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INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

International Journal of Current Research
Vol. 6, pp.018-021, July, 2010

RESEARCH ARTICLE

PERFORMANCE OF DIFFERENT RICE HYBRIDS AND AROMATIC RICE VARIETIES UNDER SATURATED AND FLOODED SOIL CONDITIONS

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ARTICLE INFO

Article History:
Received 4th May, 2010
Received in revised form
18th May, 2010
Accepted 25th June, 2010
Published online 1st, July, 2010

Key words:
Rice Hybrids; Aromatic rice; saturated soil

ABSTRACT

Rice is a crop which consumes more water than any other cereal crop. As irrigation water shrinks globally, there is a need to screen different rice varieties which perform better with less water. An experiment was conducted in the clay loam soil in TNAU, in a split plot design, with seven rice hybrids and seven aromatic rice varieties (all lowland varieties) under saturated (0.5cm of standing water) and flooded (2.5 cm of standing water) soil conditions. Varieties were evaluated for yield and water use efficiency. Rice hybrids and aromatic rice varieties recorded higher yield in flooded soil condition. But water use efficiency (35% more) was higher in saturated soil condition. Two hybrids, NDR-359 and KRH-2 and one aromatic rice variety, Mugad sugandhi recorded less yield reduction and better water productivity than other varieties in saturated soil condition.

INTRODUCTION

Rice (*Oryza sativa* L.) is the world's second most important cereal crop. More than 90% of the world's rice is produced and consumed in Asia. Rice is grown under different ecosystems including lowland, upland, semi-dry and deep water. For food security, it is essential to "produce more rice with less water" (Guerra, 1998). Water use in irrigated rice is high because it is grown under low land conditions. Puddling of soil (creating an impervious muddy layer) uses large quantities of water in low land rice production. Because of water ponding, a large quantity of water is lost through evaporation and seepage losses (Bouman and Tuong, 2001). Several technologies have been developed to reduce water loss and increase water productivity of rice. Alternate wetting and drying (Tabbal *et al.,* 2002) and the System of rice intensification (SRI) (Stoop *et al.,* 2002) are well known examples.

Rice grown in non puddled and non flooded soil saves 50-70% water, but there is a yield reduction of nearly 50-60% (Zhang *et al.,* 2004). Weeds are also a major problem in nonpuddled soil, leading to less productivity. Direct-seeded rice germinates together with weeds, eliminating the "head start" of transplanted seedlings (Moody, 1983). Weeds are estimated to cause rice yield losses of 35% in the tropics (Oerke and Dehne, 2004), but losses can be much greater in aerobic rice crops (Balasubramanian and Hill, 2002). Weeds compete with crops for nutrients, light and water and cause high yield reduction if not properly controlled.

The production system of rice is changing due to the scarcity of land, water and labor. There is a need to screen rice varieties that can perform better with less water.

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Research has been done to evaluate the performance of rice varieties under different water management systems like, alternate wetting and drying (Tabbal *et al.,* 2002) and system of rice intensification (Stoop *et al.,* 2002), but only a few studies evaluated yield and water productivity under saturated soil compared to flooded conditions. The hypothesis for this study was that some hybrids and aromatic rice varieties grown under saturated soil condition have the same yield and water productivity as that under flooded soils. The objective of the research reported in this paper was (1) to evaluate the yield performance of rice hybrids and aromatic varieties under saturated and flooded soil conditions and (2) to determine the water productivity of rice hybrids and aromatic rice varieties under both conditions

MATERIALS AND METHODS

Site description

An experiment was conducted in TNAU, India (11.00° N, 77.00° E and 426.7m MSL). Soil of the experimental field was clay loam in texture, low in organic matter, alkaline pH and high in available P and K. During the experiment, mean annual rainfall of 640 mm was received in 43 rainy days. The mean maximum and minimum temperature were 31.5°C and 27.2 °C, respectively. The relative humidity was 95 % during the forenoon and 61 per cent during the afternoon. Solar radiation averaged 400 $cal.cm^{-2}d^{-1}$.

Experimental design and sowing

The experiment was conducted using a split plot design with two main plot treatments and fourteen sub-plot treatments. Saturated and flooded soil conditions were the two main plot treatments. A water meter was used to measure the discharge (litre/second) and applied water rate when irrigating the field. The total volume of water was calculated by multiplying the depth (2.5 cm for M_1 and 0.5 cm for M_2) and the gross area of the plot. The time needed for the field to be irrigated was determined by dividing the volume used by the discharge rate.

Table 1. Sub plot treatment with duration

Hybrids	Duration	Aromatic rice varieties	Duration
PA 6444	135-140	Pusa Basmathi	145-150
NDR-359	125-130	GEB 24	145-150
CORH-3	105-110	Jeeragasamba	145-150
KRH-2	130-135	Kalanamak	125-130
Ajay	130-135	Indrabhog	115-120
Goracknath	135-140	Bhadshabhog	130-135
TNRH 185	135-140	Mugad Sugandi	130-135

Source of seed: Directorate of Rice Research (DRR, Hyderabad)

Seven rice hybrids and seven aromatic rice varieties (Table 1) were the sub plot treatments. Each variety was randomly selected and replicated thrice. Sub plot size was 5 x 4 m^2. Seeds were directly dibbled (sprouted seeds soaked for 24 hours) onto puddled soil at 20 x 10 cm spacing in the saturated treatment and were raised in a nursery and transplanted in the flooded soil condition; both treatments were seeded on the same day. Seedlings were transplanted 21 days after sowing (DAS) in the flooded soil condition at 20x15 cm spacing. Fertilizer was applied at 150:50:50 kg NPK kg ha^{-1} (P & K was applied as basal, N was applied 50 % basal, 25 % at tillering and 25% at flowering stage) for all treatments. Pre-emergence application of Butachlor (Machete) at the rate of 1.25 kg *a.i.* ha^{-1} was done three DAS or DAT (days after transplanting) followed by two hand weeding at 20 and 40 DAS or DAT to ensure weed free conditions in both the main plot treatments. Essentially the plots were kept weed free.

Grain yield and yield components

Grain was harvested from each net plot (leaving two rows of crops from either side) which was 13.44 m^2 for flooded condition and 13.92 m^2 for saturated soil condition. Grain moisture in each plot was recorded before the harvest by taking samples from each plot and measuring using a moisture meter. The crop was cut at ground level. Grain was manually threshed and grain yield was calculated per hectare after adjusting it to 14% moisture.

Panicles m^2

An area of 1m^2 (flooded condition) and 0.9m^2 (saturated condition) was chosen randomly in each net plot during physiological maturity before the harvest and ear bearing panicles were counted.

Number of grains, filled and non-filled grains per panicle

At maturity ten panicles were selected from each 1.0 or 0.9 m^2 and threshed individually and the number of total grains, filled grains and non filled grains were counted and recorded per panicle.

Test weight

One thousand filled grains were sampled from the grain harvested and weighed in each net plot and weight was adjusted to 14 per cent moisture content after drying it to constant weight at 105 $^{\circ}$C.

Water productivity

Water productivity (WP) is the grain yield divided by the total consumed water (irrigation (IW) + effective rainfall (ER)). The formulae used to calculate water productivity was:

$$WP = \text{Grain yield (kg ha}^{-1}) / IW + ER \text{ (m}^3 \text{ ha}^{-1})$$

Effective rain fall was calculated from the effective rainfall calculation table (Central Board of Irrigation and Power, 1996) where for a particular amount of rainfall, effective rainfall was standardized (199 mm was the effective rainfall in this experiment).

Statistical analysis

The data were analyzed as a split plot design using procedures suggested by (Gomez *et al.,* 1984). Wherever treatment differences were significant (using the F test), means were separated using the LSD test at five per cent probability. If there were no significant differences between treatments, it was denoted by the symbol NS. The data were analyzed using a locally available software package (Agres software, Version 3.1 1994).

RESULTS

Grain Yield

The difference in yield among different hybrids and aromatic rice varieties is represented in Fig.1. It is clear from the graph that the hybrids yield better than the aromatic rice varieties. Hybrids recorded more than twice (58%) the yield of aromatic rice varieties. The percent decrease of yield in saturated soil condition shows all varieties had lower yields compared to the flooded treatment (Fig.2). Some hybrid varieties like NDR 359, KRH-2, and PA6444 and some aromatics like Mugad sugandhi were least affected (15%) under less water. The rice hybrid Goracknath registered a 28% yield reduction and the aromatic GEB 24 registered 40% reduction under the saturated soil condition. Aromatic rice varieties were affected more under saturated soil condition. The average percent decrease of yield of hybrids was 18% compared to 27% for the aromatic rice varieties.

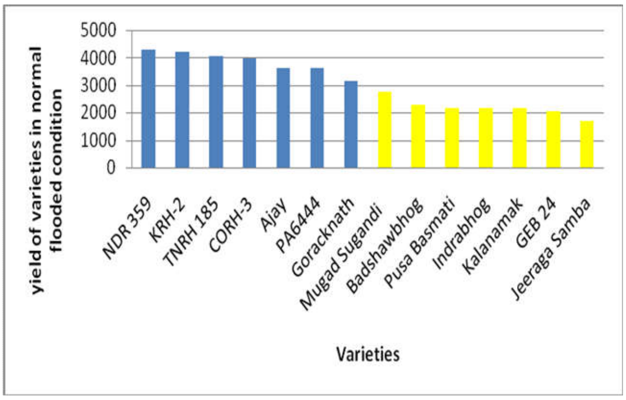

Fig. 1. Performance of varieties under flooded soil condition (Blue-Hybrids, Yellow-Aromatic rice varieties)

Yield components

Yield components like panicle m^{-2}, number of grains per panicle, seed weight and percent grain filling were recorded during the experiment under both the soil conditions and are shown in Table 2. Those varieties which recorded comparable results under both the conditions and those highly affected are only shown in the table. All yield components except grain weight had a significant effect on the yield recorded.

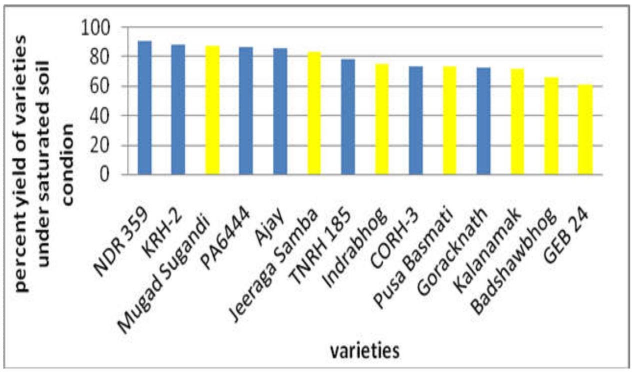

Fig. 2. Percent yield reduction under soil saturated soil condition (Blue-Hybrids, Yellow-Aromatic rice varieties)

Table 2: Yield components under flooded condition and saturated soil conditions

Soil conditions	Varieties	Panicles m^{-2*}	Filled grain $Panicle^{-1}$	Seed weight
Flooded	NDR 359	343^a	90	25.2
Saturated		298^b	82	25.2
Flooded	KRH 2	314^a	78	22.2
Saturated		244^b	75	22.2
Flooded	Mugad Sugndhi	150^a	86	18.4
Saturated		130^b	86	18.4
Flooded	Jeeraga sambba	126^a	80	17.8
Saturated		102^b	80	16.7

*Values followed by the same letter are not statistically significant from each other within variety.

Water productivity

The differences between the two main plot treatments were statistically significant. The flooded soil condition had the highest water use. There was almost 35-40% of water saving in the soil saturated condition. Results are presented in Table 3. Even though the yield was higher in the flooded soil condition, the saturated soil condition recorded higher water productivity due to lower water use. Hybrids have recorded higher water productivity because of higher yield. KRH 2 recorded the highest water productivity (6.19 kg $ha^{-1}mm^{-1}$). Crop duration also impacts water use. Varieties like CORH-3 and KRH-2 are short duration and hence consumed less water. Water productivity and total water used by the varieties are given below (Table 3). Aromatic rice Jeeraga samba recorded the lowest water productivity (1.68 kg $ha^{-1}mm^{-1}$)

DISCUSSION

Yield reduction under saturated soil conditions was related to weed infestation and some water stress. Though not measured in terms of biomass, visually it was noted that the saturated condition suffered more weed infestation than the flooded soil condition. Weeding rice is labor intensive; upland rice growers usually hand weeds their crops two or three times per season, investing up to 190 person days ha^{-1} (Roder, 2001). Weeds were estimated to cause rice yield losses of 35% in the tropics (Oerke and Dehne, 2004).

The experiment shows that some hybrids performed better under flooded condition but reported lower yields under saturated soil condition. A special breeding program is required to screen rice germplasm that performs better with less water and also is more competitive with weeds. With a decreasing amount of water all the yield components decreased, though the effect was not statistically significant for grain weight. The 1000 grain weight was recorded as filled grains only; it is also observed that number of unfilled grains was higher in the saturated condition. This is probably the reason that there is no difference in test weight of grains under both the conditions. This result indicates that yield was affected during tillering and flowering but also during the grain filling stage and that water stress occurred in the saturated treatment even though the soil was supposed to be saturated. This needs to be confirmed in future studies by using a tensiometer to measure water stress at different growth stages.

The rice varieties used in these studies are lowland hybrid and aromatic varieties that perform relatively well under flooded conditions. These varieties are not bred for less water conditions. Achieving high yields under irrigated, aerobic conditions will require new varieties of "aerobic rice" bred under that condition (Belder *et al.,* 2005). Varieties were developed in China, which are adapted better to less water conditions and two of these Chinese varieties performed well (Belder *et al.,* 2005). Traditional breeding or biotechnology methods can be used to develop good hybrids and aromatic rice varieties for saturated soil conditions. Also the varieties were grown under puddled soil condition in these studies in both main treatments. Puddling of soil uses more water than non-puddled and so if rice is grown under non puddled soil condition, even more water can be saved. Further research should concentrate on evaluating rice

Table 3. Water productivity and total water used by hybrids and aromatic rice varieties

Varieties	Saturated soil condition			Flooded soil condition		
	Irrigation Water(mm)	Total water*(mm)	Water productivity (kg $ha^{-1}mm^{-1}$)	Irrigation Water	Total water*(mm)	Water productivity (kg $ha^{-1}mm^{-1}$)
Hybrids						
KRH-2	450	649	6.19	750	949	4.57
NDR 359	500	699	5.89	800	999	4.53
CORH-3	450	649	5.12	750	949	4.24
Goracknath	500	699	3.80	800	999	3.66
Aromatic rice varieties						
Mugad sugandhi	500	699	3.17	800	999	4.33
Jeeraga samba	600	799	2.32	900	1099	1.68

*Total water = Irrigation water + effective rainfall (199mm) varieties under non puddled soil condition for this purpose.

Even though the yield is less in saturated soil condition, the varieties recorded higher water productivity due to their lower water use. Hybrids under both the soil conditions had higher water productivity because of their higher yield than aromatic rice varieties. Water productivity of a variety depends on the duration, yield and the water used. This experiment was conducted in puddled soil. Flooded soil conditions needs more water for puddling as well as to maintain 2-5 cm of standing water. The reported amount of total water input into a rice field ranges from 900 to more than 3000 mm, though the transpiration demand of the crop in the tropics is in the range of 350 to 550 mm only (Tuong, 1999; Bouman and Tuong, 2001). If varieties are developed to adapt under less water and non puddled condition water used for puddling the field and those lost due to evaporation and seepage can be saved. Higher crop duration also means more water. Most of the increase in water productivity has occurred in cultivars released after 1980 (Tuong, 1999). This is because the increase in yield from 1980s is coupled with a decrease in growth duration, whereas cultivars released before the mid-1980s have a longer duration than those released before 1980 (Peng *et al.,* 1998). Water productivity can also be increased by saving the water used for puddling the field. The main purpose of puddling is to reduce deep percolation of water, to control non-aquatic weeds and to facilitate transplanting of rice seedling by making the soil softer (Behera *et al.,* 2007).

Tools at the molecular level and genetic engineering provide new avenues for raising the yield potential and enhancing water productivity. The draft sequence of the rice genome (Barry, 2001; Yu *et al.,* 2002) is available to facilitate the discovery of genes important for breeding rice suitable for aerobic conditions. Benneth and Kush (2002) discuss the integration of molecular aspects in developing rice with salt tolerance. A similar application is anticipated for developing varieties giving higher yield per drop of water. Quality of rice is also affected by stress. The soil stress can be measured using a tensiometer. Future work will measure and correlate measured water stress with yield and yield components.

Acknowledgement

I thank Professor Peter Hobbs, Cornell University, Ithaca, New York for his valuable suggestions in development of this manuscript. This work was supported by AICRP.

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