Response of Rice Cultivars to Nitrogen Levels under Aerobic and Transplanted Conditions

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ABSTRACT
An experiment on response of rice to nitrogen under aerobic and transplanted conditions was conducted in split-split plot design with two methods of rice cultivation, seven rice varieties and five nitrogen levels. The grain yield was significantly higher in transplanted rice compared to aerobic rice. Significantly higher grain yield was observed with MTU 1001 and MTU 1010 as compared to IR 64, Tella hamsa and Rajendra and the grain yield in the former two varieties was comparable with Naveen and Erramallelu. Increase in grain yield with every 100 kg of N ha⁻¹ from 100 kg to 300 kg ha⁻¹ was significant. Significant interaction effect on grain yield was observed due to method of crop establishment, varieties and nitrogen levels. Aerobic rice received 627 mm of irrigation water as compared to 1228 mm in transplanted rice and the mean water productivity was higher under aerobic rice (0.49 kg grain m⁻³) as compared to transplanted rice (0.31 kg grain m⁻³).

Key words: Aerobic rice, Grain yield, Nitrogen levels, Transplanted rice, Varieties, Water productivity, Water requirement.

INTRODUCTION
Aerobic rice is grown like an upland crop under non-puddled, unsaturated soil without ponded water and water will be applied as and when required to bring the soil water content to the field capacity (Bouman et al., 2005). It grows well at water content of 70% to 100% of water holding capacity throughout the growing season as an irrigated dry crop with substantial water saving and improves the water productivity by eliminating seepage, percolation and minimizing evaporation and utilizes rainfall effectively. Further, it enables advanced crop establishment to make use of early season rain water (Tuong, 1999). In majority of studies, it was observed that compared to lowland rice cultivation, the water used by aerobic rice was lower by more than 30-70% (Castaneda et al., 2004; Belder et al., 2005; Bouman et al., 2005; Reddy et al., 2010) and the total water productivity was 1.6 to 1.9 times higher than that of flooded rice (Wang et al., 2002).

The rice varieties developed specifically for aerobic cultivation have ability to adapt better to aerobic conditions and the reduction in yield when water stress occurs is much lower than the varieties developed for irrigated conditions (Castaneda et al., 2002). Even though the aerobic rice is considered as potential technology to save water in rice (Tuong et al. 2004; Bouman et al, 2005), the information in terms of suitability of popular cultivars for the aerobic cultivation and their water requirements are scanty in major rice growing areas and specific rice varieties for aerobic cultivation were not available.

Significant yield responses to applied N were observed in almost all types of soils (De Datta et al., 1988) and there are reports that irrigated dry / aerobic rice responds to nitrogen application up to 100 (Danial and Wahab, 1994), 150 (Reddy et al., 1993 and Maheswari et al., 2007), 180 (Ghobrial, 1983, Lateef pasha et al., 2013) and 200 (Venugopal, 2005) kg N ha⁻¹. Zhang et al. (2009) reported that there was no interaction between N rates and water management and no effect of water treatment on the grain yield. Limited research has been done on optimizing nutrient management to produce high yield of aerobic rice. However, the exact requirement to get maximum yields depends up on the location, season and variety, among other factors. Hence, a study was conducted with an objective to identify the potential of existing rice cultivars developed for transplanted conditions at different levels N nutrition for aerobic rice cultivation.

MATERIALS AND METHODS
An experiment was conducted for three wet (kharif) seasons during 2008, 2009 and 2010 at the Agricultural College Farm,
ANGRAU, Rajendranagar, Hyderabad to explore the potentiality of conjunctive use of rain and ground water for enhanced water use efficiency and develop aerobic rice production systems focusing on varietal evaluation, water and nutrient management. The experiment was conducted in split-split plot design with three replications. The two methods of rice cultivation- aerobic (dry seeded and irrigation scheduled as that of irrigated dry crop) and paddy transplanted rice were tested under main plots and the seven popular medium and short duration cultivars (Erramallelu, Naveen, IR-64, Thella hamsa, Rajendra, MTU-1001 and MTU-1010) were tested under sub plots and five nitrogen levels (100, 150, 200, 250 and 300 kg/ha) under sub–sub plots.

The aerobic and transplanted plots were separate entities in a contiguous block with 2 m wide buffer zone with three buffer channels between main (aerobic and transplanted) plots. The land for aerobic and transplanted plots were dry ploughed to fine tilth and later the plots marked for transplanting were puddled under submergence by power tiller. The plots were bunched with 20 cm bottom and 15 cm top width bunds with 30 cm channel in between two bunds of plots to facilitate safe disposal of drain water in the event of heavy rain and to avoid the movement water soluble applied in between the adjacent plots. The size of the sub plots were 2.25 m x 5.0 m and these plots were separated from each other by 60 cm buffer zone with channel. No submergence was noticed in the aerobic rice plots during 2008 and 2009 while in kharif 2010, standing water of 3 to 6 cm depth was observed noticed 3 times due to heavy rain events during night as result there was rise in water table to a depth of 1 m below the ground.

The recommended P2O5 and K2O (60 and 60 kg ha⁻¹, respectively) were applied in the form of super phosphate and muriate of potash. Entire dose of P2O5 was applied as a basal at the time of sowing/ planting and K2O was made in two splits one at sowing/ transplanting and second at panicle initiation along with final split of N. The N was applied in the form of urea in three equal splits at sowing/ transplanting, maximum tillering and panicle initiation stages.

The experimental soil was sandy loam with low N, medium P and K. The water holding capacity of the soil was 20%. The aerobic rice and nursery for transplanting was sown on 27th June, 28th June and 3rd July in 2008, 2009 and 2010 kharif seasons, respectively. The aerobic rice was sown at 20 cm apart as solid rows. Transplanting of rice was done on 2nd August, 28th July and 5th August in 2008, 2009 and 2010, respectively. The spacing adopted under transplanted crop was 20 cm between rows and 15 cm from hill to hill. Herbicides, pendimethalin (3.0 l ha⁻¹) and Butachlor (3.0 l ha⁻¹) were applied as pre-emergence at 3 days after sowing and 5 days transplanting in aerobic and transplanted rice respectively followed by one manual weeding between 30-35 days after sowing and transplanting in aerobic and transplanted rice.

The total rain fall received during June to October was 911, 601 and 948 mm in 38, 33 and 55 rainy days in 2008, 2009 and 2010, respectively. Rainfall distribution was more or less uniform in 2008 and 2010 but in 2009, comparatively dry period prevailed in the initial crop growth period (July and August).

The crop was irrigated whenever there was no rain for 10 days during rainy season and at 4-5 day interval after cessation of rains i.e. during October and November from the ground water source (opens well). This period coincided with reproductive and maturity stages of the crop. The irrigation water was applied to each plot through HDPE pipe to which water meter was attached for measurement of water. The seepage that was collected from the puddle plots was safely disposed of through the adjacent buffer channel drawn in between paddy transplanted and aerobic plots. The effective rainfall was estimated by using CRRIWAR method (Bos et al., 2009).

The water table was more than 4 m below the surface during 2008 and 2009 and it was around 1 m below the ground level for nearly three months of crop growing period in 2010.

In each net plot (leaving one row on four sides in transplanted rice and two rows on each side and 10 cm on each side of solid row) one m² area was harvested to the ground level for recording yield attributes. After sampling, the entire net plot was harvested and threshed and grain yield was determined at 14% moisture content and the straw dry weight was determined after drying to a constant weight from net plot area after adding the m² yield.

The water productivity (WP) (kg grain m⁻³ of water) was calculated by following equation

\[
WP = \frac{Y}{WA_{(IR-ER)}}
\]

Where

Y= grain yield (kg ha⁻¹) and

WA (total water used),

(1R- irrigation, 1R- effective rainfall)

The data collected in the present experiment on yield of rice for three years were analyzed as per the statistical methods given by Gomez and Gomez (1984) and wherever the treatment differences were found significant (F test), the critical difference was calculated at 5% probability.

RESULTS AND DISCUSSION

Method of rice crop establishment

The mean grain yield of rice was significantly influenced by method of rice crop establishment (Table 1). The grain yield was significantly higher in flooded transplanted rice over aerobic rice. The grain yield under transplanted condition was 9 % higher as compared to aerobic condition. The yield attributing characters like number of panicles and grains per panicle (sink) were higher in transplanted rice over aerobic rice and these attributes are the major yield contributing characters which helped in resulting higher grain yield in transplanted rice (Peng et al., 2006).

Varieties

There was significant difference in grain yield among the varieties tested in two methods of rice crop establishment (Table 1). The varieties Naveen, Erramallelu, MTU 1001 and
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Table 1: Grain yield (t ha\(^{-1}\)) of rice varieties under two methods of crop establishment and different levels of nitrogen (mean of three seasons).

| Treatment | Nitrogen, Kg ha\(^{-1}\) | Mean of varieties over methods and N levels |
|-----------|--------------------------|---------------------------------------------|
|           | 100                      | 150                         | 200                      | 250                      | 300                      |
| Aerobic   |                           |                              |                          |                          |                          |
| Naveen    | 3.06                     | 3.56                         | 3.76                     | 4.27                     | 4.55                     | 3.84                     | 4.07                     |
| Erramallelu | 3.48                    | 3.95                         | 4.30                     | 3.99                     | 4.47                     | 4.04                     | 4.20                     |
| IR-64     | 3.33                     | 3.72                         | 3.83                     | 3.71                     | 4.29                     | 3.77                     | 3.95                     |
| Thellahamsa | 2.68                   | 3.03                         | 3.23                     | 3.51                     | 4.23                     | 3.34                     | 3.61                     |
| Rajendra  | 2.80                     | 3.44                         | 3.28                     | 3.75                     | 3.95                     | 3.44                     | 3.57                     |
| MTU-1001  | 3.62                     | 3.75                         | 4.04                     | 4.43                     | 5.28                     | 4.22                     | 4.63                     |
| MTU-1010  | 4.02                     | 4.58                         | 4.61                     | 5.00                     | 5.66                     | 4.77                     | 4.63                     |
| Mean      | 3.28                     | 3.72                         | 3.87                     | 4.10                     | 4.63                     | 3.92                     |
| Transplanted          |                           |                              |                          |                          |                          |
| Naveen    | 3.60                     | 4.19                         | 4.18                     | 4.48                     | 5.00                     | 4.30                     |
| Erramallelu | 3.37                    | 4.21                         | 4.51                     | 4.69                     | 4.98                     | 4.35                     |
| IR-64     | 3.39                     | 3.85                         | 4.08                     | 4.41                     | 4.91                     | 4.13                     |
| Thellahamsa | 3.41                   | 3.83                         | 3.74                     | 4.09                     | 4.34                     | 3.88                     |
| Rajendra  | 3.09                     | 3.30                         | 3.85                     | 4.01                     | 4.28                     | 3.70                     |
| MTU-1001  | 4.46                     | 4.56                         | 5.14                     | 5.31                     | 5.69                     | 5.03                     |
| MTU-1010  | 3.77                     | 4.10                         | 4.41                     | 4.85                     | 5.26                     | 4.48                     |
| Mean      | 3.59                     | 4.01                         | 4.27                     | 4.55                     | 4.93                     | 4.27                     |
| Mean of N levels | 3.43                      | 3.86                         | 4.07                     | 4.32                     | 4.78                     |

| S.Em      | 0.12                     | 0.34                         |
| Variety   | 0.23                     | 0.63                         |
| Nitrogen  | 0.19                     | 0.53                         |
| M x V     | 0.32                     | N.S.                         |
| M x N     | 0.27                     | N.S.                         |
| V x N     | 0.51                     | N.S.                         |
| M x V X N | 0.71                     | 2.00                         |

MTU 1010 did not differ significantly in grain yield. The grain yield of MTU 1001 and MTU 1010 was significantly higher as compared to IR 64, Tellahamsa and Rajendra. The yield of later three varieties was on par with that of Naveen. Among the varieties Rajendra yielded lower grain and MTU 1001 and MTU 1010 recorded higher yield.

Nitrogen levels

The grain yield was significantly influenced by nitrogen levels (Table 1). There was significant increase in grain yield with increase in N level from 100 kg to 200 and 300 kg ha\(^{-1}\). The increase in yield was observed with every 100 kg of N ha\(^{-1}\). The increase in yield from 100 to 200, 150 to 250 and 200 to 300 kg N application was 18.6, 11.9 and 17.4 per cent. However, when addition of 50 kg N was made there was no improvement in yield. Similar findings of improvement in yields were observed by Lampayan et al., (2010) and Kadiyala et al., (2012) in aerobic rice. Generally, the nitrogen uptake is influenced by N fertilizer rates which have positive influence on crop growth thereby the grain yield.

The interaction of different methods of rice crop establishment and varieties, methods of crop establishment and nitrogen levels and varieties and nitrogen levels on grain yield was not significant.

Significant interaction effect on grain yield was observed due to method of crop establishment, varieties and nitrogen levels (Table 1). The lowest grain yield was observed with Tellahamsa at 100 kg N ha\(^{-1}\) in aerobic and Rajendra variety at 100kg N ha\(^{-1}\) in transplanted method. On the other hand, highest yield was observed in MTU 1010 and MTU1001 respectively in aerobic and transplanted method at 300 kg N ha\(^{-1}\). The grain yield observed with 300 kg N ha\(^{-1}\) with MTU 1010 under aerobic method and MTU 1001 under transplanted condition was significantly higher over all varieties except MTU 1010 at 100 kg N ha\(^{-1}\), except IR 64, MTU 1010 and MTU 1001 at 150 kg N ha\(^{-1}\) under aerobic condition. The grain yield in former two treatments was significantly more over that of Tellahamsa and Rajendra at 200 Kg N ha\(^{-1}\) and Tellahamsa at 250 kg N ha\(^{-1}\) under aerobic conditions.

The grain yield recorded at 300 kg N ha\(^{-1}\) with MTU 1010 under aerobic method and MTU 1001 under transplanted condition was significantly higher over all varieties except MTU 1010 and MTU 1001 at 100 kg N ha\(^{-1}\), except IR 64, MTU 1010 and MTU 1001 at 150 kg N ha\(^{-1}\) under aerobic condition. The yield obtained in all other treatment combinations was comparable with each other with the former two treatments.
The dependence of rice grain yield on nitrogen dose was evident from significant positive relation existed between grain yield and nitrogen dose. Further, the crop response to applied nitrogen was higher under transplanted conditions than that in aerobic cultivation.

**Water use**

The mean of three year irrigation water applied indicated that the water consumed by aerobic rice was lower than that of transplanted rice (Table 2). The aerobic rice received 627 mm of irrigation water as compared to 1228 mm in transplanted rice. The aerobic rice consumed 49% less irrigation water than that of transplanted rice.

The total water used (irrigation + rainwater) over three years period in aerobic rice was 999 mm as compared to 1574 mm in transplanted rice. There was a saving of 36.0% in aerobic rice as compared to transplanted rice.

The water productivity was higher under aerobic rice than that under transplanted conditions. The mean water productivity of three years was 0.49 kg grain m⁻³ of water under aerobic rice compared to 0.31 kg grain m⁻³ of water in transplanted rice.

**CONCLUSION**

The results clearly demonstrate that under water scarce conditions, aerobic rice has an advantage over that of transplanted rice which can be adopted during rainy season as an alternative rice growing method. Further, the rice varieties developed for transplanted conditions adopt well for aerobic rice cultivation without any yield reduction.

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**Table 2: Irrigation water applied, total water use and water productivity of rice under aerobic and transplanted conditions in semiarid conditions of Hyderabad (mean of three years).**

| Cultivars     | Irrigation water applied, mm | Total water used, mm* | Water productivity, kg grain m⁻³ of water |
|---------------|-----------------------------|-----------------------|------------------------------------------|
|               | Aerobic | Transplanted | Aerobic | Transplanted | Aerobic | Transplanted |
| Naveen        | 645     | 1223        | 1017    | 1568        | 0.47    | 0.30        |
| Erramallelu   | 645     | 1223        | 1017    | 1568        | 0.49    | 0.32        |
| IR-64         | 578     | 1223        | 950     | 1568        | 0.50    | 0.28        |
| Thelilahamsa  | 578     | 1223        | 950     | 1568        | 0.46    | 0.28        |
| Rajendra      | 578     | 1223        | 9560    | 1568        | 0.45    | 0.27        |
| MTU-1001      | 681     | 1242        | 1053    | 1588        | 0.50    | 0.35        |
| MTU-1010      | 681     | 1242        | 1053    | 1588        | 0.55    | 0.34        |
| Mean          | 627     | 1228        | 999     | 1574        | 0.49    | 0.31        |

*Includes the effective rainfall of 372 mm for aerobic rice and 346 mm for transplanted rice.
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