Original Research Article

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).

Keywords
Aerobic rice, transplanting, line sowing, broadcasting, nitrogen level, physical and economic optimum, economics

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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\(_2\)O\(_5\) ha\(^{-1}\)) as single super phosphate at basal and potassium (50 kg K\(_2\)O 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 – cx²

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 S.Ed.   | E   | N   | N at E | E at N |
|-------------|-----|-----|--------|--------|
|             | 50  | 128 | 222    | 208    |
| C.D. (P=0.05) | 138 | 261 | 453    | 425    |

BC: Broadcasting  LS: Line sowing  TP: Transplanting

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

| Treatment   | General cost of cultivation (Rs. ha\(^{-1}\)) | Cost of establishment and fertilizer application (Rs. ha\(^{-1}\)) | Total cost of cultivation (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 | R² 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                      |

![Broadcasting graph](image1)

![Line sowing graph](image2)
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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