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Influence of different irrigation methods and weed management practices on water use studies and yield of transplanted rice (*Oryza sativa* L.) in Thamirabarani command area

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Abstract
A field experiment was conducted at Agricultural College and Research Institute, Killikulam during early *Pishanam* season of 2018-2019 to assess the effect of different irrigation practices through field water tube and weed management practices on water production parameters, grain and straw yield of transplanted rice. The experiment was laid out in strip plot design with three replications. The treatments comprised of three different methods of irrigation in vertical strips and four methods of weed management practices in horizontal strips. The experimental results showed that, field water tube method of irrigation at 10 and 15 cm depletion registered lower consumption of water with less number of irrigation, high water saving percentage, higher water use efficiency and water productivity than compare to continuous submergence of irrigation water. At the same time, maintaining weed free condition by hand weeding recorded low total water consumption with lesser number of irrigation. Weed free environment also increased the water use efficiency and water productivity of rice and it was followed by application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i. ha^{-1}.The higher grain and straw yield (6753 and 7666 kg ha^{-1}) of rice was recorded in continuous submergence with weed free environment. It was followed by irrigation management through FWT at 10 cm depletion of water coupled with application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1}.

Keywords: Irrigation water and weed management, water use studies, yield of rice

Introduction
Rice (*Oryza sativa* L.) is one of the most water consuming crop among all cereals ranging from 1200-1500mm. Since water for rice production has become increasingly scarce, water saving is the main issue in maintaining the sustainability of rice production when water resources are becoming scarce (Arif *et al.*, 2012) [1]. Therefore, it is important to cut down water supply for rice cultivation without affecting rice yield. So there is an imperative need to find ways to reduce water use, while maintaining high yields in rice cultivation. Traditional transplanted rice with continuous standing of water needs relatively high water inputs. Increasing irrigation efficiencies seems to be the practical way to save irrigation water. By applying appropriate irrigation management during growing season of rice, a large volume of water can be saved which may help to bring more area under irrigation particularly where there are limited water resources (Bouman *et al*., 2005) [4].

There are several alternatives to continuous flooding of rice and one of the approach which can be used is intermittent irrigation or alternate wetting and drying (AWD). Instead of keeping rice fields continuously flooded, the adoption of AWD methods means that irrigation water is applied to fields to restore flooded conditions on an intermittent basis, only after a certain number of days have passed since the disappearance of ponded water (Zhang *et al.*, 2009). The practice of safe AWD as a mature water saving technology entails irrigation when water depth falls to a threshold depth of below the soil surface with the use of field water tube. Several studies have shown that safe AWD reduces water input significantly without penalty in grain yield (Samoy *et al*., 2008) [20]. Aslam *et al.* (2002) [2] concluded that by maintaining a thin layer of standing water in the field, saturated, or alternate wet and dry soil conditions could save about 20-70% of irrigation water without significant yield loss as compared to continuous shallow submergence. Kulkarni (2011) [14] reported that using of field water tube in AWD is safe to limit the water use up to 25% without reduction in rice yield. One method to save water in irrigated rice cultivation is the intermittent drying of the rice fields instead of keeping them continuously flooded.

This method is referred to as alternate wetting and drying irrigation (AWDI). In certain areas and under the right conditions, AWDI is a promising method in irrigated rice cultivation with dual benefits of water saving and human disease control, while maintaining rice yields at least at the same level.
Weeds are the most important hazard cause low productivity of rice. Weeds compete with rice for moisture, nutrients, light, temperature and space. Furthermore, any delay in weeding leads to increased weed biomass which has a negative correlation with yield of crop. Traditionally weed control in rice is done by manual and mechanical weeding. Hand weeding is very easy and environment friendly but tedious and highly labor intensive. Hand weeding can control the weeds efficiently but lack of labor at critical period may lead to unsatisfactory weed control. Farmers very often fail to remove weeds in time due to unavailability of labor at peak periods. The use of herbicides offers selective and economic control of weeds right from the beginning, giving the crop an advantage of good start and competitive superiority.

Materials and methods

The field experiment was conducted during early *Pishanam* season of 2018-2019 at the BC Block Farm, Agricultural College and Research Institute, Killikulam, Tamil Nadu. The farm is geographically located in the southern part of Tamil Nadu at 8°46' N latitude and 77°42' E longitude at an altitude of 40 m above mean sea level. The soil of the experimental site was sandy clay loam in texture having alkaline pH (8.2) and medium organic carbon (6.2 g kg^{-1}). The soil was low in available nitrogen (244 kg ha^{-1}), medium in phosphorus (22 kg ha^{-1}) and medium in potassium (238 kg ha^{-1}), respectively. Rice variety ASD 16 with the duration of 110 days was used as test variety. Field experiments were laid out in strip plot design with three replications.
The treatments comprised of three different methods of irrigation *viz*., Irrigation after 10 cm depletion of Field Water Tube (FWT) (from surface level) from 10 DAT to 10 days prior to harvest (A_1), Irrigation after 15 cm depletion of Field Water Tube FWT (from surface level) up to maximum tillering stage (30-35 DAT) and 10 cm depletion of FWT to 10 days prior to harvest (A2), Continuous Submergence (farmers practice) (A_3), respectively in vertical strips and four methods of weed management practices in horizontal strips *viz.*, PE Bensulfuron methyl + Pretilachlor @ 0.6 kg a.i. ha^{-1} fb POE Bispyribac sodium @ 25g a.i. ha^{-1} (B_1), PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1} (B_2), Weed free check (B_3), Un weeded control (B_4). The total consumptive use of water, water saving percentage, water use efficiency and water productivity were calculated as per the standard procedure. Grain and straw yield were recorded and interpreted here under.

Total water consumed

The total water consumed was computed by summing the irrigation water applied and the effective rainfall. Effective rainfall calculated as sixty five percentage of total rainfall during the cropping period.

$$W = ND + Re$$

Where,
W = Total water consumed in mm
N = Number of irrigations
D = Applied water depth for each irrigation (mm)
Re = Effective rainfall (mm), during the cropping Period.

Water use efficiency

Water use efficiency (WUE) was computed using the equation of Viets (1962) [23].

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

Where,
Y = Grain yield (kg ha^{-1})
W = Total water used (I + Re) to produce the yield (mm)
I = Irrigation water applied (mm)
Re = 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) [7].

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

Water saving percentage

Water saving percentage was calculated by using the following formula,

$$\text{Water saving \%} = \frac{\text{Water supplied in flooded plot} - \text{Water supplied in treated plots}}{\text{Water supplied in flooded plot}} \text{x100}$$

Result and discussion

Studies on total consumptive water use, number of irrigation, water saving percentage, water use efficiency and its productivity will help to rationalize the water application and its use and its influence on grain and straw yield of transplanted rice.

Total water consumed (Table 1)

The amount of water required to meet the demands of evapotranspiration and metabolic activities of rice together constitute the consumptive water use, which includes the effective rainfall. As such, the farmers' practice of irrigation (A_3) *i.e.*, continuous flooding of 5 cm throughout the crop period consumed more water of 1340 mm. Increased total water consumption by rice crop with continuous submergence was also reported by Banerjee *et al*. (2008) [3] and Oliver *et al*. (2008). This was followed by irrigation after 10 cm depletion of FWT (A_1), which registered the next higher consumptive water use (1129 mm). Lesser consumptive use of water was observed under field water tube method of irrigation practice due to lesser number of irrigations and increased dry cycles with reduced evapotranspiration. There is a strong relationship between standing water depth in the field and the seepage, percolation rates. So field water tube technology played good role to reduce the water loss. This result of lower total water use by field water tube irrigation method was corroborated with the findings of Latif (2010) [16] and Faruki *et al*. (2011) [10].
Among different weed management practices, weed free check (B_3) consumed lesser water (1000 mm) as compared to other weed management practices. Application of PE Pyrazosulfuron ethyl @ 20 g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1} (B_2), registered the next higher consumptive water use of 1012 mm and it was followed by the application of PE Bensulfuron methyl + Pretilachlor @

0.6 kg a.i. ha^{-1} fb POE Bispyribac sodium @ 25g a.i. ha^{-1} (B_1) consumed 1058 mm water. In all the growing stages, unweeded control treatment (B_4) utilised more water of 1398 mm than other methods.

Water saving percentage (Table 2)

Water saving percentage was calculated on the basis of volume of water used in continuous flooding (A_3). Among the irrigation practices, irrigation after 15 cm depletion of FWT (A_2) registered higher water saving percentage of 34.2 % over continuous flooding. This was followed by irrigation after 10 cm depletion of FWT (A_1), which registered the water saving percentage of 16.1 %. Field water tube technology was used to measure the water availability in below ground level as well as water requirement by the plant. Hence, it reduces the total water consumption by the crop plant and increases the water saving percentage over continuous flooding. It exhibited right timing of irrigation to produce rice crop in water-wise way. This results in conformity with the finding of Chapagain and Yamaji (2010) [7]. Feng *et al*. (2007) [11] reported that 36.6% water saving of field water tube irrigation practice over continuous flooding and 30 % was reported by Lampayan (2013) [15].

Among different weed management practices, weed free check (B_3) recorded higher water saving percentage of 28.2 % over unweeded check and it was followed by the application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1} (B_2), registered the water saving percentage of 27%. Application of PE Bensulfuron methyl + Pretilachlor @ 0.6 kg a.i. ha^{-1} fb POE Bispyribac sodium @ 25g a.i. ha^{-1} (B_1), registered the water saving percentage 22.9 %. However, lower water saving percentage of 22.5 % was registered in unweeded control treatment (B_4).

With respect to treatment combinations, irrigation after 15 cm depletion of FWT with weed free check (A_2 B_3) recorded higher water saving percentage followed by irrigation after 10 cm depletion of FWT coupled with application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i. ha^{-1} (A_1B_2) registered higher water saving percentage.

Water use efficiency (WUE) (Table 3)

Water use efficiency determination in irrigation commands will indicate the unit quantity of grain yield obtained per unit quantity of water used. Irrigation management practices also had significant influence on WUE in all the growing seasons. The WUE was significantly higher in irrigation after 15 cm depletion of FWT (A_2), which was registered 6.2 kg ha-mm^{-1}. It was followed by irrigation after 10cm depletion of FWT (A_1) accounted 5.5 kg ha-mm^{-1}. Santheepan and Ramanathan, 2016 revealed that Field water tube irrigation practice at 10 cm depletion of water from ground level was found to be superior with highest water use efficiency of 6.14 kg ha-mm^{-1} over continuous submergence of flooded water. This is also in agreement with the findings of Bouman *et al.* (2007) [5] and Kannan (2012) [13]. The poor WUE was accounted with continuous flooding (A_3) with a water use efficiency of 4.8 kg ha-mm^{-1}.

The different weed management practices substantially influenced the WUE of the rice. Among various weed management practices, higher WUE (7.0 kg ha-mm^{-1}) was registered with weed free check (B_3). It was followed by application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1} (B_2), recorded the WUE of 6.5 kg ha-mm^{-1} and application of PE Bensulfuron methyl + Pretilachlor @ 0.6 kg a.i. ha^{-1} fb POE Bispyribac sodium @ 25g a.i. ha^{-1} (B_1) expressed the WUE of 5.7 kg ha-mm^{-1}. In all the growing stages, unweeded control treatment (B_4) recorded lower WUE (2.7 kg ha-mm^{-1}) than other practices.

Different methods of irrigation and weed management practices did not show any interaction effect.

Water productivity (WP) (Table 4)

Water productivity will indicate the unit quantity of water used to produce per unit of grain yield. Methods of irrigation and weed management practices were noticeably influenced on water productivity of rice. Irrigation management practices had significant influence on water productivity and it was significantly higher in irrigation after 15 cm depletion of FWT (A_2), which required lesser quantity of water to produce per unit of grain yield of 0.62 kg m^{-3}. However, this treatment was followed by irrigation after 10 cm depletion of FWT (A_1) which produce 0.55 kg of grain m^{-3} of water used. The poor water productivity was accounted with continuous flooding (A_3) which required larger quantity of water to produce per unit of grain yield of 0.48 kg m^{-3} of water. Adoption of field water tube method of irrigation registered higher WUE and WP due to need based irrigation using monitoring device *i.e.* field water tube coupled with maintenance of yield at an optimum level. The higher consumptive use with more frequent irrigations without corresponding increase in grain yields could have led to decreased WUE under farmers' practice of irrigation (continuous submergence).

The different weed management practices substantially influenced the water productivity of the rice. Among various weed management practices, higher water productivity was registered with weed free check (B_3) of 0.70 kg grain m^{-3} of water. Next to the above treatment, application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1} (B_2), registered the water productivity of 0.65 kg m^{-3}. It was followed by the application of PE Bensulfuron methyl + Pretilachlor @ 0.6 kg a.i. ha^{-1} fb POE Bispyribac sodium @ 25g a.i. ha^{-1} (B_1) with water productivity of 0.57 kg m^{-3}. In all the growing stages, unweeded control treatment (B_4) recorded lower water productivity (0.27 kg m^{-3}).

Different methods of irrigation and weed management practices did not show any interaction effect.

Grain and straw yield (Table 5 & 6)

Grain yield being an economic component of the crop, which reflect the resultant impact of all crop growth parameters and yield attributes that are affected by various input treatments. Irrigation management practices greatly influenced the rice grain and straw yield. Among the irrigation management practices, continuous flooding (A_3) recorded higher grain and straw yield of 6222 and 7129 kg ha^{-1}, respectively. However, comparable grain and straw yield was observed with irrigation after 10 cm depletion of FWT (A_1) accounting 5851 and 6822 kg ha^{-1}, respectively. Whereas, lower grain and straw yield of 5173 and 6127 kg ha^{-1}, respectively were obtained with irrigation after 15 cm depletion of FWT (A_2). AWD method of irrigation through FWT allow good aeration of the soil, better root growth and development, increased nutrient availability throughout the crop growth and reduced weed growth which resulted in improved yield attributes thereby increased rice yield. The results are in line with the findings of Ceesay *et al*. (2006) [6] and Uphoff (2006) [22] who reported cycles of repeated wetting and drying were found beneficial to rice plant growth through increased nutrient availability leading ultimately to higher grain and straw yield. These results are in conformity with Javier *et al.* (2005) [12]; Rajkhowa *et al.* (2007a) [18] and Son *et al.* (2008) [21].

Among the different weed management treatments tried, weed free check (B_3) significantly recorded the highest grain and straw yield of 6753 and 7666 kg ha^{-1}, respectively. This treatment was remained at par with application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1} (B_2) recorded the yield of 6478 and 7384 kg ha^{-1}. It was followed by application of PE Bensulfuron methyl + Pretilachlor @ 0.6 kg a.i. ha^{-1} fb POE Bispyribac sodium @ 25g a.i. ha^{-1}(B_1) recorded a grain and straw yield of 5956 and 6823 kg ha^{-1}, respectively. The unweeded control (B_4) significantly resulted in lower grain and straw yield of 3808 and 4897 kg ha^{-1}.

Irrigation and weed management practices had significant interaction effect with each other on grain and straw yield. Among the different irrigation and weed management combinations, ccontinuous flooding with weed free check (A_3B_3), registered higher grain and straw yield. However, it was comparable with irrigation after 10cm depletion of FWT (A_1) coupled with the application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1} (A_1B_2). It was in line with Aslam *et al.* (2002) [2] concluded that by maintaining a thin layer of standing water in the field, saturated, or alternate wet and dry soil conditions could save about 20-70% of irrigation water without significant yield loss as compared to continuous shallow submergence.

Table 1: Effect of different irrigation and weed management practices on Consumptive Use (mm) of water in transplanted rice.

Treatment	Consumptive Use (mm)				
	B_1	B_2	B_3	B_4	Mean
A_1	1095	992	979	1450	1129
A_2	830	810	790	1100	883
A_3	1249	1234	1231	1644	1340
Mean	1058	1012	1000	1398	

Table 2: Effect of different irrigation and weed management practices on water saving percentage in transplanted rice

Treatment	Water Saving (%)				
	B_1	B_2	B_3	B_4	Mean
A_1	12.3	19.6	20.5	11.8	16.1
A_2	33.5	34.4	35.8	33.1	34.2
A_3	-	-	-	-	-
Mean	22.9	27.0	28.2	22.5	

Table 3: Effect of different irrigation and weed management practices on Water Use Efficiency (kg ha-mm^{-1}) in transplanted rice

Treatment	Water Use Efficiency (kg ha-mm^{-1})				
	B_1	B_2	B_3	B_4	Mean
A_1	5.7	6.8	7.0	2.5	5.5
A_2	6.3	7.4	8.3	2.7	6.2
A_3	5.1	5.4	5.6	3.0	4.8
Mean	5.7	6.5	7.0	2.7	
	A	B	A at B	B at A	
SEd	0.16	0.14	0.32	0.15	
CD (p=0.05)	0.36	0.31	NS	NS	

Table 4: Effect of different irrigation and weed management practices on Water Productivity (kg m^{-3}) in transplanted rice

Treatment	Water Productivity (kg m^{-3})				
	B_1	B_2	B_3	B_4	Mean
A_1	0.57	0.68	0.70	0.25	0.55
A_2	0.63	0.74	0.83	0.27	0.62
A_3	0.51	0.54	0.56	0.30	0.48
Mean	0.57	0.65	0.70	0.27	
	A	B	A at B	B at A	
SEd	0.016	0.014	0.032	0.015	
CD (p=0.05)	0.035	0.031	NS	NS	

Table 5: Effect of irrigation and weed management practices on Grain yield (kg ha^{-1}) in transplanted rice

Treatment	Grain yield (kg ha^{-1})				
	B_1	B_2	B_3	B_4	Mean
A_1	6245	6720	6880	3558	5851
A_2	5210	5995	6520	2968	5173
A_3	6412	6720	6859	4898	6222
Mean	5956	6478	6753	3808	
	A	B	A at B	B at A	
SEd	256.8	235.7	249.6	235.3	
CD (p=0.05)	557.3	511.4	541.6	510.6	

Table 6: Effect of irrigation and weed management practices on Straw yield (kg ha^{-1}) in transplanted rice

Treatment	Straw yield (kg ha^{-1})				
	B_1	B_2	B_3	B_4	Mean
A_1	7110	7553	7969	4655	6822
A_2	6054	6920	7356	4177	6127
A_3	7306	7678	7672	5858	7129
Mean	6823	7384	7666	4897	
	A	B	A at B	B at A	
SEd	305.4	289.5	307.8	292.9	
CD (p=0.05)	662.8	628.2	668.0	635.5	

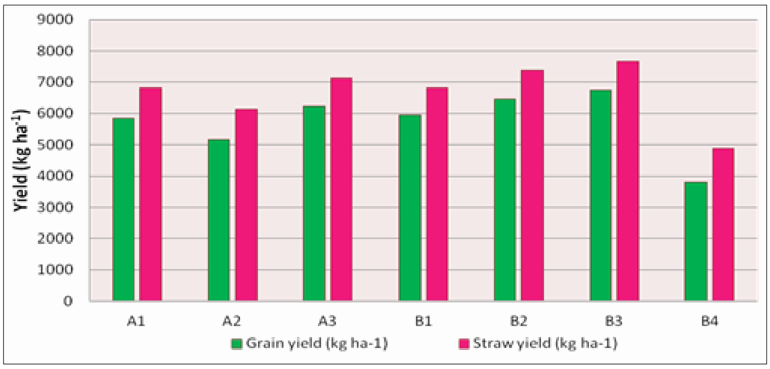

Fig 1: Effect of different irrigation regimes and weed management practices on Grain yield (kg ha^{-1}) and Straw yield (kg ha^{-1})

Conclusion

In the present study it was found that field water tube method of irrigation registered lower consumptive use of water with less number of irrigation accounting 50 and 70 % water saving on 10 cm and 15 cm depletion of FWT over continuous flooding. This treatment also recorded higher percentage of water saving, water use efficiency and water productivity without reduction in grain and straw yield obtained from continuous flooding. Though the hand weeding for weed free environment gave higher yield it was on par with application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25g a.i. ha^{-1} than other weed control measures. Adoption of field water tube with irrigation after 10 cm depletion of FWT along with application of PE Pyrazosulfuron ethyl @ 20g a.i. ha^{-1} fb POE Bispyribac sodium @ 25 g a.i.ha^{-1} was observed to be a suitable method for getting higher yield and water use efficiency.

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