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Sustaining Rice Production in Wet Direct Seeding Under Delayed Sowing Through Drought Tolerant Rice Varieties

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Abstract

Rice is a major crop of India, with significant contributions to the nation's economy and food security. Due to increasing concerns over water scarcity and labour shortages, there is a growing shift towards practices such as wet direct seeding. Many farmers in irrigated and rainfed regions face delayed rice sowing due to socio-climatic and physical constraints. Evaluating short-duration, drought-tolerant varieties is crucial, as they perform better under direct-seeded conditions. This study aimed to assess such varieties under wet direct seeding in areas with partial irrigation or puddled soils, focusing on delayed sowing windows, which are often caused by late arrival of monsoon. The study was conducted during the *kharif* seasons of 2020 and 2021 at the ICAR-Indian Institute of Rice Research, Hyderabad, where two delayed sowing dates and four drought-tolerant rice varieties were tested. Identifying rice varieties suited to wet direct seeding under delayed sowing can help farmers secure better return from rice than leaving land fallow or facing losses and support sustainable rice production. The results indicated that delayed sowing in 3-4th week of July led to better growth, yield and economic outcome than sowing further delayed in 1st week of August. Among the varieties, DRR Dhan 46 consistently performed better, showing higher grain yield (7.8% higher than average), better economic returns (12% higher than average), and a higher Benefit-Cost ratio. The study showed that DRR Dhan 46 is the most promising variety for wet direct seeding under delayed sowing conditions.

Key words: Drought tolerant, rice varieties, wet direct seeding, sustainable, rice production

Introduction

Rice, being a major food crop, plays a vital role in the life and livelihood of Indians. The crop has diverse contribution in India's economy, ranging from subsistence farming, which meets farmers' own needs, to export-oriented production of Basmati and other specialty rice varieties (Pathak *et al*., 2018). Traditionally, rice cultivation in India has predominantly been through transplanting, a method that is both labour-intensive and water-demanding (Hossen *et al*., 2018). However, the growing concern over water scarcity and labour shortages has necessitated a shift towards more sustainable practices, such as wet direct seeding (Kumar and Ladha, 2011). Wet direct seeding involves sowing pre-germinated seeds directly into puddled fields, significantly reducing labour requirements compared with puddled transplanting - studies reported labour savings in the range of ~11–29% due to elimination of nursery and transplanting operation (Isvilanonda 2002; Rashid *et al*., 2009). Despite its advantages, wet direct seeding poses challenges, especially with long duration varieties under delayed sowing conditions.

The recommended sowing time of rice in Telangana and surrounding region is June to early July and transplanting is typically carried out in July to August, once the monsoon rains have begun. Delayed sowing often occurs due to late onset of monsoon, delayed release of water from the canal, and management issues, impacting crop establishment and yield (Lavanya and Reddy, 2019). Delayed sowing typically leads to poor seed emergence and a reduced number of panicles and spikelets per panicle, ultimately lowering yields (Zhang *et al*., 2023). However, direct seeding combined with suitable rice varieties can mitigate these challenges (Farooq *et al*., 2011). Direct seeding provides several benefits, including quicker and easier planting, reduced labour requirements, earlier crop maturity (by 7-10 days), improved water-use efficiency, increased tolerance to water shortages, lower methane emissions, and the potential for higher profitability in regions with a reliable water supply (Chakraborty *et al*., 2017; Chaudhary *et al*., 2022).

Many farmers in irrigated and monsoon-dependent regions of India are often forced to delay the sowing of rice due to several socio-climatic (e.g. labour unavailability) and physical constraints, thereby face yield reduction and sometimes negative net return. To mitigate the adverse effects of these delays and improve rice yield, it is essential to select rice varieties that are less sensitive to photoperiod changes and can perform well in late-sown conditions for sustainable rice production in Telangana and India at large. Short- to medium-duration rice varieties are particularly suitable for late sowing as they experience high or low-temperature stress for a shorter period during their reproductive phase compared to long-duration varieties (Murthy and Rao, 2010). Moreover, drought-tolerant varieties are particularly recommended for areas where there may be a possibility of water stress at any stage of crop growth (Rahman *et al*., 2022). Therefore, evaluating short-duration drought-tolerant varieties is immensely important, as these varieties possess inherent characteristics that enable them to perform better under direct-seeded conditions (Singh *et al*., 2017).

Our aim was to further evaluate these varieties in wet-direct seeding for areas with assured irrigation during some parts of the crop growing stage or where farmers are bound to prepare the soil by puddling due to soil factors with a focus on delayed sowing windows. Furthermore, being of short duration, these varieties would facilitate timely sowing of subsequent *rabi* crops (Das *et al*., 2012). Telangana, a key rice-growing state in India, frequently experiences water shortages, making it an ideal region for evaluating drought-tolerant rice varieties. Identifying and promoting rice varieties that can thrive under wet direct seeding and delayed sowing conditions will not only ensure productivity but also enable economic sustainability in rice cultivation. By examining these varieties' growth, yield, and profitability in delayed sown conditions, the study seeks to provide farmers with reliable options to mitigate the risks associated with delayed sowing and improve the resilience and productivity of rice farming in the face of climate variability and resource constraints.

Materials and Methods

Experimental site, climate, and soil

The present experiment was taken up during the *kharif* seasons of (July to November) of 2020 and 2021 at the research farm of ICAR-Indian Institute of Rice Research, Hyderabad (17°19′34″ N, 78°23′01″ E). Total rainfall during the crop growth period were 1139 mm and 727.2 mm in 2020 and 2021, respectively (**Table 1**). Maximum and minimum temperatures ranged between 22-35°C and 10.5-23.5°C in 2020, and 24-36°C and 13-25°C in 2021. The soil in the experimental site had a clayey texture, was slightly alkaline in pH, low in available nitrogen and organic carbon, medium in available phosphorus, and rich in available potassium. Prior to the establishment of the experiment, the site had been under a rice-rice cropping system for several years.

Table 1: **Summary of weather condition during the study in 2020 and 2021**

	2020					2021				
	Temperature (oC)		Rainfall (mm)	Bright Sunshine (hrs.)	Evaporation (mm)	Temperature (oC)		Rainfall (mm)	Bright Sunshine (hrs.)	Evaporation (mm)
	Max.	Min.				Max.	Min.			
July	33.0	20.5	266.8	4.6	125.2	36.0	21.5	305.8	3.7	125.6
Aug	32.0	20.5	234.2	3.6	129.0	34.0	22.0	106.2	4.9	121.7
Sep	35.0	20.0	384.8	4.8	116.7	32.0	21.5	255.2	3.9	100.5
Oct	32.5	14.5	344.6	5.2	88.4	33.0	16.0	100.8	7.3	104.2
Nov	32.0	10.5	15.2	7.3	93.5	31.5	13.0	18.2	4.3	85.9

Note: *Rainfall and Evaporation are monthly totals, whereas Bright Sunshine hours is daily average of the month.*

Treatment details

The experiment was laid out in split plot design with two different dates of sowing with a gap of two weeks (2020: 25 July and 8 Aug; 2021: 17 July and 3 Aug) in main plots and four promising drought tolerant rice varieties (see **Table 2**) in sub-plots with three replications.

Table 2: Information on drought tolerant rice varieties used in the study

Name of Variety	Grain type	Duration (days)	Parentage	Special characteristics
DRR Dhan 42 (IR64 *Drt1*)	Long Slender	120	Aday Sel/*3 IR 64	Resistant to Blast, moderately resistant to bacterial blight and brown spot
DRR Dhan 43	Long bold	115	IR03L03/IRRI148	resistant to blast and moderate resistant to sheath rot and brown spot, neck blast, brown plant hopper
DRR Dhan 44	Long Slender	120	IR 71700-247-1-1-2/IR 03 L120	Resistant to blast, moderately resistant to bacterial leaf blight.
DRR Dhan 46	Long Slender	120	IR72022-46-2-3-3-2/ IR57514-TMI-5-B-1-2	Moderate Resistant to brown spot, BPH and WBPH

Field and crop management

In both seasons, land preparation in the experimental plots involved two passes with a power tiller, followed by two rounds of laddering before sowing or transplanting. Two to three sprouted seeds were dibbled in a puddled field, spaced 20 cm × 15 cm, with little to no standing water on the surface. Nutrient management for both the seasons was accomplished as recommended *i.e.,* 120 kg N, 60 kg P_2O_5 and 40 kg K_2O per hectare through urea, single super phosphate and muriate of potash. The full dose of phosphorus and half of the potassium were applied as a basal treatment, while nitrogen was applied in three equal splits at 10 days after sowing (DAS), at active tillering, and at the panicle initiation stage. The remaining half of the potassium was added at the panicle initiation stage. Water management followed an alternate wetting and drying method, with irrigation applied until the soil reached field capacity. Pests and diseases were controlled through chemical means as needed, though no severe infestations occurred during the experiment. Weed management involved a combination of herbicide use and hand-weeding when necessary. The crop was harvested when 95 per cent of panicles turned into golden colour.

Observation and Statistical analysis

Plants were separated into straw (including rachis) and spikelets by hand threshing. Straw and grain yield were recorded for each treatment in replication wise and reported in t ha^{-1}. The observed data was analysed using Statistix 8.1, analytical software, Tallahassee, Florida, USA and subjected to the analysis of variance under split-plot design. Treatment means were compared using the least significant difference (LSD) test at 5% probability level.

Results and Discussion

Effect on growth and yield parameters

The July sowing resulted in slightly taller plants (7.7% and 2.2% taller) compared to the August sowing in both years (**Table 3**). However, the differences were more pronounced in 2020 and were statistically significant. DRR Dhan 46 was found to be the tallest (10.6% and 10.4% taller than the shortest) variety in both years, with significant differences compared to the other varieties. The number of tillers was higher for the July sowing date (18.2% and 7.2% higher) compared to sowing in August in both years. This difference was significant in 2020 but not in 2021. In 2020, DRR Dhan 46 had the highest number of tillers (11.5%) followed by DRR Dhan 44 (8.2%), however, in 2021 higher tiller count was found with DRR Dhan 43 (20.3%) followed by DRR Dhan 44 (16.3%). The July sowing produced more panicles per square meter than the August sowing date in both years, with no significant differences. DRR Dhan 43 (15.9% and 21% higher) produced highest number of panicles per square meter in both years, followed by DRR Dhan 42 and DRR Dhan 44. There were more filled grains per panicle in the July sowing date compared to August in both years, with significant differences in 2020. DRR Dhan 46 had the highest number of filled grains per panicle (25.6% and 13%) in both years, followed by DRR Dhan 44 (10.4% and 4.3%). Sreedevi *et al*., (2022) reported higher percent of filled grains per panicle in DRR Dhan 44 and 46 contributed to the higher yield of the varieties in direct seeding. Test weight was relatively consistent across both sowing dates and years, with no significant differences. DRR Dhan 46 had the highest test weight in both years, with significant differences compared to other varieties.

Table 3: Growth and yield parameters of rice as influenced by delayed sowing and rice varieties

2020															
	Plant height (cm)			No. of tillers m^{-2}			Panicles m^{-2}			Filled grains $panicle^{-1}$			Test weight(g)		
	Delayed Sowing (S)			Delayed Sowing (S)			Delayed Sowing (S)			Delayed Sowing (S)			Delayed Sowing (S)		
Variety (V)	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**
DRR Dhan 42	100.3	86.4	93.4^{b}	282	227	255^{ab}	210	196	203^{b}	91	84	88^{b}	21.2	21.1	21.2^{c}
DRR Dhan 43	95.8	93.7	94.8^{b}	250	234	242^{b}	229	221	225^{a}	87	76	82^{b}	22.7	22.8	22.7^{b}
DRR Dhan 44	102.1	91.9	97.0^{b}	294	230	262^{a}	208	193	200^{b}	97	86	91^{b}	21.9	22.6	22.2^{b}
DRR Dhan 46	104.7	101.9	103.3^{a}	288	252	270^{a}	199	188	194^{b}	105	100	103^{a}	24.0	23.9	23.9^{a}
Mean	100.7^{A}	93.5^{B}		279^{A}	236^{B}		211	199		95^{A}	87^{B}		22.4	22.6	
CD (0.05)	S=3.4, V=5.3			S=26, V=19			S=NS, V=21			S=3.8, V=9.7			S=NS, V=0.82		
2021															
Variety (V)	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**
DRR Dhan 42	94.9	92.8	93.8^{b}	306	274	290^{b}	256	242	249^{b}	93	91	92^{b}	20.5	20.5	20.5^{b}
DRR Dhan 43	93.3	92.8	93.1^{b}	336	325	331^{a}	293	283	288^{a}	91	92	92^{b}	22.3	20.2	21.3^{b}
DRR Dhan 44	96.5	93.3	94.9^{b}	328	312	320^{ab}	283	274	279^{ab}	96	96	96^{ab}	21.4	20.6	21.0^{b}
DRR Dhan 46	104.0	101.5	102.8^{a}	287	263	275^{b}	248	228	238^{b}	109	99	104^{a}	26.2	23.6	24.9^{a}
Mean	97.2	95.1		314	293		270	257		97	95		22.6	21.2	
CD (0.05)	S=NS, V=5.1			S=NS, V=36			S=NS, V=33			S=NS, V=8.3			S=NS, V=1.71		

Effect on yield

Grain yield results from the interaction of several yield components, including the number of grains per panicle, the number of productive tillers, and the test weight (Huang, *et al*., 2013). Sowing in 3-4th week of July resulted in a little higher grain yield (5.9% and 2%) compared to sowing on August for both years (**Table 4**). The yield difference was statistically significant in 2020 but not in 2021. Among the varieties, DRR Dhan 46 consistently showed the highest grain yield in both years, followed by DRR Dhan 43. The differences in yield among the varieties were statistically significant. Higher grain yield varieties are mainly attributed either to a higher number of panicles per square meter or a higher number of filled grain in panicles. Although, DRR Dhan 46 had a bit lower number of panicles but number of filled grains per panicle was higher than other varieties in the study. Liu *et al*., (2024) also opined that, greater number of spikelet per panicle and total number of spikelets were the key factors to achieve high yield in rice. Straw yield followed a similar trend, with the July sowing date yielding more straw than the August sowing date. The difference was statistically significant in both years. DRR Dhan 43 and DRR Dhan 46 had significantly higher straw yields compared to other varieties in 2020 and 2021, respectively. The harvest index was slightly higher in second year of study than in the first year of study, with the August sowing date showing a marginally higher index than the July sowing date, but the difference was not statistically significant in the first year. DRR Dhan 46 had the highest harvest index, indicating it was the most efficient in converting biomass to grain.

Table 4: Yield of rice as influenced by delayed sowing and rice varieties

2020									
	Grain yield (t ha^{-1})			**Straw yield (t ha^{-1})**			**Harvest index (%)**		
	Delayed Sowing (S)			**Delayed Sowing (S)**			**Delayed Sowing (S)**		
Variety (V)	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**
DRR Dhan 42	4.50	4.36	4.43^{b}	6.45	5.89	6.17^{ab}	41.1	42.5	41.8
DRR Dhan 43	4.74	4.52	4.63^{ab}	6.49	6.37	6.43^{a}	42.2	41.5	41.9
DRR Dhan 44	4.40	4.31	4.36^{b}	6.27	5.93	6.10^{ab}	41.4	42.1	41.7
DRR Dhan 46	5.01	4.40	4.71^{a}	6.16	5.62	5.89^{b}	44.9	44.0	44.4
Mean	4.66^{A}	4.40^{B}		6.34^{A}	5.95^{B}		42.4	42.5	
CD (0.05)	S=0.24, V=0.26			S=0.35, V=0.36			S=NS, V=NS		
2021									
Variety (V)	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**
DRR Dhan 42	4.94	4.89	4.92^{c}	6.34	5.89	6.12^{c}	43.7	45.3	44.5
DRR Dhan 43	5.57	5.48	5.53^{b}	7.72	6.43	7.08^{ab}	41.9	46.0	44.0
DRR Dhan 44	5.45	5.39	5.42^{b}	6.96	6.40	6.68^{b}	43.9	45.7	44.8
DRR Dhan 46	6.20	5.98	6.09^{a}	7.56	7.04	7.30^{a}	45.1	45.9	45.5
Mean	5.54	5.43		7.14^{A}	6.44^{B}		43.7^{B}	45.7^{A}	
CD (0.05)	S=NS, V=0.32			S=0.31, V=0.41			S=1.6, V=NS		

All rice varieties experienced lower yield reductions in the second year compared to the first year, which could be attributed to improved environmental conditions, better management practices, or enhanced varietal performance (**Figure 1**). On an average 2.1 to 12% reduction in grain yield in different varieties was observed when sowing was done on August compared to July in 2020; while in 2021 the yield reduction ranged from 1.1 to 4.6%. This suggests that these varieties have the potential to perform well under late sowing conditions, and puddled direct sowing could provide farmers with a new opportunity in such scenarios. Notably, DRR Dhan 46, which showed the highest initial yield reduction in 2020, demonstrated a remarkable recovery in 2021, highlighting its potential resilience under late sown wet-DSR.

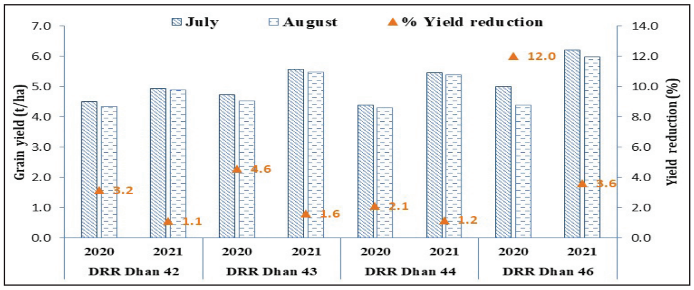

Figure 1: Grain yield and yield reduction of rice varieties due to August late sowing

Effect on economic returns

Gross and net returns were higher for the sowing in 3-4th week of July in both years. However, the difference in respect to net returns were 12.6% and 5.6% in first and second year, respectively (**Table 5**). The Benefit-Cost (B:C) ratio, which indicates profitability, was also higher for sowing in 3-4th week of July, with significant differences between the two delayed sowing dates in both years. DRR Dhan 43 and DRR Dhan 46 had the higher gross (₹1,05,772 and ₹1,40,050) and net returns (₹ 54,197 and ₹90,789), and the higher B:C (1.05 and 1.84), in the first and second year, respectively. The sowing in 3-4th week of July resulted in higher grain and straw yields, as well as better economic returns, compared to the August sowing. The yield advantage of early sowing even by two weeks can be explained by the prolonged growing period and better utilization of the available water and nutrients, which are crucial under the direct-seeded rice system (Ding *et al*., 2017; Bodner *et al*., 2015). DRR Dhan 46 followed by DRR Dhan 43 emerged as the most promising variety, demonstrating superior performance across multiple growth parameters, including plant height, number of tillers, and panicle formation. The ability of DRR Dhan 46 to maintain high productivity under both sowing windows suggests its resilience to varying climatic stresses, a trait that is increasingly valued in the context of climate change.

Table 5: Profitability of rice as influenced by delayed sowing and rice varieties

Variety (V)	2020								
	Gross return (₹ ha^{-1})			Net return (₹ ha^{-1})			B:C		
	Delayed Sowing (S)			Delayed Sowing (S)			Delayed Sowing (S)		
	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**
DRR Dhan 42	103407	99053	101230^{b}	51832	47478	49655^{b}	1.00	0.92	0.96^{ab}
DRR Dhan 43	107980	103565	105772^{a}	56405	51990	54197^{a}	1.09	1.01	1.05^{a}
DRR Dhan 44	101074	98320	99697^{b}	49499	46745	48122^{b}	0.96	0.91	0.93^{b}
DRR Dhan 46	111997	99126	105562^{ab}	60422	47551	53987^{ab}	1.17	0.92	1.05^{a}
Mean	106115^{A}	100016^{B}		54540^{A}	48441^{B}		1.06^{A}	0.94^{B}	
CD (0.05)	S=4937, V=4534			S=4937, V=4534			S=0.10, V=0.09		
2021									
Variety (V)	July	Aug	**Mean**	July	Aug	**Mean**	July	Aug	**Mean**
DRR Dhan 42	114916	112510	113713^{c}	65655	63249	64452^{c}	1.33	1.28	1.31^{c}
DRR Dhan 43	131313	125699	128506^{b}	82052	76438	79245^{b}	1.67	1.55	1.61^{b}
DRR Dhan 44	126683	123749	125216^{b}	77422	74488	75955^{b}	1.57	1.51	1.54^{b}
DRR Dhan 46	143012	137088	140050^{a}	93751	87827	90789^{a}	1.90	1.78	1.84^{a}
Mean	128981^{A}	124762^{B}		79720^{A}	75501^{B}		1.62^{A}	1.53^{B}	
CD (0.05)	S=3125, V=6910			S=3125, V=6910			S=0.06, V=0.14		

Conclusion

In late sown wet direct seeding short duration, drought tolerant rice varieties are suitable option to cope up with the late onset of monsoon or other related situation which forces the farmers for delayed sowing or transplanting. The findings suggest that optimum rice yields in direct-seeded rice can be obtained by selection of suitable variety even in late sown condition. DRR Dhan 46 could be a promising variety for wet direct seeding under delayed sowing conditions in Telangana. Additionally, it may also be suggested that, earlier sowing led to higher yields, economic returns, and a better B:C ratio, with DRR Dhan 46 being the most profitable option.

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