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Effect of Inoculation of Efficient Diazotrophic Isolates on the Yield of Rice Grown under different Rice Production Systems

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A field experiment was conducted during Rabi 2013, at wetland of Tamil Nadu Agricultural University, Coimbatore to study the nitrogen fixing potential of the selected diazotrophs on rice (ADT 43) under three different rice production systems *viz*., lowland, System of Rice Intensification (SRI) and aerobic methods of cultivation. The pH of the soil was found to be alkaline 7.5. The texure of the soil was clay loam. The available nitrogen and phosphorous was low with 192.8 and 19.8kg ha^{-1}respectively. The available potassium was found to be medium with 425.3 kg ha^{-1}. Among the three different rice growing systems, grain and straw yield were found to be maximum with application of 75% recommended dose of N with the combined inoculation of diazotrophic isolates *viz*., *Azospirillum lipoferum (As*LC$_1$I), *Azotobacter chroococcum* (*Ab*SKN) , *Beijerinckia indica* (*Be*SC$_2$S$_2$), *Derxia gummosa* (*De*LTP$_2$) and *Pseudomonas fluorescens* (*Ps*AKK$_3$) in comparison with the standard strain *A.lipoferum* (Az - 204) in SRI (7.1 t/ha and 8.78 t/ha), followed by lowland (6.1t/ha and 6.8 t/ha) and aerobic rice (4.23 t / ha and 5.5 t / ha). The nitrogen uptake was found to be maximum in the above treatment at all three rice growing systems. Among the three systems, SRI (110 kg / ha) recorded maximum nitrogen uptake followed by lowland (81.6 kg / ha) and aerobic rice (70 kg / ha).

Key words: Rice, Diazotrophs, Lowland, SRI, Aerobic, Grain and Straw yield, N uptake

India is one of the world's largest producer of rice accounting for 20% of world rice production. Rice is the India's prominent crop and is the staple food of the people of the eastern and southern parts of the country. India's rice production reached to a record high of 104.32 million tonnes in 2011-2012 crop year (July–June). Rice can be cultivated by different methods based on the type of region.

Rice production in India had increased in the past three decades continuously beginning with the green revolution, but has stagnated since 1999. It is estimated that by 2020 at least 170 to 180 mt of rice is to be produced in India, with an average productivity of 4.03 t ha^{-1}. Nitrogen is the most important input required for rice production. Rice plants are mainly grown in lowland condition, where soil is characterized by remarkable reduced conditions because of flooding (Liesack *et al*., 2000). The community structure of microorganism in submerged paddy soil differs from that in upland soil because of the anaerobic environment. Facultative and strictly anaerobic fungi, bacteria (e.g. *Clostridium* spp., *Streptococcus* spp., *Staphylococcus* spp.) and archaea (e.g. methanogenic archaea) are often dominant in submerged paddy soil. In lowland, since the soil is always flooded it creates reduced condition whereas in SRI and aerobic rice the soil is not continuously flooded and the soil is in oxidized form. In order to make the rice cultivation sustainable and less dependent on fertilizer nitrogen, there is a need to use diazotrophic bacteria that can make biologically fixed nitrogen available for the growth of rice plants (Ladha *et al*., 1997). The rhizosphere surrounding the plant root surface are being affected by plant root activities. Plant roots secrete mucilage and supply carbohydrate sources to soil micro-organisms (Jimenez *et al*., 2003). Rice roots also provide polysaccharides, amino acids and organic acids as do upland plants. As a result, the community structures of soil microorganisms in the rice rhizosphere are expected to differ greatly from bulk soil (non-rhizosphere soil) of the same paddy field. In view of above facts, the present study was undertaken to evaluate the field performance of diazotrophs isolated under the three different rice production systems *viz*., lowland, SRI and aerobic rice.

Materials and Methods

A field experiment was conducted in the wetlands of TNAU, Coimbatore during Rabi, 2013. The experiment was laid out in Randamized Block Design with three replications in three different rice production system *viz.,*Lowland, SRI and Aerobic rice. The soil fertility status was low in available nitrogen (192.8 kg ha^{-1}), medium in available

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phosphorus (19.8 kg ha $^{-1}$) and high in available potassium (425.3 kg ha $^{-1}$) respectively. Short duration rice variety (ADT - 43) was used as a test variety in the present study. The field was puddled and perfectly levelled and adequate drainage facility was provided. The different diazotrophs used in the study were screened based on their N_2 fixing potential by acetylene reduction assay and their inoculation effect on rice in seedling agar tube and pot culture conditions. Seed treatment was done at the rate of 1kg of inoculants / seed required for 1 ha, which is mixed with 1.25 litres of carboxy Methyl cellulose as adjuvant treated with the seeds, shade dried for 20 min period, soaked in water for overnight, allowed to sprout and sown in the field. A seed rate of 30 kg ha^{-1} for lowland and aerobic rice and 7.5 kg ha^{-1} for SRI and was adopted Recommended dose of fertilizer at 150: 50: 50 was applied in two split doses (maximum tillering stage and active flowering stage) as per treatment schedule for all the three rice growing systems. The entire quantity of P was applied basally as DAP. Nitrogen in the form of Urea and Potassium as Muriate of potash were applied in two split doses. The N content was estimated by following the standard procedure described by Humphries, (1956). The grain and straw yield were recorded separately for each plot.

Results and Discussion

Nitrogen uptake

In all three rice growing systems, nitrogen uptake was maximum with the combined application of the diazotrophic isolates *viz*., *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Beijerinckia indica*, *Derxia gummosa* and *Pseudomonas fluorescencs* with 75% recommended dose N. Among three rice growing systems, SRI recorded maximum N uptake (110 kg / ha) followed by lowland (81.6 kg / ha) and aerobic rice (70 kg/ha). Compared with unfertilized and uninoculated control, application of above diazotrophic isolates with 75% recommended dose N has nearly doubled the N uptake, which indicated the importance of fertilization with N, particularly in soils with low available N status (Table 3). This was proved by Iranie *et al*. (2009) who observed that under flooded conditions, despite the fact that ample water is available to the rice plant, there are numerous constraints in terms of nitrogen supply. Lowland rice generally loses more than 60% of applied N via NH_3 volatilization from the floodwater. Microbial activity as a result decomposition of soil organic matter is reduced by 50% under anaerobic conditions. The microbial biomass N is an important repository of plant nutrients that is more labile than the bulk of soil organic matter and able to contribute substantial amounts of nutrients in the soil. Of the factors that contribute to high N availability and high N use efficiency under SRI management practice, repeated wetting and drying process maybe have the greatest influence.

Table 1. Effect of inoculation of efficient diazotrophic isolates on grain yield of lowland, SRI and aerobic rice (var. ADT 43)

Treatment	Grain yield (t/ha)			
	Rice production systems			
	Lowland	SRI	Aerobic	Mean
T_1- Unfertilized and uninoculated control	3.0	5.0	3.0	3.67
T_2-75% recommended dose N	4.6	5.2	3.5	4.44
T_3 - 75% recommended dose N + *Azospirillum* (Az-204)	4.9	5.4	3.8	4.71
T_4 -75% recommended dose N + *Derxia* LTP $_2$	5.3	5.9	3.4	4.86
T_5 -75% recommended dose N + *Pseudomonas* AKK $_3$	5.5	6.5	4.2	5.40
T_6 -75% recommended dose N +*Azotobacter* SKN	5.4	6.3	4.2	5.31
T_7 -75% recommended dose N + *Pseudomonas* SAK $_2$	5.8	6.9	3.5	5.42
T_8 -75% recommended dose N + *Beijerinckia* SC $_2S_2$	5.0	5.6	4.0	4.87
T_9 -75% recommended dose N + T_7+ T_8+ T_9	6.0	7.0	4.2	5.73
T_{10}-75% recommended dose N + *Azospirillum* LC $_1$l+ *Azotobacter* SKN + *Pseudomonas* AKK $_3$+ *Derxia* LTP $_2$ + *Beijerinckia* SC $_2S_2$	6.1	7.1	4.3	5.84
T_{11} - 100% recommended dose N	5.5	6.0	3.71	5.07
Mean	5.2	6.1	3.8	
CD (0.05)	0.68	0.80	0.48	
Treatment	10			
Production system	2			
Treatment x Production system	10 x 2			

Grain and straw yield of rice

Generally, the grain and straw yield increased significantly with the application of biofertilizers in all the three rice growing systems. In three rice growing systems, application of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Beijerinckia*

Table 2. Effect of inoculation of efficient diazotrophic isolates on straw yield of lowland, SRI and aerobic rice (var. ADT 43)

Treatment	Straw yield (t/ha) Rice production systems			
	Lowland	SRI	Aerobic	Mean
T_1- Unfertilized and uninoculated control	3.9	6.0	3.9	4.60
T_2-75% recommended dose N	5.5	6.2	4.2	5.32
T_3 -75% recommended dose N + *Azospirillum* (Az-204)	5.9	6.8	4.5	5.73
T_4 -75% recommended dose N + *Derxia* LTP $_2$	6.3	7.7	4.4	6.14
T_5 -75% recommended dose N + *Pseudomonas* AKK $_3$	7.2	7.8	5.1	6.68
T_6 -75% recommended dose N +*Azotobacter* SKN	5.9	6.9	4.6	5.82
T_7 -75% recommended dose N + *Pseudomonas* SAK $_2$	6.8	8.8	4.2	6.58
T_8 -75% recommended dose N + *Beijerinckia* SC $_2S_2$	6.5	6.7	4.8	6.01
T_9 -75% recommended dose N + T_7+ T_8+ T_9	6.5	8.4	5.0	6.63
T_{10}-75% recommended dose N + *Azospirillum* LC $_1$I+ *Azotobacter* SKN + *Pseudomonas* AKK $_3$+ *Derxia* LTP $_2$+ *Beijerinckia* SC $_2S_2$	6.84	8.5	5.5	6.95
T_{11} - 100% recommended dose N	6.05	7.2	4.4	5.88
Mean	6.1	7.4	4.6	
CD (0.05)	0.83	1.09	0.54	
Treatment	10			
Production system	2			
Treatment x Production system	10 x 2			

indica, *Derxia gummosa* and *Pseudomonas fluoresens* with 75% recommended dose N produced maximum of grain and straw yield. Among three rice growing systems, SRI recorded higher grain and straw yield (7.1 t/ha and 8.78 t/ha) respectively with the application of 75% recommended dose N and *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Beijerinckia indica*, *Derxia gummosa* and *Pseudomonas fluoresens* (Table 1 and 2). In lowland rice, the grain and straw yield recorded 6.1t/ha and 6.8 t/ha respectively, which was significantly higher than unfertilized and

Table 3. Effect of inoculation of efficient diazotrophic isolates on Nitrogen uptake of lowland, SRI and aerobic rice (var. ADT 43)

Treatment	N uptake (kg ha^{-1}) Rice production systems			
	Lowland	SRI	Aerobic	Mean
T_1- Unfertilized and uninoculated control	60.0	64	43	55.71
T_2-75% recommended dose N	63.0	69	46	59.30
T_3 -75% recommended dose N + *Azospirillum* (Az-204)	65.0	72	49	62.03
T_4 -75% recommended dose N + *Derxia* LTP $_2$	70.0	79	52	67.01
T_5 -75% recommended dose N + *Pseudomonas* AKK $_3$	78.1	89	60	75.74
T_6 -75% recommended dose N +*Azotobacter* SKN	75.3	85	58	72.72
T_7 -75% recommended dose N + *Pseudomonas* SAK $_2$	79.2	92	65	78.74
T_8 -75% recommended dose N + *Beijerinckia* SC $_2S_2$	68.0	75	50	64.33
T_9 -75% recommended dose N + T_7+ T_8+ T_9	80.6	95	67	80.92
T_{10}-75% recommended dose N + *Azospirillum* LC $_1$I+ *Azotobacter* SKN + *Pseudomonas* AKK $_3$+ *Derxia* LTP $_2$ + *Beijerinckia* SC $_2S_2$	81.6	110	70	87.21
T_{11} - 100% recommended dose N	74.2	82	54	70.07
Mean	72.3	82.9	55.8	55.7
CD (0.05)	8.8	15.5	10.4	
Treatment	10			
Production system	2			
Treatment x Production system	10 x 2			

uninoculated control. In aerobic rice, the grain and straw yield were found to be 4.23 t / ha and 5.5 t / ha respectively in the same treatment. Uphoff (2002) found that SRI management practices are capable of producing higher rice yields than conventional management and aerobic rice practices. Yields with

SRI management practices are 2 to 3 times higher than the lowland and aerobic rice yield.

Conclusion

N uptake, grain yield and straw yield were found to be maximum with the application of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Beijerinckia indica*, *Derxia gummosa* and *Pseudomonas fluoresens* + 75 % at recommended dose of N in all three rice growing systems. Among three rice growing systems, SRI recorded maximum grain yield, straw yield and N uptake. The results suggested that the N contribution from the diazotrophic isolates to rice crop was higher under SRI than in lowland and aerobic rice due to the alternate wetting and thawing conditions which supported the N_2 fixation by diazotrophic isolates and utilization of the fixed nitrogen by rice crop.

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