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Nitrogen and weed management treatments effect on productivity of aerobic rice

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ABSTRACT

A field experiment was conducted to study the effect of three nitrogen levels and weed management practices on grain yield of aerobic rice at Tamil Nadu Rice Research Institute, Aduthurai during *Kharif* seasons of 2014 and 2015. The main plot treatments comprised of three nitrogen levels (75, 100 and 125 kg/ha N) and sub-plot treatments consisted five weed management treatments, *viz.* rice + *Sesbania* (dhaincha) (1:1) + pendimethalin pre-emergence application (PE) at 1.0 kg/ha followed by (*fb*) one hand weeding at 60 days after sowing (DAS); pendimethalin 1.0 kg/ha PE *fb* mechanical weeding twice at 20 and 40 DAS; rice + *Sesbania* (dhaincha) (1:1) + pendimethalin 1.0 kg/ha PE *fb* 2,4 D Na salt 0.8 kg/ha post-emergence application (PoE); mechanical weeding twice at 20 and 40 DAS and un-weeded control. The Rice + Dhaincha (1:1) + pendimethalin PE *fb* 2,4 D Na salt PoE recorded the lowest weed density at 20 DAS. At 40 and 60 DAS, pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS recorded lower weed density and biomass during both the years. Among the N levels, application of N at 125 kg/ha resulted in maximum rice plant height, number of tillers/m^2, number of panicles/m^2, panicle weight and grain yield, during both the years. Pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS resulted in higher rice plant height, number of tillers/m^2, number of panicles/m^2, panicle weight and grain yield. Application of N at 125 kg/ha along with pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS may be used for effective weed management and higher productivity of aerobic rice.

INTRODUCTION

Water scarcity is becoming severe in many rice (*Oryza sativa* L.) growing areas in the world. Many water saving technologies have been developed to cope with water scarcity in lowland rice areas, such as alternate wetting and drying and continuous soil saturation (Zhang *et al.* 2009). A new technology that responds to more severe water shortages is the aerobic rice system, in which rice is grown in well-drained, non-puddled, and non-saturated soils without standing water (Bouman *et al.* 2005). Aerobic rice systems can reduce water use in rice production system as much as 50% in clay soils (Subramanian *et al.* 2008). Nevertheless, direct-seeded aerobic rice is subject to more severe weed infestation than transplanted lowland rice, because in aerobic rice systems weeds germinate simultaneously with rice, and there is no water layer to suppress weed growth. (Rao *et al.* 2017, Karthika *et al.* 2019). Weeds are the major constraints in aerobic rice to wide adoption of aerobic rice as they cause yield loss to an extent of 50 % to 100% (Parthiban *et al.* 2013). The critical period of crop weed competition in direct-seeded rice occurs between 15 to 45 days after sowing. Hence, the timely weed management is essential to improve the productivity of direct-seeded rice. Due to increased crop-weed competition in direct-seeded condition; adoption of single weed management methods does not give fruitful results. In such conditions integrated weed management offers most practical and cost-effective means of reducing weed competition to obtain higher economic returns with minimum yield loss (Rao and Nagamani 2010).

Nitrogen is a key nutrient which regulates the growth and development of plants and plays a significant role in the competitive balance between weeds and crops. Optimum dose of nitrogen fertilization plays a vital role in growth and development and grain formation as a result of higher yield of rice plant. Excessive nitrogen fertilization encourages excessive vegetative growth which makes the plant susceptible to insect, pest and diseases, which ultimately reduces yield whereas less than optimum rate affects both yield and quality of rice to remarkable extent. Hence, it is essential to find out the optimum rate of nitrogen application for efficient utilization of this resource by rice plants and attain higher rice grain yield. Therefore, this study was conducted to quantify the effect of varying levels of nitrogen fertilizer and weed management treatments on the crop and weed growth and yield of aerobic rice.

MATERIALS AND METHODS

Field experiments were conducted at Tamil Nadu Rice Research Institute, Aduthurai during *Kharif* (rainy) seasons of 2014 and 2015 with an objective to identify optimal nitrogen rate and effective weed management method for economically attaining optimum rice grain yield and higher net return. Experiment was laid out in split plot design with three replications. The main plot treatments comprised of three nitrogen levels (75, 100 and 125 kg/ha N) and sub-plot treatments consisted of five weed management treatments, *viz.* rice + dhaincha (*Sesbania aculeata* L.) (1:1) intercrop + pre-emergence application (PE) of pendimethalin 1.0 kg/ha followed by (*fb*) one hand weeding (HW) at 60 days after seeding (DAS); pendimethalin 1.0 kg/ha PE *fb* mechanical weeding twice at 20 and 40 DAS; rice + dhaincha (1:1) + pendimethalin PE *fb* post-emergence application (PoE) of 2,4 D Na salt 0.8 kg/ha; mechanical weeding twice at 20 and 40 DAS and un-weeded control. The field was thoroughly prepared by using tractor drawn disc plough, cultivator and rotavator. The soil of the experimental field was clay loam in texture and moderately drained. The initial soil status was low in available nitrogen, high in available phosphorus and medium in available potassium. The rice variety *'ADT 45'* seeds were soaked in water for 12 hours and incubated for 10 hours. Sprouted seeds were line sown at 20 x 10 cm spacing. Irrigation was given immediately after sowing and life irrigation was given on third day after sowing. Subsequent irrigation was given based on need of the crop or once in 4-5 days to maintain the aerobic condition. Rice and dhaincha were sown simultaneously on the same day in between two rows of rice dhaincha was sown as additive series following 1:1 ratio for rice and dhaincha. For the intercrop dhaincha, the seed rate adopted was 20 kg/ha. The row-to-row spacing was 20 cm between rice with one row of dhaincha in the middle. Intercropped dhaincha was incorporated in-situ at 35 DAS using cono weeder. Mechanical weeding was done by cono weeder at 20 and 40 DAS as per the treatment schedule. Pre-emergence application of pendimethalin was done on 3 DAS and 2,4-D Na salt PoE was done on 25 DAS. The herbicides were sprayed uniformly with knapsack sprayer fitted with flat fan nozzle calibrated to deliver 500 liters/ha water volume. The application of nitrogen was done as per treatment which was applied in three splits (50% as basal, 25% N at active tillering and 25% N at panicle initiation stage). The fertilizers were applied in the form of urea (46% N), super phosphate (16% P) and muriate of potash (60% K). The phosphorous and potassium fertilizers were applied as basal. The data on yield attributes and yield of rice were recorded at the time of harvesting. The density of grasses, sedges and broad-leaved weeds was calculated by placing the quadrat (0.25/m^2 area) four times randomly and the density was expressed in no./m^2. Weed species within the area of quadrat were counted and collected and air dried in hot air oven maintained at 70 to 75ºC temperature for recording weed dry weight (weed biomass). The data obtained from the field experiment were subjected to statistical scrutiny. Wherever the treatment differences were significant, F test and critical differences were worked out at 5% probability level and the values were furnished.

RESULTS AND DISCUSSION

Effect on weeds

The weed flora of the experimental field consisted of mainly: *Echinochloa colona*, *Cynodon dactylon* and *Dactyloctenium aegyptium* amongst grasses (55.7%), *Cyperus rotundus* and *Cyperus iria* amongst sedges (17.8 per cent) and *Eclipta alba, Ammania baccifera, Ludwigia parviflora, Bergia capensis, Sphaeranthus indicus, Trianthema portulacastrum, Phyllanthus amarus* and *Boerhavia diffusa* amongst broad-leaved weeds (26.5%). Nitrogen application and weed management practices exerted pronounced impact on weed density at all the stages. Weed management treatments influenced the density (**Table 1**) and biomass (**Figure 1**) of weeds (at 60 DAS) during both the seasons. Nitrogen application did not have significant influence on the weed density during early stage. Among the N levels, application of N at 125 kg/ha resulted in higher weed density at 40 and 60 DAS during both the years indicating that N application had greater influence on the weed density at later stages (Subramanian *et al.* 2005).

The rice + dhaincha (1:1) + pendimethalin PE *fb* 2,4 D Na salt recorded the lower weed density at 20 DAS which might be due to inherent capability of the chemical to affect the cell division, cell growth and hindering the germination of weeds (Bhargaw *et al.* 2018). This might be also due to *Sesbania* intercropping which might have suppressed the weed infestation due to faster canopy cover. At 40 and 60 DAS, pendimethalin PE *fb* mechanical weeding twice recorded lower density of weeds during 2014 and 2015 and it was followed by rice + dhaincha (1:1) + pendimethalin PE *fb* 2,4-D Na salt PoE and mechanical weeding twice at 20 and 40 DAS at 60 DAS in terms of reduced weed density. This might be due to the fact that pendimethalin PE controls the complex weed flora at initial stages and 2,4- D PoE was effective against broad-leaved weeds and the weeds emerged at later stages were removed by mechanical weeding. Hence, in aerobic rice cultivation integration of the herbicide application with mechanical weeding at later stage, preferably at 40 DAS is essential to remove the unmanaged weeds and to reduce the weed competition against rice.

The observed significantly lower weed biomass, at all crop growth periods, was due to efficient control of the weeds by weed management treatments tested. The highest weed biomass was registered under un-weeded control during both the years. Similar to weed density, the weed biomass was also lesser with pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS and mechanical weeding twice at 20 and 40 DAS. Intercropping of *Sesbania* in rice appreciably enhanced the weed smothering efficiency (WSE), weed control efficiency (WCE) at 60 DAS and weed index (WI). Rice + dhaincha (1:1) + pendimethalin PE *fb* 2,4 D Na salt registered the maximum WSE at 40 DAS, weed control efficiency (WCE) at 60 DAS and weed index

Table 1. Effect of nitrogen and weed management treatments on weed density (no./m^2) in aerobic rice during *Kharif* 2014 and 2015

Treatment	Year	20 DAS				40 DAS				60 DAS			
		75 kg/ha N	100 kg/ha N	125 kg/ha N	Mean	75 kg/ha N	100 kg/ha N	125 kg/ha N	Mean	75 kg/ha N	100 kg/ha N	125 kg/ha N	Mean
Rice + dhaincha (1:1) + pendimethalin PE *fb* one HW at 60 DAS	2014	5.28 (27.33)	5.76 (32.67)	5.64 (31.33)	5.56 (30.44)	3.94 (14.99)	4.18 (16.99)	4.26 (17.67)	4.13 (16.55)	4.26 (17.67)	3.94 (14.99)	4.18 (16.99)	4.13 (16.55)
	2015	4.53 (19.99)	4.85 (23.00)	4.81 (22.67)	4.73 (21.89)	3.49 (11.67)	3.58 (12.34)	3.72 (13.33)	3.60 (12.45)	3.98 (15.33)	3.72 (13.33)	3.89 (14.67)	3.87 (14.44)
Pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS	2014	5.61 (30.99)	5.21 (26.67)	5.49 (29.67)	5.44 (29.11)	3.49 (11.67)	3.67 (12.99)	3.81 (13.99)	3.66 (12.88)	2.44 (11.33)	4.06 (15.99)	3.85 (14.33)	3.79 (13.88)
	2015	4.64 (21.00)	4.49 (19.66)	4.56 (20.33)	4.56 (20.33)	3.14 (9.33)	3.29 (10.33)	3.44 (11.33)	3.29 (10.33)	3.34 (10.67)	3.81 (14.00)	3.63 (12.67)	3.60 (12.45)
Rice + dhaincha (1:1) + pendimethalin PE fb 2,4-D Na PoE	2014	4.98 (24.33)	5.70 (31.99)	4.81 (22.67)	5.18 (26.33)	4.67 (21.33)	4.53 (19.99)	4.78 (22.33)	4.66 (21.22)	4.56 (20.33)	4.85 (22.99)	4.92 (23.67)	4.78 (22.33)
	2015	4.30 (18.00)	4.71 (21.66)	4.10 (16.34)	4.38 (18.67)	4.02 (15.67)	3.85 (14.33)	4.26 (17.67)	4.05 (15.89)	4.34 (18.33)	4.56 (20.33)	4.71 (21.67)	4.54 (20.11)
Mechanical weeding twice at 20 and40 DAS	2014	5.90 (34.33)	6.07 (36.33)	6.26 (38.67)	6.08 (36.44)	4.34 (18.33)	3.98 (15.33)	4.95 (23.99)	4.44 (19.22)	3.76 (13.67)	4.02 (15.67)	4.49 (19.67)	4.10 (16.34)
	2015	5.49 (29.67)	5.58 (30.67)	5.64 (31.33)	5.57 (30.56)	3.76 (13.67)	3.54 (12.00)	4.34 (18.33)	3.89 (14.67)	3.52 (12.33)	3.76 (13.66)	4.14 (16.67)	3.84 (14.22)
Un-weeded control	2014	5.96 (34.99)	6.47 (41.33)	6.44 (40.99)	6.29 (39.10)	6.62 (43.33)	7.11 (49.99)	7.15 (50.67)	6.96 (48.00)	7.43 (54.67)	7.24 (51.99)	7.47 (55.33)	7.38 (54.00)
	2015	5.52 (30.00)	5.59 (35.33)	5.85 (33.67)	5.79 (33.00)	5.96 (35.00)	6.39 (40.33)	6.84 (46.34)	6.41 (40.56)	6.92 (47.33)	6.62 (43.33)	7.08 (49.67)	6.88 (46.78)
Mean	2014	5.56 (30.39)	5.86 (33.80)	5.76 (32.67)		4.74 (21.93)	4.85 (23.05)	5.12 (25.73)		4.90 (23.53)	4.98 (24.33)	5.15 (26.00)	
	2015	4.92 (23.73)	5.15 (26.06)	5.04 (24.87)		4.19 (17.07)	4.29 (17.87)	4.68 (21.40)		4.62 (20.80)	4.63 (20.93)	4.85 (23.07)	
		N	W	N at W	W at N	N	W	N at W	W at N	N	W	N at W	W at N
LSD (p=0.05)	2014	0.32	0.25	0.42	0.44	0.35	0.28	0.46	0.49	0.44	0.41	0.52	0.55
	2015	0.35	0.26	0.39	0.41	0.31	0.25	0.42	0.45	0.41	0.32	0.45	0.48

Figures in the parentheses are original values which were subjected to square root $\sqrt{x+0.5}$ transformation; DAS: Days after seeding; PE: Pre-emergence; PoE: Post-emergence

Table 2. Effect of weed management treatments on weed smothering efficiency (WSE), weed control efficiency (WCE) and weed index (WI) in aerobic rice during *Kharif* season of 2014 and 2015

Treatment	WSE (%)		WCE (%)		WI	
	2014	2015	2014	2015	2014	2015
Rice + dhaincha (1:1) + pendimethalin PE *fb* weed management one HW at 60 DAS	87.0	88.0	88.7	89.4	0.74	0.75
Pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS	85.8	86.6	93.3	94.0	0.83	0.80
Rice + dhaincha (1:1) pendimethalin PE *fb* 2,4 D Na salt PoE	89.0	89.5	88.8	87.2	0.68	0.71
Mechanical weeding twice at 20 and 40 DAS	84.0	84.0	91.1	93.6	0.76	0.78
Un-weeded control		-	-	-	-	-

DAS: Days after seeding; PE: Pre-emergence; PoE: Post-emergence

Table 3. Rice growth and yield under varying nitrogen and weed management treatments in aerobic rice during *Kharif* season of 2014 and 2015

Treatment	Plant height (cm)		Tillers/m^2		Panicles/m^2		Panicle weight (g)		Grain yield t/ha	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Nitrogen level										
75 kg/ha	85.4	80.2	455	402	241	238	2.06	2.16	2.88	2.68
100 kg/ha	93.6	91.3	506	489	265	262	2.26	2.32	3.25	2.86
125 kg/ha	108.4	95.6	524	505	281	271	2.42	2.48	3.46	3.14
LSD (p=0.05)	1.8	2.5	24.2	18	16	21	0.13	0.15	0.26	0.25
Weed management										
Rice: dhaincha (1:1) + pendimethalin PE *fb* one HW (60 DAS)	86.67	83.33	484	438	303	269	2.63	2.59	3.74	3.23
Pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS	92.00	90.67	514	465	368	308	2.83	2.96	4.74	4.09
Rice: dhaincha (1:1) + pendimethalin PE *fb* 2,4-D Na salt	83.89	80.52	468	421	253	247	2.20	2.31	3.04	2.78
Mechanical weeding twice at 20 and 40 DAS	89.73	85.48	505	453	324	275	2.69	2.68	4.12	3.56
Un-weeded control	68.43	66.67	389	317	108	112	0.81	0.91	0.98	0.80
LSD (p=0.05)	1.5	2.4	20.2	16.8	14	19	0.12	0.14	0.18	0.21

DAS: Days after seeding; PE: Pre-emergence; PoE: Post-emergence

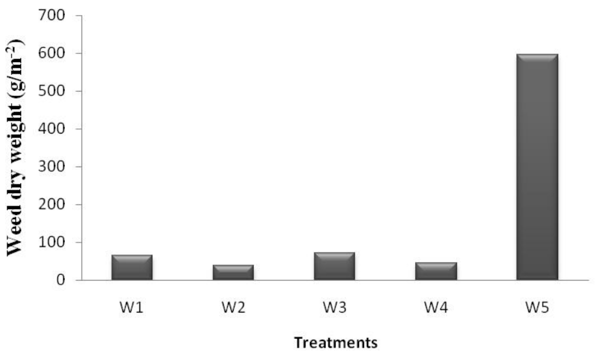

Figure 1. Weed biomass as influenced by weed management treatments at 60 DAS during *Kharif* season (pooled mean for two years)

W_1- Rice + Dhaincha (1:1) + pendimethalin PE *fb* weed management one HW at 60 DAS, W_2- pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS, W_3- rice + dhaincha (1:1) pendimethalin PE *fb* 2,4 D Na salt PoE, W_4- mechanical weeding twice at 20 and 40 DAS and W_5- un-weeded control

(WI) during 2014 and 2015 (**Table 2**). It might be due to effective ground cover by dhaincha which decreased the availability of sunlight to the late emerging weed seeds inhibiting their germination and growth (Chauhan and Mahajan 2014; Bommayasamy *et al.* 2018).

Effect on rice growth and yield attributes

Nitrogen dosage rates and weed management treatments produced significant variation in the rice growth as well as yield attributes (**Table 3**). Among the tested N levels, N at 125 kg/ha caused maximum plant height, number of tillers/m^2, number of panicles/m^2 and panicle weight during both the years indicating the aerobic rice greater responsiveness to the applied N up to the rate of 125 kg/ha. Application of nitrogen promoted rice growth due to higher availability of nitrogen to the rice plants leading to its higher uptake and translocation to the different part of the rice plant (Jain *et al.* 2018), which suppressed the negative competitive effect of weeds on rice. Application of nitrogen at 125 kg/ha recorded higher yield (3.46 and 3.14 t/ha in 2014 and 2015, respectively) and it was followed by nitrogen at 100 kg/ha. Significant increase in grain yield could be attributed to N application which might have improved the N, P and K uptake by crop plant resulting in better growth and yield attributes (Mohana Keerthi *et al.* 2018). The lowest yield was recorded with application of nitrogen at 75 kg/ha.

Among the weed management methods, pendimethalin PE followed by mechanical weeding twice at 20 and 40 DAS resulted in greater rice plant

Table 4. Economic impact of varying nitrogen and weed management treatments in aerobic rice during *Kharif* season of 2014 and 2015

Treatment	Cost of cultivation (x10^3 `/ha)		Gross returns (x10^3 `/ha)		B:C ratio	
	2014	2015	2014	2015	2014	2015
Nitrogen level						
75 kg/ha	48.50	49.20	56.16	52.26	1.16	1.06
100 kg/ha	49.10	49.85	63.37	55.77	1.29	1.12
125 kg/ha	49.80	50.35	67.47	61.23	1.35	1.22
Weed management						
Rice + dhaincha (1:1) + pendimethalin PE *fb* hand weeding once at 60 DAS	49.50	50.25	72.93	62.98	1.47	1.25
Pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS	50.25	51.20	92.43	79.75	1.84	1.56
Rice + dhaincha (1:1) pendimethalin PE *fb* 2,4 D Na salt PoE	47.15	48.20	59.28	54.21	1.26	1.12
Mechanical weeding twice at 20 and40 DAS	49.85	50.75	80.34	69.42	1.61	1.37
Un-weeded control	44.50	45.20	19.11	15.60	0.43	0.35

DAS: Days after seeding; PE: Pre-emergence; PoE: Post-emergence

height, number of tillers/m^2, number of panicles/m^2 and panicle weight. This might be attributed to efficient and timely weed management which reduced the weed density and biomass leading to higher weed control efficiency during early stage of crop growth and ultimately resulted in improved rice yield attributes and increased grain yield. Whereas, lower grain and straw yield were found in un-weeded control owing to severe crop-weed competition which resulted in the reduction of growth and yield components of aerobic rice.

Application of nitrogen at 125 kg/ha with pendimethalin PE *fb* two mechanical weeding twice at 20 and 40 DAS was found to be the best treatment combination for effective weed management and higher yield of aerobic rice.

Economics

Application of nitrogen at 125 kg/ha recorded higher gross returns and B:C ratio followed by nitrogen at 100 kg/ha (**Table 4**). Among the weed management treatments, pendimethalin PE *fb* mechanical weeding twice at 20 and 40 DAS was found to be the most economical combination for higher gross returns and B:C ratio.

It was concluded that application of 125 kg N/ha and pendimethalin PE followed by mechanical weeding twice at 20 and 40 DAS is preferable option for achieving better weed management and higher economical productivity in aerobic rice cultivation.

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