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Physical and Economic Levels of Nitrogen for Aerobic Rice under Different Establishment Methods

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A B S T R A C T

A field experiment was conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal to find out the physical and economic optimum doses of nitrogen for aerobic rice under different establishment methods in Karaikal during *Kharif* (June to September) 2018. The treatments comprised combination of three methods of establishment (broadcasting, line sowing and transplanting) and six levels of nitrogen (0, 100, 125, 150, 175 and 200 kg ha^{-1}). The experiment was conducted in a split-plot design with three replications, assigning establishment methods to the main plots and the nitrogen levels to sub-plots. A short duration rice *cv*. ADT (R) 45 was used in the study. Among the different methods of establishment, the grain yield, straw yield, gross return, net return and B:C ratio were significantly higher in transplanting than line sowing and broadcasting. Among the different nitrogen levels, the maximum grain yield, gross return, net return and B:C ratio were recorded with the application of 150 kg N ha^{-1}. The physical and economic optimum levels of nitrogen in broadcasting (157.7 and 145.4 kg ha^{-1}, respectively), line sowing (187.2 and 170.2 kg ha^{-1}, respectively) and transplanting (157.6 and 152.0 kg ha^{-1}, respectively) varied. Transplanting rice seedlings under aerobic condition along with the application of 150 kg N ha^{-1} recorded the highest grain yield (4272 kg ha^{-1}), gross return (Rs. 69821 ha^{-1}), net return (Rs.24434 ha^{-1}) and B:C ratio (1.54).

Introduction

'Rice is life'- a slogan in International Year of Rice 2004, had revealed the pivotal role of rice in human livelihood. But, increasing scarcity of fresh water especially for rice cultivation, due to water demand for the industries and other sectors, threatens the sustainability of the irrigated rice ecosystem. By 2025, out of 75 million hectares, 15 million hectares of Asia's flood-irrigated rice crop will experience water shortage (Tuong and Bouman, 2003).

"Aerobic rice" concept was initiated by IRRI which means growing rice under non-puddled and non-flooded aerobic soil by the addition of external inputs like supplementary irrigation and fertilizers in order to overcome the ever increasing food grain demand. The aerobic way of growing rice saves water by eliminating continuous seepage and percolations, land preparation and reducing evaporation (Bouman *et al.*, 2002). Under aerobic rice cultivation the water usage can be reduced and water productivity can be increased by 27 to 51 per cent and 32 to 88 per cent, respectively (Bouman *et al.*, 2005).

Different establishment methods significantly influenced the yield of aerobic rice. The seedling transplanting and direct dibbling recorded more grain yield under upland condition (Laary *et al.*, 2012). In aerobic rice, line sowing registered higher yield than broadcasting method due to maintenance of less weed population and higher weed control efficiency (Prashanthi *et al*., 2017). Nitrogen is the kingpin of plant nutrition and it is the most limiting nutrient for the growth and yield of rice, irrespective of the environment (Yoshida, 1981). Nitrogen application could overcome the yield decline under continuous aerobic rice cropping (Nie *et al.*, 2008). However, the nitrogen demand of rice is not the same under different growing environments and establishment methods. Hence, the present study was undertaken with the objectives of to find out the effect of different methods of establishment and nitrogen levels on yield and economics of aerobic rice as well as to optimize the dose of nitrogen under different establishment methods.

Materials and Methods

A field experiment was conducted during *kharif* 2018, at east farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal. The soil of the experimental field was sandy clay loam in texture with a neutral pH (6.9). The soil was high in organic carbon (1.13 %), low in available nitrogen (216 kg ha^{-1}) and medium in available phosphorus (21 kg ha^{-1}) and available potassium (126 kg ha^{-1}).The experiment was conducted in a split-plot design with three replications.The treatments comprised combination of three establishment methods in main plots (broadcasting, line sowing and transplanting) and six levels of nitrogen in sub-plots (0, 100, 125, 150, 175 and 200 kg ha^{-1}).

The seeds of short duration cultivar [ADT (R) 45] was used at the rate of 60 kg ha^{-1} for the study. Under broadcasting method, the seeds were broadcasted uniformly and covered with soil. In line sowing method, rills were opened at 20 cm spacing, two to three seeds were sown in each hill at a spacing of 10 cm and the seeds were covered with soil. In transplanting method, the seeds were sown in dry flatbed nursery and later 22 days old seedlings were pulled out and transplanted in the plots according to the treatments. The nitrogen was applied as per the treatment in the form of urea in three equal splits at basal, active tillering and panicle exertion stages. Phosphorus (50 kg P_2O_5 ha^{-1}) as single super phosphate at basal and potassium (50 kg K_2O ha^{-1}) as muriate of potash in two splits (basal and panicle exertion stages) were applied uniformly to all the treatments. Immediately after sowing, the field was irrigated and life irrigation was given at 4 DAS. The plots were subsequently irrigated depending upon the soil moisture condition. Weed management and plant protection measures were taken up as per the recommendations of the Crop Production Guide.

Data on grain and straw yields were recorded. The total cost of cultivation, gross return, net return and B:C ratio were computed. The physical and economic optimum levels of nitrogen were computed using Spillman-Mitscherlich yield response function (Spillman, 1923).

$$Y = a + bx - cx^2$$

Where,
Y = Yield
a = maximum or potential yield obtainable by not applying N under the conditions of the experiment
b = increase in yield resulting from N applied
c = ratio of successive increments in output 'a' to total output Y
x = level of nitrogen

Results and Discussion

Yield

The different establishment methods significantly influenced the grain and straw yields. Transplanting rice seedlings under aerobic conditions recorded the maximum grain and straw yields (3564 and 5074 kg ha^{-1}, respectively) followed by line sowing (2716 and 4387 kg ha^{-1}, respectively). The lowest yields were recorded in broadcasting method of establishment (Table 1). The yield increase in transplanting and line sowing methods as compared to broadcasting may be attributed to the higher values of yield attributes recorded in these establishment methods as compared to those in broadcasting method.

Application of 150 kg N ha^{-1} recorded the maximum grain yield (3277 kg ha^{-1}) followed by 175 kg N ha^{-1} (3164 kg ha^{-1}), 125 kg N ha^{-1} (3144 kg ha^{-1}) and 200 kg N ha^{-1} (3072 kg ha^{-1}). However, they were on par with each other. Whereas, application of 175 kg N ha^{-1} recorded the maximum straw yield (5055 kg ha^{-1}) followed by 200 kg N ha^{-1} (5030 kg ha^{-1}), 150 kg N ha^{-1} (4837 kg ha^{-1}) and 125 kg N ha^{-1} (4706 kg ha^{-1}) which were on par with each other and significantly higher than that at 100 kg N ha^{-1} (4542 kg ha^{-1}). Control recorded the lowest grain (1990 kg ha^{-1}) and straw yields (3393 kg ha^{-1}), which were significantly lower than those in all other levels of nitrogen application.

The interaction effects were significant only for grain yield. Transplanting rice seedlings along with the application of 150 kg N ha^{-1} recorded the maximum grain yield (4272 kg ha^{-1}). However, it was at par with application of 125 and 175 kg ha^{-1} in transplanting method of establishment. The least grain yield was recorded in broadcasting method of establishment with no nitrogen application (1801 kg ha^{-1}).

Increase in nitrogen level beyond 150 kg ha^{-1} marginally decreased the grain yield. Similarly, a slight reduction in straw yield was noticed when the N was applied beyond 175 kg ha^{-1}. This corroborates with the findings of Mahajan and Timsina (2011), Reddy *et al.*, (2017) and Goswami *et al.*, (2018). The higher yield with the application of 150 kg N ha^{-1} was due to the increased values in the yield attributes achieved with this level of nitrogen when compared to other levels, which in turn might be due to the increased availability of nitrogen. A straw yield of 5055 kg ha^{-1} was obtained with 175 kg N ha^{-1}. The increase in straw yield with increase in nitrogen might be due to higher nitrogen uptake which promoted more vegetative growth. This is in confirmation with the findings of Nayak *et al.,* (2015).

Economics

Among the different methods of establishment, the total cost of cultivation was maximum for transplanted rice (Rs. 45,000 ha^{-1}) followed by line sowing (Rs. 38,250 ha^{-1}) while the lowest total cost of cultivation was registered in broadcasting method of establishment (Rs. 35,600 ha^{-1}). The gross return, net return and B:C ratio were higher in transplanting (Rs. 58,537 ha^{-1}, Rs. 13,537 ha^{-1} and 1.30, respectively) followed by line sowing (Rs. 45,125 ha^{-1}, Rs. 6,875 ha^{-1} and 1.18, respectively). Broadcasting resulted in the lowest gross return, net return and B:C ratio (Table 2).

Among the various levels of nitrogen, the total cost of cultivation was higher for the application of 200 kg N ha^{-1} (Rs. 40,648 ha^{-1}) followed by 175 kg N ha^{-1} (Rs. 40,323 ha^{-1}). Skipping nitrogen application resulted in the lowest total cost of cultivation (Rs. 37,681 ha^{-1}). Among the different nitrogen levels, the highest gross return and net return were attained with the application of 150 kg N ha^{-1} followed by 175 kg N ha^{-1}. The lowest gross return was recorded in N control (Rs. 33,241 ha^{-1}). A loss of Rs. 4439 ha^{-1} was obtained when nitrogen was not applied. Application of 150 kg N ha^{-1} recorded the highest B:C ratio (1.34) followed by 175 kg N ha^{-1} (1.30). The lowest B:C ratio was recorded in N control (0.89). Application of nitrogen beyond 150 kg N ha^{-1} decreased the economic feasibility. This is in line with the findings of Mahajan and Timsina (2011), Reddy *et al.*, (2017) and Goswami *et al.*, (2018).

Among the various treatment combinations, the total cost of cultivation was maximum in transplanting with application of 200 kg N ha^{-1} (Rs. 46,031 ha^{-1}) followed by 175 kg N ha^{-1} in transplanting method of establishment (Rs. 45,706 ha^{-1}) whereas, the total cost of cultivation was least in broadcasting with N control treatment (Rs. 33,664 ha^{-1}). Application of 150 kg N ha^{-1} under transplanting method resulted in the maximum gross return, net return and B:C ratio (Rs. 69,821 ha^{-1}, Rs. 24,434 ha^{-1} and 1.54, respectively) followed by application of 125 kg N ha^{-1} under transplanting (Rs. 64,510 ha^{-1}, Rs. 19,441 ha^{-1} and 1.43, respectively). Irrespective of method of establishment, a loss of Rs. 2,029 to Rs. 7,734 ha^{-1} was observed when nitrogen was not applied (Table 2).

Table.1 Grain and straw yields (kg ha^{-1}) as influenced by establishment methods and nitrogen levels in aerobic rice

N -levels	Grain yield (kg ha^{-1})					Straw yield (kg ha^{-1})			
	BC	LS	TP	Mean		BC	LS	TP	Mean
0 kg ha^{-1}	1801	2055	2114	1990		3093	3460	3625	3393
100 kg ha^{-1}	2597	2609	3453	2886		4522	4205	4901	4542
125 kg ha^{-1}	2603	2886	3943	3144		4240	4508	5370	4706
150 kg ha^{-1}	2643	2918	4272	3277		4322	4449	5741	4837
175 kg ha^{-1}	2659	2982	3851	3164		4810	4933	5422	5055
200 kg ha^{-1}	2618	2845	3753	3072		4934	4770	5388	5030
Mean	2487	2716	3564			4320	4387	5074	
For	**E**	**N**	**N at E**	**E at N**		**E**	**N**	**N at E**	**E at N**
S.Ed.	50	128	222	208		46	172	298	276
C.D. (P=0.05)	138	261	453	425		129	352	NS	NS

BC: Broadcasting LS: Line sowing TP: Transplanting

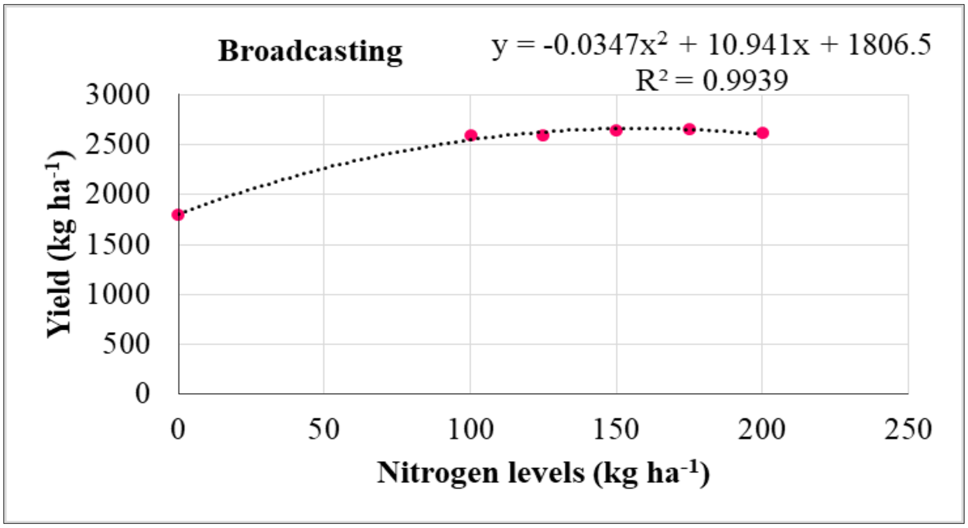
Table.2 Economics of aerobic rice cultivation under varied establishment methods and nitrogen levels

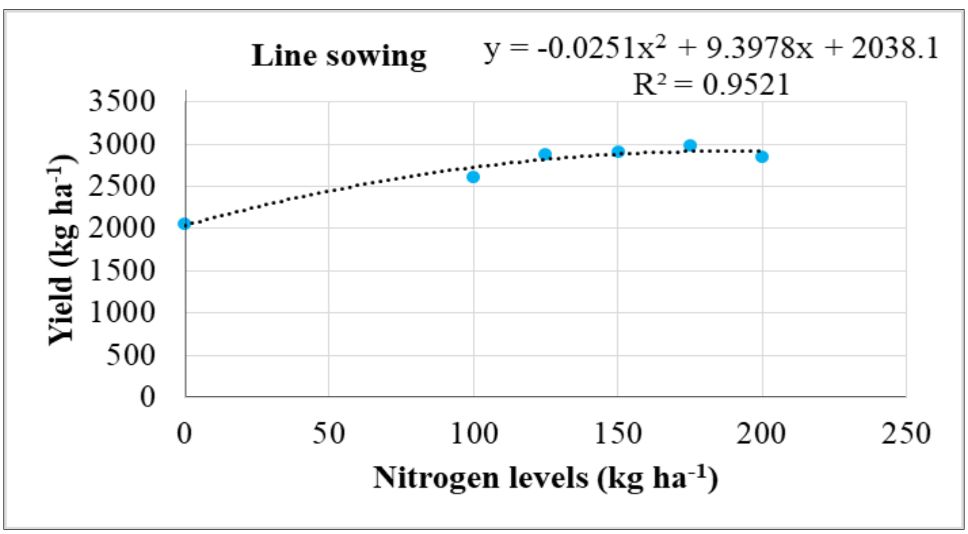
Treatment	General cost of culti-vation (Rs. ha^{-1})	Cost of establish-ment and fertilizer application (Rs. ha^{-1})	Total cost of culti-vation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
Establishment methods						
E_1 - BC	33264	2336	35600	41621	6021	1.17
E_2 - LS	33264	4986	38250	45125	6875	1.18
E_3 - TP	33264	11736	45000	58537	13537	1.30
Nitrogen levels						
N_0 - 0 kg N ha^{-1}	33264	4417	37681	33241	-4439	0.89
N_1 - 100 kg N ha^{-1}	33264	6097	39361	47837	8477	1.21
N_2 - 125 kg N ha^{-1}	33264	6422	39686	51865	12180	1.30
N_3 - 150 kg N ha^{-1}	33264	6740	40004	53999	13995	1.34
N_4 - 175 kg N ha^{-1}	33264	7059	40323	52514	12192	1.30
N_5 - 200 kg N ha^{-1}	33264	7384	40648	51108	10460	1.25
E_1 N_0	33264	400	33664	30108	-3556	0.89
E_1 N_1	33264	2080	35344	43472	8128	1.23
E_1 N_2	33264	2405	35669	43284	7615	1.21
E_1 N_3	33264	2723	35987	43962	7975	1.22
E_1 N_4	33264	3042	36306	44697	8391	1.23
E_1 N_5	33264	3367	36631	44202	7571	1.21
E_2 N_0	33264	3050	36314	34285	-2029	0.94
E_2 N_1	33264	4730	37994	43345	5351	1.14
E_2 N_2	33264	5055	38319	47803	9484	1.25
E_2 N_3	33264	5373	38637	48214	9577	1.25
E_2 N_4	33264	5692	38956	49663	10707	1.27
E_2 N_5	33264	6017	39281	47440	8159	1.21
E_3 N_0	33264	9800	43064	35330	-7734	0.82
E_3 N_1	33264	11480	44744	56696	11952	1.27
E_3 N_2	33264	11805	45069	64510	19441	1.43
E_3 N_3	33264	12123	45387	69821	24434	1.54
E_3 N_4	33264	12442	45706	63183	17477	1.38
E_3 N_5	33264	12767	46031	61683	15652	1.34

Data statistically not analyzed BC: Broadcasting LS: Line sowing TP: Transplanting

Table.3 Physical and economic optimum levels of nitrogen for aerobic rice under different establishment methods

Method of establishment	N- Response curve	R^2 value	Physical optimum (kg ha^{-1})	Economic optimum (kg ha^{-1})
Broadcasting	$y = 1806.5 + 10.941N - 0.0347N^2$	0.994**	157.7	145.4
Line sowing	$y = 2038.1 + 9.3978N - 0.0251N^2$	0.952**	187.2	170.2
Transplanting	$y = 2076.9 + 23.923N - 0.0759N^2$	0.936**	157.6	152.0
Across all methods	$y = 1973.8 + 14.748N - 0.0452N^2$	0.976**	163.1	153.7





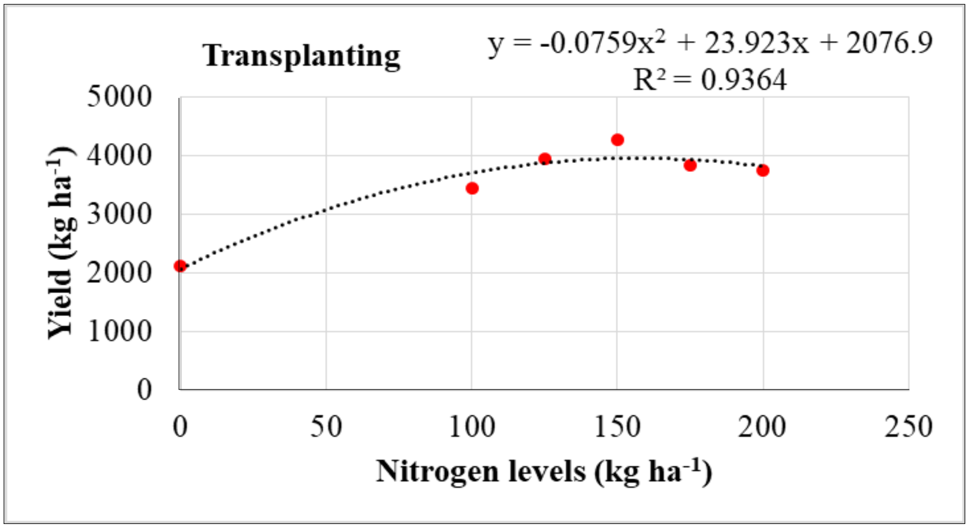


Fig.1 Response of aerobic rice to nitrogen under different establishment methods

Physical and economic optimum

The N response curves under different methods of establishment are presented in Fig.1. The N response curves adequately explain the grain yield response of aerobic rice to different nitrogen levels under varied establishment environments.

The physical and economic optimum nitrogen levels in broadcasting (157.7 and 145.4 kg ha^{-1}, respectively), line sowing (187.2 and 170.2 kg ha^{-1}, respectively) and transplanting (157.6 and 152.0 kg ha^{-1}, respectively) varied. Across the methods of establishment, the physical optimum level of nitrogen was found to be 163.1 kg ha^{-1} whereas the economic optimum level of nitrogen was found to be 153.7 kg ha^{-1} (Table 3).

From the above results, it is clear that rice could be transplanted under aerobic conditions to achieve better growth and yield. To achieve higher yield and economic return, it is recommended that rice can be transplanted under aerobic condition with application of 150 kg N ha^{-1}.

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