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Effect of crop establishment methods and irrigation scheduling on water use efficiency, water productivity and yield of rice

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Abstract
Field experiment was carried out at Soil and Water Management Research Institute, kattuthottam, Thanjavur during *rabi* season of 2016-2017 to study the Effect of crop establishment methods and irrigation scheduling on water use efficiency, water productivity and yield of rice. The experiment was laid out in split plot design in three replication. The treatments comprised of three establishment methods *viz*., direct seeded rice, non-puddled machine transplanted rice and puddled transplanted rice in main plots and seven irrigation scheduling practices in sub plots *viz*., alternate wetting and drying irrigation at 10 cm depletion of ponded water, alternate wetting and drying irrigation at 15 cm depletion of ponded water, alternate wetting and drying irrigation at 20 cm depletion of ponded water, alternate wetting and drying irrigation at 10 cm depletion of ponded water and submergence at flowering, alternate wetting and drying irrigation at 15 cm depletion of ponded water and submergence at flowering, alternate wetting and drying irrigation at 20 cm depletion of ponded water and submergence at flowering and irrigation on the day of disappearance of ponded water. It was found that direct seeded rice consumed less consumptive use of water with higher water use efficiency and water productivity. Among the irrigation scheduling, alternate wetting and drying irrigation at 10 cm depletion of ponded water and submergence at flowering registered higher water use efficiency and water productivity under all crop establishment methods. Direct seeded rice higher grain and straw yield followed by puddled transplanted rice.

Keywords: direct seeded rice, puddled transplanted rice, awdi irrigation, water use efficiency, water productivity

Introduction
Rice (*Oryza sativa* L.) is one of the most important staple food crop in the world. In Asia, more than two billion people are getting 60-70 per cent of their energy requirement from rice and its derived products. Manual transplanting requires a lot of labours besides involving drudgery and is also very expensive. Scarcity of labours is another major problem in some paddy growing areas of the country. Manual transplanting takes about 250-300 man hours/ha which is roughly about 25 per cent of the total labour requirement of the crop. Hence, less expensive, farmer friendly and labour saving method of paddy transplanting is urgently needed. The mechanical transplanting or sowing of paddy has been alternate and the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity (Usha *et al.* 2015) [11]. Urbanisation, migration of labour from agriculture to non-agriculture sector and increased labour costs are seriously treating the cultivation of crops in general and rice in particular (Yadav *et al.*, 2014) [14].
Rice is one of the greatest water user among cereal crops, consuming about 80% of the total irrigated fresh water resources in Asia. In Asia, with relatively more suitable growing conditions for rice, production has declined due to increasing water stress (Tao *et al*., 2004) [10]. With the decreasing availability of water for use in agriculture due to climate change and increased competition from other players like the industrial and urban sectors, water use in rice production systems has to be reduced in order to maintain production. At the same time, output per unit volume of irrigation water has to be increased so as to meet the increasing demand for rice in the world. There are various methods which have been used in reducing water use in rice production. One of the most tried methods is alternate wetting and drying (AWD) of rice paddy fields (Kepha *et al.* 2014) [5].
Rice cultivation under AWDI is generally practiced in orbitary timing based on the disappearance of ponded water. Need based water management is required to ensure more sustainable way to use the water. Moreover, success of AWDI depends on irrigating the field at the right time, when the rice plant needs water. AWD can lower water use for irrigated rice

By 35 per cent (Zhang *et al.*, 2009) [16], increase rice yield by 10 per cent relative to continuous flooding (Yang *et al.*, 2009) [15].

Vanitha and Ravikumar (2017) [12] reported that, AWD method saved the irrigation water about 23%, over the continuous flood irrigation method. Field water tube with intermittent irrigation reduced the total consumption with lesser number of irrigation. This method of irrigation also increased the water use efficiency and water productivity of rice (Suresh kumar and Pandian, 2017) [9]. Hence, the present investigation was taken up to study the effect of different crop establishment methods and irrigation scheduling on water use efficiency, water productivity and yield of rice.

Materials and Methods

A Field experiment was conducted during *rabi* season 2016-2017 at Soil and Water Management Research Institute, kattuthottam, Thanjavur Tamil Nadu. The experimental field is situated in Cauvery Delta Zone of Tamil Nadu geographically located at 10° 45N latitude, 79 °E longitude with an altitude of 50 m above mean sea level. The soil of the experimental site was sandy clay loam in texture having neutral pH (6.47), EC (0.15) and medium organic carbon (0.58%), With regard to nutrient status, the soil was low in available nitrogen (251 kg ha^{-1}), medium in phosphorus (15.8 kg ha^{-1}) and high in potassium (420.8 kg ha^{-1}), respectively. Rice variety CR 1009 with the duration of 165 days was used as test variety.

Experiment was laid out in split plot design with three replication. The treatments comprised of three establishment methods *viz*., direct seeded rice (M_1), non puddled machine transplanted rice (M_2) and puddled transplanted rice (M_3), respectively in main plots and seven method of irrigation scheduling in sub plots *viz.*, alternate wetting and drying irrigation at 10 cm depletion of ponded water, alternate wetting and drying irrigation at 15cm depletion of ponded water, alternate wetting and drying irrigation at 20 cm depletion of ponded water, alternate wetting and drying irrigation at 10 cm depletion of ponded water and submergence at flowering (I_4), alternate wetting and drying irrigation at 15 cm depletion of ponded water and submergence at flowering, alternate wetting and drying irrigation at 20 cm depletion of ponded water and submergence at flowering and irrigation on the day of disappearance of ponded water. Each individual plot was separated with buffer cannels for proper maintenance of the treatments. The irrigation water was measured with the parshall flume. In order to evaluate the effect of crop establishment methods and irrigation scheduling practices on water use efficiency (WUE), water productivity and yield, the data were statistically analyzed using "Analysis of variance test". The critical difference at 5% level of significance was calculated to find out the significance of different treatments over each other (Gomez and Gomez, 1984) [4]. The total consumptive use of water, water use efficiency and water productivity were calculated as per the standard procedure.

Water use efficiency

Water use efficiency (WUE) was computed using the equation of Viets (1962) [13].

$$WUE = Y/W \text{ (kg ha-mm}^{-1}\text{)}$$

Where,
Y = Grain yield (kg ha^{-1})
W = Total water used (I + Pe) to produce the yield (mm)

Where,
I = Irrigation water applied (mm)
Pe = Effective rainfall (mm)

Water productivity

Water productivity is a function of total water used and grain yield produced by the crop and expressed in kg m^{-3} (Chapagain and Yamaji, 2010) [1].

$$\text{Water productivity} = \frac{\text{Grain yield (kg)}}{\text{Total water consumed (m}^3\text{)}}$$

Results and Discussion

Effect on water use efficiency (WUE) and water productivity (WP)

Higher water use efficiency (WUE) and water productivity (WP) could be increased either by increasing yield or by maintaining the yield level with reduced quantity of water input. Among establishment method, direct seeded rice registered higher WUE of 5.56 kg ha^{-1} mm^{-1} and WP of 0.556 kg m^{-3} and it was followed by puddled transplanted rice. Whereas, lower WUE and WP found with non puddled machine transplanted rice (Table 1).

The irrigation scheduling, significantly influenced the WUE of rice crop. The higher WUE of 5.14 kg ha^{-1} mm^{-1} and WP of 0.514 kg m^{-3} were observed under alternate wetting and drying at 10 cm and submergence at flowering and it was followed by irrigation at 5 cm on the day of disappearance of ponded water (4.85 kg ha^{-1} mm^{-1} and 0.485 kg m^{-3}, respectively). The lowest WUE and WP were accounted with alternate wetting and drying irrigation at 20 cm depletion of ponded water and submergence at flowering. The present study findings were in agreement with those of Oliver *et al.* (2008) [7] and Zhou *et al.* (2017) [17].

Table 1: Effect of crop establishment methods and irrigation scheduling on Water Use Efficiency (kg $ha^{-1}mm^{-1}$) and Water Productivity (kg m^{-3})

Treatments	Water Use Efficiency (kg ha-mm^{-1})				Water Productivity (kg m^{-3})			
	DSR	NPMT	PTR	Mean	DSR	NPMT	PTR	Mean
I_1	5.28	3.93	4.37	4.53	0.528	0.393	0.437	0.453
I_2	5.67	4.67	4.99	5.11	0.567	0.467	0.499	0.511
I_3	5.59	4.73	4.87	5.07	0.559	0.473	0.487	0.507
I_4	6.09	4.27	5.07	5.14	0.609	0.427	0.507	0.514
I_5	5.48	4.22	4.82	4.84	0.548	0.422	0.482	0.484
I_6	5.06	4.25	4.53	4.61	0.506	0.425	0.453	0.461
I_7	5.71	4.18	4.65	4.85	0.571	0.418	0.465	0.485
Mean	5.56	4.32	4.76		0.556	0.432	0.476	
	M	I	Mat I	I at M	M	I	Mat I	I at M
SEd	0.06	0.12	0.21	0.22	0.006	0.012	0.021	0.022
CD (p=0.05)	0.18	0.25	NS	NS	0.018	0.025	NS	NS

Effect on grain and straw yield

Crop establishment methods and irrigation scheduling practices significantly influenced the grain and straw yield of rice and are shown in Table 2. Direct dry seeded rice recorded higher grain yield (5671 kg ha^{-1}) and straw yield (6657 kg ha^{-1}) and was followed by puddled transplanted rice (5298 and 6214 kg ha^{-1}, respectively). Higher yield realized might be attributed by better vegetative growth, higher number of tillering and root growth, increased number of productive tillers per square meter and filled grains per panicle resulting in higher grain and straw yield. Direct seeded rice recorded higher grain and straw yield and was followed by puddled transplanted rice was also reported by Patel (2000) [8] and Gangwar *et al* (2008) [2].

Table 2: Effect of crop establishment methods and irrigation scheduling on Grain yield (kg ha^{-1}) and Straw yield (kg ha^{-1}) of rice

Treatments	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
	DSR	NPMT	PTR	Mean	DSR	NPMT	PTR	Mean
I_1	5762	4465	5195	5141	6770	5148	6109	6009
I_2	4965	4352	4850	4722	5879	5127	5733	5579
I_3	4503	4025	4423	4317	5336	4762	5029	5042
I_4	6810	5035	6170	6005	8056	5977	7318	7117
I_5	5840	4698	5573	5370	6804	5534	6426	6255
I_6	4862	4210	4784	4619	5504	4921	5676	5367
I_7	6954	5265	6094	6104	8247	6076	7209	7177
Mean	5671	4579	5298		6657	5363	6214	
	M	I	Mat I	I at M	M	I	Mat I	I at M
SEd	83	146	249	253	99	172	293	298
CD (p=0.05)	232	296	525	513	275	349	619	604

Irrigation management practices greatly influenced the rice grain yield. Among the Irrigation scheduling, irrigation on the day of disappearance of ponded water recorded higher grain and straw yield of 6104 and 7177 kg ha^{-1}. This was on par with alternate wetting and drying at 10 cm and submergence at flowering. The increased yields under irrigation scheduling might be due to favourable growth & yield attributes and nutrient supply with increased uptake of nutrients under irrigation on the day of disappearance of ponded water which leads to plants with higher growth characters and enhanced the yield attributing characters with higher source to sink conversion, which consecutively resulted in higher grain and straw yield. These findings in are agreement with Geethalakshmi *et al*. (2009) [3] and Majeed *et al.* (2017) [6].

Interaction was found to exist between crop establishment methods and irrigation scheduling with respect to rice grain and straw yields. Direct dry seeded rice with irrigation on the day of disappearance of ponded water registered higher grain and straw yield. However, it was on par with direct dry seeded rice with alternate wetting and drying irrigation at 10 cm depletion of ponded water and submergence at flowering. Invariably, lowest straw yield was recorded under non puddled machine transplanted rice with alternate wetting and drying irrigation at 20 cm depletion of ponded water. In combination also, these two treatments combinations produced favourable growth and yield attributes which inturn reflected on grain and straw yields.

Conclusion

Direct dry seeded rice along with irrigation on the day of disappearance of ponded water recorded higher grain yield which was found to be on par with alternate wetting and drying irrigation at 10 cm depletion of ponded water and submergence at flowering. Hence direct seeded rice is an alternate crop establishment method over puddled transplanted rice during labour and water scarcity situation.

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