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Effect of Alternate Wetting and Drying (AWD) Irrigation Method on Grain Yield Economics and Water Productivity of Different Rice (*Oryza sativa* L.) Varieties in Telangana State of India

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ABSTRACT

The field experiment was conducted at Regional Sugarcane and Rice Research Station, Rudrur, Professor Jayashankar Telangana State Agriculture University ,India in a split plot design. The treatment combination includes three irrigation regimes as main plots (I_1-irrigation of 5 cm when water level falls below 5 cm from soil surface in field water tube, I_2- irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tube and I_3- recommended submergence of 2-5 cm water level as per crop stage as main treatments and four popular rice varieties in the Telangana region V_1-RNR 15048 (Telangana Sona), V_2 - KNM 118 (Kunaram Sannalu),V_3-MTU 1001 (Vijeta) and V_4- BPT 5204 (Sambamashuri) as sub plots treatments respectively replicated thrice . AWDI of 5 cm irrigation when water level falls below 5 cm in the field water tube (I_1) recorded significantly higher yield with mean yield of 8248.41 kg ha^{-1} over other irrigation regimes AWDI of 5 cm when water level falls below 10 cm in Boumans tube I_2 (7515.09 kg ha^{-1}) and recommended submergence as per crop growth stage I_3 (7685.60 kg ha^{-1}).There was 4.72% yield enhancement with I_1 over I_3 and significantly higher net returns (Rs 86634.61 ha^{-1}) and benefit cost ratio (1.47) with water productivity of 5.85 kg ha mm^{-1} compared to recommended submergence of 2-5 cm water level as per crop stage (4.37 kg ha mm^{-1}).Variety KNM 118 performed superior to other varieties with significantly higher mean grain yield of 8406.73 kg ha^{-1} followed by RNR 15048 8071.92 kg ha^{-1} fetching significantly higher economic returns Rs 89803.91 ha^{-1} and Rs 81494.60 ha^{-1} respectively. Least economic benefit was realized from variety BPT 5204 Rs 66215.84 ha^{-1} followed by MTU 1001 Rs 74600.06 ha^{-1}. Varieties KNM 118 and RNR 15048 being shorter duration also recorded higher water productivity of 6.12 kg ha mm^{-1}and 6.08 kg ha mm^{-1} respectively and least water productivity was recorded with BPT 5204 4.17 kg ha mm^{-1} followed by MTU 1001 5.15 kg ha mm^{-1} which may be attributed to lower grain yield and longer duration of these varieties.

Keywords Wetting and drying, Irrigation method, Grain yield, water productivity, *Oryza sativa.*

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INTRODUCTION

Rice, is a staple crop cultivated on more than 167 million hectares annually worldwide (FAO 2018). It feeds more than half of the world's population and provides 20% of daily calories (Carrijo *et al*. 2017), 13% per capita protein and 19% per capita energy requirements globally (GRSP 2013). Per capita, rice consumption is growing throughout the world (Ricepedia 2009). Asia contributes 87% of global rice cultivation area and consumes 90% of total rice production (FAO 2018). However, rice production also utilizes a large proportion of irrigated freshwater resources (Bouman and Tuong 2001). More than 75% of the world's rice is produced in irrigated rice lands, which are predominantly found in Asia. The abundant water environment in which rice grows best differentiates it from all other important crops. But water is becoming increasingly scarce. By 2025, the per capita available water resources in Asia are expected to decline by 15–54% compared with 1990 (Moya *et al.* 2001). Due to increasing scarcity of freshwater resources available for irrigated agriculture and escalating demand of food around the world, in the future, it will be necessary to produce more food with less water. Since, more irrigated land is devoted to rice than to any other crops in the world, wastage of the resource in the rice field should be minimized (IRRI 2018).

There is an immediate need to reduce and optimise irrigation water use in the light of declining water availability for agriculture in general and to rice in particular. Since irrigated rice production is the leading consumer of water in the agricultural sector and country‟s most widely consumed staple crop, finding ways to reduce the need for water to grow irrigated rice should benefit both producers and consumers contributing to water security and food security. To overcome this problem and increase the rice grain production to meet the food security we need to develop novel technologies that will sustain or enhance the rice production by increasing irrigation efficiencies. If rice is grown under traditional conditions, farmers resort to continuous submergence irrigation resulting in enormous wastage of water and lower water use efficiency. Hence it becomes essential to develop and adopt strategies and practices for more efficient use of water in rice cultivation

In the present study, we evaluated the response of four rice varieties to three different irrigation regimes The objectives were to determine how much water could be saved and to analyze the varietal performance on grain yield and economics.

MATERIALS AND METHODS

The field experiment was conducted at Regional Sugarcane and Rice Research Station, Rudrur, Professor Jayashankar Telangana State Agriculture University situated at an altitude of 286.3. m above mean sea level (MSL) at 180 49'41' latitude and 78056'45" E longitude. during *kharif* and *rabi* 2018-19.

Treatments and design

The experiment was laid out in a split plot design with three irrigation regimes as main plots and four different rice varieties as sub plots and replicated thrice. The treatment combination includes three irrigation regimes (I_1-irrigation of 5 cm when water level falls below 5 cm from soil surface in field water tube, I_2- irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tube and I_3- recommended submergence of 2-5 cm water level as per crop stage as main treatments and four popular rice varieties in the Telangana region V_1-RNR 15048 (Telangana Sona), V_2 - KNM 118 (Kunaram Sannalu),V_3-MTU 1001 (Vijeta) and V_4- BPT 5204 (Sambamashuri) as sub plots treatments respectively. The experimental plot size was 6 × 4.2 m. The 21days old seedlings of different rice varieties were transplanted by adopting a spacing of 15 × 15 cm. The experimental field was provided with proper irrigation channels, buffer channels and the individual plots were demarcated by bunds . The upper root zone of the experimental field was tilled with high puddling intensity. The experimental soil was sandy loam in texture, moderately alkaline in reaction, non-saline, low in organic carbon content, low in available nitrogen (N- 225.4 kg ha^{-1}), high in available phosphorous (P_2O_5- 76.5 kg ha^{-1}) and potassium (K_2O- 410.5 kg ha^{-1}) . A uniform dose of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied. The N, P and K were applied in the form basally in the form of urea, single super phosphate and muriate of potash respectively. The entire P fertilizer was applied as basal in the form of single super phosphate (16% P_2O_5). The K fertilizer was applied in the form of muriate of potash (60%

K_2O ha^{-1}) in two equal splits as basal and at panicle initiation stage. The fertilizer N was applied in the form of prilled urea (46% N) in three equal splits at basal, active tillering stage and at panicle initiation stage. Zinc was applied in the form of $ZnSO_4$ as foliar spray @ 2g lt-1 to the plots twice at 12 and 20 DAS. Carbofuran 3G @ 25 kg ha^{-1} were applied at 30 DAS. Other plant protection measures were taken up as and when required.

Details of treatments

Continuous standing water (5 cm) was maintained in all the plots up to 28 days after transplantation (DAT) to help recovery from transplanting shock and suppress weeds. In conventional method of irrigation (I_3) the field was kept flooded up to 3 cm depth from 15 DAT to panicle initiation and up to 5 cm depth of irrigation from panicle initiation to physiological maturity. The irrigation water was applied through plastic pipe from the source. The field water tubes (PVC tubes) of 40 cm length and 15 cm in diameter with perforations are inserted into the ground until 20 cm protrudes above the soil level. It enables farmers to monitor the water level inside the tube. Field water tubes were placed in each main plot to measure the depth of standing water and water tables in the field, either above the surface or below the surface. irrigation water was applied when the water level inside the pipe reached a predetermined position as per treatment. Water levels in the tube were measured by simple ruler. AWDI of 5 cm, when water level falls below 5 cm from soil surface in perforated (I1). AWDI of 5 cm, when water level falls below 10 cm from soil surface in perforated (I2). The field was kept flooded up to 3 cm depth from 15 DAT to panicle initiation and up to 5 cm depth of irrigation from panicle initiation to physiological maturity (I3). Irrespective of treatments from one week before to a week after flowering, the field was kept flooded, topping up to a depth of 5 cm as needed. After flowering, during grain filling and ripening, the water level was again allowed to drop again to 5-10 cm below the soil surface as per treatments. In all the irrigation regimes irrigation was with-held 15 days ahead of harvest.

The crop was harvested manually with the help of sickles. After harvesting the crop in each net plot of all treatments, threshing, cleaning and drying of the grain was done and weight of the grain and straw of each treatment was recorded and expressed as kg ha^{-1}. Quantitative information related to yield and all the yield contributing characters viz., plant height, effective tillers, length of the panicle, no. of filled and unfilled grains per panicle, 1000 grain weight, grain yield, straw yield, harvest index and water use efficiency and water productivity were analyzed to obtain the effect for AWD on rice production.

All the data were subjected to analysis of variance (ANOVA) as per the standard procedures. The comparison of treatment of means was made by critical difference (CD) at p=0.05.

Data collection

Data recording Germination count data m^{-2} was recorded in case of DSR at 10 days after seeding while in case of transplanting methods, number of plants m^{-2} were recorded at 8 days after transplanting. Plant height of 20 primary tillers selected randomly was measured from the base of the plant to the tip of the highest panicle from each of the experimental unit and then averaged. The numbers of panicle bearing tillers was recorded at harvest from an area of 1 m^2 from three different places in each plot and were averaged to calculate the number of tillers m^{-2} Twenty panicles of primary tillers were randomly selected from ear marked area in each plot at harvest time to determine the number of grains per panicle. 1000-grain weight of the normal kernels replicated from each experimental unit was recorded in grams using electrical balance. After harvesting and threshing, the clean rough rice was air dried, bulked and weighed. Moisture content in grain was determined by using LKB-PRODUK TERAB-Sweden Grain Moisture Meter. The grain weight was adjusted at 14% moisture content and the yield of clean rough rice was expressed in kg ha^{-1}

Grain yield (kg/ha) = *Plot yield kg* ×*MC adj* ×10,000/*plot size* × 1000

Where MC adj = 100−MC/100−86 and MC= grain moisture at harvest

The cost of inputs, labor charges and prevailing market rates of farm produce were taken into consideration in order to work out the economics.

Table 1. Grain yield ((kg ha^{-1}) and economics of rice varieties as influenced by irrigation regimes during 2018-19.

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Net returns Rs ha^{-1}		
	Kharif	*Rabi*	Pooled	*Kharif*	*Rabi*	Pooled	*Kharif*	*Rabi*	Pooled
Factor A (Irrigation regimes)									
I_1(AWD when water level falls below 5 cm in Boumans tube)	8026.300	8470.53	8248.41	8828.91	9317.58	9073.25	82747.59	90521.75	86634.61
I_2(AWD when water level falls below 10 cm in Boumans tube)	7342.49	7238.44	7515.09	8304.91	8228.29	8266.60	74837.00	77248.50	76042.76
I_3 (conventional Irrigation as per crop stage)	7632.73	7480.28	7685.60	8395.99	8512.34	8454.16	70597.75	72219.50	71408.45
SEm+	34.03	88.71	67.14	48.26	97.53	61.64	596.68	1515.05	829.06
CD (p=0.05)	137.20	357.64	198.16	194.59	393.23	248.49	2405.60	6108.13	3342.47
Factor B (Varieties)									
V_1 (RNR 15048)	7819.84	8223.98	8071.92	8381.83	9046.38	8714.10	76264.00	86725.45	81494.60
V_2 (KNM 118)	8116.65	8696.78	8406.73	8928.31	9566.51	9247.40	84791.22	94816.89	89803.91
V_3 (MTU 1001)	7687.45	7548.75	7618.09	8456.19	8303.62	8379.90	75847.22	73353.22	74600.06
V_4 (BPT 5204)	7244.73	7116.17	7318.72	8273.43	7827.76	8050.59	67340.66	65090.78	66215.84
SEm+	121.34	284.54	77.5	136.11	104.54	88.11	2123.98	1660.41	1510.77
CD (p=0.05)	363.40	95.03	228.82	407.54	313.00		6359.57	4971.57	4523.52
Interaction (AXB)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 1. Continued.

Treatments	BC ratio			Water productivity (kg ha mm^{-1})		
	Kharif	*Rabi*	Pooled	*Kharif*	*Rabi*	Pooled
Factor A (Irrigation regimes)						
I_1 (AWD when water level falls below 5 cm in Boumans tube)	1.45	1.90	1.67	6.11	5.58	5.85
I_2 (AWD when water level falls below 10 cm in Boumans tube)	1.40	1.44	1.42	6.63	5.69	6.16
I_3 (conventional Irrigation as per crop stage)	1.12	1.48	1.30	4.78	4.02	4.37
SEm+	0.01	0.18	0.09	0.38	0.05	0.21
CD (p=0.05)	0.04	NS	NS	NS	0.21	0.84
Factor B (Varieties)						
V_1 (RNR 15048)	1.34	1.74	1.54	6.48	5.55	6.08
V_2 (KNM 118)	1.49	1.89	1.68	6.54	5.87	6.21
V_3 (MTU 1001)	1.30	1.48	1.39	5.53	4.78	5.15
V_4(BPT 5204)	1.14	1.32	1.23	4.73	4.21	4.47
SEm+	0.03	0.03	0.02	0.15	0.06	0.08
CD (p=0.05)	0.10	0.08	0.075	0.47	0.18	0.25
Interaction (A × B)	NS	NS	NS	0.63	NS	1.12

Net return is also referred to as net profit and represents the actual income to farmer. It is calculated as follows:

Net return (Rs /ha) = Gross return (Rs /ha) – Cost of cultivation (Rs /ha).

Benefit: Cost ratio provides an estimate of the benefit derived from the expenditure incurred in adopting a particular cultivation practice. It is calculated by the following formula.

Benefit: cost ratio = Net return (Rs /ha) Total cost of cultivation (Rs /ha)

Effective rainfall was calculated by daily water balance sheet

Amount of water used: (Total number of irrigation × Total area × Depth of ponding water) + (Total rainfall)

% water saving: Water used in continuous irrigation (flooded) – Water used in AWD/Water used in continuous irrigation (flooded) × 100

RESULTS

Grain yield

Grain yield and straw yield of rice was significantly influenced by different rice varieties and irrigation regimes (Table 1). However, there was no significant effect of interaction between different rice varieties and irrigation regimes. During both the growing seasons, AWDI of 5 cm irrigation when water level falls below 5 cm in the field water tube (I_1) recorded significantly higher yield with mean yield of 8248.41 kg ha^{-1} over other iriigation regimes AWDI of 5 cm when water level falls below 10 cm in Boumans tube I_2 (7515.09 kg ha^{-1}) and recommended submergence as per crop growth stage I_3(7685.60 kg ha^{-1}).There was 4.72% yield enhancement with I_1 over I_3 which might be due to favourable growing and nutrition supply environment resulted in higher dry matter and increased uptake of nutrients which lead the plants with superior growth. These results are in line with findings of Thiyagarajan *et al*. (2002) and Geethalakshmi *et al*. (2009). Yield penalty of 170.51 kg ha^{-1} was observed with I_2 compared to I_3 indicating that irrigation of 5 cm when water level falls below 10 cm in Boumans tube has not met the crop water requirement (Bouman and Tuong 2001, Yadav *et al.* 2012).

Similar trend was observed for straw yield with significantly higher mean straw yield of 9073.25 kg ha^{-1} in AWDI of 5 cm irrigation when water level falls below 5 cm in the field water tube (I_1) followed by 8266.60 kg ha^{-1} and 8454.16 kg ha^{-1} in AWDI of 5 cm when water level falls below 10cm in Boumans tube I_2 and recommended submergence as per crop growth stage I_3 respectively. There was saving of water to the extent of 30% during *kharif* and 40% during *rabi* with irrigation when water level falls below 10 cm from soil surface in perforated tube over normal irrigation, but grain yield was reduced to the extent of 4-5% with this practice in both the seasons. But irrigation when water level falls below 5 cm in perforated tube recorded water saving to the tune of 16-20% with increase in grain yield to the extent of 5-6% over normal irrigation. Mao *et al.* (2001) stated that AWD conformed to the physiological water demand of paddy rice by rationally controlling water supply during rice‟s key growth stages so that irrigation water was cut down.

Among varieties studied, RNR 15048, KNM 118, MTU 1001 and BPT 5204, variety KNM 118 performed superior to other varieties with significantly higher mean grain yield of 8406.73 kg ha^{-1} followed by RNR 15048 8071.92 kg ha^{-1}.These two varieties being short duration (120-125 days) have performed better over other two varieties MTU 1001 (7618.09 kg ha^{-1}) and BPT 5204 (7318.72 kg ha^{-1}) which are of longer maturity group (135-150 days).

Economic analysis

Among the different irrigation regimes, net returns (Rs 86634.61 ha^{-1}) and benefit cost ratio (1.47) were significantly higher with AWDI of 5 cm irrigation when water level falls below 5 cm in the field water tube (I_1). AWDI of 5 cm when water level falls below 10 cm in Boumans tube I_2 recorded higher netreturns (Rs 76042.76 ha^{-1}) and benefit cost ratio (1.42) compared to recommended submergence as per crop growth stage I_3 (Rs 71408.45 ha^{-1}, 1.30). it is mainly due to cost saved in reduced number of irrigations. It is pertinent to mention that though I_2 recorded lower grain yield, cost saved in irrigation resulted in more economic returns over I_3.

Variety KNM 118 fetched significantly higher economic returns Rs 89803.91 ha^{-1} followed by RNR 15048 Rs 81494.60 ha.$^{-1}$ Least economic benefit was realised from variety BPT 5204 Rs 66215.84 ha^{-1}followed by MTU 1001 Rs 74600.06 ha^{-1}.Similar was the trend for benefit cost ratio with higher values recorded with KNM 118 (1.68) followed by RNR 15048 (1.54) and MTU 1001(1.39) and least with BPT 5204 (1.23).

Water use studies

Field water use mostly depends on irrigation frequen-

Table.2. Water use and water productivity effected by irrigation regimes and varieties during *kharif* 2018.

Varieties	Irrigation regimes Irrigation of 5 cm, when water level falls below 5 cm from soil surface in perforated field tube Total water use (mm) Eff. RF + Irrigation	Water productivity (kg ha mm^{-1})	Water saving compared to conventional practice (%)	Water productivity (kg ha mm^{-1}) Irrigation of 5 cm, when water level falls below 10 cm from soil surface in performed field tube Total water use (mm) Eff.RF + Irrigation	Water productivity (kg ha mm^{-1})	Water saving compared to conventional practice (%)	Recommended submergence of 2-5 cm water level as per crop stage Total water use (mm) Eff.RF + Irrigation	Water productivity (kg ha mm^{-1})
				Kharif 2018				
V1(RNR 15048)	1216	6.59	19.78	916	7.75	39.58	1516	5.11
V2(KNM 118)	1216	7.06	19.78	916	8.33	39.58	1516	5.37
V3(MTU 1001)	1366	5.76	18.00	1066	6.58	36.01	1666	4.48
V4(BPT 5204)	1516	5.03	16.51	1166	5.93	35.79	1816	3.96
		Average	18.52%		Average	37.74%		
				Rabi 2018				
V1(RNR 15048)	1450	6.00	21.62	1250	6.22	32.43	1850	4.57
V2(KNM 118)	1450	6.35	21.62	1250	6.60	32.43	1850	4.46
V3(MTU 1001)	1550	5.13	20.51	1350	5.30	30.76	1950	3.67
V4(BPT 5204)	1650	4.33	21.42	1450	4.46	30.95	2100	3.19
		Average	21.29%		Average	31.64%		

cy and the quantity of water used by the crop. Water input (irrigation plus effective rainfall) in different treatments varied between from 1216 mm to 1650mm in I_1 and 916 to 1450 mm in I_2 and 1516 to 2100mm in I_3 during *kharif* and *rabi* respectively.The recommended submergence of 2-5 cm water level as per crop stage (I_3) consumed more water among different irrigation regimes. This was followed by irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube (I_1) and irrigation of 5 cm when water level falls below 10 cm from soil surface in field water tube. Increased consumptive use of water registered under recommended submergence of 2-5 cm water level as per crop may be attributed to more frequent irrigations and deep percolation losses. On the contrary, lesser consumptive use of water was observed under AWDI 5 cm when water level falls below 10 cm from soil surface in field water tube was due to lesser number of irrigations. There was saving of water to the extent of 18.52% during *kharif* and 21.29% during *rabi* with average water productivity of 5.85 kg ha mm^{-1} irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube (I_1) and 37.74% during *kharif* and 31.64% during *rabi* with average water productivity of 6.16 kg ha mm^{-1} with irrigation of 5 cm when water level falls below 10 cm from soil surface in field water tube compared to recommended submergence of 2-5 cm water level as per crop stage (4.37 kg ha mm^{-1}. Chapagain and Yamaji (2010) recorded higher water productivity (1.74 g L^{-1}) in AWD compared to continuously flooded rice (1.23 g L^{-1}).Water productivity of continuous submergence (0.56 kg m^{-3}) was lowest as compared to AWD - Flooding to a water depth of 5 cm when water level drops to 10 cm below ground level (0.94 kg m^{-3}) (Kishor *et al.* 2017).Varieties KNM 118 and RNR 15048 being shorter duration recorded higher water productivity of 6.12 kg ha mm^{-1} and 6.08 kg ha mm^{-1} respectively and least water productivity was recorded with BPT 5204 4.17 kg ha mm^{-1} followed by MTU 1001 5.15 kg ha mm^{-1} which may be attributed to lower grain yield and longer duration of these varieties (Table 2.).

DISCUSSION

Reduced water use in AWD systems can be attributed, at least in part, to reduced percolation and seepage. Percolation and seepage are significantly reduced in the absence of flood water; For example, in a sandy loam soil in India, Sharma *et al.* (2002) measured 51% of the total water input in the rice field being lost by percolation, while in clayey California rice soils, Linquist *et al.* (2015) reported about 15% of applied water being lost to percolation and seepage. Another important in-built advantage with AWD which is critical in the context today's much scared global warming impacts is that it also has the potential of reducing greenhouse gas (GHG) emissions from rice fields, especially methane (Wassmann *et al.* 2010 and Li *et al.* 2006). Linquist *et al.* (2014) reported that AWD reduced global warming potential (CH_4 + N_2O) by 45-90% compared to continuously flooded systems.

In the present study, experimental site was sandy loam where AWDI of 5 cm when water level falls below 5 cm from surface soils was more productive and economic. Similar results for sandy loam soils were reported by (Sathish *et al*. 2017). Hence it is established that for sandy loam soils of Telangana state, I_1-irrigation of 5 cm when water level falls below 5 cm from soil surface in field water tube can be considered safe AWD. It is also observed that since AWD was not imposed through out the growing season and crop water requirement during peak growing season was met by submergence of 5 cm of irrigation giving 4.72% yield advantage compared to conventional practice. When AWD was conducted only during the vegetative or reproductive phase. There was no yield reduction compared to an 8.1% yield reduction when it was practiced throughout the whole season there. (Daniela *et al*. 2017) With regard to varieties tested, variety KNM 118 a coarse grain medium duration variety was more productive and economic followed by RNR 15048 which is superfine and short duration variety. Selection of these varieties depend upon the preference of farmers.

CONCLUSION

AWD appears promising and farmer approachable technology for irrigating rice over other criteria for irrigation. Potential of AWD to reduce water inputs without jeopardizing yield and reduced GHGs emissions draw the attention towards sustainable rice cultivation. In Telangana state in heavy black soils cotton and soybean is grown where as in sandy loam soils rice-rice is practiced. Hence present study has wide range of adaptability. However it need refinement for every ecosystem to make it more farmer friendly.

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