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Effect of pink pigmented facultative methylotrophs (PPFMs) and plant growth promoters on yield and nutrient uptake of semi dry rice

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Abstract
Water and nutrient availability are two major constraints in most rice-based rainfed shallow lowland systems of Asia. Biotic and abiotic stresses interacts which leads to low productivity and widespread poverty in this environment. Field experiment was conducted from *kharif* 2017-18 to study the effect of Pink Pigmented Facultative Methylotrophs (PPFMs) and growth promoters on growth and yield of semi dry Rice. Introduction of direct dry seeding of rice, in upland environment was found to be used in water scarcity condition. Among the different combinations of PPFM and growth promoters, application of 100% RDF + *Azophos* as soil application @ 2 kg ha^{-1}+ PPFM as foliar application 500 ml ha^{-1} registered significantly higher growth attributes, yield and nutrient uptake at flowering and harvest stages which was followed by RDF + Brassinolide (1 ppm).

Keywords: Pink pigmented facultative methylotrophs, azophos, brassinolide

Introduction
Rice is the second important crop globally, producing 715 million mt paddy (482 million mt milled rice). China is the largest producer with 210.1 million mt from an area of 29.5 million ha followed by India producing 165.3 million mt from an area of 44.1 million ha (FAO stat 2017). It is an important staple food for more than 50 % of world population. Rice is one of the greatest water users among cereal crops, consuming about 80 per cent of the total irrigated fresh water resources in Asia. In Asia, with relatively more suitable growing conditions for rice, production had declined due to increasing water stress (Tao *et al*., 2004).
Water limited condition (also referred to as drought), affecting 23 m ha of rice in India regularly is a condition related to insufficient soil moisture available to support average crop production (Pandey *et al.,* 2007). The response of plants to water stress depends on the duration and severity of the stress (Araus *et al.,* 2002; Bartels and Souer, 2004) and the developmental stage (Zhu *et al.,* 2005). Rice is sensitive to drought stress particularly during flowering stage, resulting in severe yield losses (Liu *et al.,* 2006). The physiological processes during the sensitive flowering stage, negatively affects spikelet fertility under water stress.

Materials and methods
Field experiments were conducted in the farmer's field, Therkutheru, Melur block, Madurai district, *kharif* season 2017-18 and 2018-19 to assess the performance of biofertilizer, PPFMs and growth promoters for mitigating induced water stress on the growth and yield of semi dry rice. Crop was supplied with fertilizers (NPK) and other cultivation operations including plant protection measures as per recommended package of practices of Tamil Nadu Agricultural University, Coimbatore. The experiment was laid out in factorial randomized block design with three replications. The treatments *viz*., Control, RDF + PPFM (500 ml ha^{-1}), RDF + Brassinolide (1 ppm) and RDF + Salicylic acid (100 ppm) were used for this experiment. PPFM and plant growth promoters treatments were given as foliar spray at 25 and 45 days after transplanting.

Effect of PPFMs and growth promoters on nutrient uptake (kg ha^{-1}) of semi - dry rice

Nitrogen uptake

In general, nutrient uptake gradually increased from active tillering to harvest stage. A well developed and healthy root system could play an important role in uptake and translocation of nutrients from the soil (Kumar *et al*., 2013) [3]. This finding is in line with the reports of Sridevi and Chellamuthu (2012) [2] who reported that higher uptake of N, P and K under moisture stress free control was mainly attributed due to more solubilisation of all the above nutrients, better root activity, better aeration and increased Dry Matter Production (DMP). Availability of nutrients produced higher DMP, which ultimately recorded increased nutrient uptake (Table 1). From the pooled result of the nitrogen uptake due to the affect of Azophos @ 2 kg ha^{-1} mean values expanded from 10.8 to 13.3, 40.8 to 48.8 and 11.7 to 15.8, 29.6 to 33.8 kg ha^{-1} at 30 DAS, 60 DAS and grain and straw individually. An examination of information in revealed that PPFM and plant growth promoter's application extended from 18.0 to 8.29, 62.6 to 34.7 and 22.3 to 9.60, 41.3 to 25.3 kg ha^{-1} at 30 DAS, 60 DAS in grain and straw whereas, conjoint application of soil and foliar application were critical at all development stages. The maximum nitrogen uptake, RDF + Azophos @ 2 kg ha^{-1} and PPFM ranged from 24.2, 78.7 and 30.4, 49.4 kg ha^{-1} followed by 30.4, 49.4 and 28.6, 47.6 kg ha^{-1} were though consolidating brassinolide @ 1ppm at 30 DAS, 60 DAS and grain and straw exclusively.

Phosphorus uptake

According to Ibramsa (1991) [8] reported that under water deficit conditions, the total nutrient contents of the plants were significantly reduced at all stage of crop growth. The reduction in transpiration would also hamper the uptake of nutrients under stressed environment. From the pooled result of the phosphorus uptake due to the effect of biofertilizers @2 kg ha^{-1} mean values expanded from 6.45 to 6.75, 15.8 to 16.4 and 5.04 to 5.34, 10.5 to 11.2 kg ha^{-1} at 30 DAS, 60 DAS and grain and straw individually (Table 2). An examination of information in revealed that PPFM @ 500 ml ha^{-1} and plant growth promoters application extended from 8.01 to 4.66, 20.3 to 9.20 and 6.12 to 4.01, 13.3 to 7.07 kg ha^{-1} at 30 DAS, 60 DAS in grain and straw whereas, conjoint application of biofertilizers and PPFM application were critical at all development stages. The maximum phosphorus uptake, RDF + Azophos @ 2 kg ha^{-1} and PPFM ranged from 9.15, 23.2 and 6.78, 15.5 kg ha^{-1} followed by 8.58, 20.7 and 6.60, 14.6 kg ha^{-1} were though consolidating RDF + brassinolide @ 1ppm at 30 DAS, 60 DAS in grain and straw exclusively.

Potassium uptake

The pooled analysis exposed that distinct sources of Azophos application @ 2 kg ha^{-1} uniquely impacted potassium uptake in all the stages of crop growth. Potassium uptake ranged from 22.6 to 23.3, 45.8 to 49.1 and 16.8 to 17.3, 40.0 to 41.4 kg ha^{-1} at 30 DAS, 60 DAS in grain and straw (Table 3). An examination of information enables uncovered that PPFM @ 500 ml ha^{-1} and plant growth promoters moreover essentially impacted potassium uptake in all the growth stages in the field experiments. Potassium uptake ranged from 27.3 to 16.8, 57.3 to 37.6 and 19.5 to 13.9, 49.3 to 30.6 kg ha^{-1} at 30 DAS, 60 DAS in grain and straw.

Information relating that the interaction of soil and foliar application on potassium uptake was found to be statistically significant. With respect to the foliar application of RDF + Azophos @ 2 kg ha^{-1}and PPFM was recorded maximum potassium uptake of 31.3, 65.8 and 21.6, 57.7 at 30 DAS, 60 DAS in grain and straw and followed by 29.4, 61.6 and 20.8, 54.3 kg ha^{-1} were whereas joining RDF + brassinolide @ 1 ppm at 30 DAS, 60 DAS in grain and straw. Use of stress ameliorants such as PPFM and brassinolide supplementation could be able to mitigate the ill-effects of moisture stress with better absorption of nutrients. Plant growth regulators produced growth promoting substance like cytokinin, IAA and GA which might have enhanced better root growth and canopy development which resulted in better nutrient (N, P and K) uptake. Similar finding was reported by Senthil kumar (2003) [3].

Effect of PPFMs and growth promoters on number of grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index of semi - dry rice

Grain and straw yield

Among the different treatments, from the pooled analysis, it was observed that the application of biofertilizers @ 2 kg ha^{-1} mean values ranged from 3760 to 4261 kg ha^{-1} separately. A examination of data revealed that PPFM @ 500 ml ha^{-1} and plant growth promoters application values ranged from 5044 to 3415 kg ha^{-1} at harvest stage respectively. Significant improvement in grain yield with the supplementation of PPFM was also reported in several crops like soybean (Holland, 1997), blackgram, groundnut and sugarcane (Madhaiyan, 2002) [7] and rice and cotton (Thangamani, 2005) [5] grown under moisture stress free situations. Overall effect of PPFM in increasing the grain yield in these crops were attributable to the availability of nutrients, through nitrogen fixation by PPFM production of plant growth promoting (PGP) substances like; cytokinins, IAA and GA and vitamins especially B_{12} produced in the rhizosphere soils.

Further the data showed a concomitant increment with respect to grain yield by the combined application of RDF + Azophos @ 2 kg ha^{-1}and PPFM @ 500 ml ha^{-1} application recorded the maximum grain yield of 5956 kg ha^{-1} respectively (Fig.1), which was followed by 5740 kg ha^{-1} were though joining RDF + brassinolide @ 1 ppm at harvest stage. As observed in the present investigation, favourable role of brassinolide to improve various metabolic activities through enhanced nucleic acid metabolism and protein synthesis was also reported earlier (Vardhini and Rao, 1998) [4].

The pooled analysis revealed that, it was observed that the application of biofertilizers @ 2 kg ha^{-1} straw yield mean values ranged from 4627 to 5213 kg ha^{-1} separately. An examination of data revealed that PPFM @ 500ml ha^{-1} and plant growth promoters application mean values ranged from 6321 to 4304 kg ha^{-1} at harvest stage repectively. Further the data showed a concomitant increment with respect to straw yield by the combined application of RDF + Azophos @ 2 kg ha^{-1} and PPFM @ 500 ml ha^{-1} application recorded the highest straw yield of 7659 kg ha^{-1} respectively, which was followed by 7286 kg ha^{-1} were though joining RDF + brassinolide @ 1 ppm at harvest stage. This is in conformity with the findings of Sridevi and Chellamuthu (2012) [2] and Revathi (2009).

Conclusion

From the experimental results, foliar application of RDF + PPFM (500 ml ha^{-1}) (*Methylobacterium* sp.) was found to be highly effective than RDF + brassinolide (1 ppm) which helps in sustaining the productivity through mitigating the ill-effects of water stress condition in rice and was proved to be economically feasible.

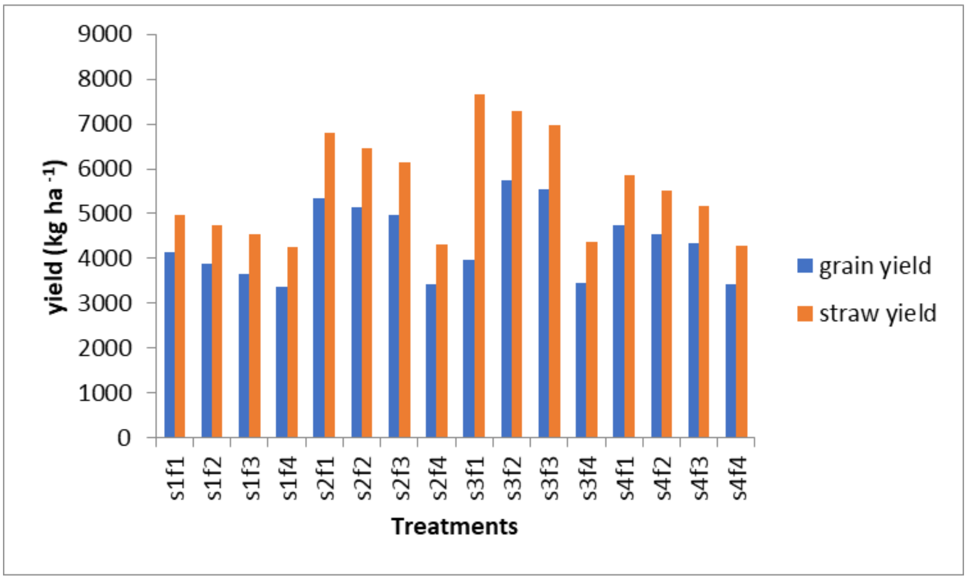

Fig 1: Effect of PPFMs and growth promoters on nitrogen uptake (kg ha^{-1}) of semi - dry rice

Table 1: Effect of PPFMs and growth promoters on nitrogen uptake (kg ha^{-1}) of semi - dry rice (Pooled data of two years)

Soil	Nitrogen uptake (kg ha^{-1})																			
	30 DAS					60 DAS					Grain					Straw				
	Foliar application					Foliar application					Foliar application					Foliar application				
	F1	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**
S1	13.0	11.4	10.7	8.25	10.8	46.6	43.2	39.7	33.9	40.8	14.4	12.6	10.8	9.26	11.7	33.3	31.5	29.8	24.2	29.6
S2	19.2	18.3	1.8	8.30	15.6	67.9	64.4	60.7	34.8	56.9	24.9	23.1	21.4	9.56	197	43.9	42.2	40.4	25.9	38.1
S3	24.2	22.3	20.4	8.33	18.8	78.7	75.2	71.4	35.7	65.3	30.4	28.6	26.6	9.95	23.9	49.4	47.6	45.6	26.9	42.4
S4	15.7	14.8	14.3	8.29	13.3	57.2	53.6	50.2	34.5	48.8	19.6	17.8	16.7	9.64	15.8	38.5	36.8	35.1	24.8	33.8
Mean	18.0	16.6	15.6	8.29		62.6	59.1	55.4	34.7		22.3	20.5	18.7	9.60		41.3	39.5	37.7	25.3	
	S	F	S x F			S	F	S x F			S	F	S x F			S	F	SxF		
SEd	0.18	0.18	0.36			0.53	0.53	1.07			0.10	0.10	0.20			0.94	0.94	1.88		
CD (P=0.05)	0.36	0.36	0.74			1.10	1.10	2.20			0.21	0.21	0.42			0.46	0.46	0.92		

Table 2: Effect of PPFMs and growth promoters on phosphorus uptake (kg ha^{-1}) of semi - dry rice (Pooled data of two years)

Soil	Phosphorus uptake (kg ha^{-1})																			
	30 DAS					60 DAS					Grain					Straw				
	Foliar application					Foliar application					Foliar application					Foliar application				
	F1	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**
S1	7.24	7.12	6.97	4.48	6.45	18.5	18.2	17.7	8.91	15.8	5.58	5.43	5.28	3.87	5.04	11.9	11.6	11.4	7.33	10.5
S2	8.05	7.89	7.76	4.71	7.10	20.3	19.9	19.5	9.31	17.3	6.19	6.07	5.99	4.06	5.58	13.3	13.0	12.8	7.68	11.7
S3	9.15	8.58	8.25	4.86	7.71	23.2	20.7	20.4	9.47	18.5	6.78	6.60	6.25	4.20	5.96	15.5	14.6	13.5	7.81	12.8
S4	7.60	7.44	7.36	4.61	6.75	19.2	18.8	18.5	9.23	16.4	5.91	5.79	5.66	4.01	5.34	15.5	12.2	12.0	7.90	11.2
Mean	8.01	7.76	7.58	4.66		20.3	19.4	19.0	9.20		6.12	5.97	5.66	4.01		13.3	12.8	12.4	7.70	
	S	F	S x F			S	F	S x F			S	F	S x F			S	F	SxF		
SEd	0.08	0.08	0.16			0.13	0.13	0.25			0.05	0.05	0.11			0.10	0.10	0.20		
CD (P=0.05)	0.16	0.16	0.33			0.25	0.25	0.51			0.11	0.11	0.23			0.21	0.21	0.42		

Table 3: Effect of PPFMs and growth promoters on potassium uptake (kg ha^{-1}) of semi - dry rice (Pooled data of two years)

Soil	Potassium uptake (kg ha^{-1})																			
	30 DAS					60 DAS					Grain					Straw				
	Foliar application					Foliar application					Foliar application					Foliar application				
	F1	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**	**F1**	**F2**	**F3**	**F4**	**Mean**
S1	24.8	24.6	24.4	16.5	22.6	50.5	49.0	47.7	35.9	45.8	18.1	18.0	17.7	13.7	16.8	43.8	43.6	42.9	29.6	40.0
S2	27.4	27.1	26.4	17.2	24.5	58.3	56.9	55.1	38.2	52.2	19.6	19.3	18.9	14.5	17.9	49.7	48.7	47.9	30.8	44.3
S3	31.3	29.4	28.4	17.4	26.6	65.8	61.6	60.0	39.2	56.6	21.6	20.8	20.1	14.2	19.2	57.7	54.3	50.6	31.4	48.5
S4	25.8	25.3	25.1	16.9	23.3	54.5	52.7	51.9	37.3	49.1	18.7	184	18.3	13.9	17.3	45.9	44.9	44.5	30.6	41.4
Mean	27.3	26.6	26.1	16.8		57.3	55.1	53.7	37.6		19.5	19.1	18.7	13.9		49.3	47.8	46.5	30.6	
	S	F	S x F			S	F	S x F			S	F	S x F			S	F	SxF		
SEd	0.29	0.29	0.58			0.53	0.53	1.06			0.15	0.15	0.30			0.40	0.40	0.80		
CD (P=0.05)	0.59	0.59	1.19			1.08	1.08	2.16			0.31	0.31	0.62			0.82	0.82	1.63		

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