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Effect of limited irrigation on growth and yield of rice varieties in a typic Haplustalf soil of Red and Laterite zone of West Bengal

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ABSTRACT

A field experiment was conducted to explore the potentiality of growing rice varieties under limited supply of irrigation water. Seven varieties of rice under 5 water management practices were evaluated in the farmers' field at Jhargram. Water management practices exerted significant influence on height, grain and straw yield and the highest grain yield (3.38 t ha^{-1}) was recorded under continuously flooded water regime (CF). Limited supply of irrigation water at different stages of growth decreased grain yield ranging from 27.5 to 43.5% compared to that in CF.Rice genotypes exhibited differential response to water management practices. Though UPLRi -7 produced the highest grain yield (4.39 t ha^{-1}) under CF, under limited water supply IR -36 was still the best variety producing the highest average grain yield (3.31 t ha^{-1}).The present research work pointed out that without ensuring adequate supply of irrigation water rice cultivation during boro season may not be profitable in the Red and Laterite zone of West Bengal.

***Keywords**: Boro* rice, limited irrigation, Red and Laterite zone and genotype

Rice is considered the main food staple for more than 50% of the world's population and is particularly important in Asia, where approximately 90% of world's rice is produced and consumed (Zeigler and Barclay, 2008; Khush, 2004). It is the grain that has shaped the culture, diet, and economies of billions of people in the world (Farooq *et al.,* 2009). Being the staple food for almost two thirds of the population supplying almost 31% of calories of Indian diet, rice plays a pivotal role in Indian economy (Rabindra Babu, 2013).India ranks first in the world in area of rice cultivation with 43.97 million ha and second in production with 104.32 million tons (Anon., 2013).While rice production under flooded conditions in the irrigated ecosystem is highly sustainable (Bouman *et al.,*2007), the rainfed rice ecosystem, which is subjected to different water regimes - from submerged to water stress, also contribute significantly to food security in many countries including India. To fight poverty and provide food security, rice production must increase from the present level to at least 760 mt by the year 2020 (Kundu and Ladha, 1995) from same or even shrinking land due to increasing competition for land and declining water availability. A major challenge in rice (*Oryza sativa* L.) production now is to achieve the dual goal of increasing food production and saving water. Exploring ways to produce more rice with less water is essential for food security and in this direction water-saving rice production systems, such as aerobic rice culture, system of rice intensification (SRI), ground-cover rice production system (GCRPS), raised beds, and alternate wetting and drying (AWD), have been tested. These methods though can drastically cut down unproductive water outflows and increase water-use efficiency (WUE), these technologies can sometimes lead to some yield penalty, if the existing lowland varieties are used (Farooq *et al.,*2009). To achieve high and sustainable yields in non-flooded soil, identification of varieties with better water use efficiency assumes great importance. Shifting of rice lands from being continuously anaerobic to being partly or even completely aerobic will produce profound changes in water conservation, soil organic matter turnover, nutrient dynamics, carbon impounding, weed flora, and greenhouse gas emissions. The challenge will be to develop suitable water management practices and identify efficient varieties which would allow profitable rice cultivation under limited water availability.

Owing to poorstatus of organic matter, nitrogen, phosphorus, sulphur and acidic soil reaction, the soils in the Red and Laterite agro-climatic zone of West Bengal are hungry and light and poroustexture have made it thirsty too. In this agro-climatic zone of undulating topography rice is the only crop grown in 3 out of 4 agro-ecological situations and in the lowest strata of undulating topography of this zone no other crop except rice could be grown after harvest of *kharif* (wet rainy season) rice.Scarcity of irrigation water is the main hindrance for cultivation of *boro* rice in this

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zone. Hence it becomes imperative to find a way out apart from traditional system of flooded rice cultivation where some amount of water could be curtailed at different phenological growth stages and can be saved for horizontal expansion of rice during the *boro* season. The above facts concurrently propound an intensive study to explore the suitability of some locally grown rice varieties under limited supply of irrigation water and also to quantify possible reduction in rice grain yield due to suboptimum supply of water at different phonological stages of growth in farmer's field for two seasons (during *boro* season) in a typic Haplustalf.

MATERIALS AND METHODS

Two field experiments were conducted in succession during *rabi* (pre-summer) season (January-April), 2008 and 2009 in a farmer's field at Jhargram located at $22^0 45^/$ N and $86^0 98^/$ E at an elevation of 81 m above MSL. The sand, silt and clay contents of the surface (0-0.15 m) soil were 77.12%, 6.0% and 16.88%, respectively, categorizing it as sandy loam in texture.Maximum water holding capacity (MWHC) was determined by tightly packing dry soil in a KR box and then equilibrating the soil through capillary action by placing the KR box on a petridish containing distilled water to a depth of 1/4 inch overnight (Baruah and Barthakur, 1999). The water holding capacity of soil was calculated from the gain in weight and expressed in percentage.Percent clay, silt and sand were determined by Hydrometer method (Bouyoucous, 1922 & 1962). Soil pH and EC were determined at 1:2.5 soil–water ratios using a glass electrode and conductivity bridge, respectively. Cation exchange capacity (CEC) was measured by 1N NH_4OAc, pH 7.0 solution method (Schollenberger and Simon,1945); soil organic carbon (SOC) was determined by dichromate oxidation (Walkley and Black, 1934); total soil N by the Kjeldahl method (Bremner and Mulvaney, 1982).Available phosphorus (P) in soil was determined by extracting samples with Bray and Kurtz No. 1 extractant [0.03 (N) ammonium fluoride (NH_4F) in 0.025 (N) hydrochloric acid (HCl)] (Bray and Kurtz, 1945) and determining P colorimetrically using ascorbic acid method (Murphy and Riley, 1962). Available potassium was determined using 1N ammonium acetate extraction followed by emission spectrometry (Jackson, 1973). Some of the basic chemical and physico-chemical properties of the surface (0-0.15 m) soil are presented in table1. A uniform dose of fertilizer N, P_2O_5 and K_2O (80:40:40 kg ha^{-1}, respectively) through urea, single super phosphate and muriate of potash were applied in the experimental plots (5 m x 4 m). Two days before transplanting, half of the nitrogen and total of phosphate and potassic fertilizers were applied as basal dose. Seven varieties of rice and five water management practices were replicated thrice and laid out in a factorial Randomized Complete Block design (Gomez and Gomez, 1984). The remaining half of nitrogen was applied as uniform top dressing after 21 days of transplanting. Two rice seedlings of each of the seven varieties of rice viz., IET-10899; IET- 8682; CN-907-6-2; UPLRi-7; IET – 4786; Khitish and IR-36 were transplanted per hill in plots with specified spacing between the hills and rows (0.15 m x 0.20 m). The crop was transplanted during 2^{nd} week of January. Usual agronomic practices were followed during the entire period of crop growth. The crop was grown to maturity under 5 water management practices viz., CF (Continuously flooded throughout the entire growth periods); FC (Field capacity maintained throughout the entire growth periods); SD – 5-7 [CF except soil Drying (SD) to FC maintained during maximum tillering stage (5-7 weeks after transplanting)]; SD 7-9 [CF except FC maintained during panicle initiation stage (7-9 weeks after transplanting)]; and SD 9-11 [CF except FC maintained during flowering stage (9-11 weeks after transplanting)]. Scheduled water regimes were maintained by supplying irrigation water as required. The crop was harvested at maturity; grain and straw yields and other growth parameters were recorded. Percentage change in grain yield (or straw yield) with respect to that in CF was calculated using the following formula:

$$\text{\% change from CF} = \frac{\text{(Yield in a treatment-Yield in CF) * 100}}{\text{Yield in CF}}$$

Statistical analysis of results was done with the help of SPSS 7.5, 1997, software.

RESULTS AND DISCUSSION

Plant height at harvest

Mean value of plant height (at harvest) of seven genotypes under the influence of five water management practices, pooled over two seasons (Table 2), revealed, significance statistically of the effect of water management, genotypes and their interaction effects. Irrespective of genotypes, rice plants had the shortest height under continuous field capacity (FC) water regime. This was true for plant height in individual genotypes also. Soil drying up to field capacity for two weeks during different stages of growth viz., tillering (SD 5-7), flowering/ booting (SD 7-9) and grain filling (SD 9-11) resulted in increased height of plants of all the rice genotypes as compared to their continuously flooded (CF) counterparts. With the exception of IET-4786, plants of all the genotypes showed the tallest plants when soil drying was imposed for 2 weeks during booting/flowering stage (SD 7-9). While the genotype IET-10889 produced the tallest plant height (115.9 cm), rice variety IR -36 had the shortest plants (69.9 cm) at harvest.Our results corroborate to the findings of Kato *et al.* (2006) who also observed differential response of three rice varieties to different levels of water availability. Limited supply of water resulted in stunted plant growth through its effects on the depth of root development which in turn affected the amount of N uptake.

Grain yield

Mean grain yield of seven genotypes of rice under the influence of five water management practices, pooled over two seasons (Table 3), revealed significant influence of the effect of water management, genotypes and their interaction on grain yield. Irrespective of genotypes, highest rice grain yield (3.38 t ha^{-1}) was obtained under continuously flooded (CF) water regime. Soil drying up to field capacity for 2 weeks at different stages of growth brought about different degrees of grain yield reduction. While the highest mean reduction in grain yield (43.49%) was observed when soil drying was imposed for 2 weeks during tillering stage (SD 5-7), this reduction was at the lowest (27.51%) when soil drying was imposed during grain filling / maturity stage (SD 9-11). Keeping the soil at field capacity (FC) throughout the rice growing periods led to 38.17% decline in rice grain yield. Among the seven genotypes of rice, the highest grain yield was obtained in IR -36 (3.31 t ha^{-1}). Mean grain yield of different genotypes pooled over the 2 seasons, followed the order IR -36 (3.31 t ha^{-1})>Khitish (2.77 t ha^{-1}) > IET 4786 (2.61 t ha^{-1}) > IET 8682 (2.22 t ha^{-1}) >UPLRi 7 (2.17 t ha^{-1}) >IET-10889 (2.03 t ha^{-1}) > CN 907-6-2 (1.82 t ha^{-1}). Lower photosynthetic rate in water stressed plants was the reason for this decrease in grain yield (Feng and Shiung, 1997). Castillo *et al.,* (1992) also observed reduced plant height and grain yields when plants were subjected to deficit water supply during the vegetative growth stage. Borell *et al.* (1991) opined that significantly lower rice yields in most tropical rice fields were due to intermittent drying or keeping soils saturated during the growing season either vegetative or reproductive phase. Interaction of water management with rice genotypes brought to the focus some interesting information. While under optimum water supply (CF), highest grain yield was recorded in UPLRi7, under deficit water supply scenario IR 36 produced the highest grain yield. The degree of grain yield reduction due to deficit water supply at different growth stages revealed its highest value in genotype UPLRi 7 (64.69%) under SD 5-7 water regime while the lowest value (6.37%) was observed in IR 36 under SD 9-11 water regime. Deficit supply of irrigation water resulted in highest grain yield reduction ranging from 60.82% to 64.69% was observed in UPLRi7 and the lowest ranging from 6.37% to 24.40% was recorded in IR 36. Among the seven tested genotypes of rice, IR 36 was the least affected by deficit supply of irrigation at different stages of crop growth.Limited supply of irrigation water might have resulted in low N uptake in these varieties due to restricted root growth and thus lower dry matter yield. Kato *et al.,* (2006) also observed differential response of different rice genotypes to limited water supply in Japan. Limited supply of irrigation water might have resulted in low N uptake in these varieties due to restricted root growth and thus lower dry matter yield. Sinha, et al (2009) also observed significant variation in grain yield. 1000 grain weight and dry matter accumulation among the rice varieties. Zaman *et al.* (2005) also observed lower rice grain yield (cv. IR-36) under limited supply of irrigation water in an Entisol soil of West Bengal.

Straw yield

Mean straw yield of seven genotypes of rice under the influence of five water management practices, pooled over two seasons (Table 4), revealed significant influence of the effect of water management, genotypes and their interaction effect on straw yield. Irrespective of genotypes, the lowest rice straw yield (5.09 t ha^{-1}) was obtained under continuously flooded (CF) water regime. Soil drying up to field capacity for 2 weeks at different stages of growth brought about different degrees of increase in straw yield. The highest mean increase in straw yield ((10.61%) was observed when soil drying was imposed for 2 weeks during grain filling / maturity stage (SD 9-11).Keeping the soil at field capacity (FC) throughout the rice growing periods led to 2.75% increase in rice straw yield. Among the seven genotypes of rice, the highest straw yield was obtained in CN-907-6-2(6.92 tha^{-1}). Mean strawyield of different genotypes pooled over the 2 seasons, followed the order > CN 907-6-2 (6.92t ha^{-1}) >UPLRi 7 (5.82 t ha^{-1}) >IET-10889 (5.35t ha^{-1}) >Khitish (5.32 t ha^{-1}) > IET 8682 (5.30 t ha^{-1}) >IR -36 (4.78 t ha^{-1})>IET 4786 (4.20 t ha^{-1}). Interaction of water management with rice genotypes brought to the focus some interesting information. Under optimum water supply (CF), highest straw yield was recorded in CN-907-6-2, under deficit water supply scenario also the same genotype produced the highest straw yield. The degree of straw yield increase due to deficit water supply at different growth stages revealed its highest value in genotype UPLRi 7 (45.11%) under SD 5-7 water regime while the lowest value (0.20%)was observed in IET-10899 under SD 5-7 water regime. The effect of deficit supply of irrigation water was altogether different in case of IR 36 where reduction in straw yield ranging from 13.58% to 32.45% was observed. The same response was also observed in IET – 4786 where straw yield reduction ranging from 5.31% - 16.17% was recorded. Like grain yield, limited supply of irrigation water also resulted in decreased straw yield (Kato *et al.,* 2006).

Water management practices exerted differential influence on height, grain and straw yield of the seven rice genotypes studied. Though limited supply of irrigation water during different rice growth stages had positive influence on plant height and straw yield, it resulted in grain yield reduction ranging from 27.5 to 43.5% compared to that in CF. Soil drying to field capacity for two weeks during the maximum tillering stage (SD 5-7) resulted in maximum (43.5%) grain yield reduction but among the seven tested varieties, the detrimental effect of limited irrigation was the least in IR -36. Although varietal interaction with water regime indicated the necessity to identify water efficient varieties,the present research work pointed out that rice cultivation without ensuring adequate supply of irrigation water may not be profitable in the Red and Laterite Zone of West Bengal, particularly during the *boro* season.

Table 1: Some important properties of the experimental soil

Soil characteristics	Results
Mechanical analysis	
Sand (%)	77.12
Silt (%)	6.00
Clay (%)	16.88
Textural class	Sandy loam
Water holding capacity (%)	31.73
Bulk density (g/cm^3)	1.34
pH (soil: water = 1 : 2.5)	4.64
Electrical conductivity (dsm^{-1})	0.07
CEC [c mol(p^+)kg^{-1}]	8.84
Organic carbon (%)	0.428
Total nitrogen (mg/Kg)	861
Available phosphorus (mg kg^{-1})	8.48
Available potassium (mg kg^{-1})	100.14

Table 2: Plant height (cm) at harvest of rice varieties under different water regimes (Pooled of 2 seasons)

Varieties	Water regimes					
	CF	FC	SD-5-7	SD-7-9	SD-9-11	Mean
IET-10889	119.6	110.0	116.8	117.6	115.8	**115.9**
IET-8682	103.9	98.8	105.3	105.5	106.1	**103.9**
CN-907-6-2	89.2	84.0	90.4	96.0	91.3	**90.4**
UPLRi-7	89.0	92.3	97.3	95.1	94.3	**93.6**
IET-4786	78.5	70.2	78.0	80.9	87.7	**79.1**
Khitish	83.0	77.0	83.7	84.2	77.1	**81.0**
IR-36	70.6	69.1	69.4	70.4	70.0	**69.9**
Mean	**90.6**	**85.9**	**91.6**	**92.9**	**91.7**	

	Varieties	Water regime	Interaction
SEm (±)	**0.29**	**0.41**	**1.07**
LSD (0.05)	**0.58**	**0.81**	**2.15**

Table 3: Grain yield (t ha^{-1}) of rice varieties under different water regimes (Pooled 2 seasons)

Varieties	Water regimes					
	CF	FC	SD-5-7	SD-7-9	SD-9-11	Mean
IET-10889	2.59	1.88(-27.41)*	1.76(-32.05)	1.56(-39.77)	2.35(-9.27)	2.03
IET-8682	3.23	1.43(-55.73)	1.60(-50.46)	1.87(-42.11)	2.98(-7.74)	2.22
CN-907-6-2	2.38	1.80(-24.37)	1.27(-46.64)	2.13(-10.50)	1.50(-36.97)	1.82
UPLRi-7	4.39	1.58(-64.01)	1.55(-64.69)	1.72(-60.82)	1.63(-62.87)	2.17
IET-4786	3.43	2.67(-22.16)	2.37(-30.90)	2.25(-34.40)	2.32(-32.36)	2.61
Khitish	3.85	2.17(-43.64)	1.95(-49.35)	3.07(-20.26)	2.83(-26.49)	2.77
IR-36	3.77	3.08(-18.30)	2.85(-24.40)	3.32(-11.94)	3.53(-6.37)	3.31
Mean	**3.38**	**2.09(-38.17)**	**1.91(-43.49)**	**2.27(-32.84)**	**2.45(-27.51)**	

	Varieties	Water regime	Interaction
SEm (±)	**0.03**	**0.027**	**0.072**
LSD (0.05)	**0.06**	**0.05**	**0.14**

·Figures in the parentheses represent % change in grain yield with respect to the CF water regime

Table 4: Straw yield (t ha^{-1}) of rice varieties under different water regimes (Pooled of 2 seasons)

	Water regimes					
Varieties	CF	FC	SD-5-7	SD-7-9	SD-9-11	Mean
IET-10899	5.04	5.40(7.14)	5.05(0.20)	5.53(9.72)	5.73(13.69)	5.35
IET- 8682	5.03	4.73(-5.96)	5.32(5.77)	5.73(13.92)	5.70(13.32)	5.30
CN-907-6-2	5.90	6.50(10.17)	7.87(33.39)	6.97(18.14)	7.37(24.92)	6.92
UPLRi-7	4.50	5.90(31.11)	6.53(45.11)	6.00(33.33)	6.17(37.11)	5.82
IET – 4786	4.33	4.10(-5.31)	3.63(-16.17)	3.93(-9.24)	5.00(15.47)	4.20
Khitish	5.17	5.35(3.48)	5.90(14.12)	5.57(7.74)	4.60(-11.03)	5.32
IR-36	5.67	4.63(-18.34)	3.83(-32.45)	4.90(-13.58)	4.87(-14.11)	4.78
Mean	**5.09**	**5.23(2.75)**	**5.45(7.07)**	**5.52(8.45)**	**5.63(10.61)**	

	Varieties	Water regime	Interaction
SEm (±)	**0.04**	**0.04**	**0.11**
LSD (0.05)	**0.08**	**0.08**	**0.22**

·Figures in the parentheses represent % change in straw yield with respect to the CF water regime

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