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Performance of Azophos on rice variety PMK 3 under irrigated, semidry and rainfed conditions

Jeya Bharathi, M. K. Kumar, J. Prabakaran and S. Gurumoorthy*

**** Agricultural Research Station, Paramakudi, Tamil Nadu, India***

ABSTRACT

The performance of Azophos with different levels of NPK fertilizers on the rice variety PMK 3 was assessed under irrigated, semidry and rainfed field conditions. Growth and yield of rice were more by the application of recommended dose of NPK fertilizers, than those for the Azophos inoculation under irrigated condition. However, Azophos effected more growth, yield, nutrient content of PMK 3 than those of the recommended doses of NPK fertilizers under semidry, and rainfed condition i.e. under the water stress situations. The results concluded that Azospirillum produced growth hormone and Phosphobacteria increased root biomass through phosphorus solubilization, which gave drought tolerance to the plant under stress conditions.

Key words: *Azophos, Azospirillum, phosphobacteria, rice, response, water stress*

The total area under irrigated rice has decreased due to the non-availability of adequate water and the farms of the eastern India. The farmers identified drought stress as the foremost yield constraint. Thus, crop improvement for drought resistance and management for water stress would boost rice production in the rainfed low lands. Besides, the biofertilizers also enhance yield without affecting the environmental safety. Inoculation of *Azospirillum* and phosphobacteria combination increases the root length and root volume due to production of the growth hormones and phosphorus solubilization in different plants (Arangarasan *et al*., 1998). Therefore, performance of Azophos was compared with that of either *Azospirillum* or phosphobacteria under different moisture levels *viz*., irrigated, semidry and rainfed conditions along with NPK fertilizers to develop suitable strategy for enhancement of rice production.

MATERIALS AND METHODS

Filed experiments were conducted on the rice var. PMK3 at the Agricultural Research Station, Paramakudi, Ramanathapurum district, Tamil Nadu, India during the October 2005 to February 2006. The soil conditions of the station are as follows pH was strongly alkaline (8.5 –9.0), EC was 1.12 s m^{-1}, highly calcareous, cation exchange capacity was more, has higher water holding capacity, wet, low in organic matter *i.e*. N 201 kg ha^{-1}, P 11 kg ha^{-1} and K 625 kg ha^{-1}. The field experiments were laid out in a randomized block design with 8 treatments and three replications. The treatments were T_1 – Control, T_2 – *Azospirillum* + NPK (50: 100: 100 (%) of the recommended dose), T_3 – Phosphobacteria + NPK (100: 50: 100 (%) of the recommended dose), T_4 – Azophos + NPK (50: 50: 100 (%) of the recommended dose), T_5 – *Azospirillum* + NPK (75: 100:100 (%) of the recommended dose), T_6 – Phosphobacteria + NPK (100: 75: 100 (%) of the recommended dose), T_7 – Azophos + NPK (75: 75: 100 (%) of the recommended dose) and T_8 – Recommended dose of NPK (100:50:50 kg ha^{-1}) In irrigated rice, Azophos/*Azospirillum*/phosphobacteria were applied through seed treatment (1 kg rice husk ash based inoculant ha), seedling root dipp (1 kg ha^{-1}) and soil application (2 kg ha^{-1}). In semidry and rainfed rice Azophos/*Azospirillum*/phosphobacteria were applied in the soil. The quantity of fertilizer for different treatments were calculated based on the recommended dose 100: 50: 50 kg ha^{-1} of NPK for irrigated and semidry or rainfed (50:25:25 kg ha^{-1}) rice. Nitrogen was applied 50% as basal and two top dressings @ 25% at active tillering and panicle initiation stages for irrigated rice but @ 50% at active tillering and panicle initiation stages for semidry and rainfed conditions. The experimental plots were 8 x 5 m and transplanted @ 2 seedlings hill^{-1} at 15 x 10 cm spacing maintained with 5 cm water depth till maturity. The other fields were broadcasted manually @ 60 kg seeds/ha. The semidry fields were irrigated to maintain the field at saturated conditions and the rainfed fields received only the monsoon rains.

The biometric observations on root *viz.*, length, volume, number of main and lateral roots plant^{-1}; shoot length; plant dry weight, total tillers hill^{-1} and productive tillers hill^{-1} were recorded. The total N content of the plant samples was estimated by microkjeldhal method (Humphries, 1956). Available N, P and K content were estimated from 30 DAS, 60 DAS and 90 DAS by alkaline permanganate (Subbian and Asija, 1956), calorimetric (Olsen *et al.*, 1954) and flame photometeric (Standford and English, 1949) methods, respectively. The rhizosphere soil was collected from 5 cm depth for microbial population analysis one day before, but for NPK analysis soil samples were collected one week before and stored in a BOD incubator at 5æ%C for further studies. The plant samples were collected by removing whole plant for growth parameters analysis. The survival of *Azospirillum* and phosphobacteria in the rhizosphere of rice var. PMK3 was estimated by MPN and standard plate count method respectively. The chlorophyll content was estimated calorimetrically (Witham, 1971) on wet weight basis and proline level was estimated according to Bates *et al.* (1973). The grain and straw yields were recorded at the time of harvest.

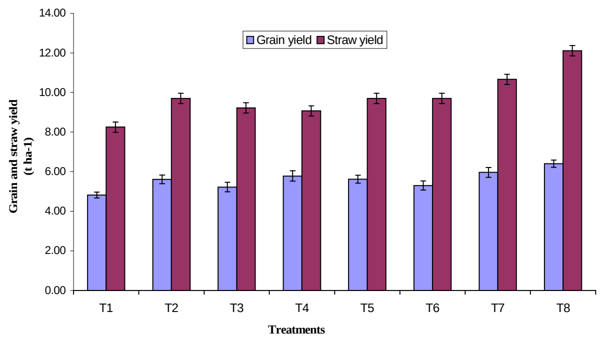
RESULTS AND DISCUSSION

At 90 days after sowing (DAS) under irrigated condition, maximum available N (235 kg ha^{-1}), K (656 kg ha^{-1}) contents were recorded for recommended doses of the NPK fertilizers application but maximum P (48.4 kg ha^{-1}) was observed for phosphobacteria inoculation (Table 1). Maximum total N content (0.53%) and proline levels (1660 µg g^{-1}) were obtained on 90 and 60 DAS respectively for Azophos and recommended doses of NPK fertilizers applications, respectively (Table 2). The grain (6.40 t ha^{-1}) and straw (12.1 t ha^{-1}) yields were maximum for the recommended dose of NPK fertilizer application (Fig. 1). The result of the irrigated field experiments clearly showed that recommended doses of NPK fertilizers application was more effective than the individual and combined inoculation of *Azospirillum* and phosphobacteria, which

Table 1. Effect of Azophos inoculation on available N, P and K content of rice var. PMK 3 under irrigated (90 DAT), semidry and rainfed (90 DAS) field conditions.

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	I	S	R	I	S	R	I	S	R
Control	220.4	180.0	163.0	31.9	22.0	18.0	540	364	340
Azospirillum + NPK (50: 100: 100 (%))	241.8	243.0	215.0	34.0	24.0	24.0	540	372	360
Phosphobacteria + NPK (100: 50: 100 (%))	227.5	173.0	170.0	46.0	37.0	28.0	547	390	351
Azophos + NPK (50: 50: 100 (%))	225.8	210.0	180.0	44.0	33.0	27.0	558	410	370
Azospirillum + NPK (75: 100: 100 (%))	243.8	250.0	191.0	35.2	27.0	25.0	548	372	340
Phosphobacteria + NPK (100: 75: 100 (%))	234.8	190.0	181.0	48.4	37.0	33.0	584	420	380
Azophos + NPK (75: 75: 100 (%))	237.7	220.0	175.0	45.3	36.0	31.0	583	410	390
Recommended dose of NPK for irrigated field (100: 50: 50 kg ha^{-1})	285.8	-	-	45.0	-	-	656	-	-
Recommended dose of NPK for semidry field (50: 25: 25 kg ha^{-1})	-	270.0	-	-	39.0	-	-	404	-
Recommended dose of NPK for rainfed field (50: 25: 25 kg ha^{-1})	-	-	160.0	-	-	29.0	-	-	370
CD	0.36	2.48	6.80	0.61	1.22	0.62	3.38	0.04	1.23

* NPK doses are portions of recommended doses.
I – Irrigated; S – Semidry; R – Rainfed; DAT – Days after transplanting and DAS – Days after sowing
* The results are the means of three replications.



T1 -Control, T2- *Azospirillum* +NPK (50:50:50), T3- Phosphobacteria + NPK (100:25:50), T4- Azophos + NPK (50:25:50), T5- *Azospirillum* + NPK (75:50:50), T6- Phosphobacteria + NPK (75:37.5:50), T7- Azophos + NPK (50:25:25), T8 - Recommended dose of NPK (100:50:50)

Fig. 1. Effect of Azophos on grain and straw yield of rice var. PMK 3 under irrigated conditions

could be due to the availability of water for uptake of nutrients, but in case of semidry and rainfed condition, Azophos produced maximum yield and growth than the recommended dose of NPK fertilizers due to increased root growth caused by nutrients uptake from deeper layers. This was supported by the findings of Kucey (1983) reported that the many microbes in the soil are able to solubilize the unavailable form of calcium bound phosphate by excreting organic acids, which directly dissolve rock phosphate by chelating calcium ions to bring phosphorus into solution and makes easy P available to plants and increases root growth. Inoculation with bacterial mixture of N_2 fixing and P solubilising bacteria provided a more balanced nutrition for the plants (Belimov *et al.*, 1995).

The results of the semidry field experiments indicated that maximum available N (220.0 kg ha^{-1}), P (39 kg ha^{-1}) and K 656 (kg ha^{-1}) contents were recorded due to application of recommended dose of NPK fertilizer application at 90 DAS (Table 1). The maximum total N (0.48%) at 90 DAS and proline content (1365.7 µg g^{-1}) on 60 DAS was recorded due to inoculation of *Azospirillum* and recommended dose of NPK fertilizer application, respectively (Table 2). The maximum grain (4.98 t ha^{-1}) and straw yield (7.93 t ha^{-1}) (Fig. 2) were observed due to *Azospirillum* and phosphobacteria inoculation, respectively. This result was supported by the finding of Belimov *et al.* (1995) who reported Inoculation with bacterial mixture of N_2 fixing and P solubilising bacteria provided a more balanced nutrition for the plants. Bashan and Holguin (1997) reported that mixed cultures provided conditions more suitable for N_2 fixation than those present in pure cultures. Radhakrishnan (1996) reported that the dual inoculation of *Azospirillum* and phosphobacteria resulted in higher root biomass in cotton.

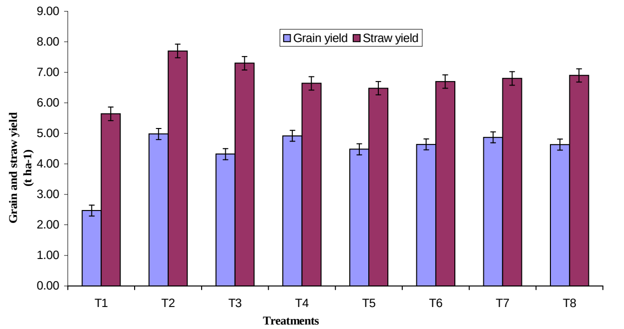
The results of the rainfed field experiments indicated that maximum available N (215 kg ha^{-1}), P (33 kg ha^{-1}) and K (656 kg ha^{-1}) contents was observed due to *Azospirillum*, phosphobacteria and Azophos inoculation at 90 DAS, respectively (Table 1). The maximum grain (3.60 t ha^{-1}) and straw yield (6.78 t ha^{-1}) (Fig. 3) was observed due to Azophos inoculation. The maximum total N (0.46%) at 90 DAS and proline

Table 2. Effect of Azophos inoculation on total N and proline content of rice (PMK 3) under irrigated (90 DAT), semidry and rainfed (90 DAS) field conditions.

Treatments	Total N (%)			Proline (µg g^{-1})		
	I	S	R	I	S	R
Control	0.41	0.41	0.39	1.37	0.80	0.88
Azospirillum + NPK (50%: 100%: 100% of the recommended dose)	0.51	0.47	0.45	1.81	0.90	0.93
Phosphobacteria + NPK (100%: 50%: 100% of the recommended dose)	0.45	0.42	0.41	1.56	1.13	0.90
Azophos + NPK (50%: 50%: 100% of the recommended dose)	0.51	0.43	0.42	1.52	1.09	0.93
Azospirillum + NPK (75%: 100%: 100% of the recommended dose)	0.52	0.48	0.46	1.40	1.12	
Phosphobacteria + NPK (100%: 75%: 100% of the recommended dose)	0.46	0.43	0.41	1.58	1.22	880
Azophos + NPK (75%: 75%: 100% of the recommended dose)	0.53	0.44	0.42	1.63	1.07	900
Recommended dose of NPK for irrigated field (100: 50: 50 kg ha rice^{-1})	0.41	-	-	1.66	-	-
Recommended dose of NPK for semidry and rainfed field (50: 25: 25 kg ha^{-1})	-	0.44	-	-	1.37	-
CD	0.27	0.19	0.02	2.48	0.08	3.57

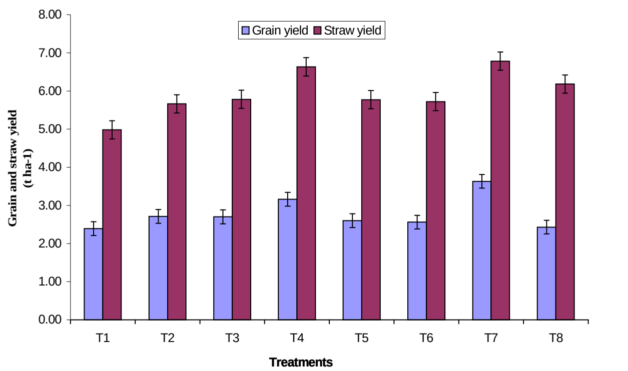
I – Irrigated; S – Semidry; R – Rainfed; DAT – Days after transplanting and DAS – Days after sowing

* The results are the means of three replications.



T1 -Control, T2- Azospirillum +NPK (25:25:25), T3- Phosphobacteria + NPK (50:12.5:25), T4- Azophos + NPK (25:12.5:25), T5- Azospirillum + NPK (37.5:18.75:25), T6- Phosphobacteria + NPK (50:18.75:25), T7- Azophos + NPK (37.5:18.75:25), T8 - Recommended dose of NPK (50:50:25)

Fig. 2. Effect of Azophos on grain and straw yield of rice var. PMK 3 under semidry conditions



T1 -Control, T2- Azospirillum +NPK (25:25:25), T3- Phosphobacteria + NPK (50:12.5:25), T4- Azophos + NPK (25:12.5:25), T5- Azospirillum + NPK (37.5:18.75:25), T6- Phosphobacteria + NPK (50:18.75:25), T7- Azophos + NPK (37.5:18.75:25), T8 - Recommended dose of NPK (50:50:25)

Fig 3. Effect of Azophos on grain and straw yield of rice var. PMK 3 under rainfed conditions

content (768 µg g^{1}) on 60 DAS were observed due to *Azospirillum* and Azophos inoculation, respectively (Table 2). Application of Azophos more positively influenced rice cv.PMK 3 by recording maximum root length, main and lateral roots, root volume, available N, P, total N, dry weight, shoot length, total and productive tillers, chlorophyll content, proline content grain and straw yield, which facilitate the growth of rice in stress situation. The results were supported by the findings of Kapulnik *et al*. (1981) who observed in wheat and sorghum early flowering, increase in shoot and root weight, total nitrogen, plant height, leaf length, 1000 grain weight and increased yield due to *Azospirillum* inoculation in both sterilized and unsterilized soil. Sadasivan and Neyra (1979) noted that *Azospirillum* has the capacity to produce non-motile, highly refractive, encapsulated cyst and flocs containing abundant poly â hydroxyl drought butyrate under stress conditions that showed increased resistance to desiccation and UV radiation. *Azospirilllum* spp. can accumulate compatible solute such as glycine betaine, glutamate, proline and trehalose to allow adaptation to fluctuation in soil salinity/osmotalarity. Narula *et al.* (1998) indicated that the temperature during the month of May reach 44.5^{o}c and *Azospirillum* cells also have the capacity to form cysts and capable of long-term survival in the soil under stress conditions. Kundu and Gaur (1980) noticed increased availability of soil phosphorus due to phosphobacteria inoculation. Many microbes in the soil are able to solubilize the unavailable form of calcium bound phosphate by excreting organic acids, which directly dissolve rock phosphate by chelating calcium ions to bring phosphorus into solution (Kucey, 1983).

A comparative analysis of the performance of Azophos / *Azospirillum* / phosphobacteria inoculation in PMK 3 rice under irrigated, semidry and rainfed field conditions revealed that the growth and yield of PMK 3 as irrigated rice were found to be better with recommended dose of NPK fertilizer application. However, the effect of inoculation of Azophos/ *Azospirillum*/phosphobacteria on growth, yield and nutrient content of plant and soil was more pronounced than recommended dose of NPK fertilizer under semi dry and rainfed condition, compared to irrigated field conditions. The results suggested the positive influence of Azophos/*Azospirillum*/phosphobacteria inoculation on the growth and yield of rice crop under water stress situations imposed by the semi-dry and rainfed field conditions.

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