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INFLUENCE OF DIFFERENT CROP ESTABLISHMENT METHODS AND IRRIGATION SCHEDULING ON YIELD AND ECONOMICS OF RICE (*ORYZA SATIVA* L.)

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ABSTRACT

The investigation on influence of different crop establishment methods and irrigation scheduling on yield and economics of rice (*Oryza sativa* L.) was carried out in sandy clay soils at Agriculture Research Station, Kampasagar, Nalgonda district for two *kharif* seasons of 2021 & 2022. The experiment was laid out in split plot design with three main plots and 3 sub-plots replicated thrice. The analysed data pertaining to yield and economics were influenced by various treatments. From results it can be concluded that among establishment methods wet direct seeded rice (WDSR) showed significantly highest grain and straw yield during both the years of study *i.e.*, 6446 kg ha^{-1} and 8858 kg ha^{-1} on mean basis, respectively which is on par with TPR i.e., 6370 kg ha^{-1} and 8491 kg ha^{-1} on mean basis, respectively. However, non-significant difference was reported among irrigation scheduling with higher yield seen with continuous submergence (CS) followed by alternate wetting and drying irrigation (AWDI) and saturation. Similar trends were depicted in case of economics with highest gross and net returns with WDSR *i.e.*, 141613/- and 88613/- on mean basis, respectively. Lower yields and returns were observed with dry direct seeded rice (DDSR) for both the years of study. Contrastingly, B:C ratio is highest in WDSR (2.69) followed by DDSR (2.53) and lowest in TPR (2.38), respectively.

Key words : Yield, Alternate wetting and drying, Dry direct seeded rice, Establishment methods, B:C ratio.

Introduction

Rice (*Oryza sativa* L.) is an important cereal crop of developing countries and staple food of more than half of the world's population (Shekara *et al.*, 2010). In terms of global paddy production in 2024-25, China led the way with 145.3 million metric tonnes, followed by India with 145.00 million metric tonnes (WAP, 2025). In India, rice occupied an area of 50.0 million hectares with a productivity of 4.35 t ha^{-1} (DES, 2025). In Telangana, it was grown in 26.3 lakh hectares during *kharif* (*Vanakalam*) with production and productivity of 15.3 million metric tonnes and 5.2 t ha^{-1}, respectively (GoT, 2024).

However, the increasing demand for rice production, coupled with diminishing water resources, poses a significant challenge to sustainable cultivation. According to the Food and Agriculture Organization (FAO), rice cultivation accounts for 34–43% of global irrigation water use, making it one of the most water-intensive crops. In countries like India and China, where rice is a major agricultural commodity, water scarcity is becoming a critical issue due to declining water availability and the growing competition for water resources (Surendran *et al.*, 2021). Projections indicate that by 2030, the demand for water in India could exceed the supply by 50%, making water-efficient rice cultivation practices imperative (Gulati *et al.*, 2019).

To address this challenge, alternative water-saving rice production techniques, such as Direct Seeded Rice (DSR), are gaining attention. DSR offers several advantages over conventional puddled transplanted rice (PTR), including reduced water usage, labor savings, improved soil structure and lower greenhouse gas emissions (Kaur *et al*., 2024). By eliminating the need for continuous flooding and utilizing techniques like alternate wetting and drying (AWD), DSR helps optimize water use while maintaining comparable yields. Given the pressing need for sustainable rice production, exploring efficient crop establishment methods and irrigation practices is essential for ensuring food security and environmental sustainability in the coming decades (Kumar *et al*., 2018).

Moreover, due to higher irrigation water requirement of rice as compared to other cereal crops, a water-saving irrigation technology assumes importance to deal with water scarcity and its sustainability. There are various water - saving technologies which help to cope with water scarcity in irrigated environments. This water - saving technologies enhance the water productivity by reducing unproductive seepage and percolation losses and to a lesser extent by reducing evaporation (Bouman *et al*., 2005). Among different water saving technologies Alternate Wetting and Drying (AWD) is one which saves water to the extent of 20-50 per cent compared to farmers practice of continuous flooding (Avil Kumar and Rajitha, 2019). In India, rice is mainly grown under puddled transplanted rice (PTR), wet and dry direct seeded rice (DSR). The dry DSR method of rice establishment is taken up to minimize outflows from the rice field by growing the crop as upland crop like wheat or maize. In this system, the rice is grown in non-puddled and non-saturated soil (i.e., aerobic condition) without flooding the field. Bouman (2007) observed that, when rice is grown as an upland crop in areas with high seepage and percolation rates, a large amount of water is being saved at the field level. DSR rice farming is very effective in minimizing water losses by seepage, percolation and evaporation and saves considerable amount of water used for puddling activity besides restoration of soil structure which gets affected due to puddling activities in System of Rice Intensification (SRI) and conventional puddled cultivation methods.

This article explores the impact of water scarcity on rice cultivation and highlights innovative strategies to improve water productivity and ensure the sustainability of rice farming in the face of global environmental challenges.

Materials and Methods

The field experiment was conducted during *kharif* seasons of 2021 and 2022 at the Agriculture Research Station, Kampasagar, Nalgonda district of Telangana state. The farm is geographically situated in the southern part of Telangana at $16^0$51'9.559'' N latitude and 79°28'26.581" E longitude at an altitude of 126.93 m above mean sea level and falls under Southern Telangana Agro-climatic Zone (STZ) of Telangana.The experimental field was sandy clay in texture with a pH of 8.0 and EC of 0.27 dS m^{-1}, low in organic carbon (0.41%) and available nitrogen (237.7 kg ha^{-1}), high in available phosphorus (27.1 kg ha^{-1}) and potassium (369.3 kg ha^{-1}). The experiment was laid out in split- plot design with three different rice establishment methods as main plot treatments *viz*., Dry direct seeding with seed drill (M_1-DDSR), Wet direct seeding with drum seeder (M_2WDSR) and manual transplanting (M_3-TPR) and three irrigation treatments as sub-plots *viz*., Continuous submergence (I_1-CS), Maintaining saturation after disappearance of ponded water (I_2-Saturation) and Alternate Wetting and Drying Irrigation (AWDI) of 5 cm when water level in pipe falls 5 cm below surface (I_3). The experimental field was provided with irrigation channels, buffer channels and the individual plots were demarcated by bunds. Each plot was bounded by 0.2 m high earthen bunds with polythene sheet lining which extended from the top of the bund to a depth of 0.5 m below the soil surface to minimize lateral movement of water through and below the bunds. There was also a 1 m wide buffer between all plots to further reduce the possibility of interference between plots. The irrigation water measured with the help of water meter. Main field was ploughed twice with cultivator and rotavator to obtain fine tilth. In DDSR sowing rice seeds was done using a tractor-drawn seed drill @ 25 kg seed ha^{-1} on well moistened soils and in WSR and TPR @ 50 kg seed ha^{-1} after ploughing, fields were flooded and puddled with tractor mounted cage wheels and levelled with rotovator. Prior to sowing, the seeds were soaked for 12 hours in water. After draining out the water, seeds were incubated for sprouting. In WSR well sprouted seeds were sown on following day through four-row drum seeder with a row to row spacing of 30 cm and in TPR sprouted seeds were broadcasted uniformly in nursery beds. In conventional transplanting (TPR) 25 days old rice seedlings were transplanted, with 2 seedlings per $hill^{-1}$ with spacing of 15 cm × 15 cm. The nutrient management was done as per recommendation made in package of practices for nursery bed preparation was 10-5-5 kg of $N:P_2O_5:K_2O$ per 1000 m^{-2} and for all the three rice establishment methods RDF *i.e.*, 120-60-40

N, P_2O_5 and K_2O kg ha^{-1}, respectively. The entire P fertilizer was applied as basal in the form of DAP (46 % P_2O_5 + 18 % N). The K fertilizer was applied in the form of muriate of potash (60 % K_2O) in two equal splits as basal and at panicle initiation stage. The fertilizer N was applied in the form of urea (46 % N) in three equal splits at basal, active tillering stage and at panicle initiation stage in DDSR and for WSR and TPR fertilizer N was applied in three equal splits at 15-20 DAS, active tillering stage and at panicle initiation stage.

Statistical analysis

The data on various parameters studied during the investigation were statistically analysed as suggested by Gomez and Gomez (1984). Wherever statistical significance was observed, critical difference (CD) at 0.05 level of probability was worked out for comparison. Non-significant comparison was indicated as 'NS'.

Results and Discussion

Grain yield (kg ha^{-1})

Among different establishment methods, WDSR (M_2) recorded highest grain yield during *kharif* 2021, 2022 and on mean basis *i.e.*, 6335, 6557 and 6446 kg ha^{-1}, respectively and it has shown on par with TPR (M_3) of rice *i.e.*, 6216, 6524 and 6370 kg ha^{-1}, respectively. Significantly, lower grain yield was obtained with DDSR (M_1) during *kharif* 2021, 2022 and on mean basis i.e., 5902, 6095 and 5999 kg ha^{-1}, respectively. Wet direct seeding with drum seeder (M_2) in rice recorded 7.3 %, 7.6 % and 7.5 % higher grain yield over dry direct seeding with seed drill (M_1) during *kharif* 2021, 2022 and on mean basis.

Higher grain yield in WDSR might be attributed by faster crop establishment and a longer tillering period better vegetative growth, higher number of tillering and root growth, increased number of productive tillers m^{-2} and filled grains $panicle^{-1}$ resulting in higher grain yield. The early establishment, growth and development of the crop, as well as irrigation methods, may be responsible for the increase in grain production in drum seeded rice. Lower yields in DDSR may be attributed due to lower effective tillers which resulted in more sterile spikelet's and chaffy grains (Lavanya and Reddy, 2019). These results are in line with findings of Kaur and Singh (2017) and Singh (2008).

In case of irrigation scheduling non-significant effect has been seen with yield of rice during both the years *viz.*, *kharif* 2021, 2022 and on mean basis (Table 1). However, continuous submergence (I_1) registered higher grain yield (6226, 6444 and 6335 kg ha^1 during *kharif* 2021, 2022 and onmean basis, respectively) followed by AWDI of 5 cm when water level in pipe falls 5 cm below

Table 1 : Yield and HI of rice as influenced by different establishment methods and irrigation scheduling during *kharif* 2021 & 2022.

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest Index		
Main	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
M_1: DDSR	5902	6095	5999	8478	8831	8643	41.05	40.84	40.97
M_2: WDSR	6335	6557	6446	8643	9073	8858	42.29	41.95	42.12
M_3: TPR	6216	6524	6370	8259	8723	8491	42.99	42.80	42.89
SEm±	61	73	63	47	66	55	0.38	0.39	0.37
CD (P=0.05)	241	287	247	185	258	215	NS	NS	NS
Sub									
I_1: CS	6226	6444	6335	8542	8994	8757	42.17	41.76	41.99
I_2: Saturation	6115	6317	6216	8455	8841	8648	41.95	41.66	41.80
I_3: AWDI	6112	6415	6264	8383	8791	8587	42.20	42.17	42.19
SEm±	92	98	73	138	100	103	0.59	0.50	0.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
SEm±	144	157	121	200	156	156	0.91	0.81	0.74
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
SEm±	160	170	126	239	173	179	1.02	0.86	0.79
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

DDSR: Dry direct seeding of rice with seed drill, **CS:** Continuous submergence, **WDSR:** Wet direct seeding of rice with drum-seeder, **AWDI:** Alternate wetting and drying irrigation, **TPR:** Manual transplanted puddled rice.

surface (I_3) *i.e.*, (6112, 6415 and 6264 kg ha^{-1}, respectively) and lower yields observed with maintaining saturation (I_2) i.e., irrigation after disappearance of ponded water (6115, 6317 and 6216 kg ha¹ during *kharif* 2021, 2022 and on mean basis, respectively).

Rice plants under AWDI and saturation irrigation have demonstrated performance comparable to continuous submergence, indicating that maintaining standing water continuously is not always necessary. This is attributed to the semi-aquatic nature of irrigated rice, which has adapted to intermittent flooding conditions over time (Mote *et al.*, 2017). One of the key physiological responses to intermittent irrigation is the role of cytokinins, which are known to promote cell division and delay senescence. Increased cytokinin levels in spikelets during reflooding under moderate soil drying conditions may contribute to an improved grain-filling rate and higher grain weight by enhancing sink strength through endosperm cell division, regulating carbon assimilation from source to sink, and upregulating the expression of genes encoding key enzymes involved in the sucrose-to-starch pathway in the grains, such as cell wall invertases (Archana *et al.*, 2022). Furthermore, intermittent irrigation can influence hormonal changes, including an increase in cytokinin levels in the leaves during reflooding, potentially enhancing photosynthetic activity and leading to better grain filling of spikelets. Additionally, mild soil drying during cyclic intermittent irrigation may elevate abscisic acid (ABA) accumulation in rice plants, which can further improve grain filling. A higher ABA level during the grain-filling stage under AWD irrigation regimes may increase the grain-filling rate of spikelets, enhance the remobilization of pre-stored assimilates from vegetative tissues to grains, and reduce stomatal conductance, ultimately leading to an increase in grain weight (Duvvada *et al.*, 2020). These physiological and biochemical responses suggest that controlled water management strategies such as AWD can not only conserve irrigation water but also optimize rice growth and yield by leveraging the plant's inherent adaptive mechanisms.These results are in line with findings of Chapagain and Yamaji (2010), Chandra and Kumar (2020). The findings align with previous research, confirming that consistent water management through submergence significantly impacts crop performance, resulting in higher grain yields.

The interaction effect of different establishment methods and irrigation scheduling on grain yield during both the years *viz.*, *kharif* 2021, 2022 and on mean basis was found to be non-significant.

Straw yield (kg ha^{-1})

The interaction effect of different establishment methods and irrigation scheduling on straw yield during both the years *viz.*, *kharif* 2021, 2022 and on mean basis was found to be non-significant.

Straw yield of rice was significantly influenced by different establishment methods and irrigation scheduling in both the years (Table 1). Among different establishment methods, WDSR (M_2) recorded highest straw yield during *kharif* 2021, 2022 and mean of two years i.e., 8643, 9073 and 8858 kg ha^{-1}, respectively and it has shown on par with TPR (M_3) of rice *i.e.*, 8259, 8723 and 8491 kg ha^{-1}, respectively. Significantly, lower straw yield was obtained with DDSR (M_1) during *kharif* 2021, 2022 and mean of two years *i.e.*, 8478, 8831 and 8643 kg ha^{-1}, respectively. WDSR (M_2) in rice recorded 1.9 %, 2.7 % and 2.5 % higher straw yield over DDSR (M_1) during *kharif* 2021, 2022 and mean of two years.

Higher straw yield in WDSR may be attributed to more tillers per unit area which was apparently related to their higher plant height and tiller density and greater accumulation of dry matter in this particular treatment. These results are in line with findings of Lavanya and Reddy (2019), Shabana *et al.* (2019) and Padma *et al.* (2023).

Irrigation scheduling has shown non-significant influence on the straw yield of rice during both the years *viz.*, *kharif* 2021, 2022 and on mean basis (Table 1). Continuous submergence (I_1) registered higher straw yield (8542, 8994 and 8757 kg ha¹ during *kharif* 2021, 2022 and on mean basis, respectively) followed by maintaining saturation (I_2) i.e., irrigation after disappearance of ponded water (8455, 8841 and 8648 kg ha¹ during *kharif* 2021, 2022 and on mean basis, respectively) and AWDI of 5 cm when water level in pipe falls 5 cm below surface (I_3) *i.e.*, (8383, 8791 and 8587 kg ha^{-1}, respectively).

The continuous supply of irrigation water helped in quick absorption and translocation of nutrients thus increased the plant height and number of tillers per clump. It resulted in improvement of biomass production that ultimately reflected the straw yield. These results are in line with findings of Yakubu, (2016), Chandra and Kumar, (2020), Duvvada *et al.* (2020), Das *et al.* (2022) and Sridhar *et al.* (2022).

Harvest index

Harvest index of rice showed non-significant effect by different establishment methods and irrigation scheduling (Table 1). However, among the different establishment methods, manual transplanting (M_3)

Table 2 : Economics of rice as influenced by different planting methods and irrigation scheduling during *kharif* 2021 & 2022.

Treatments	Gross returns			Net returns			B:C ratio		
Main	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
M_1: DDSR	127219	137586	132402	75596	84333	79964	2.47	2.59	2.53
M_2: WDSR	135863	147363	141613	83656	93570	88613	2.62	2.75	2.69
M_3: TPR	132975	146184	139580	75202	86547	80875	2.31	2.46	2.38
SEm±	1133	1450	1204	1418	1696	1530	0.05	0.05	0.04
CD (P=0.05)	4449	5693	4727	5567	6656	6006	0.18	0.19	0.16
Sub									
I_1: CS	133588	144943	139266	77648	87194	82421	2.39	2.52	2.46
I_2: Sat	131314	142126	136720	77975	87083	82529	2.48	2.59	2.54
I_3: AWDI	131155	144063	137609	78832	90173	84503	2.52	2.69	2.60
SEm±	1759	1974	1405	2425	2037	1479	0.07	0.05	0.04
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
SEm±	2734	3146	2323	3711	3343	2592	0.11	0.08	0.07
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
SEm±	3047	3419	2433	4200	3528	2562	0.13	0.08	0.07
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

DDSR: Dry direct seeding of rice with seed drill, **CS:** Continuous submergence, **WDSR:** Wet direct seeding of rice with drum-seeder, **AWDI:** Alternate wetting and drying irrigation, **TPR:** Manual transplanted puddled rice.

recorded highest harvest index during *kharif* 2021, 2022 and on mean basis *i.e.*, 42.99, 42.80 and 42.89, respectively followed by wet direct seeding with drum seeder (M_2) *i.e.*, 42.29, 41.95 and 42.12 during *kharif* 2021, 2022 and on mean basis, respectively and M_1-dry direct seeding with seed drill (41.05, 40.84 and 40.97 during *kharif* 2021, 2022 and on mean basis, respectively). Among irrigation scheduling, I_3- AWDI of 5 cm when water level in pipe falls 5 cm below surface (42.20, 42.17 and 42.19 during *kharif* 2021, 2022 and on mean basis, respectively) followed by continuous submergence (I_1) recorded higher harvest index during *kharif* 2021, 2022 and on mean basis *i.e.*, 42.17, 41.76 and 41.99, respectively and I_2- maintaining saturation i.e., irrigation after disappearance of ponded water (41.95, 41.66 and 41.80 during *kharif* 2021, 2022 and on mean basis, respectively).

The harvest index was not significantly influenced by either crop establishment methods or irrigation scheduling. Similar result was reported by Lavanya and Reddy (2019), Archana *et al.* (2022) and Das *et al.* (2022). The interaction effect of different establishment methods and irrigation scheduling on harvest index during both the years *viz.*, *kharif* 2021, 2022 and on mean basis was found to be non-significant.

Economics

Among different establishment methods, WDSR (M_2) recorded highest gross returns during *kharif* 2021, 2022 and on mean basis *i.e.*, 135863,147363 and 141613 Rs. ha^{-1}, respectively and it has shown on par with TPR (M_3) *i.e.*, 132975, 146184 and 139580 Rs. ha^{-1}, respectively. Significantly, lower gross returns was obtained with DDSR (M_1) during *kharif* 2021, 2022 and on mean basis *i.e.*, 127219, 137586 and 132402 Rs. ha^{-1}, respectively. WDSR (M_2) in rice recorded 6.8 %, 7.1 % and 7.0 % higher gross returns over DDSR (M_1) during *kharif* 2021, 2022 and on mean basis. Similar trend was recorded in case of net returns also in which M_2 reported significantly highest followed by M_3 and lowest in M_1 during *kharif* 2021, 2022 and on mean basis. WDSR (M_2) in rice recorded 10.7 %, 11.0 % and 10.8 % higher net returns over DDSR (M_1) during *kharif* 2021, 2022 and on mean basis. B:C ratio of rice showed significant effect by different establishment methods and non-significant difference between irrigation scheduling treatments (Table 2). It was highest in M_2 (2.62, 2.75 & 2.69) followed by M_1 (2.47, 2.59 and 2.53) and lowest in M_3 (2.31, 2.46 and 2.38) during *kharif* 2021, 2022 and on mean basis, respectively. There was non-significant effect of interaction between different establishment methods and irrigation scheduling in case of economics.

This may be attributed to the higher costs associated with labour-intensive transplanting, as well as potential yield variations due to the establishment of a uniform crop stand. The variations in gross returns among the treatments can be attributed to factors such as differences in crop establishment, irrigation intervals, agronomic practices and input requirements. Due to enhancement of grain and straw yield consequently incurred the highest net return and B:C ratio. These results are in pipeline with earlier findings of Duvvada *et al.* (2020) and Padma *et al*. (2023).

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