Madras Agric. J., 105 (4-6): 151-155, June 2018

Impact of Irrigation Scheduling and Weed Management on Water Use Efficiency and Yield of Direct Dry Seeded Rice

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Field experiment was conducted at Soil and Water Management Research Institute, Kattuthottam, Thanjavur during *kharif* season (July - October) of 2017 to assess the water use efficiency and yield of direct seeded rice under different irrigation scheduling and weed management practices. Field experiment was laid out in split plot design which was replicated thrice. The treatments comprised of four different irrigation scheduling *viz*., AWDI at 10 cm depletion of water below the soil surface, AWDI at 15 cm depletion of water below the soil surface, AWDI at 20 cm depletion of water below the soil surface and irrigation on the day of disappearance of ponded water, in main plots and three weed management practices in sub plots *viz.*, PE pendimethalin 1kg a. i. ha^{-1} on 3-5 DAS *fb* EPOE bispyribac sodium @ 25 g a. i. ha^{-1} (Two to three leaf stages of weeds), EPOE bispyribac sodium @ 25 g a. i. ha^{-1} (Two to three leaf stages of weeds) *fb* hand weeding at 35- 45 DAS (S_2) and weedy check. It was found that AWDI at 10 cm depletion of water below the soil surface recorded higher water use efficiency and comparable yield when related to irrigation on the day of disappearance which was recorded higher yield. On the other hand, AWDI at 20 cm depletion of water below the soil surface reduced total water consumption and recorded lower grain yield. Among weed management, EPOE bispyribac sodium @ 25 g a. i. ha^{-1} (Two to three leaf stages of weeds) *fb* hand weeding at 35-45 DAS had recorded higher grain yield which was on par with PE pendimethalin 1kg a. i. ha^{-1} on 3-5 DAS *fb* EPOE bispyribac sodium @ 25 g a. i. ha^{-1} (Two to three leaf stages of weeds). But, due to higher labour cost involved in hand weeding, EPOE bispyribac sodium @ 25 g a. i. ha^{-1} (Two to three leaf stages of weeds) *fb* hand weeding at 35-45 DAS recorded higher cost of cultivation. Thus, in water and labour scarce situation AWDI at 10 cm depletion of water below the soil surface with PE pendimethalin 1kg a. i. ha^{-1} on 3-5 DAS *fb* EPOE bispyribac sodium @ 25 g a. i. ha^{-1} (Two to three leaf stages of weeds) was the best option to get higher productivity in rice.

Key words: Direct seeded rice, Water use efficiency, Weed management, Yield

Rice is the most inevitable cereal food crop of the world. It is an indispensible crop for more than 50% of the world's population and providing 35 - 60 % of the calories consumed. More than 75% of rice cultivation was done through conventional transplanted puddled condition. There are two major problems in today's rice cultivation. First and foremost problem is the increasing scarcity and competition for water worldwide. Rice requires 4000- 5000 litres of water approximately to produce 1 kg of rice. According to the report of IRRI, rice is consuming about 34 - 43% of total world's irrigated water which includes over 24 - 30% of world's fresh water reserves. It is expected that the per capita available water resources in Asia are to decline by 15 - 54 % by 2025 when compared with 1990 availability. By 2025,15 - 20 million hectare of irrigated rice field may suffer from water scarcity (Guerra *et al*., 1998). Second most important problem of rice cultivation in transplanted puddled condition is labour availability and labour cost. Due to increasing labour shortage and labour cost, rice growing in conventional transplanted puddled system is becoming an important question. These features demand a major shift from puddled transplanting to less water and less labour requiring direct seeded rice cultivation in irrigated rice ecosystems to sustain the long-term production of rice. DSR save 55% human labour, 10% machine labour and 33% irrigation water in DSR as compared to conventional transplanted rice with only 5% reduction in rice yield (Vinay *et al*., 2016). Further advanced strategy to address this need is the use of safe alternate wetting and drying irrigation method in direct seeded rice (DSR). The "safe" (no yield loss) AWDI which is the applying of irrigation (to standing water depth of 5 cm) when the perched water table falls to 15 cm below the soil surface (Bouman *et al*., 2007). But in direct seeded rice, weed management is the major bottleneck. This is due to the emergence of weeds along with the rice or even before the emergence of rice and also due to the absence of submerged condition. Unattendeed weed growth in DSR can reduce the rice yield upto the extend of 90%. Hence, the present investigation was taken up on effect of different irrigation scheduling and weed management on water use efficiency and yield of direct seeded rice.

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Material and Methods

Field experiment was conducted at Soil and Water Management Research Institute, Kattuthottam, Thanjavur during *Kharif* season (July to October) of 2017. The farm is situated in New Cauvery Delta Zone of Tamil Nadu which is geographically located at 10˚45' N latitude, 79˚ E longitude and at an altitude of 50 m above mean sea level. The soil of the experimental field was sandy loam in texture with pH of 6.53, EC 0.15 dSm^{-1} and organic carbon of 0.62 % With respect to soil nutrient status, soil was low in available nitrogen (224 kg/ha), high in phosphorus (25 kg/ha) and medium in available potassium (120 kg/ha).

The experiment was laid out in split plot design which was replicated thrice. The treatments comprised of four different irrigation scheduling *viz*., AWDI at 10 cm depletion of water below the soil surface (M_1), AWDI at 15 cm depletion of water below the soil surface (M_2), AWDI at 20 cm depletion of water below the soil surface (M_3) and irrigation on the day of disappearance of ponded water (M_4), respectively in main plots and three methods of weed management practices in sub plots *viz*., PE pendimethalin 1kg a. i. ha^{-1} on 3-5 DAS *fb* EPOE bispyribac sodium @ 25 g a. i. ha^{-1} (S_1), EPOE bispyribac sodium @ 25 g a. i. ha^{-1} (Two to three leaf stages of weeds) *fb* hand weeding at 35-45 DAS (S_2) and weedy check (S_3). The short duration rice variety (ADT 45) with the duration of 110 days was used as test variety.

In order to evaluate the effect of different irrigation scheduling and weed management practices on water use efficiency (WUE) 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). The total consumptive use of water and water use efficiency were calculated as per the standard procedure.

Total water consumed

The water consumed was measured by using parshall flume and total water consumed in irrigation was measured by adding water measured in each irrigation. Total water was calculated by summing the irrigation water applied and effective rainfall (FAO, 1986).

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

Effective rainfall was calculated using the following formula given by FAO, (1986),

Pe = 0.8P-25 [If P >75 mm/month]

Pe = 0.6 P-10 [If P < 75 mm/month]

Where, Pe = Effective precipitation or rainfall

P = Precipitation or rainfall

Water use efficiency

Water use efficiency (WUE) was computed using the equation of Viets (1962) which is given below,

WUE = Y/W (kg/ha-mm)

Where,

Y = Grain yield (kg/ha)

W = Total water used (I + Re) to produce the yield (mm)

Where,

I = Irrigation water applied (mm)

Re = Effective rainfall (mm)

Result and Discussion

Consumptive use of water

The amount of water required in meeting the demands of evapotranspiration and metabolic activities of rice together constitute the consumptive water use, which includes the effective rainfall during the growing season. Among the treatments, AWDI at 20 cm depletion of water below the soil surface consumed lesser water (858 mm). This is due to increased interval between the irrigation which paved way to lesser number of irrigation which inturn results in lower consumptive use of water. Whereas higher consumptive use of water was recorded in irrigation on the day of disappearance of ponded water (1293 mm) which was due to minimum irrigation interval and increased number of irrigation. While weed management didn't have any influence on the total water consumption. The result of reduced total water use by AWDI method was corroborated with the findings of Barman *et al.,* (2016) and Faruki *et al*. (2011).

Water use efficiency

Irrigation scheduling and weed management practices has profound influence on water use efficiency and the data are presented in the Table. 1. With regard to water management practices, AWDI at 10 cm depletion of water below the soil surface registered higher WUE due to optimum need based irrigation using monitoring device *i.e.* field water tube which reduced number of irrigation and total water consumption without major reduction in grain yield. Irrigation on the day of disappearance of ponded water recorded significantly lower water use efficiency. The higher consumptive use with more frequent irrigations without corresponding increase in grain yields could have led to decreased WUE under irrigation on the day of disappearance of ponded water. This was also documented by Santheepan and Ramanathan, (2016) and Oliver *et al*., (2008).

Table 1. Effect of irrigation scheduling and weed management on total water consumption (mm) and water use efficiency (kg/ha mm^{-1}) on direct dry seeded rice

Treatments	Total water consumption (mm)					Water use efficiency (Kg/ha-mm)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	1005	914	858	1293	1017	4.99	4.78	4.41	4.24	4.60
S_2	1003	911	857	1292	1015	5.11	4.93	4.54	4.37	4.74
S_3	1009	915	860	1296	1020	2.33	2.28	2.12	2.01	2.18
Mean	1005	913	858	1293		4.14	4.00	3.69	3.54	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	16	19	35	38		0.06	0.08	0.14	0.16	
CD(p=0.05)	38	NS	NS	NS		0.14	0.17	NS	NS	

Both the weed management practices had significantly higher water use efficiency than weedy check. EPOE bispyribac sodium 25g a. i. ha^{-1} *fb* hand weeding had registered higher WUE which was on par with PE pendimethalin 1 kg a. i. ha^{-1} *fb* EPOE bispyribac sodium 25 g a. i. ha^{-1}. Since weed management had no influence on total water consumption, this difference in WUE was due to difference in yield.

Yield attributes

Irrigation scheduling and weed management had significant influence of number of productive tillers and total grains per panicle which is presented in Fig. 1, 2. Irrigation on the day of disappearance of ponded water recorded higher number of productive tillers and total grains per panicle. This is due to absence of stress condition during critical period of crops facilitataed higher leaf area and dry matter production which inturn results in greater conversion of photosynthates from source to sink. AWDI at 20 cm depletion of water below the soil surface recorded lower number of productive tillers per m^2 and total number of grains per panicle. This was due to the severe moisture stress experienced by plants during the cropping period and hence they were unable to extract nutrients from the soil which ultimately led to poor growth, lesser number of productive tillers and total number of grains per panicle. Among weed management, EPOE bispyribac sodium 25g a. i. ha^{-1} *fb* hand weeding and PE pendimethalin 1 kg a. i. ha^{-1} *fb* EPOE bispyribac sodium 25 g a. i. ha^{-1} had no significant difference with respect to number of productive tillers per m^2 and total grains per panicle. This was due to efficient management of weeds by both the treatments resulted in higher LAI and tillers and better availability of resources result in more number of productive tillers and grains. Undoubtably, weedy check registered lower number of productive tillers and grains. This was due to higher crop - weed competition for nutrient and moisture prevailed during the cropping period which ultimately resulted in reduced uptake of moisture and nutrients which inturn results in lesser photosynthates production

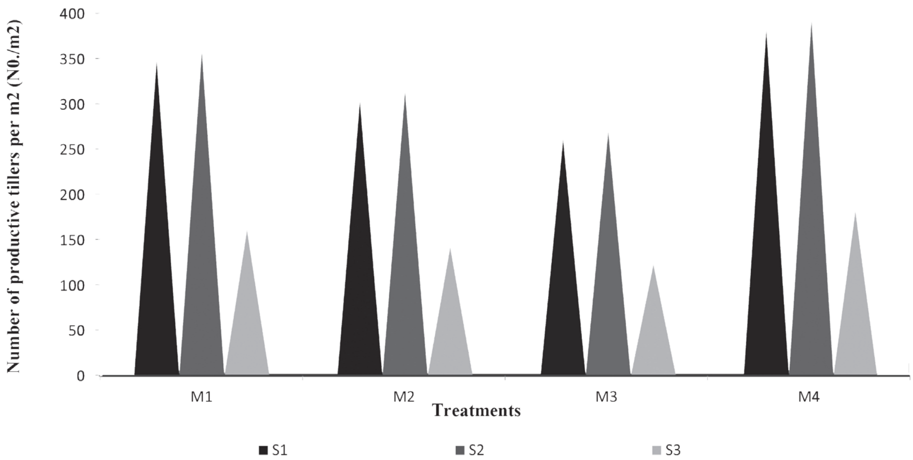
Table 2. Effect of irrigation scheduling and weed management on grain and straw yield (kg ha^{-1}) on direct dry seeded rice

Treatments	Grain yield (kg ha^{-1})					Straw yield (kg ha^{-1})				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	5017	4364	3783	5476	4660	6301	5494	4774	6856	5856
S_2	5128	4492	3888	5648	4789	6436	5651	4899	7060	6011
S_3	2351	2086	1823	2598	2215	3068	2733	2394	3377	2893
Mean	4165	3647	3165	4574		5268	4626	4022	5764	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	58	77	139	155		74	98	176	196	
CD (p=0.05)	143	164	303	328		180	207	383	415	

and translocation. Similar result was obtained by Ramakrishna *et al*. (2007) and Tadepalli and Singh (2017).

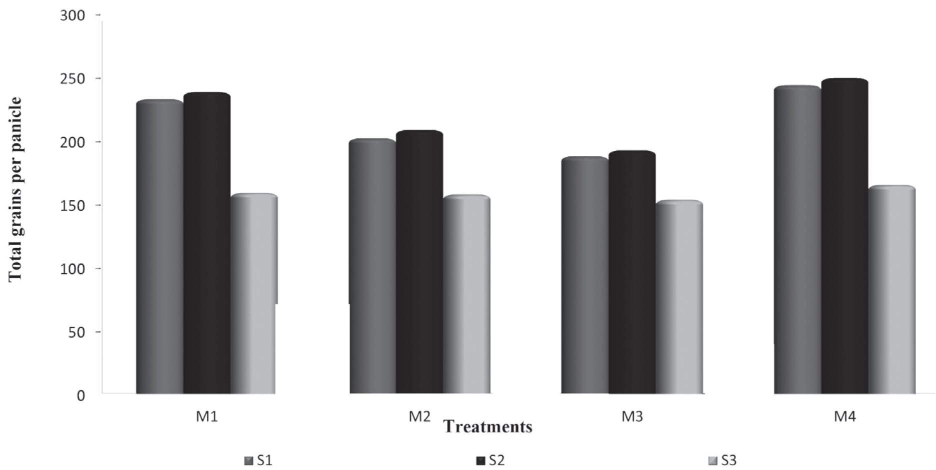
Grain and straw yield

The grain yield and straw yield of rice was greatly influenced by the irrigation scheduling and weed management practices which is presented in Table 2. Higher grain and straw yield were recorded in irrigation on the day of disappearance of ponded water which was comparable with AWDI at 10 cm depletion of water below the soil surface. The increased yields might be due to increased availability of water to crops. Thus, crops grown vigorously without any moisture stress. Therefore, roots function normally and resulted in increased nutrient availability throughout the cropping period which improved growth attributes like leaf area, dry matter production which inturn results in better accumulation of photosynthates leads to higher yield attributes such as increased number of productive tillers per m² and higher number of grain per panicle and thereby resulted in higher rice yield. This result was in line with Bouman and Tuong, (2001) and Rolaniya *et al*., (2015).



Main plot: Irrigation scheduling - AWDI at M_1- 10 cm; M1- 15 cm; M_3 - 20 cm depletion of water below the soil surface; M_4 - Irrigation on the day of disappearance of ponded water. **Sub plot:** Weed management - S_1- Pendimethalin @ 1 kg a.i. ha^{-1} *fb* Bispyribac sodium @ 25g a.i. ha^{-1}; S_2 - Bispyribac sodium @ 25g a.i. ha^{-1} *fb* Hand weeding @ 40 DAS; S_3 - Weedy check.

Fig.1. Effect of irrigation scheduling and weed management on number of productive tillers per m² (No. /m²) of direct seeded rice



Main plot: Irrigation scheduling - AWDI at M_1- 10 cm; M1- 15 cm; M_3 - 20 cm depletion of water below the soil surface; M_4 - Irrigation on the day of disappearance of ponded water. **Sub plot:** Weed management - S_1- Pendimethalin @ 1 kg a.i. ha^{-1} *fb* Bispyribac sodium @ 25g a.i. ha^{-1}; S_2 - Bispyribac sodium @ 25g a.i. ha^{-1} *fb* Hand weeding @ 40 DAS; S_3 - Weedy check.

Fig.2. Effect of irrigation scheduling and weed management on number of grains per panicle (No. /panicle) of direct seeded rice

EPOE bispyribac sodium 25g a.i/ha *fb* hand weeding recorded higher grain yield which was on par with PE pendimethalin 1 kg a. i. ha^{-1} *fb* EPOE bispyribac sodium 25 g a. i. ha^{-1}. The possible reason might be that the weed seedling were killed at early stage of crop growth and favoured the vigorous growth of rice seedlings without crop weed competition due to prolonged control of weeds. The competition free environment has increased the capacity of source and sink and in turn the length of panicle and number of filled grains/panicle which results in higher yield. While, weedy check registered significantly lower yield over other treatments. Rice grain yield was reduced in weedy check due to severe competition for soil moisture, nutrients and space between crop and weeds. This is evident from the result that reduction in all growth and yield parameters and reduced nutrient uptake by crops which leads to severe yield loss. These results corroborate with the findings of Chauhan and Johnson, (2011) and Malviya *et al*., (2014).

Irrigation and weed management practices recorded significant interaction in grain and straw yield of direct seeded rice. Irrigation on the day of disappearance of ponded water with EPOE bispyribac sodium 25g a.i/ha *fb* hand weeding had recorded higher yield which was on par with irrigation on the day of disappearance of ponded water with PE pendimethalin 1 kg a. i. ha^{-1} *fb* EPOE bispyribac sodium 25 g a. i. ha^{-1}. This was due to the better availability of water and efficient control of weeds throughout the cropping season which induced better growth and yield attributes which resulted in higher yield. AWDI at 20cm disappearance with weedy check registered 68% lower grain and straw yield than irrigation on the day of disappearance of ponded water with either EPOE bispyribac sodium 25g a. i. ha^{-1} *fb* hand weeding which might be due to increased water stress and unattended weed growth which suppressed the crop growth thereby resulted in inferior yield attributes which inturn resulted in lower yield.

From the experiment, it can be concluded that in sandy loam soil of new cauvery delta zone, direct dry seeded rice with irrigation on the day of disappearance of ponded water with EPOE bispyribac sodium @ 25 g a. i. ha^{-1} *fb* hand weeding was best interms of higher grain yield and could be viable option when the resources are abundant. AWDI at 10 cm depletion of water below the soil surface with PE pendimethalin 1kg a. i. ha^{-1} *fb* EPOE bispyribac sodium @ 25 g a. i. ha^{-1} was found to be an ideal agronomic option to save water, improve water use efficiency and to get higher productivity of rice in resource (water and labour) constraint situation.

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Received : May 14, 2018; Revised : June 23, 2018; Accepted : June 27, 2018