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Research Article

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Impact of Irrigation Practices on Production and Water Productivity of Transplanted Rice Under NSP Canal Command Area

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Abstract

The two years adoptive research work carried out to study the effect of alternate wetting and drying method of irrigation and submerged irrigation method (Control) on water use, water productivity and yield of paddy during *kharif* season (June to November, 2014-15 and 2015-16) in farmer's field under NSP canal command area of Khammam district, Telangana. Soil was clay loam, mild alkaline, low in available nitrogen, medium in available Phosphorus and Potassium. Field capacity and permanent wilting point of soil was 28.7, 14.9%, respectively. Results were shown as highest effective tillers and number of panicles per square meter inturn resulted as higher grain and straw yields in alternate wetting and drying method of irrigation over the submerged irrigation method. Over the years, lower water input (mm ha^{-1}) at 795 mm to 1180 mm and higher water productivity at 0.52 to 0.66 kg m^{-3} resulted with alternate wetting and drying method of irrigation and it saved the water at 20.2 to 23.4% over control. Due to intermittent irrigation application to maintain the soil saturation at critical stages avoided moisture stress and resulted better crop growth and produced higher yields with lower water usage inturn saved the irrigation water and it would get the higher water productivity in alternate wetting and drying method irrigation. This may provide the valuable information on the aspect of alternate wetting and drying method of irrigation to get the higher yields and water productivity in paddy.

Keywords: Alternate wetting and drying, grain yield submerged condition, water productivity

1. Introduction

Rice (*Oryza sativa* L.) is the most widely consumed cereal grain on earth and is the staple food for over half of the world's population. Asia's food security depends mainly on irrigated lowland rice fields, which produce three-quarters of all rice harvested. At present the productivity of Asia's irrigated rice systems is increasingly threatened by water scarcity. In the next 25 years, 15 to 20 million hectares of lowland rice in Asia are projected to suffer from water scarcity. In India, rice is the most important staple and extensively grown food crop it occupying an area of 127.6 million hectares with a production of 284.8 million tonnes and productivity of 2.2 t ha^{-1} (Annonymous, 2018). It is estimated that by 2030 at least 140-150 million tons of milled rice is to be produced in India to

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maintain the present level of self sufficiency (Shetty et al., 2013). According to the projections made by the Population Foundation of India, India's population will be 1,546 million by the end of 2030 (Anonymous, 2011).

In Telangana state most of the agricultural production depends upon the distribution of rainfall, ground water level, canals and bore wells. Rice is being cultivated at 82% of total irrigation potential area of 1.04 lakhs hectares of Nagarjuna Sagar Project (NSP) canal command. Paddy is the staple food crop of Telangana state and it is one of the major crops in the state and the area under the crop is 1.97 million hectares with a production 6.25 million tonnes and productivity of 3.2 t ha^{-1} (Anonymous, 2018).

Irrigated agriculture is by far the biggest user of freshwater, accounting for more than 70% of water withdrawals worldwide. More than 50% of all water used for irrigation is used to irrigate rice (Barker et al., 1999). This ecosystem, however, is increasingly threatened by water shortage. The water-use efficiency of rice is much lower than that of other crops. On an average, 2500 litres of water is used, ranging from 800 litres to more than 5000 liters to produce 1 kg of rough rice (Bouman, 2009 and Shantappa et al., 2016).

Water is one of the essential inputs for crop production as it affects plant development by influencing its vital physiological processes. For realizing potential yield of any crop, it must not be allowed to suffer from water stress at any of the critical growth stages. Water stress, especially at reproductive stages, may substantially reduce the yield (O'Toole, 1982). On the other hand, water should also be utilized efficiently for getting higher yield per unit of water applied. Water management has a significant influence on rice growth, grain production and water productivity. There is a possibility of reducing water requirement of rice without affecting grain yield in comparison to continuous submergence. Intermittent irrigation appears to be as effective as continuous submergence. Several studies reported a positive effect of intermittent aerobic conditions on flooded rice growth indicating that continuous flooding may not be the best method of irrigating rice (Lin et al., 2005; Horie et al., 2005; Mahajan et al., 2019). Flood-irrigated rice utilizes two or three times more water than other cereal crops such as wheat and maize.

Due to increasing water scarcity, a shifting trend towards less-water demanding crops against rice is noticed in most parts of the India and this warrants alternate methods of rice cultivation that aims at minimal use of water and high crop productivity. Increasing water scarcity is becoming real threat to rice cultivation. Hence water-saving technology maintains soil health and sustainability as well as economically beneficial, needs to be developed. Practice of alternate wetting and drying method of irrigation technology is an alternative practice to solve water crisis, and as a methodology for increasing the productivity of irrigated rice (Subramaniam et al., 2013; Tapsoba and Wang, 2018). Hence, this adoptive research carried out in farmer's fields to study effect of alternate wetting and drying method (AWD) of irrigation technology on growth, yield and water productivity of transplanted rice under NSP canal command area.

2. Materials and Methods

The adoptive research was conducted at farmer's field of Nagarjuna Sagar Projest (NSP) canal command area under Telangana State Water Sector Improvement Project. The five locations are located at Upper/Tail, Upper/mid and Tail/upper reaches of NSP canal command area of Khammam district ($16^0$45' and $18^0$35' N and $79^0$47' and $81^0$47' E and 122 m above sea level), Telangana state. The district has the mean maximum and minimum temperature of 34.6 °C and 23.2 °C respectively. South-west monsoon normally reaches around June every year. The normal rainfall of the district is 1015 mm, June to October are the usual rainy months accounting for 79% of the total rainfall. Soil of the experimental field was clay loam in texture, categorized as medium in organic C (0.65%), low in available nitrogen (224.4 kg ha^{-1}), medium in available phosphorus (15.6 kg ha^{-1}) and medium in available potassium (148.5 kg ha^{-1}). The available Zn content was 0.62 ppm. Soil reaction was in mild alkaline (pH 7.4-7.8). Field capacity and permanent wilting point moisture content of soil was 28.7, 14.9%, respectively. The annual total rainfall received for the year (June, 2014-May, 2015) was 526.1 mm against decennial rainfall of 1011 mm and during crop period received rainfall was 228.7 mm (from 26-08-2014 to 17-01-2015). The mean maximum temperature for the year was 35˚C, while the mean minimum temperature was 25.6˚C. During crop period mean maximum temperature was 32.2˚C and minimum temperature was 23.8˚C. The annual total rainfall received for the year (June, 2015-May, 2016) was 725.1 mm against decennial rainfall of 902.4 mm and during crop period received rainfall was 317.4 mm (from 08-07-2015 to 27-11-2015). Mean maximum temperature was 35.1˚C and minimum temperature was 30.3˚C recorded for this year. During crop period mean maximum temperature was 32.4˚C and minimum temperature was 27.7˚C.

The rice variety BPT 5204 (Samba Mashuri) was sown for nursery in 1st year of study on 28th August, 2014, transplanted on 21st September, 2014 and harvested on 17th January, 2015. In 2nd year of study it was sown for nursery on 08th July, 2015, transplanted on 5th August, 2015 and harvested on 27th November, 2015. The recommended doses of inorganic fertilizers were given at the rate of 120:60:40 kg N, P_2O_5 and

K_2O ha^{-1} in the form of urea, di-ammonium phosphate (DAP) and murate of potash (MOP). The nitrogen was given in three equal splits *i.e*., 50% at basal and remaining 50% was divided into two equal splits and applied at maximum tillering and panicle initiation stages, while P_2O_5 and K_2O were applied along with Zinc at 50 kg ha^{-1} as basal doses.

Irrigation applied by using 5 HP motor to draw the water from farm pond. The discharge rate of water from motor was calculated by using 100 liter plastic drum and it indicated as number of liters discharged per hour and quantified as total water used. The depth of irrigation water applied at each irrigation was fixed at 60mm. Under continuous submergence treatment 5 cm depth of water was maintained throughout the crop growth period. Flooding irrigation treatment plots were kept flooded whenever required to maintain a layer of 5–6 cm depth of water. In saturation treatment plots 2 cm of water maintained until maturity and in AWD every 5 days interval plots were flooded up to 5 cm of standing water, every time water was applied by using IRRI pipe and all the plots were drained 15 days before harvest. Weeds were controlled with pre-emergence application of butachlor @ 2.5 l ha^{-1} followed by post-emergence application of bispyribac-sodium @ 250 ml ha^{-1} and manual weeding was done at tillering stage.

The number of effective tillers and panicles was counted from one square meter and filled grains $panicle^{-1}$ recorded from five hills at harvest stage. 1000 grain weight recorded as test weight (g) at harvest. For computing grain and straw yields, the crop from the net profit area of 20 m^2 was harvested plot-wise dried, thrashed and weighed. All yields were determined at 14% moisture content. Observations on yield attributes and yield characters were recorded at harvest of the crop. Water productivity was worked out by dividing the grain yield with total water used.

Field observation data were compiled using Microsoftexcel software. The collecting data of each sample was analyzed separately using standard technique to evaluate the variance of treatment effects. The student's t-test was employed to test the significance of difference between the two water management treatments. The observed data on the crop were statistically analysed with the help of 'MS-excel' software. The experimental data was interpreted by using the standard technique of analysis of variance (ANOVA) by Gomez and Gomez (1984) standard procedures. The significance of treatment means was compared at 5% probability level with using t-calculated value and t-table value.

3. Results and Discussion

3.1. Yield attributes and yield

Flooded irrigation with standing water throughout the rice growing season was used in the traditional rice cultivation. Recent evidence suggests that there is no necessity to maintain continuous standing water since irrigated rice had formed adaptability to the intermittently flooded conditions as semi-aquatic in the process of rice development. Water application during rice cultivation has certain degree of changeability and flexibility. 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. Besides, with wetting and drying cycles, AWD strengthens the air exchange between soil and the atmosphere thus sufficient oxygen is supplied to the root system to accelerate soil organic matter mineralization and inhibit soil N mobilization, all of which should increase soil fertility and produce more essential plant-available nutrients to favour rice growth (Bouman et al., 2007; Dong et al., 2012; Tan et al., 2013).

Results obtained in accordance with this concept, irrigation at different methods greatly influenced all the yield attributes like number of effective tillers m^{-2}, number of panicles m^{-2}, filled grains $panicle^{-1}$ and test weight (g) (Table 1). Significantly high values of all yield attributes recorded with the alternate

Table 1: Influence of alternate wetting and drying (AWD) method of irrigation on yield attributes in transplanted rice

Treat-ments	Effective tillers m^{-2}			Number of panicles m^{-2}			Filled grains $panicle^{-1}$			Test weight (g)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	430*	334*	382*	369*	279*	324*	177*	193*	185*	12.5*	13.8*	13.2*
T_2	411	319	365	361	268	315	160	178	169	11.9	12.7	12.3
t-cal	0.56	0.35	0.42	0.81	0.55	0.67	0.45	0.14	0.07	0.10	0.08	0.47

T_1: Alternate wetting and drying (AWD); T_2: Control/submerged condition; *: Statistically different at (p=0.05) level of significance

wetting and drying method of irrigation. The number of effective tillers m^{-2} recorded as higher in alternate wetting and drying (430, 334 and 382) than submerged condition (411,319 and 365) during 2014-15, 2015-16 and pooled respectively. More number of panicle m^{-2} was recorded in alternate wetting and drying (369, 279 and 324) than submerged condition (361, 268 and 315) during both the years and pooled respectively. Similarly recorded as higher filled grains panicle^{-1} in alternate wetting and drying (177, 193 and 185) than submerged condition (160, 178 and 169). Test weight was also higher in alternate wetting and drying (12.5, 13.8 and 13.2) than submerged condition (11.9, 12.7 and 12.3) during both the years and pooled respectively. This might be due to the intermittent irrigation in alternate wetting and drying that creates favorable soil physical, chemical and biological properties making the plant to grow under anaerobic situation and deeper rooting depth and creates favorable micro-climate for availability of micronutrients, good anchorage to root system and effective use of applied fertilizers by checking the leaching loss. Similar results were found with yadav et al., 2011; Shantappa et al., 2014 and Mote et al., 2017.

Grain yield is the complex character and it depends on many morphological and bio-chemical events that occur within plant during the crop growth and development. Optimization of the physical inputs through appropriate bio-hydro chemical technologies along with proper water management practices can results better yields. Significantly recorded the higher grain yield of 5212, 6143 and 5678 kg ha^{-1} and straw yield of 7280, 7758 and 7519 kg ha^{-1} in alternate wetting and drying than submerged condition which was recorded as grain yield of 4822, 6032 and 5427 kg ha^{-1} and straw yield of 6884, 7497 and 7191 kg ha^{-1} during 2014-15, 2015-16 and pooled respectively. Harvest index of alternate wetting and drying was 41.7, 44.1 and 43.0% and submerged condition recorded as 41.2, 44.4 and 43.0% during 2014-15, 2015-16 and pooled respectively (Table 2 and Figure 1). The higher grain yield was owing to

Table 2: Influence of AWD method of irrigation on grain and straw yield (kg ha^{-1}) and harvest index (%) in transplanted rice

Treat-ments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest index (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	5212	6143	5678	7280	7758	7519	41.7	44.1	43.0
T_2	4822	6032	5427	6884	7497	7191	41.2	44.4	43.0
t-cal	0.59	0.89	0.67	0.69	0.75	0.67	-	-	-

T_1: Alternate wetting and drying (AWD); T_2: Control/submerged condition; *: Statistically different at (p=0.05) level of significance

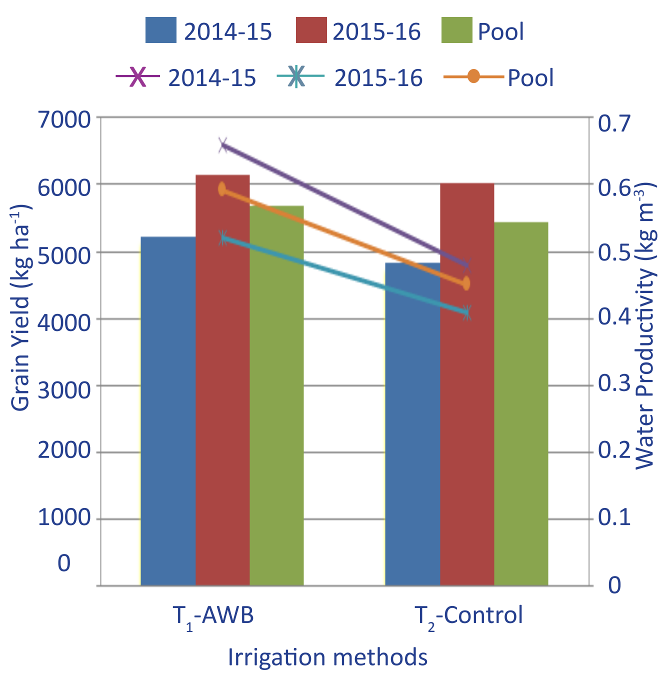

Figure 1: Grain yield (kg ha^{-1}) and water productivity (kg m^{-3}) comparison in alternate wettingand drying (AWD) and submerged condition (control)

outcome of higher values of yield-attributing characters. This might be due to intermittent irrigation applied to maintain soil at saturation through optimum irrigation schedule which inturn resulted as significantly higher crop growth rate and yield with no moisture stress. It is in conformity with findings of several research workers (Maheswari et al., 2007; Mote et al., 2017; Hayat Ullah et al., 2019; Shekara et al., 2010; Anning et al., 2019).

3.2. Water usage and water productivity

Studies have demonstrated that excessive irrigation with large depths of standing water in paddy fields would lead to high water losses by evaporation, percolation, seepage and surface runoff. Therefore, greater water productivity was consistently observed in AWD irrigation method than continuous flooding irrigated crop (Bouman et al., 2007; Mote et al., 2017). Our results were in accordance with these studies significantly decreased water losses without concurrent reduction in grain yield.

The variation in water usage, water saving and water productivity under different irrigation methods are presented in Table 3. Irrigation water productivity was higher in AWD treatment as 0.66, 0.52 and 0.59 kg m^{-3} than submerged condition it recorded as 0.48, 0.41 and 0.45 kg m^{-3} (Figure 1) this might be due to larger reductions in quantity of water used in alternate wetting and drying as 795, 1180 and 988 mm ha^{-1} but the quantity of water used was higher in submerged condition as 1020, 1456 and 1238 mm ha^{-1} in 2014-15, 2015-16 and pooled respectively (Figure 2). Further, per cent of water saved in AWD was found to be 22, 23.4 and 20.2% over submerged condition during 2014-15, 2015-16 and pooled respectively (Figure 3). Similar observations were found with results of Bouman et al., 2005; Yadav et al., 2011;

Table 3: Comparison of water inputs as influenced by irrigation method in transplanted rice

Treat-ments	Water input (mm ha^{-1})			Water productivity (kg m^{-3})			% of water saved over control		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	795	1180	988	0.66	0.52	0.59	22.0	23.4	20.2
T_2	1020	1456	1238	0.48	0.41	0.45	-	-	-

Note: water data not analyzed statistically

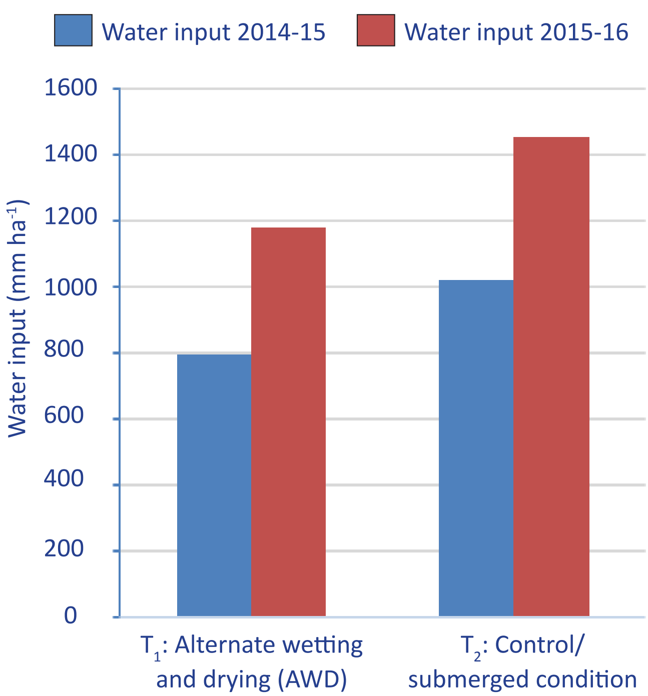

Figure 2: Water inputs under alternate wetting and drying (AWD) and submerged condition

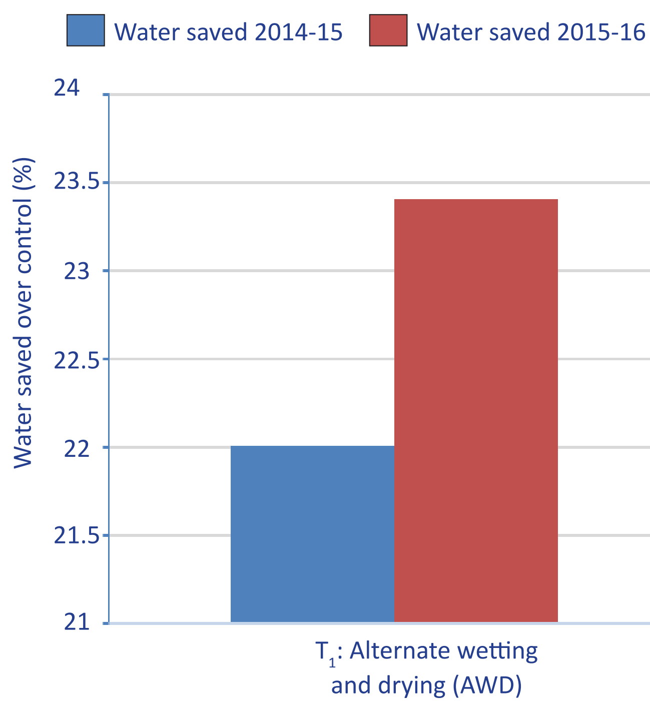

Figure 3: Percentage of water saved over control under alternate wetting and drying (AWD)

Chapagain and Yamaji, 2010; Randriamiharisoa and Uphoff, 2002; Thiyagarajan et al., 2002; Mote et al., 2017; Hayat et al., 2019; Anning et al., 2019.

4. Conclusion

The alternate wetting and drying (AWD) method of irrigation can be advocated in transplanted rice due to realization of higher grain yield (5212 to 6143 kg ha^{-1}) and water productivity (0.52 to 0.66 kg m^{-3}) along with considerable water saving of 20.2 to 23.4% over the control without any significant yield decline under clay loam soils of Khammam district, Telangana State of India.

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