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Research Communication

Yield and quality of rice (*Oryza sativa*) hybrids grown by SRI method with and without plant growth promoting rhizobacteria

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ABSTRACT

A field experiment was conducted at the Indian Agricultural Research Institute, New Delhi during *kharif* 2007 to assess the performance of six rice (*Oryza sativa* L.) hybrids ('KRH 2', 'Arize 6444', 'PHB 71', 'Indam 100-001', 'PRH 10' and 'Indam 100-003') with and without inoculation of plant growth-promoting rhizobacteria (*Azospirillum brasilense* 'CD 4', *Bacillus subtilis* 'RP 24' and control), grown by system of rice intensification (SRI) method. Hybrid 'PHB 71' recorded the highest surface area, diameter and volume of roots. Highest grain yield was recorded in 'KRH 2', which was at par with 'Arize 6444' and 'PHB 71', but significantly higher than 'Indam 100-003', 'PRH 10' and 'Indam 100-001'. Inoculation of rice seedlings with plant growth-promoting rhizobacteria had a favourable effect on root growth, yield and quality of rice hybrids. Inoculation of rice with *Azosprillum brasilense* and *Bacillus subtilis* improved all quality parameters, *viz*. hulling, milling, head rice recovery and protein content significantly over the control.

***Key words**:* PGPR, Rice hybrids, Rice quality, System of rice intensification, Yield

The productivity of rice (3.36 t/ha) in India is well below the world's average yield of 4.30 t/ha (FAOSTAT, 2012). One of the strategies to increase rice productivity could be to bring more area under hybrids. Rice hybrids produce a mean grain yield of 6.0–7.9 t/ha, which is 10–44% higher over the popular high yielding varieties (Wanjari *et al.* 2006). Adoption of hybrids may help tremendously to raise the rice productivity in India. Simultaneously, rice yields can be increased by efficient utilization of limited water. The system of rice intensification (SRI) is known to save water and increase rice yields over traditional method of rice cultivation.

The scarcity of water for agricultural production is becoming a major problem in many countries, particularly in the world's leading rice-producing countries, China and India, where competing and growing demands for freshwater are coming from other sectors. In such scenario, the SRI appears to be a good alternative of rice cultivation, that saves the expensive inputs (e.g. water, seed, nutrients and pesticides *etc.*), improves soil health/quality and protects the environment substantially (Satyanarayana *et al.*, 2007). In a field study comparing SRI with conventional transplanted rice (CTR), significantly higher NPK uptake and grain yield of rice was recorded with SRI method than CTR (Shekhar *et al.*, 2009). The SRI system differs markedly from traditional flooded rice cultivation. The SRI practices are: transplanting young seedlings (<14 days old), singly, carefully, and widely spaced (25 cm × 25 cm), in fields, where soil conditions are kept mostly aerobic, with active soil aeration and increased organic-matter amendments (Kumar and Shivay, 2004). The SRI changes the environment of rice growth from anaerobic to aerobic soil conditions, with no standing water during the vegetative growth period and only a thin layer of water on the field (1–2 cm) from panicle initiation until 10–15 days before harvest. However, in conventional transplanted rice (CTR), two to three seedlings (20–25 days old) are transplanted per hill at a narrow spacing (20 cm × 10 cm or 15 cm × 15 cm). The fields are generally flooded with standing water (5 ± 2 cm) until two weeks before harvest of rice. Contrary to the CTR, the SRI practices have been shown to contribute also to larger and apparently more active populations of (aerobic) soil organisms (Zhao *et al.*, 2010). Hence, inoculation of rice seeds with plant growth promoting rhizobacteria (PGPR) may further help in im-

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proved nutrient availability, rice growth, yield and quality (Zahir *et al.*, 2003). The modes of action of PGPRs include nitrogen fixation, increasing the availability of nutrients in the rhizosphere, positively influencing root growth and morphology and promoting other beneficial plant–microbe symbioses (Vessey, 2003). No information is available on the above aspects in north India. Therefore, a field experiment was conducted to assess the growth, grain yield and quality of six rice hybrids grown by the SRI method, along with inoculation of rice seedlings with three PGPR.

The field experiment was conducted at the research farm of Indian Agricultural Research Institute, New Delhi (77°12' E and 28°40' N; 228.4 m above mean sea level) during *kharif* (July-October) 2007. New Delhi has semi-arid and sub-tropical climate with hot and dry summers and cold winters, and mean annual rainfall of about 710 mm, most of which (about 84%) is received between July and September. The soil was sandy clay loam having 0.53% organic carbon, 7.9 soil pH, 0.05% total N, 14.5 kg/ha available P, 248 kg/ha available K. The chemical analysis of soil samples was done as per the methods prescribed by Prasad *et al.* (2006). Eighteen treatments combinations of six rice hybrids ('PRH 10', 'KRH 2', 'PHB 71', 'Arize 6444', 'Indam 100-001' and 'Indam100-003') and three plant growth promoting rhizobacteria (control, *Azospirillum brasilense* 'CD4' and *Bacillus subtilis* 'RP24'), were experimented in a factorial randomized block design with three replications. The rice nursery was raised as per the SRI method (Satyanarayana *et al.* 2007). A uniform basal dose of 26 kg P, 33 kg K and 5 kg Zn/ha through single superphosphate, muriate of potash and zinc sulphate, respectively, was applied just before transplanting. Nitrogen was applied as urea at 120 kg/ha in three equal splits *viz.*, as basal, 13 DAT (days after transplanting) and 35 DAT. The 14–days old seedlings were immediately inoculated after uprooting with appropriate strains of rhizobacteria, as per treatment and transplanted in a square pattern (25 cm × 25 cm) using one seedling per hill. The plots were kept moist by applying water intermittently up to panicle initiation (PI) followed by maintenance of 1-2 cm deep standing water during the reproductive stage. Two rotary weedings were done at 20 and 40 DAT.

To study the root volume, length and surface area, root samples were taken from 0-20 cm soil root depth with the help of core sampler at 60 DAT. Root volume and length was determined by using a root scanner. Sun-dried paddy samples of each treatment weighing 100 g from each replication were hulled in a mini 'Stake Rice Medium' and weight of brown rice was recorded to compute the hulling percentage. To obtain uniformly polished grains, the hulled brown rice was passed through Stake Rice Whitening and Caking Machine for 2 minutes. The polished rice was weighed and milling percentage was worked out. The milled produce was sieved with the help of appropriate sieves to separate whole kernels from the broken ones. Small proportion of whole kernels which passed along with broken one was hand separated and the head rice recovery (%) was computed.

The effect of different rice hybrids on plant height was significant at 60 DAT and harvest (Table 1). Rice hybrid 'Indam 100-001' produced tallest plants, being at par to

Table 1. Effect of hybrids and plant growth promoting rhizobacteria (PGPR) on shoot and root growth of rice

Treatment	Plant height (cm)		No. of tillers/ hill	Root growth (60 DAT)		
	60 DAT	Harvest	60 DAT	Surface area (cm^2)	Diameter (mm)	Volume (cm^3)
Rice hybrid						
'KRH 2'	91.6	117.5	19.5	541	0.243	8.2
'Arize 6444'	83.3	101.8	20.4	576	0.297	9.4
'PHB 71'	80.7	110.0	20.6	735	0.352	13.1
'Indam 100-001'	101.2	120.4	24.6	709	0.332	12.1
'PRH 10'	95.5	106.3	17.4	503	0.250	7.5
'Indam 100-003'	92.3	115.7	23.2	730	0.279	11.3
SEm±	3.9	2.6	0.7	23	0.007	0.6
CD (P=0.05)	11.2	7.4	2.0	69	0.021	1.8
PGPR[1]						
Control	90.2	111.1	20.3	595	0.284	9.6
Azospirillum[2]	90.8	112.5	21.4	668	0.301	11.0
Bacillus[3]	91.2	112.1	21.1	634	0.292	10.2
SEm±	2.7	1.8	0.5	16	0.005	0.4
CD (P=0.05)	NS	NS	NS	47	0.016	1.1

[1]PGPR: Plant growth promoting rhizobacteria; [2]*Azospirillum brasilense* CD4; [3]*Bacillus subtilis* RP24; NS: Not significant; DAT: days after transplanting

'KRH 2', 'Indam 100-003' and 'PRH 10'. At harvest, 'Indam 100-001' was significantly taller than all the other 5 hybrids. At 60 DAT, 'Indam 100-001' produced more tillers/hill, being at par to 'Indam 100-003' and both produced significantly more number of tillers/hill than rest of the four hybrids. The effect of plant growth promoting rhizobacteria (PGPR) on plant height and tillers/hill was non-significant. 'PHB 71' recorded the highest surface area, diameter and volume of roots. Rice hybrid 'PRH 10' recorded the least value of surface area of roots. Root surface area of 'PHB 71' was at par with 'Indam 100-001' and 'Indam 100-003', and significantly higher than 'KRH 2', 'Arize 6444' and 'PRH 10'. The root volume of 'PHB 71' was at par with 'Indam 100-001', but significantly higher than rest of the hybrids. The plant growth promoting rhizobacteria (PGPR) had a positive and significant impact on root growth of rice. The highest values of root growth parameters, *viz*., surface area, diameter and volume, were observed with the inoculation of *Azospirillum brasilense*, which were at par to *Bacillus subtilis* inoculation, and significantly higher over un-inoculated control.

'KRH 2' recorded the highest grain yield, which was at par with 'Arize 6444' and 'PHB 71', but significantly higher than 'Indam 100-003', 'PRH 10' and 'Indam 100-001' (Table 2). Hybrids 'PRH 10' and 'Indam 100-003' produced at par grain yield, but both produced significantly higher grain yield than 'Indam 100-001'. Rice hybrids 'KRH 2', 'Arize 6444' and 'PHB 71' produced 74.7%, 65.5% and 56.0% more grain yield, respectively over 'Indam 100-001'. The main reason for higher yields with KRH 2, Arize 6444 and PHB 71 over Indam 100-001 could be due to differences in their growth behavior and heterosis. In fact, the heterosis effect and their genetic constitution may have caused a significant variation in grain yield of different hybrids. Salgotra (2005) evaluated the performance of eight rice hybrids and a significant heterosis for grain yield was observed for most of the hybrids. Plant growth promoting rhizobacteria (PGPR) influenced the grain yield of rice significantly. Although, inoculation of rice with *Bacillus subtilis* did not increase the grain yield significantly over control, but inoculation with *Azospirillum brasilense* increased the grain yield of rice significantly over both control (non-inoculated) and *Bacillus subtilis* inoculation. One of the benefits that PGPR provide to plants is fixed nitrogen in exchange for fixed carbon released as root exudates (Glick, 1995, Biswas *et al*., 2000), production of plant growth hormones such as gibberellic acid, Indole-3-acetic acid, and cytokinin, which promote root growth (Idris *et al*., 2009, Sokolova *et al*., 2011). Moreover, Brown (1974) suggested that diseases could be suppressed by bacterial inoculation, which in turn, stimulates growth of plant. Hence, grain yield of rice in the present study might, therefore, has increased by *Azospirillum* inoculation due to one or more, of these mechanisms, i.e. biological N_2-fixation, hormone secretion and/or disease suppression. The highest straw yield was observed in 'Indam 100-001', which was significantly higher than all the other 5 hybrids. 'PRH 10' recorded the lowest straw yield, being at par to 'Indam 100-003', and significantly lower to rest of the hybrids. The effect of plant growth promoting rhizobacteria (PGPR) on straw yield was non-significant.

Table 2. Effect of hybrids and plant growth promoting rhizobacteria (PGPR) on yield and quality of rice.

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Hulling, %	Milling, %	Head rice recovery, %	Protein content, %
Rice hybrid						
'KRH 2'	5.52	9.85	80.0	65.7	58.0	5.65
'Arize 6444'	5.23	12.22	79.1	67.9	55.7	5.95
'PHB 71'	4.93	10.07	81.0	66.8	56.0	6.54
'Indam 100-001'	3.16	15.14	74.0	62.0	49.8	8.33
'PRH 10'	4.32	8.13	77.1	64.0	51.9	7.76
'Indam 100-003'	4.59	9.41	73.0	61.0	51.0	7.14
SEm±	0.30	0.63	1.4	0.7	0.9	0.30
CD (P=0.05)	0.88	1.82	4.0	2.1	2.7	0.90
PGPR[1]						
Control	4.42	10.37	73.2	60.7	49.0	6.13
Azospirillum[2]	5.09	10.87	80.3	67.1	56.8	7.91
Bacillus[3]	4.39	11.17	78.7	66.0	55.3	6.72
SEm±	0.21	0.45	0.9	0.5	0.7	0.24
CD (P=0.05)	0.62	NS	2.8	1.5	1.9	0.65

[1]PGPR: Plant growth promoting rhizobacteria; [2]*Azospirillum brasilense* CD4; [3]*Bacillus subtilis* RP24; NS: Not significant; DAT: days after transplanting

The highest hulling percentage was recorded with rice hybrid 'PHB 71', being at par with 'KRH 2', 'Arize 6444' and 'PHB 71' and significantly greater than 'Indam 100-001' and 'Indam 100-003'. 'Arize 6444' had the highest milling percentage, being at par with 'PHB 71' and significantly higher than the remaining four hybrids. Rice hybrid 'KRH 2' had the highest head rice recovery, being at par with 'Arize 6444' and 'PHB 71'. Contrary to the above results, hybrid 'Indam 100-001' had the highest crude protein content in grain, being at par with 'PRH 10' alone. Inoculation of rice with *Azosprillum brasilense* and *Bacillus subtilis* improved all the quality parameters significantly over the control. However, inoculation of rice seed either with *Azosprillum brasilense* or *Bacillus subtilis* had statistically similar values of grain quality parameters, with the exception of protein content, which was significantly higher with the *Azosprillum brasilense* than with *Bacillus subtilis*. The interaction effects of rice hybrids and PGPR were non-significant with respect to all the growth, yield and quality attributes studied, hence, not presented in tables.

It is concluded that with respect to yield and quality (hulling, milling, head rice recovery and protein content), rice hybrids 'KRH 2' and 'Arize 6444' were most promising under SRI technique. Inoculation of rice seedlings with *Azospirillum brasilense* 'CD4' gave the best results both in terms of grain yield and rice quality.

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