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Research Paper

Effect of irrigation and methods of weed management on weed dynamics and yield of summer rice (*Oryza sativa*) under system of rice intensification

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ABSTRACT

A field experiment was conducted during the summer season of 2014 and 2015 to study the effect of irrigation and methods of weed management on weed dynamics, yield and nutrient uptake of rice (*Oryza sativa* L.) under system of rice intensification (SRI). Application of 50 mm water on the day before weeding operation was significantly superior to saturation (15 mm) on the day before weeding operation for grain yield (5.5 t/ha) owing to the lowest weed density (172.2/m^2), weed dry weight (76.1 g/m^2), and the highest number of panicles/plant (35.1) and filled grains/panicle (94). Pre-emergence application of pretilachlor @750 g/ha at 3 days after transplanting (DAT) followed by post-emergence application of chlorimuron ethyl + metsulfuron methyl @ 4 g/ha at 20 DAT proved to be most effective in minimizing the density of weeds (139.8/m^2), their dry weight (65.5 g/m^2) and enhancing weed-control efficiency (57.6%), grain yield (5.6 t/ha), N-P-K uptake of 66.1, 20.2, 23.0 kg/ha respectively by grain, net returns (52,714₹/ha) and benefit: cost ratio (3.35).

Key words **:** Chlorimuron + metsulfuron, Pretilachlor, System of rice intensification, Water application method, Weed-control efficiency, Weed density, Weed dry weight, Yield

Rice is not an aquatic plant and does not necessarily require flooding for producing best yields. However, conventional rice cultivation practices around the world involve the continuous flooding and maintain standing water in rice field from transplanting till 15–20 days before maturity (Dass *et al*., 2015). This leads to yield loss as well as huge water losses from rice fields through evaporation, seepage and deep percolation resulting in low water productivity. System of rice intensification (SRI) offers efficient use of limited water and gives higher yield. In SRI, cycles of repeated wetting and drying were found beneficial to rice plant growth through increased nutrient availability leading to higher yield (Hameed *et al.,* 2011 and Sinha and Talati, 2007). The general practice of controlling weeds in SRI is to use Cono or Mandwa weeder. In clay-loam soil, more labour is required for running the weeder in absence of proper moisture in the soil. So it is necessary to standardize the required moisture regime in soil before using the weeder.

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Operating the weeder at 7 or 10 days interval reduces weed problem to a large extent in SRI. The problem of weeding by weeder is that it can not run smoothly after 30 DAT, because of profuse lateral vegetative growth of rice, which creates obstruction in weeder operation (Haden *et al*., 2007). Use of proper post-emergence herbicide can solve this problem by suppressing new flushes of weeds at later stages of growth (Babar and Velayutham, 2012). Any approach that would lessen the amount of water use and control weed without compromising the rice yield would certainly be a welcome strategy. Hence the present field experiment was conducted to study the effect of different depths of water application one day before weeding operation and weed management practices on growth and yield of rice raised under systems of rice intensification.

MATERIALS AND METHODS

A field study was conducted at Regional Research and Technology Transfer Station, Chiplima, Sambalpur, under West Central Table Land Zone Odisha during the summer seasons of 2014 and 2015 to evaluate the effect of irrigation and methods of weed management on weed dynamics, yield and nutrient uptake of rice under system of rice intensification (SRI). The soil of experimental field was clay loam with bulk density 1.50 Mg/m^3, porosity 39.28%, infiltration rate 0.26 cm/hr, water holding capacity 25.6% on weight basis, field capacity 19.7% on weight basis, permanent wilting point 10%, *p*H 5.65 and low in organic carbon content (0.47%) and available N ($KMnO_4$ method), P (Olsen method) and K (NH_4OHC method) content were 242, 9.2 and 155 kg/ha respectively. The experiment was laid out in split-plot design with 3 replications. Main plot treatments consisted of 3 irrigation schedules, viz. I_1, 50 mm water on the day before weeding operation, I_2, 25 mm water on the day before weeding operation and I_3, saturation (15 mm) on the day before weeding operation. The sub-plots received 4 weed management practices , viz. W_1, weeding by Mandwa weeder at an interval of 7 days starting from 10 DAT up to 50 DAT; W_2, application of pre-emergence herbicide pretilachlor @ 750 g/ha at 3 DAT + use of Mandwa weeder at 20 DAT at an interval of 7 days up to 50 DAT; W_3, W_1 + application of a post-emergence herbicide chlorimuron ethyl + metsulfuron methyl @ 4g/ha at 20 DAT; W_4, application of pre-emergence herbicide pretilachlor @ 750 g/ha at 3 DAT followed by post-emergence herbicide chlorimuron ethyl + metsulfuron methyl @ 4 g/ha at 20 DAT. The amount of water applied for puddling was 250 mm for all the treatments. Irrigation was done by alternate wetting and drying method. The water use was quantified for each plot areas with the help of module designed to discharge water @ 3 litres/sec. The total number of irrigation for I_1, I_2 and I_3 were 20, 21 and 23 respectively. For weeding operation as per treatment 6, 5, 5, 2 numbers of irrigations were given to W_1, W_2, W_3 and W_4 respectively over and above the normal schedule. Irrigation treatments were isolated with buffer channels, so that water movement can be effectively controlled and managed. Rice 'MTU 1010' of 125 days duration was grown under SRI. Seeds were soaked for 24 hrs and incubated in moist gunny bags for 2 days. Pre-germinated seeds were broadcast uniformly on nursery beds of 1 m width separated by channels of 30 cm width and 15 cm depth. Soil: farmyard manure mixture (1:1) was spread in a thin layer for covering the seeds. The beds were irrigated daily and thoroughly before lifting the seedlings. The FYM @ 5 t/ha was incorporated 2 weeks before transplanting. Seedlings of 12 days were used for transplanting. Marker was used for square planting with 25 cm × 25 cm spacing. Recommended dose of fertilizer, i.e. 80, 40 and 40 kg/ha N, P_2O_5 and K_2O was applied. All P_2O_5 was applied as basal and N was applied in 3 splits, i.e. 50% as basal, 25% at 45 DAT and 25% at 60 DAT, while K_2O was applied in 2 splits, i.e. 50% as basal and 50% at 60 DAT. The plant protection measures were taken as and when required. Other cultural operations like gap filling and rouging were carried out as per recommendation and weed management was followed as per treatment. Rainfall received during the crop growth period was 30 mm (6 rainy days) in 2014 and 62 mm (9 rainy days) in 2015 respectively during summer season. The average rate of evaporation during crop growing season was 3.5 mm/day. The yield parameters were recorded and the economics was calculated at the prevailing price of inputs and minimum support price of produce. The weeds were counted and the weed dry weight was taken at 60 DAT. The weed-control efficiency (WCE) was calculated from the mean data over 2 years by using formulae.

WCE (%) = (WDc – WDt)/WDc × 100

where, WCE, weed-control efficiency;

WDc, weed dry biomass (g/m^2) in control plot;

WDt, weed dry biomass (g/m^2) in treated plot.

The data were statistically analyzed in split-plot analysis as per Gomez and Gomez (2010).

RESULTS AND DISCUSSION

Weed density and biomass

The major weed flora in the experimental field comprised of grasses, viz. *Echinochloa crusgalli* (L.) P Beav., *Echinochloa colonum* (L.) Link, *Digitaria sanguinalis* (L.) Scop; *Panicum repens* (L.); sedges, viz. *Cyperus difformis* (L.), *Cyperus iria* (L.), *Fimbristylis miliacea* (L.) Vahal and broad-leaved weeds (BLW), viz. *Ludwigia parviflora* (L.), *Ammania baccifera* (L.) Roxb., *Eclipta prostrata* (L.), *Eclipta alba* (L.), *Lippa nodiflora* Nich, *Marsilea quadrifolium* (L.), *Sphenoclea zeylanica* Gaertn., *Commelina benghalensis* (L.). The composition of sedges was found to be the highest followed by grasses and broad leaf weeds.

Use of chemical herbicide with or without mandwa weeder was found superior to only mandwa weeder operated treatment (Table 1). Significantly lower total weed density and biomass were recorded under 50 mm water application on the day before weeding operation (I_1) up to 25.1 and 44.9, 30.1 and 50.1% compared to application of 25 mm water (I_2) and saturation (I_3) respectively. The lower weed population in this treatment was perhaps due to creation of anaerobic conditions that led to formation of hydrogen peroxides. These peroxides have lethal effect on germination of weed seeds. Higher weed population in saturated plot might be due to the optimum conditions for weed seed germination (Haefele *et al*., 2004). Application of pre and post-emergence herbicide (W_4) proved 57.6% more effective in controlling weeds over mandwa weeded plot (W_1). Control of weeds by herbicides during early stage of rice resulted in lower competition for moisture, nutrient and sunlight that influenced the crop to grow better as evidenced in increased yield attributes and yield (Singh *et al*., 2005).

Yield attributes and yield

In the main-plots application of 50 mm water on the day before weeding operation resulted in higher grain yield (5.5 t/ha) being 19 and 12.3% higher over 25 mm water on the day before weeding operation and saturation respectively (Table 2). Increased yield with application of 50 mm water on the day before weeding operation was attributed to higher filled grains/panicle (94) and panicles/ plant (35.1). Increase in yield attributes and yield in this practice of water application might be as a result of better condition for operating weeder in clay-loam soil, causing better aeration and root growth and providing sufficient nutrients for vegetative and reproductive growth.

Pre and post-emergence application of herbicides (W_4) showed significantly higher grain yield (16.7%) compared to mandwa weeded plot (W_1). The higher yield was owing to higher number of panicles/plant (29.8), length of panicle (26 cm) and filled grains/panicle (89.8) over the mandwa weeded treatment. The higher yield might be due to longer weed free period in chemical weed control practices, which reduced partitioning of available resources like moisture and nutrients. Total weed control with application of pre-emergence followed by post-emergence herbicide proved that chemical control of weed is more effective than mechanical and or mechanical and chemical integration in system of rice intensification. Dewangan *et al*. (2011) also recorded higher grain yield with longer weed free period.

Interaction effect of water application methods and weed management on grain yield of rice (Table 3) was found significant. Each weed management practice produced its maximum yield when 50 mm irrigation was given on the day before weeding operation (I_1). Except I_3, all other irrigation treatment produced its maximum yield, when applied with pre- and post-emergence herbicide (W_4).

Water use

The total quantity of irrigation water used was 881, 783 and 693 mm/ha in 50, 25 mm water and saturation on day before weeding operation respectively (Table 2). Irrigation water-use efficiency (IWUE) was found to be the highest (6.19 kg/ha-mm), when 25 mm water was applied on the day before weeding (I_2), however, the highest water saving (187.5 mm/ha) was recorded in the saturated plot (I_3). The highest water saving at saturation could be due to the retention of seepage and deep percolation losses. Because of lower yield recorded in this treatment (I_3) resulted in lower IWUE (6.06) as compared to I_2. Shantappa *et al.* (2014) reported more quantity of water saved (34%) in alternate wetting and drying than continuous submergence without reduction in seepage and percolation losses in rice field. Chemical weed management with application of both pre- and post-emergence herbicides (W_4) saved more water (39

Table 1. Effect of water application methods and weed management on weeds at 60 days after transplanting (DAT) of rice (Mean data of 2 years)

Treatment	Weed density (Nos./m^2)				Weed biomass (g/m^2)				WCE
	Grasses	Sedges	Broad leaved	Total	Grasses	Sedges	Broad leaved	Total	(%)
Water application method (I)									
I_1	21.0	143.6	7.6	172.2	5.7	66.8	3.7	76.1	50.1
I_2	32.0	189.2	8.6	229.8	9.6	89.6	9.5	108.8	30.1
I_3	38.0	255.6	18.4	311.9	16.0	122.8	13.9	152.6	
SEm±	2.0	4.9	0.9	3.5	0.9	2.4	0.5	6.5	
CD (P=0.05)	5.6	14.4	2.7	10.3	2.6	7.2	1.5	19.1	
Weed management practices (W)									
W_1	18.6	281.9	11.5	312.0	8.6	136.0	9.9	154.5	
W_2	21.9	236.5	17.5	275.9	9.0	113.3	9.2	131.4	14.9
W_3	15.0	188.2	17.3	220.5	7.2	89.1	8.7	105.0	32.0
W_4	6.8	122.5	10.5	139.8	4.1	56.3	5.2	65.5	57.6
SEm±	6.0	11.5	2.0	3.6	0.9	5.8	0.4	8.5	
CD (P=0.05)	NS	34.5	5.9	10.6	2.5	17.3	1.1	25.5	

I_1, 50 mm water on the day before weeding operation, I_2, 25 mm water on the day before weeding operation, I_3, Saturation on the day before weeding operation (≈ 15 mm).

W_1, weeding by Mandwa weeder at an interval of 7 days starting from 10 DAT up to 50 DAT; W_2, application of pre-emergence herbicide, pretilachlor @ 750 g/ha at 3 DAT + use of Mandwa weeder at 20 DAT at an interval of 7 days up to 50 DAT; W_3, weeding by Mandwa weeder at 10 DAT + application of a post-emergence herbicide, chlorimuron ethyl + metsulfuron methyl @ 4g/ha at 20 DAT, W_4, application of pre-emergence herbicide pretilachlor @ 750 g/ha at 3 DAT followed by post emergence herbicide chlorimuron ethyl + metsulfuron methyl @ 4 g/ha at 20 DAT; WCE., Weed control efficiency mm/ha) than Mandwa weeded (W_1) plot (15 mm/ha).

Nutrient uptake by rice

Application of 50 mm water on the day before weeding operation (I_1) recorded the highest N, P and K uptake of 64.9, 19.8, 22.6 and 44.4, 2.2 and 124.3 kg/ha of grain and straw respectively, followed by application of 25 mm water (Table 4). Weed management practices exerted positive influence on nutrient uptake. Pre-emergence application of pretilachlor followed by post-emergence application of chlorimuron ethyl + metsulfuron methyl registered highest N-P-K uptake of 66.1, 20.2 and 23.0 kg/ha of grains respectively. This treatment was on par with weeding by Mandwa weeder at 10 DAT + application of a post emergence herbicide (chlorimuron ethyl + metsulfuron methyl) at 20 DAT. Pretilachlor as pre-emergence at 750 g/ha + Mandwa weeding from 10 DAT at 7 days interval recorded N-P-K uptake of 63.7, 19.4 and 22.1 kg/ha, respectively. The lowest N, P and K uptake in grain and straw was found in weeding by Mandwa weeder at an interval of 7 days starting from 10 DAT up to 50 DAT (W_1). This was mainly due to less grain and straw yields observed

Table 2. Effect of water application methods and weed management practices on yield attributes, yield, water use and economics of rice in SRI (mean data of 2 years)

Treatment	Tillers/ plant	Panicles/ plant	Length of panicle (cm)	Filled grains/ panicle	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	IWU (mm/ha)	IWUE (kg/ha-mm)	Water savings (mm/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio
Water application methods (I)												
I_1	42.2	35.1	21.4	94.0	21.5	5.5	7.4	881	5.82	-	49.0	2.88
I_2	40.3	31.1	22.2	84.0	21.6	5.2	6.8	783.5	6.19	90	44.8	2.72
I_3	38.3	25.4	21.4	82.0	21.4	4.6	5.8	693.5	6.06	187.5	36.3	2.35
SEm±	1.53	2.43	0.92	2.76	0.43	0.21	0.25					
CD (P=0.05)	NS	7.31	NS	8.51	NS	0.58	0.69					
Weed management practices (W)												
W_1	38.7	20.3	19.3	73.7	21.3	4.8	6.2	810.5	4.78	15	36.7	2.21
W_2	52.9	20.1	20.1	79.0	21.7	4.9	6.3	825.5	5.55	-	39.1	2.45
W_3	35.2	25.2	23.5	89.1	22.1	5.4	7.2	825.5	7.25	-	48.0	2.95
W_4	49.7	29.8	26.0	89.8	22.0	5.6	7.5	786.5	8.7	39.0	52.7	3.35
SEm±	1.63	0.61	0.48	3.26	0.51	0.18	0.32					
CD (P=0.05)	4.96	1.89	1.44	9.85	NS	0.57	0.99					

Input price (₹/kg) rice seed, 22; urea, 5.52; di ammonium phosphate, 24.45; muriate of potash, 17.44; chlorimuron +metsulfuron, ₹220/8g, Sale rate of rice grain (₹14,100/t), rice straw (₹800/t) and manual labour (₹127/day); IWU, irrigation water use; IWUE, irrigation water-use efficiency

I_1, 50 mm water on the day before weeding operation, I_2, 25 mm water on the day before weeding operation, I_3, Saturation on the day before weeding operation (≈ 15 mm).

W_1, weeding by Mandwa weeder at an interval of 7 days starting from 10 DAT up to 50 DAT; W_2, application of pre-emergence herbicide, pretilachlor @ 750 g/ha at 3 DAT + use of Mandwa weeder at 20 DAT at an interval of 7 days up to 50 DAT; W_3, weeding by Mandwa weeder at 10 DAT + application of a post-emergence herbicide, chlorimuron ethyl + metsulfuron methyl @ 4g/ha at 20 DAT, W_4, application of pre-emergence herbicide pretilachlor @ 750 g/ha at 3 DAT followed by post emergence herbicide chlorimuron ethyl + metsulfuron methyl @ 4 g/ha at 20 DAT; WCE., Weed control efficiency

Table 3. Interaction effect of water application methods and weed management on grain yield of rice in SRI (mean data of 2 years)

Treatment	Yield (t/ha)			
	W_1(Mandwa weeding	W_2 (W_1 + Pre em. herbicide)	W_3 (W_1 + Post em. herbicide)	W_4 (Pre fb. post- em. herbicide)
I_1	4.6	4.5	5.3	6.2
I_2	4.4	4.4	4.9	5.6
I_3	4.5	4.5	5.2	4.9
			SEm±	CD (P=0.05)
		I in W	1.31	3.90
		W in I	1.02	3.06

Table 4. Effect of water application methods and weed management practices on nitrogen, phosphorus and potassium uptake (kg/ha) by SRI rice (mean data of 2 years)

Treatment	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
Water application methods (I)						
I_1	64.9	44.4	19.8	2.2	22.6	124.3
I_2	61.3	40.8	18.7	2.0	21.3	114.2
I_3	54.3	34.8	16.6	1.7	18.9	97.4
SEm±	0.68	0.12	0.2	0.01	0.9	2.3
CD (P=0.05)	1.88	0.33	0.55	0.0	2.5	6.4
Weed management practices (W)						
W_1	56.6	37.2	17.3	1.9	19.7	104.2
W_2	57.8	37.8	17.6	1.9	20.1	105.8
W_3	63.7	43.2	19.4	2.2	22.1	121.0
W_4	66.1	37.5	20.2	2.3	23.0	126.0
SEm±	0.78	0.19	0.26	0.01	1.17	2.99
CD (P=0.05)	2.4	0.59	0.81	0.03	3.63	9.27

I_1, 50 mm water on the day before weeding operation, I_2, 25 mm water on the day before weeding operation, I_3, Saturation on the day before weeding operation (≈ 15 mm).
W_1, weeding by Mandwa weeder at an interval of 7 days starting from 10 DAT up to 50 DAT; W_2, application of pre-emergence herbicide, pretilachlor @ 750 g/ha at 3 DAT + use of Mandwa weeder at 20 DAT at an interval of 7 days up to 50 DAT; W_3, weeding by Mandwa weeder at 10 DAT + application of a post-emergence herbicide, chlorimuron ethyl + metsulfuron methyl @ 4g/ha at 20 DAT, W_4, application of pre-emergence herbicide pretilachlor @ 750 g/ha at 3 DAT followed by post emergence herbicide chlorimuron ethyl + metsulfuron methyl @ 4 g/ha at 20 DAT; WCE., Weed control efficiency

under this treatment. Similar results have been reported by Babar and Velayutham (2012).

Economics

Application of 50 mm water on the day before weeding operation (I_1) recorded 8.6 and 25.9% higher net returns than application of 25 mm of water (I_2) and saturation (I_3) respectively (Table 2). It also recorded higher benefit: cost ratio (2.88) over the other two water application method.

Highest net returns (₹52,714/ha) and benefit: cost ratio (3.35) was found with pre and post – emergence application of herbicides (W_4) owing to the highest yield and cultivation cost. One time use of herbicide either as pre- or post-emergence reduced the net returns to 6–23.6% as in case of W_2 and W_3 and the lowest net returns was recorded with W_1 due to ineffective weed control and higher labour cost for weeding. This is in conformity with the finding of Walia *et al*. (2012), who reported that sole application of pre or post-emergence herbicide did not provide effective control of weeds as compared to combination of pre and post-emergence herbicide.

The results of the study showed that application of 50 mm water on the day before weeding (I_1) and pre- emergence herbicide (pretilachlor) at 3 DAT, followed by post-emergence herbicide (chlorimuron ethyl + metsulfuron methyl) at 20 DAT (W_4) recorded the highest yield in rice.

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