-chemical properties of the topsoil used in the field experiment.

Soil texture	EC 1:2.5	pH	OM	OC	N	P	K
	(dS m^{-1})		----------------(%)		-----------------	------(mg kg^{-1})------	
Clay loam	6.65	7.2	0.68	0.304	0.05	6.13	123

OM= Organic matter, OC= Organic carbon

Table 2. Agro-climatic conditions of experimental site.

Months	Total rain	Temperatures		Relative humidity	Sunshine hours	Wind		Evap:
	(mm)	Min. °C	Max. °C	%	(Hrs)	Speed (km hr^{-1})	Directions	(mmday^{-1})
June	0.3	25.7	39.8	55	10.3	12.7	SW	7.2
July	0.0	26.2	37.4	63	8.5	15.4	SW	7.4
August	5.2	24.8	35.9	70	6.7	10.0	SW	5.2
September	0.0	23.0	36.7	64	10.3	12.3	SW	5.9
October	0.0	20.8	37.1	57	8.7	8.1	SW	4.8
Average	1.1	24.1	37.38	61.8	8.9	11.7	-	6.1

Enumeration and isolation of total microbial population: The total microbial abundance was assessed from rhizosphere of rice plant after 40 days of transplanting in specific media plates whereas, nutrient agar media was used for enumerating general bacterial colony forming units (cfu), while Nfb media was used for N_2 fixing bacteria as described by Parasad *et al.*, (2001). Pikovskaya media served for enumeration of phosphate solubilizing bacteria (Pikovskaya, 1948). Ten (10) g of soil sample with its adhering soil was placed in 250 mL Erlenmeyer flask having 90 mL sterilized water. The contents were shaken for 15 to 20 min on mechanical shaker to have a homogenous mixture. A sequence of dilutions were organized from 10^{-1} to 10^{-8} and 0.1 ml aliquots were plated on to the media plates and incubated at 28±2°C in incubator for 3 days. The numbers of colony forming units were counted on colony counter and the microbial population was enumerated according to their dilution and the amount of aliquot plated. Bacterial isolates differing in colony morphology were selected from the media plates. The purity of bacterial isolates was determined, observing their morphological characteristics under microscope.

Growth data collection and nutrient concentration in plant: The plants were harvested from one square meter area of each treatment and their growth and yield data was documented. The plant height, root length and numbers of leaves per plants were observed at harvesting. The plant samples were cleaned to eliminate all soil debris and dried out in a hot air oven at 70ºC for 3 days to record plant dry biomass. The nutrient uptake was calculated by the dry-ashing method (Dobermann and Fairhurst, 2000; Ryan *et al.*, 2001). Protein in rice grain was measured using Jones s' factor (Protein % = N × 5.95) modified from Merrill and Watt (1973).

Statistical analysis

The experimental data were statistically analyzed through analysis of variance (SAS Institute, 2004, Version 9.3) and treatment means were compared using Tukey's test at 5% level of significance (SAS, 2012).

Results

Microbial abundance in rhizosphere of various rice genotypes: The microbial abundance was observed after 45 days of rice transplanting. Significant variations were noted in bacterial population in the rhizosphere of rice genotypes in response to different P levels. Relatively, the total bacterial population was higher than the nitrogen (N_2) fixing and phosphate solubilizing bacterial populations (Fig. 1). Bacterial abundance was significantly (p=<0.05) higher in rice genotype Shandar i.e. 7.54 log cfu g^{-1} soil, in plots with P application @ 30 kg P_2O_5 ha^{-1} followed by (7.46 log cfu g^{-1} soil) in rice genotype MR219-9 @30 kg P_2O_5 ha^{-1}. Nevertheless, the lowest population (7.14 log cfu g^{-1} soil) prevailed in MR219-9 @ 60 kg P_2O_5 ha^{-1}(Fig. 1a).

Relatively, N_2 fixing bacteria were less abundant than the total bacterial population in the rice genotypes in all treatments. The N_2 fixing bacterial population was recorded highest (6.26 log cfu g^{-1} soil) at 30 kg P_2O_5 ha^{-1} in genotype MR219-9 followed by (6.22 log cfu g^{-1}soil) at 30 at kg P_2O_5 ha^{-1} in Shandar genotype (Fig. 1b). Whereas, lowest abundance (5.29 log cfu g^{-1} soil) was noted in Shandar genotype at @ 90kg P_2O_5 ha^{-1} of P application.

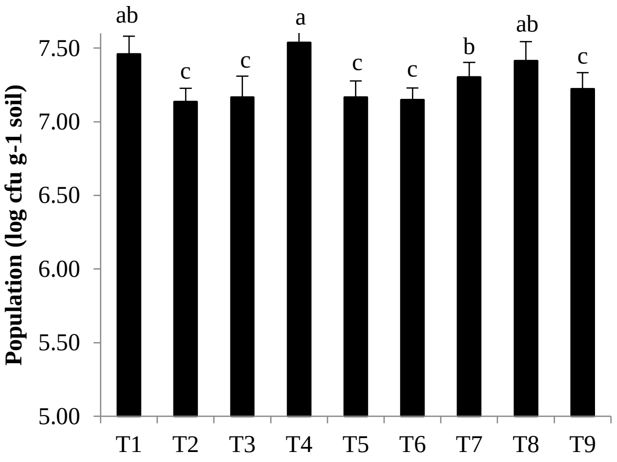
Correspondingly, the phosphate solubilizing bacterial (PSB) abundance varied among P levels. Significantly high PSB abundance (6.97 log cfu g^{-1}soil) was recorded in Shandar genotype followed by DR-92 (6.83 log cfu g^{-1} soil) at 30 kg P_2O_5 ha^{-1}respectively. However, the minimum PSB (5.04 log cfu g^{-1} soil) prevailed in DR-92 at 90 kg in P_2O_5 treatment (Fig. 1c).

Effects of phosphate fertilizer levels on plant growth parameters of rice genotypes: The levels of phosphatic fertilizer also affected plant growth parameters among the rice genotypes. The significantly (p<0.05) highest plant height (87.26 cm) was observed in Shandar at 90kg P_2O_5 followed by MR219-9 (84.20 cm) at 60 kg P_2O_5 ha^{-1}applied P levels. The maximum root length (9.25 cm), number of tillers (16.60 $plant^{-1}$), number of panicles (15.76 $plant^{-1}$) and size of the panicle (25.20 cm) were recorded in Shandar at 90 kg P_2O_5 applied levels. However, DR-92 rice genotype performed least in growth parameters (Table 3).

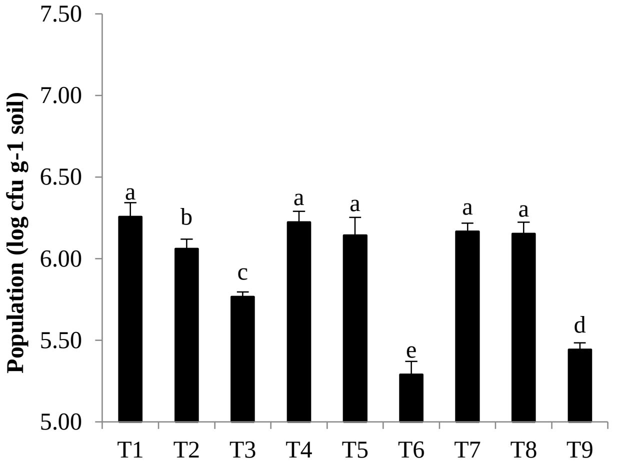
Effects of phosphatic fertilizer levels on rice yield attributes: The levels of phosphate fertilizer affected the unfilled grain (%), 1000 grain weight, grains and straw yield, and harvest index in among the rice genotypes. Among the treatments, significantly (p<0.05) highest percentage of unfilled grains (19.32%) was obtained by DR-92 at 30 kg P_2O_5 ha^{-1} applied P whereas, the minimum values were (14.01%) recorded in MR219-9 at 90 kg P_2O_5 ha^{-1} treatment. Significantly ($p \leq 0.05$) maximum thousand grain weight (22.16 g) was recorded in genotype Shandar @ 90 kg P_2O_5 ha^{-1} and lowest in DR-92 (17.78 g) at 30 kg P_2O_5 ha^{-1} applied levels. The maximum grain yield (5.53 t ha^{-1}) and straw yield (12.23 t ha^{-1}) was observed in genotype Shandar at 90 kg P_2O_5 ha^{-1} and minimum in DR-92 at 30 kg P_2O_5 ha^{-1} applied treatments (Table 4).

Effects of phosphorus levels on nutrient and protein contents of rice plant tissue and grain: The various levels of P application significantly affected nutrient (N & P) contents of rice plant and grain. The nutrient had increasing trend at higher levels of phosphorus application in various rice genotypes (Table 5). However, significantly (p<0.05) the highest nitrogen (1.10 & 1.16 %) and phosphorus concentration (0.37 & 0.47 %) in plant and grain tissue was observed in Shandar at 90 kg P_2O_5 ha^{-1} application respectively. The lowest nutrient concentrations in rice grains and tissues were recorded at lower P (30 kg P_2O_5 ha^{-1}) applications in DR92 rice genotype.

(a) Total bacterial population



(b) N2 fixing bacterial population



(c) Phosphate solubilzing bacterial population

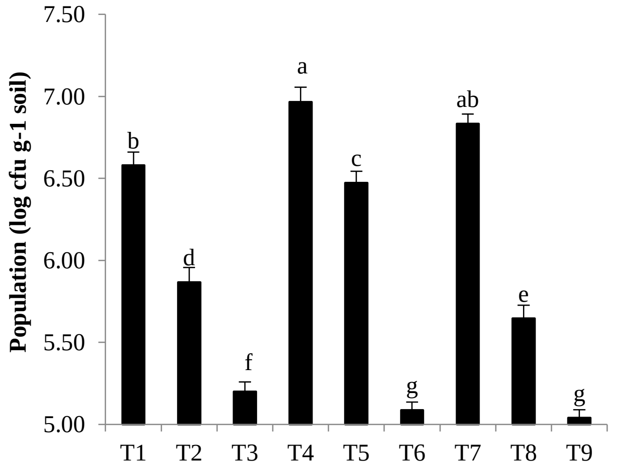


Fig. 1. Soil microbial activity in rice genotypes at various phosphate fertilizer rates.

Where, T1= MR219-9@30 kg P_2O_5 ha^{-1}, T2= MR219-9@60 kg P_2O_5 ha^{-1}, T3= MR219-9@90 kg P_2O_5 ha^{-1}, T4= Shandar@30 kg P_2O_5 ha^{-1}, T5= Shandar@60kg P_2O_5 ha^{-1}, T6= Shandar@90kg P_2O_5 ha^{-1}, T7= DR-92@30 kg P_2O_5 ha^{-1}, T8= DR-92@60 kg P_2O_5 ha^{-1}, T9= DR-92@90 kg P_2O_5 ha^{-1}. The data values are means of four replications and same letters within each column are not significantly different (p<0.05) among the treatments.

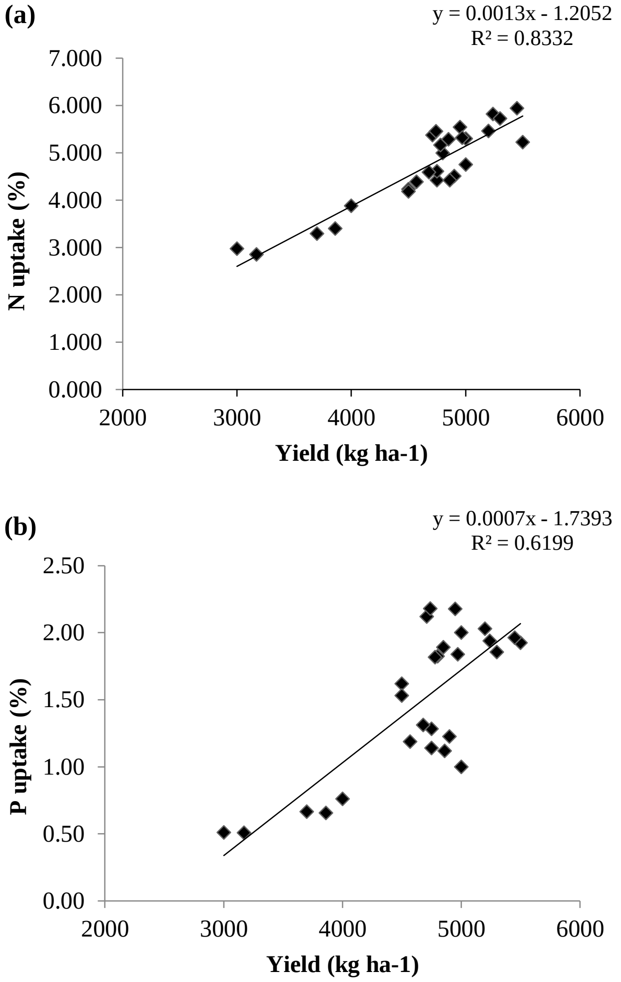


Fig. 2.Correlation of rice grain yield and (a) N uptake (b) P uptake.

Effects of phosphorus levels on the nutrient (N & P) uptake and protein content of rice genotypes: The various phosphorus levels enhanced the plant N and P uptake in rice genotypes. An increasing trend in nutrient uptake with increasing P levels was observed. Significantly (p<0.05) high N uptake (5.45 %) was recorded in the Shandar genotype at 60 kg P_2O_5 ha^{-1}followed by (5.45 %) at 90 kg P_2O_5 ha^{-1}. Nevertheless, the maximum plant phosphorus (2.16 %) and total protein content (6.90%) were observed at 90 kg P_2O_5 ha^{-1}, while lower concentrations were found at lower phosphorus applications (Table 6).

Correlation of grain yield and N & P uptake: The P fertilizer application increased P uptake which significantly increased the rice grain yield. Significant (p<0.05) positive relationships were found between grain yield & N uptake (R^2=0.8332) and grain yield & P uptake (R^2=0.8199) (Figs. 2a & 2b).

Discussion

The present study demonstrates the abundance of microbes at various levels of P in different rice genotypes. The soil rhizosphere is well known part in soil prejudiced by the plant where organic matter is present through rhizo-deposition which has been exhibited to increase soil microbial activity in soil rhizosphere related to the bulk soil (Wu *et al.*, 2009). In the current study general bacteria hold maximum abundance followed by the N_2fixing bacteria (diazotrophs) and PSB. Earlier reports Panhwar *et al.*, (2012) also revealed the abundance of microbial populations under P fertilized treatments. The rice plant harbors a dissimilar group of microbes, among them certain useful soil microorganisms like N_2 fixing and PSB are colonized with rice roots, and provide essential soil nutrients for plant growth enhancement. The presence of beneficial microbes in rice helps in enhancing plant growth and health during the plant growth (Razaq *et al.*, 2017). Furthermore, the rice plant development, as affected by activation of beneficial microbes (*B. kururiensis*) that had ability to colonize rice, enhance plant growth and grain yield (Mattos *et al.*, 2008).

The microbes play a major role in several processes which influence the P transformation in soil and are consequently an essential part of the soil P cycle. In actual, soil microorganisms have potential to fix atmospheric N_2 and release P in soil from both inorganic and organic pools via P solubilization and mineralization (Rodriguez & Fraga, 1999). In addition, PSB strains have ability to solubilize enough quantity of P from organic and inorganic soil P by mobilization (Khan *et al.*, 2009). The population of these beneficial microbes is highly affected by the various P rates in the rice genotypes. The population of microbes at different P rates varied among the various rice genotypes that indicate the distinction for the potential of microbial colonization in the rice plants.

The application of various P levels improved the growth of rice genotypes. The P is a vital element for crop ecosystem, plant structure and various other physiological functions including plant biomass and growth (Hu *et al.*, 2005). The application of P in combination with nitrogen enhances root surface area, root length, and root-shoot mass (Song *et al.*, 2010). In the current study it was observed that application of P along with the nitrogen improved the rice growth and yield of all three rice genotypes. Development of plant growth and root length in different plant species, due to various nutrient rates has also been reported earliar (Gruber *et al.*, 2013).The phosphorus is an essential element for the growth development of plants and its deficiency severely affects the plant growth. The addition of P not only enhances the plant growth but it proliferates the plant root. Correspondingly, the growth promoting function of P application has been demonstrated significantly for enhancing plant height and root length compared to the treatment having no P application (Razaq *et al.*, 2017). Furthermore, the P application not only improves the plant growth but also profess a synergetic effect for plant growth and nutrient concentrations (Razaq *et al.*, 2017).

Table 3. Effects of phosphate fertilizer levels on plant growth parameters of various rice genotypes.

Treatments		Plant height (cm)	Root length (cm)	Number of tillers plant^{-1}	Number of panicles plant^{-1}	Panicle length (cm)
Genotypes	Phosphorus (P_2O_5 kg ha^{-1})					
MR219-9	30	58.33f	5.1d	12.86d	11.700c	20.56c
	60	84.20b	6.86c	14.33c	13.46b	22.60b
	90	75.87c	6.90c	15.46ab	14.40ab	23.03b
Shandar	30	68d	7.26b	14.67c	14.16ab	20.06c
	60	81.33bc	8.00ab	15.83a	14.63ab	23.20b
	90	87.26a	9.25a	16.60a	15.76a	25.20a
DR-92	30	60.66d	6.23c	13.20d	12.06ab	19.20d
	60	65.33de	6.56c	14.73c	13.47b	20.40c
	90	66.67d	6.73c	15.26b	13.74b	22.56b

The same letters within each column are not significantly different ($p<0.05$) among the treatments

Table 4. Effects of phosphatic fertilizer levels on the grain and straw yield of rice.

Treatments		Number of unfilled grains (%)	1000 grain weight (g)	Total grain yield (t ha^{-1})	Total straw yield (t ha^{-1})	Harvest index (%)
Genotype	Phosphorus (P_2O_5 kg ha^{-1})					
MR219-9	30	17.64b	19.06c	4.00d	7.16e	0.55a
	60	15.08d	20.87ab	4.83b	10.60c	0.45b
	90	14.01e	21.25a	5.00b	11.50b	0.43b
Shandar	30	16.31c	19.81bc	4.84b	10.30c	0.47b
	60	16.04c	20.98ab	4.89b	11.60b	0.41b
	90	15.03d	22.16a	5.53a	12.23a	0.44b
DR-92	30	19.32a	17.78d	3.57e	7.11e	0.50a
	60	17.05b	18.48c	4.67c	9.08d	0.51a
	90	15.21d	19.96b	4.87b	10.02c	0.48b

The same letters within each column are not significantly different ($p<0.05$) among the treatments

Nevertheless, the access rate of P application deals to partially reduced crop yield, even massive waste of resource, severe environmental pollution, and several other problems (Alam *et al.*, 2009). On the other side, various types of soils have different optimum P levels, for instance in normal soil which may not be optimal in saline-alkaline soil for a similar crop. Hence, in this study various P rates were observed with different rice genotypes. The ideal P application is contingent on the soil conditions and crop varieties/genotypes (Tian *et al.*, 2017). In addition, the earlier results suggest that various crops cultivation pattern like in upland and wetland rice return contrarily for cultivation method and various P levels (Jhang *et al.*, 2012).

Furthermore, P levels affected the P concentration in plant tissue and grain of rice genotypes. The rice genotypes had differential response for increasing P level. The application of P in both ways either in broadcasted or in combined into the soils before transplanting of the rice seedlings with various levels of P fertilizers applications enhanced rice yield parameters. The proliferations were due to increased nutrient availability (Massawe & Mrema, 2017). In the soil the differential response may be attributed to distinct PGPR root colonization of rice genotypes, as PGPR play a significant function for the nutrient supplement. The application of PGPR with the low rates of fertilizer enhanced nutrient uptake, crop maturity and plant growth biomass (Panhwar *et al.,* 2020; Rehman *et al.*, 2017). Moreover, the beneficial microbes perform a vital role for the nutrient availability. Among them the PGPR are chiefly derived from morphological and physiological variations of the plant roots and the enhancement of nutrient uptake (Panhwar *et al*., 2014). Besides N_2-fixing and P-solubilizing bacteria are essential in plant nutrition providing N and P uptake to the plants, and performing an important role in growth of many crops (Turan *et al*., 2014). Particularly the phosphate solubilizing bacteria (PSB) are probably assisting as an effective biofertilizers particularly in deficient P soils to enhance the inclusive crop enactment (Khan *et al*., 2014).

In this study it was proven that there was positive relationship between P and N uptake of rice, enhancement of rice growth with various P levels. Similar findings were reported earlier that positive relationships among the rice development, P accumulation and translocation at various P applications were reported (Cicek *et al*., 2010; Dewit, 1992).

Table 5. Effects of phosphorus application on nutrient (N & P) content of plant tissue and grains of rice genotypes.

Treatments		**N**		**P**	
		Plant	**Grain**	**Plant**	**Grain**
Genotypes	**Phosphorus (P_2O_5 kg ha^{-1})**	-------------------------- (%) ----------------------			
MR219-9	30	0.75f	0.99d	0.16e	0.21e
	60	0.81d	0.96de	0.21d	0.38bc
	90	0.99b	1.07c	0.26c	0.41b
Shandar	30	0.71g	0.94e	0.19d	0.27d
	60	0.79e	1.11b	0.31b	0.38c
	90	1.10a	1.16a	0.37a	0.47a
DR-92	30	0.65g	0.91f	0.17e	0.20e
	60	0.89c	0.99d	0.25c	0.29d
	90	0.96b	1.10bc	0.32b	0.40bc

The same letters within each column are not significantly different ($p<0.05$) among the treatments

Table 6. Effects of phosphorus levels on nutrient (N & P) uptake and total protein content in rice

Genotypes	**Phosphorus**	**N uptake**	**P uptake**	**Total protein content**
	(P_2O_5 kg ha^{-1})	----------------------------- (%) ------------------------------		
MR219-9	30	3.87c	0.76d	5.89e
	60	4.55b	1.69c	5.71f
	90	5.25a	1.95b	6.36d
Shandar	30	4.45b	1.16	5.59g
	60	5.83a	1.92b	6.60b
	90	5.45a	2.16a	6.90a
DR-92	30	3.18c	0.61d	5.41h
	60	4.53b	1.26c	5.89e
	90	5.26a	1.85b	6.54c

The same letters within each column are not significantly different ($p<0.05$) among the treatments

Conclusion

The study demonstrates that the beneficial microbes colonized plant roots of various rice genotypes. The rice genotype Shandar rice had potential to colonize maximum bacteria at lower rates of P. The P application significantly increased plant growth and grain yield of rice. Among rice genotypes, Shandar had excellent retortin growth and yield at recommended P levels. Genotypic difference for nutrient concentration and uptake was recorded in rice varieties at various rates of P. Shandar rice genotype accumulated maximum nutrient concentration and with increase of applied P levels. The various rice genotypes with different P responses may be useful for successful rice cultivation P-deficient and tolerant rice varieties.

References

Agrochart. 2015. Pakistan. Rice Annual 2015. http://www.agrochart.com/en/news/2833/pakistan-rice-annual-apr-2015.html.

Alam, M., M. Ali, A. Amin and M. Hasanuzzaman.2009. Yield attributes, yield and harvest index of three irrigated rice varieties under different levels of phosphorus. *Adv. Biol. Res.,* 3: 132-139.

Benton, J. Jr. 2001.Laboratory Guide for Conducting Soil Tests and Plant Analysis. CRC Press LLC, New York.

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen-total. In Page, A. L. (ed.) Methods of Soil Analysis. Chemical and Microbiological Properties. 2nd Edition. Madison, WI, USA. pp. 595:624.

Cicek, E., F Yilmaz and M. Yilmaz. 2010. Effect of N and NPK fertilizers on early field performance of narrow-leaved ash *Fraxinus angustifolia*. *J. Enviro. Biol.,* 31(1-2): 109-114.

Dewit, C.T. 1992. Resource use efficiency in agriculture. *Agric. Syst*., 40-125-151.

Dobermann, A. and T. Fairhurst. 2000. Rice: Nutrient disorders & nutrient management; international rice research institute. Vol. 1. Los Benos, Philippines.

Epstein, E. and A.J. Bloom. 2004. Mineral nutrition of plants: Principles and perspectives (Second Edition). Sunderland, MA: Sinauer Associates, Inc.; 402p.

Gee, G.W. and J.W. Bauder. 1986. Particle-size analysis. In A. Klute (ed.) Methods of soil analysis. Part 1.2nd ed. *Agron. Monogr.* 9. ASA and *SSSA, Madison, WI*. p. 383-411.

Gruber, B.D., R.F.H. Gieh, S. Friedel and N. Wirén. 2013. Plasticity of the Arabidopsis root system under nutrient deficiencies. *Plant Physiol.,* 163(1): 161-179.

Haney, C.H., B.S. Samuel, J. Bushand and F.M. Ausubel. 2015. Associations with rhizosphere bacteria can confer an adaptive advantage to plants. *Nat. Plants.* 1:15051.doi: 10.1038/nplants.

Hu, Y.C. and U. Schmid halter. 2005. Drought and salinity comparison of their effects on mineral nutrition of plants. *J. Plant Nut. Soil Sci.,* 168(4): 541-549.

Jhang, Y., J. Huay, Y. Li, Y. Chen and J. Yang. 2012. Effects of phosphorus on grain quality of upland and paddy rice under different cultivation. *Rice Sci.,* 19(2): 135-142.

Khan, A.L., M. Waqas, S.M. Kang, A. Al-Harrasi, J. Hussain, A. Al-Rawahi, S. Al-Khiziri, I. Ullah, L. Ali and H.Y. Jung. 2014. Bacterial endophyte *Sphingomonas* sp. LK11 produces gibberellins and IAA and promotes tomato plant growth. *J. Microbiol.,* 52: 689-695.

Khan, A.A., G. Jilani, M.S. Akhtar, S.M.S. Naqvi and M. Rasheed. 2009. Phosphorus solubilizing bacteria: Occurrence, mechanisms and their role in crop production. *J. Agric. Biol. Sci.,* 1: 48-58.

Kim, Y.C., J. Leveau, B.B.M. Gardener, E.A. Pierson, L.S. Pierson and C.M. Ryu. 2011. The multifactorial basis for plant health promotion by plant-associated bacteria. *Appl. Environ. Microbiol*., 77: 1548-1555.

Kuzyakov, Y. 2002. Review: factors affecting rhizosphere priming effects. *J. Plant Nutr. Soil Sci.,* 165: 382-396.

Massawe, P.I. and J. Mrema. 2017. Effects of different phosphorus fertilizers on rice (*Oryza sativa* L.) yield components and grain yields. *Asian J. Adv. Agri. Res.,* 3(2): 1-13.

Mattos, K.A., V.L.M. Padua, A. Romeiro, L.F. Hallack, B.C. Neves, T.M.U. Ulisses, C.F. Barros, A. R. Todeschini, J.O. Previato and L. Mendonca-Previato. 2008. Endophytic colonization of rice (*Oryza sativa* L.) by the diazotrophic bacterium *Burkholderia kururiensis* and its ability to enhance plant growth. *Anaisda* Academia *Brasileira de Ciências*. 80(3): 477-493.

Naher, U.A., O. Radziah, M.S. Halimi, Z.H. Shamsuddin and I.M. Razi. 2009. Influence of root exudate carbon compounds of three rice genotypes on rhizosphere and endophytic Diazotrophs. *J. Tropical Agri.,* 32: 209-223.

Panhwar, Q.A., A. Ali, N. Depar and J.A. Shah. 2020. Screening of plant growth promoting rhizobacteria for sustainable wheat (*Triticum aestivum* L.) crop production. *Pak. J. Bot*., 52(1): 1-20.

Panhwar, Q.A., O. Radziah, A.Z. Rahman, M. Sariah and I.M. Razi.2012. Isolation and characterization of phosphate-solubilizing bacteria from aerobic rice. *Afr. J. Biotechnol.,* 11: 2711-2719.

Panhwar, Q.A., O. Radziah, A.Z. Rahman, M. Sariah and I.M. Razi. 2011. Role of phosphate-solubilizing bacteria on rock phosphate solubility and growth of aerobic rice. *J. Environ. Biol.,* 2: 607-612.

Prasad, G., E.K. James, N. Mathan, P.M. Reddy, B.B. Reinhold-Hurek and J.K. Ladha. 2001. Endophytic Colonization of Rice by a Diazotrophic Strain of *Serratiamarcescens. J. Bacteriol.,* 183(8): 2634-2645.

Pieterse, C.M.J., C. Zamioudis, R.L. Berendsen, D.M. Weller, S.C. Van Wees and P.A. Bakker. 2014. Induced systemic resistance by Beneficial microbes. *Annu. Rev. Phytopathol.,* 1: 1-29.

Pikovskaya, R.I. 1948. Mobilization of phosphorus in soil in connection with vital activity of some microbial species. *Microbiologiya,* 17: 362-370.

Razaq, M., P. Zhang, Shen and H. Salahuddin. 2017. Influence of nitrogen and phosphorous on the growth and root morphology of Acer mono. *PLoS ONE.* 12(2): e0171321. doi:10.1371/journal. pone. 0171321.

Rehman, A., A.Z. Khan, A. Muhammad and A. Jalal. 2017. Performance of nitrogen fixing bacteria with increasing nitrogen ratios on growth, maturity and biomass of winter wheat varieties. *Biosci. Res.,* 14(2): 114-121.

Rodriguez, H. and R. Fraga. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotech. Adv*., 17: 319-339.

Ryan, J., G. Estefen and A. Rashid. 2001. Soil and plant analysis laboratory manual. 2nd ed. ICARDA Press: Aleppo, Syria.

SAS (Statistical Analysis Software). 2012. SAS Software, version 9.3; SAS Institute: Cary, NC, USA.

Shen, J.P., L.M. Zhang, J.F. Guo, J.L. Ray and J.Z. He. 2010. Impact of long-term fertilization practices on the abundance and composition of soil bacterial communities in Northeast China. *App. Soil Ecol.,* 46(1): 119-124.

Santos, S.G., P.R.A. Silva, A.C. Garcia, J.E. Zilli and R.L. Berbara. 2017. Dark septate endophyte decreases stress on rice. *Braz. J. Micro.,* 48: 333-341.

Song, C.J., K.M. Ma, L.Y. Qu, Y. Liu, X.L. Xu and B.J. Fu. 2010. Interactive effects of water, nitrogen and phosphorus on the growth, biomass partitioning and water-use efficiency of *Bauhinia faberi* seedlings. *J. Arid Environ.,* 74(9): 1003-1012.

Soultanpur, P.N. and A.P. Schwab. 1977. A new soil test for simultaneous extraction of micro and macro nutrients in alkaline soils. *Comm. Soil Sci. Plant Anal.,* 8(3): 195-207.

Tian, Z., J. Li, X. He, X. Jia, F. Yang and Z. Wang. 2017. Grain Yield, dry weight and phosphorus accumulation and translocation in two rice (*Oryza sativa* L.) Varieties as Affected by Salt-Alkali and Phosphorus. *Sustainability*. 9:1461; doi:10.3390/su9081461.

Turan, M., M. Ekinci, E. Yildirim, A. Gunes, K. Karagoz, R. Kotan and A. Dursun. 2014. Plant growth-promoting rhizobacteria improved growth, nutrient, and hormone content of cabbage (*Brassica oleracea*) seedlings. *Turk J. Agric*., 38: 327-333.

Walkley, A. and I.A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci.,* 37: 29-38.

Wu, W.X., X. Liu, H.H. Lu, Y.X. Chen, D. Medha and T. Janice. 2009. Use of13C labeling to assess carbon partitioning in transgenic and nontransgenic (parental) rice and their rhizosphere soil microbial communities. FEMS *Microbiol. Ecol*., 67: 93-102.

Xu, B.C., F.R. Niu, D.P. Duan, W.Z. Xu and J. Huang. 2012. Root morphological characteristics of *Lespedeza davurica* (L.) intercropped with *Bothriochlo aischaemum* (L.) Keng under water stress and P application conditions. *Pak. J. Bot*., 44(6): 1857-1864.

Zapata, F. and A.R. Zaharah. 2002. Phosphate availability from phosphate rock and sewage sludge as influenced by addition of water soluble phosphate fertilizers. *Nut. Cycl. Agroecosys*., 1(63): 43-48.

(Received for publication 22 January 2019)