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Influence of puddling intensity and water-management practices on weed dynamics and yield of transplanted rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted at Tirupati during winter (*rabi*) season of 2003 and 2004 to evaluate the efficiency of low-dose herbicides under different puddling and water-management practices on yield attributes and yield of transplanted rice (*Oryza sativa* L.). Intensive puddling with continuous submergence (IPCS) recorded the lowest weed density and dry weight, highest stature of yield attributes (panicles/m^2, length of the panicle and filled grains/panicle), higher grain and straw yields and higher economic returns, but it was comparable with intensive puddling with irrigation a day after disappearance of ponded water (IPDDPW) treatment. The increase in grain yield was 40.1, 31.2 and 13.6% in IPCS, IPDDPW and normal puddling with continuous submergence (NPCS) respectively over normal puddling with irrigation a day after disappearance of ponded water (NPDDPW). Significantly lowest water requirement and highest water-use efficiency (WUE) was registered with IPDDPW followed by IPCS. Among the weed-management practices, oxadiargyl 75 g/ha + hand-weeding (HW) at 40 days after transplanting (DAT) recorded the highest values of all the yield attributes, yield and economic returns with lesser weed density and dry weight over the unweeded check, which was on a par with HW twice (20 and 40 DAT). On an average, the increase in grain yield was 39.5 and 34.2% in oxadiargyl 75 g/ha + HW (40 DAT) and HW twice (20 and 40 DAT) respectively over the unweeded check. The highest WUE was registered with oxadiargyl 75 g/ha + HW (40 DAT), followed by HW twice (20 and 40 DAT); however the difference in water requirement of rice due to different weed-management practices was not statistically evident.

Key words : Economics, Low-dose herbicides, Puddling, Transplanted rice, Water management, Yield

Among the cereals, rice (*Oryza sativa* L.) is the major source of calories for 40% of the world population. The cultivation of high-yielding dwarf varieties responsive to fertilizers and irrigation, as well as the new intensive cropping systems have brought to the forefront of serious weed problems. The yield loss in transplanted rice due to unchecked weed growth is 47% (Mukherjee and Singh, 2004). Puddling and water management are extremely important operations to suppress the weed growth, which are frequently overlooked by the farmers. Water management not only controls the weeds but also decides the efficiency of the applied herbicide in rice. Most of the herbicides used in rice fields were required in quite large quantities of active ingredients such as butachlor (1-1.5 kg/ha), pretilachlor (1 kg/ha), anilofos (0.5-1.0 kg/ha) etc., and these herbicides may leave more residues in the soil. Repeated use of any single herbicide in any crop generates a shift in the composition of weed flora, leading to dominance of secondary weeds. Some of the low-dose herbicides other than sulfonyl urea are available to control the weeds very effectively in field crops. Hence to reduce the herbicide pollution, weed-management practices may be planned on integrated manner by using limited quantity of high-efficiency, environment-friendly and low-dose herbicides along with puddling and water-management practices to suppress the weed growth. Keeping these points in view, the present study was undertaken to study the efficiency of two low-dose herbicides (oxadiargyl and cinmethylin) on yield attributes and yield of transplanted rice under different puddling intensities and water-management practices.

MATERIALS AND METHODS

The field experiment was conducted at S.V. Agricultural College Farm, Tirupati during winter (*rabi*) season of 2003 and 2004. The soil was sandy clay-loam, low in organic carbon (0.22%) and available N (179 kg/ha), medium in available P (23 kg/ha) and K (184 kg/ha) and slightly alkaline (pH 7.8) in reaction. The experiment was laid out in split-plot design by keeping four combinations

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of puddling and water-management practices in main plots, viz. Normal puddling with continuous submergence (NPCS) (5 cm), Normal puddling with irrigation a day after disappearance of ponded water (NPDDPW), Intensive puddling with continuous submergence (IPCS) (5 cm) and Intensive puddling with irrigation a day after disappearance of ponded water (IPDDPW); and six weed-management practices were allotted to subplots, viz. unweeded check, hand-weeding (HW) twice [20 and 40 days after transplanting (DAT)], oxadiargyl 75 g/ha, cinmethylin 75 g/ha, oxadiargyl 75 g/ha + HW (40 DAT), cinmethylin 75 g/ha + HW (40 DAT). All the treatments were replicated thrice.

The plots meant for intensive puddling were puddled twice with measured quantity of water, starting 2 weeks before transplanting with *Bose* plough and these plots were again puddled twice with *Bose* plough and once with bullock-drawn wetland puddler a week before transplanting. For nursery, intensive puddling and normal puddling plots respectively 40 mm, 450 mm and 200 mm irrigation water was used, and there was no contribution of ground water to the crop during its growth period. The total rainfall received during the crop-growth period was only 7.4 mm during 2003, and no rainfall was received during 2004. Normal-puddling plots were puddled twice with *Bose* plough and once with bullock-drawn wetland puddler a week before transplanting. The depth of submergence was maintained as per the treatment by replenishing the daily water loss due to evapo-transpiration and percolation. The depth of water in the field was measured by using inverted T-type graduated gauge. Trimmed bund of 50 cm and buffer strip of 75 cm width between the plots were provided to minimize the seepage loss. To drain out the excess water from the plots, an overflow arrangement was provided for each plot by installing a brick outlet at 5 cm still well. Irrigation was withheld in all the plots after physiological maturity.

Rice variety 'Shravani' was transplanted at 15 cm × 10 cm spacing on 9 November 2003 and 12 November 2004, and harvested on 20 March 2004 and 22 March 2005 respectively. Recommended level of fertilizer nutrients (120 kg N + 26.2 kg P + 50 kg K/ha) were applied. Half the recommended dose of N in the form of urea and full dose of P and K through single superphosphate and muriate of potash were applied basal and the remaining N was top-dressed in two equal splits at tillering and panicle-initiation stages. Herbicides oxadiargyl and cinmethylin were applied at 4 and 7 days after transplanting as per the treatment, with the help of a knapsack sprayer fitted with flat-fan nozzle by using spray volume of 600 litres/ha, and hand-weeding was done as per the treatment. Observations on total density and dry weight of weeds were recorded at harvest from two randomly selected quardrats of 0.25 m^2 in each plot. The weed flora of the experimental field was composite in nature, consisting of four species of grasses such as *Echinochloa crus-galli* L., *Digitaria sanguinalis* L., *Panicum repens* L. and *Cynodon dactylon* L.; three species of sedges such as *Cyperus difformis* L., *Cyperus iria* L. and *Cyperus rotundus* L.; and five species of broad-leaf weeds such as *Eclipta alba* L., *Ammania baccifera* L., *Monochoria vaginalis* Burm., *Phyllanthus niruri* L. and *Commelina benghalensis* L.

RESULTS AND DISCUSSION

Effect on weeds

All the puddling and water-management practices significantly influenced the weed density and dry weight in the transplanted rice. Significantly lowest weed density and dry weight were recorded with IPCS over the rest of the puddling and water-management practices, followed by IPDDPW and NPCS with significant difference between them. On an average, the reduction in weed density and dry weight was 73.9 and 68.9% in IPCS, and 49.1 and 48.7% in IPDDPW respectively over NPDDPW (Table 1). The highest weed-control efficiency (WCE) was registered with IPCS, followed by IPDDPW. This might be due to effective control of all types of weeds during intensive puddling before transplanting. Continuous submergence after transplanting suppresses the weed-seed germination. These findings are in accordance with those of Vandana and Reddy (1999). Among weed-management practices, the lowest weed density and dry weight of weeds were registered with oxadiargyl 75 g/ha + HW (40 DAT), which was on a par with that of HW twice (20 and 40 DAT) for dry weight of weeds. On an average, the maximum WCE of 85.3 and 82.6% was registered with oxadiargyl 75 g/ha + HW (40 DAT) and HW twice (20 and 40 DAT). This could be attributed to greater reduction in dry weight of weeds by the combined effect of oxadiargyl and hand-weeding. Gitspoulos and Froud Williams (1999) also reported similar results with oxadiargyl due to its longer persistence and release of toxic singlet oxygen in susceptible weeds.

Effect on yield attributes and yield

There was significant effect of combination of puddling and water-management practices on yield attributes and yield of transplanted rice. The highest number of panicles/m^2 along with longest panicles with more number of filled grains/panicle were recorded with IPCS. All the yield attributes were on a par with IPCS and IPDDPW (Table 1). On an average, 20.0, 19.0 and 9.2% increase in number of panicles/m^2, 22.9, 23.8 and 6.9% increase in panicle length, and 22.3, 22.6 and 8.5% increase in number of

Table 1. Effect of puddling, water and weed-management practices on weed growth and yield attributes of transplanted rice

Treatment	Weed density (no./m²)		Dry weight of weeds (g/m²)		Weed-control efficiency (%)		Panicles/m²		Panicle length (cm)		Filled grains/panicle	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Puddling and water-management practice												
NPCS	8.61	8.39	9.04	9.34	53.53	53.59	314	324	21.27	21.14	79.3	81.9
	(86.33)	(81.43)	(92.43)	(99.61)								
NPDDPW	10.12	9.79	11.94	11.42	49.08	48.80	288	296	19.92	20.67	72.9	75.6
	(120.65)	(112.82)	(157.58)	(143.90)								
IPCS	5.25	4.99	6.19	6.63	54.05	54.92	352	360	25.81	26.81	94.3	96.9
	(32.01)	(28.88)	(43.73)	(49.64)								
IPDDPW	7.31	6.97	8.09	8.35	52.54	52.82	342	353	24.59	25.65	89.9	92.2
	(62.49)	(56.33)	(74.77)	(79.29)								
SEm±	0.12	0.15	0.17	0.10			3	3	0.42	0.76	1.7	1.5
CD (P=0.05)	0.42	0.51	0.58	0.35			11	10	1.45	2.65	5.9	5.2
Weed-management practice												
Unweeded check	12.89	12.38	13.52	13.78			298	307	20.50	21.00	70.8	73.0
	(175.13)	(162.62)	(190.81)	(195.17)								
HW twice (20 and 40 DAT)	4.89	4.79	5.65	5.69	81.87	83.24	337	347	24.07	25.01	91.4	94.0
	(24.95)	(23.95)	(34.01)	(33.38)								
Oxadiargyl 75 g/ha	9.00	8.65	10.16	10.25	43.98	44.92	320	330	22.25	22.80	82.3	85.1
	(85.25)	(78.38)	(108.75)	(108.61)								
Cinmethylin 75 g/ha	10.66	10.24	11.68	11.87	25.92	26.21	309	317	21.82	22.68	77.4	79.5
	(119.15)	(110.02)	(142.68)	(145.66)								
Oxadiargyl 75 g/ha + HW (40 DAT)	4.12	3.97	5.24	5.41	85.55	85.06	344	352	24.71	25.60	95.2	98.1
	(17.95)	(16.39)	(29.15)	(30.72)								
Cinmethylin 75 g/ha + HW (40 DAT)	5.6	5.18	6.64	6.61	76.50	77.17	335	344	23.56	24.55	87.6	90.1
	(29.79)	(27.73)	(47.38)	(45.12)								
SEm±	0.17	0.17	0.16	0.09			2	3	0.44	0.58	1.8	1.6
CD (P=0.05)	0.49	0.50	0.47	0.28			5	8	1.25	1.66	5.2	4.6

Data subjected to square-root ($\sqrt{x+0.5}$) transformation; Figures in parentheses are original values

Treatment details of puddling and water-management practices are given under Materials and Methods

filled grains/panicle were recorded with IPCS, IPDDPW and NPCS respectively over NPDDPW. The highest grain and straw yields were recorded with IPCS, which was on a par with IPDDPW. On an average, the increase in grain yield was 40.1, 31.2 and 13.6% and in straw yield was 27.4, 26.4 and 8.7% in IPCS, IPDDPW and NPCS respectively over NPDDPW (Table 2). This might be due to reduced crop-weed competition, better availability of soil nutrients and efficient translocation of photosynthates from source to sink, leading to increased yield in IPCS and IPDDPW than NPDDPW. These findings are in accordance with those of Belder *et al.* (2004).

Among the weed-management practices, oxadiargyl 75 g/ha + HW (40 DAT) and HW twice (20 and 40 DAT) were at par for panicles/m^2, length of the panicle and number of filled grains/panicle, and both the weed-management practices were significantly superior to unweeded check. The increase in number of panicles/m^2 and number of filled grains/panicle were 15.0 and 34.4% under oxadiargyl 75 g/ha + HW (40 DAT), and 13.1 and 28.9% under HW twice (20 and 40 DAT). Significantly highest grain yield was obtained with oxadiargyl 75 g/ha +HW (40 DAT), which was comparable to that of HW twice (20 and 40 DAT). On an average, the increase in grain yield was 39.5 and 34.2% in oxadiargyl 75 g/ha + HW (40 DAT) and HW twice (20 and 40 DAT) over the unweeded check. Singh *et al.* (2004) also reported similar trend for straw yield.

Water productivity

Significantly lowest water requirement was recorded with IPDDPW among the puddling and water-management practices, followed by IPCS and NPDDPW, and the differences were found significant. Mean data of 2 years show that water requirement of transplanted rice decreased by 42.9, 25.0 and 18.4% in IPDDPW, IPCS and NPDDPW respectively over NPCS. This might be due to increased bulk density and decreased hydraulic conductivity (Sidhu *et al.*, 2003). The highest WUE was recorded with IPDDPW, which was significantly superior to all other puddling and water-management practices, followed by IPCS and NPDDPW, with significant disparity between them. This might be due to lower water requirement and comparable grain yield in IPDDPW than in IPCS. There was no significant difference between the weed-management practices for water requirement of transplanted rice; however, the highest WUE was registered with oxadiargyl 75 g/ha + HW (40 DAT), followed by HW

Table 2. Effect of puddling, water and weed-management practices on yield, water-use efficiency and economics of transplanted rice

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Irrigation water applied (mm)		Water-use efficiency (kg/ha-mm)		Net return (Rs/ha)		B : C ratio	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Puddling and water-management practice												
NPCS	4.50	4.83	5.79	6.01	2,396	2,426	1.93	2.00	18,037	19,378	2.15	2.23
NPDDPW	4.50	4.22	5.33	5.53	1,952	1,984	2.07	2.13	14,233	15,486	1.90	2.00
IPCS	5.68	5.91	6.77	7.05	1,799	1,817	3.15	3.24	25,149	26,817	2.59	2.70
IPDDPW	5.32	5.53	6.73	7.00	1,365	1,386	3.90	3.99	23,248	24,801	2.50	2.60
SEm±	0.12	0.11	0.06	0.05	42	30	0.02	0.03	548	577	0.03	0.03
CD (P=0.05)	0.43	0.39	0.21	0.20	147	103	0.08	0.09	1,920	2,022	0.11	0.10
Weed-management practice												
Unweeded check	4.02	4.18	5.37	5.59	1,896	1,931	2.25	2.30	14,706	15,920	1.99	2.07
HW twice (20 & 40 DAT)	5.39	5.62	6.66	6.93	1,832	1,900	3.02	3.10	22,964	24,594	2.43	2.53
Oxadiargyl 75 g/ha	4.84	5.31	6.32	6.27	1,832	1,901	2.72	2.80	19,614	21,020	2.26	2.36
Cinmethylin 75 g/ha	4.47	4.66	5.65	5.88	1,882	1,894	2.53	2.62	17,044	18,379	2.09	2.18
Oxadiargyl 75 g/ha + HW (40 DAT)	5.61	5.83	6.71	6.98	1,876	1,904	3.14	3.20	24,672	26,287	2.56	2.67
Cinmethylin 75 g/ha + HW (40 DAT)	5.21	5.42	6.41	6.77	1,870	1,891	2.91	3.02	21,998	23,523	2.38	2.49
SEm±	0.09	0.09	0.08	0.07	45	26	0.03	0.05	598	616	0.04	0.04
CD (P=0.05)	0.27	0.27	0.23	0.19	NS	NS	0.07	0.09	1,710	1,761	0.10	0.11

Cost of rice seed @ Rs 6.00/kg during both the years

Treatment details of puddling and water-management practices are given under Materials and Methods

Table 3. Interaction effect of puddling and water vs weed-management practices on dry weight of weeds (g/m^2) of transplanted rice

Puddling and water-management practice	Unweeded check		HW twice (20 and 40 DAT)		Oxadiargyl 75 g/ha		Cinmethylin 75 g/ha		Oxadiargyl 75 g/ha + HW (40 DAT)		Cinmethylin 75 g/ha + HW (40 DAT)	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
NPCS	14.11	14.88	5.85	5.84	10.25	10.64	11.98	12.55	5.25	5.57	6.80	6.56
	(198.84)	(221.00)	(34.25)	(33.69)	(105.00)	(112.83)	(143.20)	(157.04)	(27.10)	(30.55)	(46.20)	(42.67)
NPDDPW	17.60	16.78	7.90	7.50	13.75	13.06	15.46	15.01	7.50	7.49	9.43	8.72
	(309.50)	(281.12)	(62.50)	(55.84)	(189.80)	(170.29)	(238.60)	(224.81)	(55.90)	(55.73)	(89.20)	(75.61)
IPCS	9.74	10.36	3.95	4.26	7.25	7.65	8.31	8.79	3.50	3.73	4.41	5.04
	(95.20)	(106.85)	(15.30)	(17.71)	(52.20)	(58.10)	(68.70)	(76.78)	(12.00)	(13.44)	(19.00)	(25.00)
IPDDPW	12.64	13.12	4.92	5.17	9.40	9.68	10.98	11.16	4.70	4.86	5.95	6.14
	(159.70)	(171.71)	(24.00)	(26.28)	(88.00)	(93.22)	(120.20)	(124.04)	(21.60)	(23.18)	(35.10)	(37.31)

	2003 SEm±	*2003* CD (P=0.05)	*2004* SEm±	*2004* CD (P=0.05)
Weed-management practices at same level of puddling and water management	0.40	0.94	0.19	0.56
Puddling and water-management practices at same level of weed-management practices	0.34	1.03	0.18	0.54

Data subjected to square-root ($\sqrt{x+0.5}$) transformation; Figures in parentheses are original values

Treatment details of puddling and water-management practices are given under Materials and Methods

Table 4. Interaction effect of puddling and water vs weed-management practice on grain yield and and water-use efficiency in transplanted rice

Puddling and water-management practice	Unweeded check		HW twice (20 and 40 DAT)		Oxadiargyl 75 g/ha		Cinmethylin 75 g/ha		Oxadiargyl 75 g/ha + HW (40 DAT)		Cinmethylin 75 g/ha + HW (40 DAT)	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Grain yield												
NPCS	3.00	3.71	5.22	5.46	4.50	4.70	4.04	4.20	5.49	5.71	4.99	5.19
NPDDPW	3.00	3.16	4.65	4.84	3.92	4.07	3.40	3.55	4.92	5.11	4.42	4.60
IPCS	5.05	5.27	6.01	6.25	5.62	5.85	5.41	5.63	6.11	6.35	5.89	6.12
IPDDPW	4.42	4.60	5.69	5.92	5.29	5.50	5.05	5.26	5.92	6.15	5.55	5.77
Water-use efficiency (kg/ha-cm)												
NPCS	1.49	1.51	2.18	2.25	1.89	1.94	1.69	1.74	2.29	2.35	2.02	2.14
NPDDPW	1.52	1.57	2.40	2.45	2.03	2.04	1.73	1.79	2.54	2.58	2.24	2.35
IPCS	2.76	2.84	3.31	3.42	3.12	3.23	3.03	3.13	3.37	3.47	3.30	3.38
IPDDPW	3.22	3.28	4.21	4.22	3.88	3.97	3.69	3.81	4.35	4.46	4.07	4.21

	Grain yield 2003 SEm±	*Grain yield* 2003 CD (P=0.05)	*Grain yield* 2004 SEm±	*Grain yield* 2004 CD (P=0.05)	*Water-use efficiency* 2003 SEm±	*Water-use efficiency* 2003 CD (P=0.05)	*Water-use efficiency* 2004 SEm±	*Water-use efficiency* 2004 CD (P=0.05)
Weed-management practices at same level of puddling and water management	0.19	0.53	0.19	0.54	0.05	0.15	0.10	0.28
Puddling and water-management practices at same level of weed-management	0.19	0.57	0.18	0.56	0.07	0.23	0.09	0.27

Treatment details of puddling and water-management practices are given under Materials and Methods

twice (20 and 40 DAT), as these weed management practices recorded the highest grain yield and lesser water requirement than unweeded check.

Economics

Intensive puddling with continuous submergence recorded the highest net returns, which were comparable with IPDDPW, and both of them were significantly higher than with other puddling and water-management practices. Normal puddling with irrigation a day after disappearance of ponded water was uneconomical, as it gave lower net returns and benefit : cost ratio. Among the weed-management practices, significantly highest net returns and benefit : cost ratio were registered with oxadiargyl 75 g/ha + HW (40 DAT), followed by HW twice (20 and 40 DAT). This might be due to less cost of weeding and higher grain and straw yield in these treatments.

Interaction

The interaction effect of puddling and water as well as weed-management practices significantly influenced the dry weight of weeds, yield attributes and grain yield of transplanted rice. The lowest dry weight of weeds was obtained with oxadiargyl 75 g/ha + HW (40 DAT) along with IPCS, which was comparable with HW twice (20 and 40 DAT) with same puddling and water-management practice. Application of oxadiargyl with or without HW was effective in controlling the weeds better than cinmethylin among all the puddling and water management practices (Table 3).

The maximum number of panicles/m^2 (373) and filled grains/panicle (107) were recorded with oxadiargyl 75 g/ha + HW (40 DAT) along with IPCS or IPDDPW, which were comparable with HW twice (20 and 40 DAT) under IPCS treatment. This is mainly due to reduced dry weight of weeds and increased number of panicles/m^2 and filled grains/panicle in these treatment combinations. On an average, application of oxadiargyl 75 g/ha + HW along with IPCS recorded 49.5% increase in grain yield and decrease in dry weight of weeds by 95.7% over the unweeded check combined with NPDDPW.

Oxadiargyl with or without HW recorded higher yield attributes and grain yield than cinmethylin at all the puddling intensities and water management practices. The highest WUE was obtained with oxadiargyl + HW (40 DAT) along with IPDDPW, which was statistically on a par with HW twice (20 and 40 DAT) along with IPDDPW (Table 4). Irrespective of the weed-management practices, IPDDPW recorded the lowest irrigation water applied to rice, which gave grain yield equal to that of IPCS. The lowest grain yield and WUE were recorded in unweeded check along with NPDDPW, which were on a par with cinmethylin at 75 g/ha along with NPDDPW due to severe weed infestation, reduced number of panicles/m^2 (256), filled grains/panicle (64) and slight phytotoxicity of cinmethylin immediately after application in NPDDPW (Yuan-Shuzhomg *et al.*, 2002).

The present study revealed that pre-emergence application of oxadiargyl 75 g/ha + HW 40 DAT or HW twice (20 and 40 DAT) along with IPCS gave the highest grain yield and economic returns. However, the lowest water requirement, higher WUE and comparable grain yield were recorded with IPDDW in transplanted rice.

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