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Effect of varieties and nitrogen application on growth and yield of aerobic rice

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ABSTRACT

Field experiments were conducted at Agricultural College and Research Institute, Madurai, Tamil nadu, India, during Kharif and Rabi, 2007-2008 to study the effect of agronomic management practices on aerobic rice. The experiments were laid out in a split-plot design with three replications. The main plots consisted of three varieties (V_1-PMK 3, V_2 - ASD 16 and V_3- ADT 43) and three levels of nitrogen (N_1 - 125 kg N ha^{-1}, N_2 -150 kg N ha^{-1} and N_3 - 175 kg N ha^{-1}). The sub plots includes three nitrogen splits viz., S_1 - 3 splits (three equal splits at 15 DAS, tillering and panicle initiation), S_2 - 4 splits (four equal splits at 15 DAS, tillering, panicle initiation and heading) and S_3 - 5 splits (five equal splits at 15 DAS, initial tillering, active tillering, panicle initiation and heading). The growth parameters like plant height (84.28 cm), tiller production per plant (12.71), Dry Matter Production (8232 kg ha^{-1}), LAI (3.91) and SPAD N values (34.94) were superior for variety PMK 3 (V_1). Yield parameters (panicles m^{-2} (318), panicle weight (3.2g), number of grains panicle^{-1} (118) filled grains panicle^{-1} (112)) were also significantly higher with PMK 3 (V_1). Application of higher dose of nitrogen at 175 kg N ha^{-1} (N3) enhanced the growth parameters, yield parameters and yield. However, these parameters were comparable at 150 kg N ha^{-1}(N_2). All the growth parameters, yield parameters and yield were significantly higher with five split application of N (S_3). The four split application of N (S_2) was on par with five splits (S_3) in growth parameters, growth analytical and yield parameters and yield of aerobic rice. Based on the results, it is inferred that cultivation of rice variety PMK3 with the application of 150 kg N ha^{-1} in four splits will be the best agronomic management practice for realizing higher yield in aerobic rice cultivation.

Key words: *Aerobic rice, nitrogen levels, split application, growth and yield*

Aerobic rice is a new concept of growing rice: it is high yielding rice grown in non-puddled, aerobic soils under irrigation and high-extended inputs (Bouman 2001). Suitable rice verities when grown under non saturated soil conditions (soil dryness upto field capacity) there is an increase in water productivity due to reduced irrigation water input and comparable yield(Kumar *et al*. 2016, 2017). However, new varieties must be developed if this concept of aerobic rice is to be successful. Upland rice variety exists but is targeted for unfavourable environments without access to irrigation, with low external inputs and hence with a low yield potential. Among different nutrients, nitrogen is the kingpin in rice farming and the most limiting for rice in yield realization of rice. However, nitrogen use efficiency (NUE) is quite low in rice production compared to other cereals in Asia. Theoretically, the amount of N fertilizer to be applied to irrigated rice would need to be increased about three fold with the current NUE to increase rice production by 60%, which is required to meet the demand of the growing population (Robertson and Vitousek 2009). Keeping these in view, the present study was undertaken to find out the suitability of rice cultivars and nitrogen levels and time of application under aerobic cultivation.

Field experiments were carried out during *Kharif*, 2007 and *Rabi*, 2007-2008 at Agricultural College and Research Institute, Madurai. The soil of the experimental fields was sandy loam classified as Typic Udic Hapludalf, neutral in reaction, with low in available N (210 and 203 kg ha^{-1}) and medium in available P_2O_5 (14.5 and 12.7 kg ha^{-1}) and K_2O(290 and 282 kg ha^{-1}) during kharif and *rabi* respectively. The experiments were laid out in a split-plot design with three replications. The main plots consisted of three varieties (V_1- PMK 3, V_2 - ASD 16 and V_3- ADT 43) and three levels of nitrogen (N_1 - 125 kg N ha^{-1}, N_2 - 150 kg N ha^{-1} and N_3 - 175 kg N ha^{-1}). The sub plots includes three nitrogen splits *viz.*, S_1 - 3 splits (three equal splits at 15 DAS, tillering and panicle initiation), S_2 - 4 splits (four equal splits at 15 DAS, tillering, panicle initiation and heading) and S_3 - 5 splits (five equal splits at 15 DAS, initial tillering, active tillering, panicle initiation and heading). Uniform plant population was maintained by dibbled seeds in non-puddled soil at a spacing of 20 x 10 cm with a plot size of 4 m x 4 m. The field was irrigated immediately after sowing and the life irrigation was given on 3 DAS. Irrigation was given once in 7 days at 5 cm depth of water using parshall flume. Nitrogen as urea (46 % N) at varied levels was split applied as per the treatment schedule. The entire dose of P_2O_5 (50 kg ha$^{-1)}$ as single super phosphate was applied as basal at the time of planting. Potassium (50 kg ha^{-1}) as muriate of potash was split applied along with nitrogen. Zinc sulphate @ 25 kg ha^{-1} was applied basally. Pre-emergence herbicide, pendimethalin was applied (0.75 kg ai ha^{-1}) on 3 DAS by mixing with sand (50 kg ha^{-1}). This was followed by hand weeding on 35 DAS. Observations on growth and yield characters were taken at critical stages of crop growth. The data obtained were subjected to statistical analysis and were tested at five per cent level of significance to interpret the treatment differences.

The growth parameters such as plant height, tiller production, Dry Matter Production (DMP), LAI and SPAD N values were significantly influenced by varieties, nitrogen levels and split application of N (Table 1). Among the varieties tested, cultivar PMK 3 showed significantly higher plant height (84.28 and 85.56 cm), DMP (8232 and 9401 kg ha^{-1}) at harvest and higher tiller number (12.71 and 13.38), LAI (3.91 and 4.12) and SPAD N values (34.94 and 36.32) at flowering during *kharif* and *rabi* respectively under aerobic condition. Maintenance of higher biomass is an important criterion for screening rice cultivar suitable under aerobic condition (Belder *et al.* 2005). The present investigation showed that PMK 3 exhibited highest dry matter production under aerobic condition while ADT 43 recorded lowest dry matter production. This might be due to higher plant height, tiller number and leaf area. Moreover, the plant height and LAI were also significantly correlated with DMP and yield. Leaf area index particularly at reproductive stage have a specific role in deciding dry matter production of rice. More than 80% of the total variance in grain yield among the treatments could be explained by Leaf Area Duration and LAI. This indicates that light interception and thus the availability of assimilate but not its portioning is limiting yield (Hongbin Tao 2004). Gowri (2005) reported that LAI was reduced under aerobic condition in ADT 43 than PMK 3.

Among the N levels, application of 175 kg N ha^{-1} (N_3) recorded taller plants at all the stages of crop growth during both the seasons. The plant height recorded was 78.00 and 83.37 cm, and DMP (7.2 t ha^{-1} and 8.0 t ha^{-1}) at harvest, tiller production (11.14 and 12.38), LAI (3.26 and 3.52), SPAD N Values (32.97 and 34.40) at flowering during *kharif* and *rabi* respectively. This was comparable with 150 kg N ha^{-1} (N_2) in all the growth parameters. The increased plant height, tiller production and DMP at higher N level might be due to the presence of increased substrate for protein synthesis and thereby stimulated meristematic growth. With the increasing supply of nitrogen, plant height was found to increase as evidenced by Sugandhi *et al.* (2003). Increased N supply might have promoted early tillering due to more nutrient availability as was in conformity with the findings of Sritharan (2015). Belder *et al.* (2005) also observed increased LAI in response to higher nitrogen supply which might be due to nitrogen-induced enhancement of leaf area. Kumar *et al.* (2001) had reported that N fertilization influenced SPAD readings. It might be because of N, which is the primary compound of chlorophyll (Balasubramanian 2000) and hence SPAD N values are directly proportional to chlorophyll content.

Split application of N had a significant influence on growth parameters at all the stages of crop growth during both the seasons. At harvest, the plant height (78.74 and 82.16 cm) and DMP (7.2 t ha^{-1} and 7.9 t ha^{-1}) recorded with five split application of N (S_3) was significantly higher during *kharif* and *rabi* respectively.

Table 1. Effect of varieties, nitrogen levels and splits on growth parameters of aerobic rice

Treatments	*Kharif*					*Rabi*				
	Plant height at harvest (cm)	Tiller production at flowering (No)	DMP at harvest (kg/ha)	LAI at flowering stage	SPAD N at flowering	Plant height at harvest (cm)	Tiller production at flowering (No)	DMP at harvest (kg/ha)	LAI at flowering stage	SPAD N at flowering
Varieties										
V_1	84.28	12.71	8232	3.91	34.94	85.56	13.38	9401	4.12	36.32
V_2	75.32	10.98	7208	2.83	31.16	83.74	11.83	7634	3.09	32.41
V_3	68.68	9.16	5020	2.25	29.26	73.37	9.92	5342	2.51	30.77
SEd	1.67	0.27	337	0.08	0.50	1.51	0.09	392	0.20	0.71
CD (P=0.05)	3.54	0.58	715	0.17	1.06	3.21	0.20	833	0.44	1.51
N levels										
N_1	73.44	11.14	6101	3.26	32.97	77.65	12.38	6708	3.52	34.40
N_2	76.84	11.03	7098	3.19	32.25	81.84	12.27	7617	3.49	33.49
N_3	78.00	10.69	7261	2.54	30.15	83.37	10.48	8051	2.71	31.61
SEd	1.67	0.27	337	0.08	0.50	1.51	0.09	392	0.20	0.71
CD (P=0.05)	3.54	0.58	715	0.17	1.06	3.21	0.20	833	0.44	1.15
N Splits										
S_1	78.74	11.10	7284	3.25	33.18	82.16	12.67	7898	3.50	34.54
S_2	77.69	11.08	7227	3.24	32.98	81.92	12.60	7841	3.49	34.40
S_3	71.84	10.68	5950	2.50	29.20	78.79	9.86	6638	2.73	33.55
SEd	0.51	0.02	104	0.02	0.23	0.27	0.05	122	0.06	0.39
CD (P =0.05)	1.03	0.06	227	0.05	0.48	0.56	0.11	248	0.13	0.80

Equally four split application of N (S_2) increased plant height (77.69 and 81.92 cm) and DMP (7.2 and 7.8 t ha^{-1}) at harvest during *kharif* and *rabi* respectively. With regards to tiller production, LAI and SPAD N values also the significantly higher tillers (11.10 and 12.67), LAI (3.25 and 3.50) and SPAD N (33.18 and 34.54) was recorded with five split application of N (S_3). The growth parameters recorded were significantly higher with five splits and it was comparable with four splits. This might be due to higher N uptake synchronizing the critical stage of N-demand by the crop. Nitrogen is well recognized as a promoter of vegetative growth and it stimulates meristematic growth and cytokinin biosynthesis (Beringer *et al.* 1980). Application of N in five splits greatly influenced the growth and development of shoot, ultimately resulted in increased plant height as was evidenced by Nageswari (2004) and Kavitha (2009). Five split application of N produced higher leaf area index and it was on par with four split application of N. This might be due to expansion and development of cells in a constant manner and thus would have helped to have more leaf area. The results are in line with Panda and Rao (1991) and Nagesewari (2004). The strategy of applying N splits from initial tillering to flowering had higher leaf N concentration and hence higher SPAD N values (Mahendran *et al.* 2005).The interaction effect was found non-significant in all the growth parameters.

Varieties, nitrogen levels and splits exerted favourable influence on yield parameters under aerobic condition (Table 2). Among the varieties, PMK 3 (V_1) produced significantly higher number of panicles m^{-2} (318 and 353), higher panicle weight (3.2 and 3.3 g), more number of grains per panicle (118 and 148), and highest number of filled grains per panicle (112 and 118) during *kharif* and *rabi* respectively. The variety ASD 16 (V_2) followed this, while ADT 43 (V_3) has shown poor performance when compared to all other varieties. Maintenance of higher growth parameter, such as plant height, LAI, DMP, and RLWC results in higher translocation of photosynthetic assimilates from source to sink, which in effect increased the yield attributing characters of rice.

Regarding nitrogen levels, application of 175 kg N ha^{-1} (N3) has recorded higher number of panicles

Table 2. Effect of varieties, nitrogen levels and splits on yield parameters and yield of aerobic rice

Treatments	*Kharif*					*Rabi*				
	Panicles m^{-2} (No)	Panicle weight (g)	Number of grains panicle^{-1}	Filled grain panicle^{-1}(No)	Yield (kg/ha)	Panicles m^{-2} (No)	Panicle weight (g)	Number of grains panicle^{-1}	Filled grain panicle^{-1}(No)	Yield (kg/ha)
Varieties										
V_1	318	3.2	118	112	3217	353	3.3	148	118	3587
V_2	264	2.9	100	92	2510	295	2.9	126	101	2947
V_3	192	2.5	88	81	1567	206	2.7	123	89	1843
SEd	10	0.58	2	2	91	18	0.05	4	2	96
CD (P=0.05)	23	0.12	5	5	194	38	0.10	8	4	204
N levels										
N_1	226	2.6	93	89	2227	242	2.8	119	93	2479
N_2	265	2.9	106	96	2512	293	3.0	135	106	2929
N_3	283	3.0	108	100	2556	318	3.0	143	109	2973
SEd	10	0.06	2	2	91	18	0.05	4	2	96
CD (P=0.05)	23	0.12	5	5	194	38	0.10	8	4	204
N Splits										
S_1	217	2.5	90	83	2130	249	2.7	120	90	2459
S_2	275	2.9	108	100	2566	299	3.1	137	108	2946
S_3	282	3.0	109	102	2598	305	3.1	140	110	2972
SEd	3	0.02	1	1	19	4	0.02	1	1	20
CD (P =0.05)	7	0.05	2	2	39	9	0.05	3	2	41

m^{-2} (283 and 318). The number of panicles m^{-2} produced with 150 kg N ha^{-1} (N_2) (265 and 293) was on par with 175 kg N ha^{-1} (N_3) during *kharif* and *rabi* respectively. Similarly, Nitrogen at 175 kg ha^{-1} (N_3) recorded higher panicle weight (2.9 and 3.0 g), grains per panicle (108 and 143) and number of filled grains per panicle (100 and 109) during *kharif* and *rabi* respectively. However, all the yield parameters recorded with 150 kg N ha^{-1} (N_2) was comparable with 175 kg N ha^{-1} (N_3). Increase in yield parameters under increasing N levels was found in the present study might be due to the N-induced enhancement in photosynthetic activity and the translocation of photosynthates from the leaves and culms to the grain (Dhurandher and Tripathi 1999).

Split application of N significantly influenced the yield parameters. Five split applications of N (S_3) has produced significantly higher number of panicles m^{-2} (282 and 305) and it was comparable with four split application of N (S_2) (275 and 299 during *kharif* and *rabi* respectively). Similarly application of five splits (S_3) had registered higher panicle weight (2.9 and 3.1 g), number of grains per panicle (109 and 140 during *kharif* and *rabi* respectively) and number of filled grains (102 and 110). Comparable value of panicle weight (2.9 and 3.1 g), number of grains per panicle (108 and 137) and filled grains was produced by four split application of N (S_3) (100 and 108) during *kharif* and *rabi* respectively. Split application of N at different stages of crop growth helped in better tiller production and sustenance leading to higher number of panicles. The interaction was found not significant among varieties, nitrogen levels and splits on aerobic rice.

Varieties, nitrogen levels and splits significantly influenced grain yield of aerobic rice during both the seasons of investigation (Table 2). Among the varieties tested, PMK 3 (V_1) has recorded significantly higher grain yield (3.2 and 3.6 t ha^{-1} during *kharif* and *rabi* respectively) than other varieties. This was followed by ASD 16 (V_2) (2.5 and 2.9 t ha^{-1} during *kharif* and *rabi* respectively). The grain yield was significantly lower with ADT 43 (V_3) (1.6 and 1.8 t ha^{-1} during *kharif* and *rabi* respectively). The superiority of upland varieties under aerobic conditions appears to be a function of their higher harvest index under aerobic condition (Altin *et al.* 2006). On the other hand, the cultivars ASD 16 and ADT 43 showed reduced yield under the aerobic condition indicating insufficient adaptability of the cultivars to non-flooded culture as was evidenced by George *et al.* (2002). The percent increase in grain yield of PMK 3 over ADT 43 was 54 percent and 48 percent respectively during *kharif* and *rabi* respectively.

Regarding nitrogen levels, 175 kg N ha^{-1} (N_3) recorded higher grain yield (2.6 and 3.0 t ha^{-1} during *kharif* and *rabi* respectively). This was comparable with 150 kg N ha^{-1} (N_2) (2.5 and 2.9 t ha^{-1} during *kharif* and *rabi* respectively). The grain yield was significantly less with 125 kg N ha^{-1} (N_1) (2.2 and 2.5 t ha^{-1} during *kharif* and *rabi* respectively). Higher grain yield could be realized with added fertilizer N level upto 180 kg N ha^{-1}, due to cumulative effect of N supply on the various growths and yield attributes (Nair and Gupta 1999).

Among nitrogen splits, five split application of N (S_3) recorded higher grain yield (2.6 and 3.0 t ha^{-1} during *kharif* and *rabi* respectively). Four split application of N (S_2) produced comparable grain yield (2.6 and 2.9 t ha^{-1} during *kharif* and *rabi* respectively) with five split application of N (S_3). Application of N in three splits (S_1) produced significantly lower grain yield (2.1 and 2.5 t ha^{-1} during *kharif* and *rabi* respectively). The split application of N over the basal application at each N level significantly increased the grain and straw yields possibly due to reduced N losses and better utilization of added N by the crop (Majumdar *et al*. 2005). The interaction was found not significant.

Based on the results of the present investigation, it is concluded that cultivation of PMK 3 with the application of 150 kg N ha^{-1} in four splits will be the best agronomic management practice for realizing higher yield in aerobic rice cultivation.

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