Adaptability of aerobic rice to different establishment methods and levels of nitrogen under irrigated aerobic condition

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Abstract
A field experiment was conducted at Agronomy Main Research Farm, Department of Agronomy, Odisha University of Agriculture and Technology in summer 2016 and 2017. The experiment was laid out in split plot design with three replications under irrigated aerobic condition. Treatments comprising of five establishment methods like direct seeding in solid rows 20 cm apart (E1), direct seeding by punji method (dibbling) at 20 cm x 20 cm (E2), transplanting (under puddle un flooded condition i.e. aerobic) with 1 seedling at 2 leaf stage at 20 cm x 20 cm (E3), 2-3 seedlings at 4 leaf stage at 20 cm x 10 cm (E4) and 2-3 seedlings at 4 leaf stage at 20 cm x 20 cm (E5), in main plots, and four nitrogen level (N1-30, N2-60, N3-90 and N4-120kg N ha⁻¹) in sub plots. Result revealed that aerobic rice adapted with significant superiority when 2-3 seedlings at 4 leaf stage were transplanted in square geometry of 20 cm x 20 cm (E5) on pulverised soil after a pre-soaking irrigation. The method recorded the highest yield attributing characters like EBT/ hill, panicle length, filled grains per panicle ,1000 grain weight and harvest index contributing to significantly higher grain yield of 4760 and 5142 kg/ha in the year 2016 and 2017, respectively. The corresponding straw yield was 5626 and 5938 kg/ha. Yields was found to increase with N-levels and was associated with higher values of yield attributing characters. The same treatment also registered highest net return (Rs.31663and Rs. 39675.) and B: C ratio (1.75an 1.95) in 2016 and 2017, respectively. Two factor interactions between methods and N levels was also significant and significantly the highest grain and straw yield was recorded when the crop was transplanted under E5 treatment at 120kg N/ha. Functional relationship of nitrogen was established and optimum economic dose of nitrogen was found to be 110 and 118 kg N/ha in 2016 and 2017, respectively with corresponding optimum yield of 4546 and 5087 kg/ha.

Keywords: Establishment methods, growth parameters and aerobic rice

Introduction
Rice is the major contributor of this energy and supports nearly half of the world’s population as staple food and accounts for more than 20% of all calories that mankind consumes and the researchers are facing an uphill task to keep pace with burgeoning population under the challenging environment of present day. Rice is traditionally grown by transplanting seedlings on puddle soil for facilitating easy seedling establishment and suppressing growth of weeds. However, repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers and forming hard-pans at shallow depths, besides, the method is labour and energy intensive (Kumar et al., 2018) [14]. Under the looming water crises it is projected that in the next 25 years, 15–20 million hectares of lowland rice in Asia are to suffer from water scarcity (Tuong and Bouman, 2003) [10]. Thus, some adaptation strategies need to be developed for sustaining rice production and achieving global food security. Aerobic rice culture is an emerging technology designed to enhance water productivity in rice production, where, rice is grown like irrigated dry crop under non-flooded, well drained, un puddle and non-saturated soils with moderate use of external inputs and supplementary irrigation. Moisture status is maintained at or near field capacity that helps in increasing water productivity by 32-88% due to reduction in non- ET components (Tuong and Bouman, 2003) [10]. The soil thus, remains aerated throughout its growing season facilitating greater microbial activity, root aeration and overall crop growth and development.
Lafitte et al. (2002) termed this system of rice cultivation with provision of irrigation as aerobic rice. However, limited research endeavors have been done in different rice growing areas for optimizing the establishment techniques to assess its adaptability. The present investigation was aimed at to study the adaptability of aerobic rice to different establishment methods and levels of nitrogen under irrigated aerobic condition.

Materials and Methods

Field experiment was carried in the year 2016 and 2017 during summer at Agronomy Research Farm, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar, Odisha. situated at 20° 15’ N latitude and 85° 52’ E longitudes in East and South Eastern Coastal Plain Agro-Climatic Zone of Odisha. The soil of the experimental site was sandy loam, moderately acidic (pH 5.7) and medium in organic carbon (0.61%), available nitrogen (265.6kg ha⁻¹), phosphorus (20.25 kg ha⁻¹) and potassium (232.5 kg ha⁻¹). The crop received a total amount of 127.6 mm rainfall in first and 117.7 mm in second year in 13 and 9 rainy days, respectively. Supplemental irrigation was given to meet the crop water requirement. The maximum and minimum temperature during the period of growth ranged from a minimum of 15.7 °C in January to maximum of 40.8 °C in April, 2016 and 14.5 °C in January to 38.8 °C May, 2017. The field experiment was laid out in split plot design under irrigated aerobic un puddle un flooded condition with three replications comprising five establishment methods like direct seeding in solid rows 20 cm apart (E₁), direct seeding by punji (dibbling) at 20cm x 20cm spacing (E₂), transplanting (under un puddle un flooded condition) with 1 seedling at 2 leaf stage at 20 cm x 20 cm spacing (E₃), with 2-3 seedlings at 4 leaf stage at 20 cm x 10 cm spacing (E₄) and with 2-3 seedlings at 4 leaf stage at 20 cm x 20 cm spacing (E₅) allotted to main plots with four nitrogen level (0, 60, 120 and 240 kg N ha⁻¹) and with 2 seedling hill (20.51). Garbe et al. [16] opined that under wider spacing significant the highest (369 and 397) EBT/m² in the year 2016 and 2017, respectively, though at par with E₁ treatment with 347 and 394 EBT/m² in corresponding years, but plant height was the less (table 1). Further perusal of data (pooled over 2 years) indicated that all the establishment methods produced significantly higher ear bearing tillers over the treatment E₁ where seeds were directly seeded in solid rows that counted 296 EBT / m². All other characters like panicle weight, panicle length, filled grains per panicle and 1000 grain weight responded in similar way in both the years of study. Data based on pool over two years revealed that E₅ treatment produced significantly higher panicle weight (2.13 g), panicle length (26.1 cm), filled grains per panicle (113) and 1000, grain weight (20.51). However, the number of chaff per panicle and sterility percentage was significantly the highest in direct seeded treatment E₁ and E₂ in both the years. Values based on pool over two years were 25.6 and 26.2, and 19.7 and 19.4 5 in treatments E₁ and E₂, respectively. Significantly the lowest values for these two characters were noticed in treatment E₅ (table 2).

The results are in conformity with the earlier worker. Hugar et al. (2009) [5] recorded the tallest plant under normal method of paddy cultivation and the shortest under aerobic method during summer under irrigated conditions of Bhadra command area on red clay loam soils. Das et al. (2017) [7] reported that under aerobic condition 25 cm x 25 cm spacing with two seedling hill¹ recorded significantly the highest EBT m²² (353.9) Kipgen et al. (2018) [15] measured longest panicle (24.21cm) with 20 cm x 20 cm spacing being statistically at par with 20 cm x 15 cm (23.83 cm) and 15 cm x 15 cm (23.04 cm), Garbe et al., (2013) [16] opined that under wider spacing with less competition for nutrients, moisture and light, more photosynthetic product might be produced at the source and in turn it translocated to the sink. Sekhar et al. (2014) [9] reported minimum spikelet sterility (11.3%) with transplanted rice.

Yield of grain and straw

A perusal of data on yield (table 3) would reveal that yield of grain and straw harvest were found to be affected significantly due to various establishment methods and transplanting aerobically with 2-3 seedlings having 4 leaves in a square geometry of 20 m x 20 cm (E₅) harvested significantly higher grains in both the years and it was 4951 kg/ha on pooled over two years. However, it was at par with treatment E₄ where, 2-3 seedlings having 4 leaves were

12 irrigations in E₄ & E₅, during 2016 and 2017, respectively. The irrigation was scheduled at 20% of field capacity taking into account the rainfall received. Plant protection measures were taken as per recommendation against BLB infestation and insect pest like stem borer and leaf folder. The data on various yield attribute, yield and economics were collected following standard methods. Yield from net plots was recorded and expressed in kg/ha and reported at 14% moisture. Collected data were subjected to analysis of variance (ANOVA) as per standard statistical methods (Gomez and Gomez, 1984) [19].

Results and Discussion

Effect of establishment methods

The data revealed that number of ear bearing tillers / m², panicle weight, panicle length and 1000, grain weight were significantly affected due to various establishment methods in both years of study. Treatment (E₅) transplanting with 2-3 seedlings at 4 leaf stage in square geometry of 20 cm x 20cm counted significantly the highest(369 and 397) EBT/m² in the year 2016 and 2017, respectively, though at par with E₁ treatment with 347 and 394 EBT/m² in corresponding years, but plant height was the less (table 1). Further perusal of data (pooled over 2 years) indicated that all the establishment methods produced significantly higher ear bearing tillers over the treatment E₁ where seeds were directly seeded in solid rows that counted 296 EBT / m². All other characters like panicle weight, panicle length, filled grains per panicle and 1000 grain weight responded in similar way in both the years of study. Data based on pool over two years revealed that E₅ treatment produced significantly higher panicle weight (2.13 g), panicle length (26.1 cm), filled grains per panicle (113) and 1000, grain weight (20.51). However, the number of chaff per panicle and sterility percentage was significantly the highest in direct seeded treatment E₁ and E₂ in both the years. Values based on pool over two years were 25.6 and 26.2, and 19.7 and 19.4 5 in treatments E₁ and E₂, respectively. Significantly the lowest values for these two characters were noticed in treatment E₅ (table 2).

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Effect of Nitrogen levels

Data revealed that plant height, yield attributing characters and yield of rice increased with each successive incremental dose and were the maximum at 120 kg N/ha. Though it was at par with 90 kg N/ha. On two years pooled basis the maximum plant height at harvest (105.8 cm), number of ear bearing tillers/m² (378), panicle weight (2.58 g), panicle length (26.2cm), 1000, grain weight (20.52g) and number of filled grains per panicle (112) were the highest under 120 kg N/ha. These higher values were associated in producing higher yield of grain (4910 kg/ha), straw (5939 kg/ha) and harvest index (44.38%). The two factor interaction between E x N was also significant and transplanting aerobiocally with 2-3 seedlings having 4 leaves in a square geometry of 20 m x 20 cm (E5) produced significantly higher yield of grain of 5836 kg/ha under 120 kg N/ha (Fig.2). The higher values of these characters at higher levels of nitrogen application have also been reported by Metwally et al (2017) [8] and Gewaily et al. (2018) [9]. The number of chaffs and sterility percentage, however, showed a inverse relation with increasing N levels (table 1, 2, 3 & 4)

Functional relationship of nitrogen was established and optimum economic dose of nitrogen was found to be 110 and 118 kg N/ha in 2016 and 2017, respectively with corresponding optimum yield of 4546 and 5307 kg/ha. The resultant quadratic equation in 2016 was y= - 0.252x² + 5637 + 1402 and in 2017 was y = 0.269 X²+ 6429 + 1467 (Fig 3).

Economics

Transplanting treatment E3 was found to be more remunerative registering significant higher net return and B:C ratio of Rs. 35669/ha and 1.86, respectively (Fig.4). Direct seeding (E1) registered significantly the lowest with corresponding values of Rs. 10429/ha and 1.30, the cost of cultivation, however, was significantly less in E1 treatment (Rs. 37275/ha).

During the growing season a particular combination of soil, environment and the competition among the crops plants form a unique environment which, when interacts with the genotype, leads to the expression of the genotype, and ultimately the yield (Fisher, 2015) [17]. Optimum plant population and timely establishment is, thus, crucial for realizing the maximum of the inherent yield potential. It also answers the ability of a genotype to adapt itself. Direct seeding is common in upland situations and transplanting is the traditional way of establishing rice under low land puddle conditions. In present study the aerobic rice variety Pyari was subjected to different establishment methods involving direct seeding and transplanting on un puddle soil conditions i.e. irrigated aerobic conditions. An analysis of data (Fig 1) pooled over two years indicated that mean yield of grain, straw and harvest index was 27.8, 11.4 and 7.1% higher under aerobic transplanting (mean of E1,E2 and E3) over direct seeding (mean of E1 and E2). Similarly, the net return and benefit: cost ratio was higher by 60.7 and 15.2%, respectively, though the direct seeding registered a low cost of cultivation (6.7% less).

Table 1: Yield and economics indices as influenced by direct seeding and transplanting methods

| Particulars | Mean of Direct seeding treatments (E1 and E2) | Mean of transplanting treatments (E3, E4 and E5) |
|-------------|-----------------------------------|----------------------------------|
|             | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Grain yield, kg/ha | 3330 | 3869 | 3599 | 4322 | 4876 | 4599 |
| Straw yield, kg/ha | 4625 | 5373 | 4999 | 5295 | 5843 | 5569 |
| Harvest Index | 40.76 | 40.69 | 40.73 | 44.59 | 44.77 | 44.68 |
| Net return, Rs./ha | 13911 | 23572 | 18742 | 25300 | 35748 | 30524 |
| B: C ratio | 1.37 | 1.65 | 1.51 | 1.61 | 1.86 | 1.74 |

Table 2: Yield attributing characters as influenced by different treatments under aerobic condition in summer

| Treatment | Plant height (cm) at harvest | Ear bearing tillers (EBT) m⁻² | Panicle weight (g) | Panicle length (cm) |
|-----------|-------------------------------|-------------------------------|-------------------|-------------------|
| Establishment methods | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| E1 | 102.5 | 105.4 | 104.0 | 279 | 313 | 296 | 2.12 | 2.14 | 2.13 | 24.7 | 24.8 | 24.8 |
| E2 | 101.0 | 103.0 | 102.0 | 320 | 384 | 352 | 2.30 | 2.30 | 2.30 | 25.5 | 25.2 | 25.3 |
| E3 | 98.1 | 99.9 | 99.0 | 310 | 363 | 337 | 2.43 | 2.43 | 2.43 | 25.7 | 25.8 | 25.7 |
| E4 | 100.8 | 100.9 | 100.8 | 347 | 394 | 371 | 2.40 | 2.40 | 2.40 | 25.9 | 26.0 | 25.9 |
| E5 | 100.3 | 101.8 | 101.0 | 369 | 397 | 383 | 2.48 | 2.50 | 2.49 | 26.1 | 26.2 | 26.1 |
| SE=+ | 1.218 | 1.107 | 0.823 | 8.083 | 7.886 | 5.647 | 0.062 | 0.036 | 0.036 | 0.374 | 0.350 | 0.256 |
| CD (0.05) | NS | NS | 2.467 | 26.36 | 25.71 | 16.93 | 0.20 | 0.12 | 0.11 | NS | NS | 0.77 |
| N. Levels (kg h⁻¹) | | | | | | | | | | | | |
| N1 | 96.8 | 97.1 | 96.9 | 280 | 331 | 306 | 1.93 | 1.95 | 1.94 | 24.7 | 24.9 | 24.8 |
| N2 | 99.5 | 100.8 | 100.2 | 304 | 364 | 334 | 2.33 | 2.29 | 2.31 | 25.4 | 25.2 | 25.3 |
Table 3: Yield attributing characters as influenced by different treatments under aerobic condition in summer

| Treatment          | Filled grains panicle⁻¹ | 1000 grain weight (g) | Chaffs panicle⁻¹ | Sterility % |
|--------------------|-------------------------|-----------------------|------------------|-------------|
| Establishment methods |                         |                       |                  |             |
| E                  | 104                     | 105                   | 104              | 100         |
| N                  | 103                     | 104                   | 103              | 100         |
| E                  | 111                     | 111                   | 111              | 100         |
| N                  | 103                     | 104                   | 103              | 100         |
| E                  | 111                     | 111                   | 111              | 100         |
| N                  | 103                     | 104                   | 103              | 100         |
| CD(0.05)           | 4.52                    | 3.79                  | 2.89             | 1.26        |
| Pooled Interaction |                         |                       |                  |             |
| E within N         | 1.973                   | NS                    | 0.326            | 0.451       |
| N within E         | 2.283                   | NS                    | 0.413            | 0.486       |

N. Levels (kg h⁻¹)

- N1 103.4 kg h⁻¹
- N2 104.2 kg h⁻¹
- N3 105.8 kg h⁻¹
- N4 108.7 kg h⁻¹

Table 4: Grain and straw yield (kg ha⁻¹) and harvest index (H) as influenced by different treatments under aerobic condition in summer

| Establishment methods | Grain yield (kg ha⁻¹) | Straw yield (kg ha⁻¹) | Harvest index (%) |
|-----------------------|-----------------------|-----------------------|-------------------|
| E                    | 2875                  | 3224                  | 3049              | 4140        |
| N                    | 3808                  | 4376                  | 4092              | 4924        |
| E                    | 4653                  | 5093                  | 4828              | 5352        |
| N                    | 4507                  | 5313                  | 4910              | 5467        |
| CD(0.05)             | 156.39                | 218.20                | 123.40            | 252.80      |

N. Levels (kg h⁻¹)

- N1 2888 kg h⁻¹
- N2 3808 kg h⁻¹
- N3 4497 kg h⁻¹
- N4 4507 kg h⁻¹

CD(0.05) 154.34 kg h⁻¹
**Fig 1:** Yield and economics indices as influenced by direct seeding and transplanting.

**Fig 2:** Interaction effect of establishment methods x nitrogen levels (E×N) on grain yield (kg ha⁻¹) under aerobic condition in summer.

**Fig 3:** Functional relationship of grain yield and nitrogen under irrigated aerobic condition during summer.
Conclusion
The aerobic rice variety Pyari, showed better adaptability to establishment method, aerobic transplanting with 2-3 seedlings at 4 leaf stage in square geometry of 20 cm x 20 cm) by recording higher values of growth and yield parameters besides being economically remunerative. It responded to application of nitrogen and optimum economic dose ranged from 110 to 118 kg N/ha, the functional relation being quadratic.

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