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Production potential, water-use efficiency and economics of hybrid rice under different levels of irrigation and weed management practices

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ABSTRACT

The effect of irrigation levels and weed management practices on yield, yield components, water-use efficiency and economics of hybrid rice (cv. Pro Agro 6444) was studied. The results revealed that continuous submergence of 5 ï 2 cm with weed free check (at fortnight interval) showed maximum grain yield (8.22 t ha^{-1}) and yield attributes. Continuous submergence with unweeded control consumed maximum water (153 cm) and lowest water-use efficiency (4.02 kg ha^{-1} mm^{-1}), while irrigation (5 cm) at 3 days after disappearance of ponded water with weed free check gave the maximum water-use efficiency (16.31 kg ha^{-1}mm^{-1}). The maximum net return (Rs.33,565 ha^{-1}) was obtained under continuous submergence with weed free check, however, the benefit: cost ratio (1.94) was highest under continuous submergence with pre-emergence application of Pyrazosulfuron ethyl 10% WP @ 25 g ha^{-1} at 7 days after transplanting.

Key words: *Hybrid rice, irrigation, weed management, yield potential, water-use efficiency, economics*

Proper water and weed management practices are important factors that control the ultimate yield of hybrid rice crop, as water requirement of rice is fairly higher than other crops and water management is more important especially for introduction of hybrids rice which do not withstand higher depth of water. Besides, weeds are considered as a major pest, which stand on the way in increasing rice production (Labrada, 1996). The present investigation was undertaken to study the effect of different irrigation levels and weed management practices on yield potential, water-use efficiency and economics of hybrid rice in winter season.

MATERIALS AND METHODS

The field experiment was carried out during two dry seasons of 2002-03 and 2003-04 (December- May) at the Instructional Farm, BCKV, Jaguli, Mohanpur, Nadia (W.B.), having sandy-clay loam soil, pH 6.8, organic carbon 0.51%, total N 0.054%, available P 21.06 kg ha^{-1} and available K 160.68 kg ha^{-1}. The experiment was conducted in split plot design with 3 replications and 20 treatment combinations. The main plots consisted of 4 irrigation levels, viz. continuous submergence of 5 ± 2 cm irrigation water (I_1), irrigation (5 cm) at 1 day after disappearance of ponded water (I_2), irrigation (5 cm) at 2 days after disappearance of ponded water (I_3) and irrigation (5 cm) at 3 days after disappearance of ponded water (I_4), while sub-plot treatments consisted of 5 weed management practices, viz. unweeded control (W_0), weed free check at fortnight interval (W_1), pre-emergence application of pyrazosulfuron ethyl (PSE) 10% WP @ 25 g a.i. ha^{-1} at 7 days after transplanting (DAT) (W_2), pre-emergence application of pretilachlor 50 EC @ 400 g a.i. ha^{-1} at 3 DAT (W_3) and hand weeding twice at 25 and 45 DAT (W_4). Depth of water in each irrigation treatment was measured by 'drum culture method'. The seedlings of hybrid rice variety 'Pro Agro 6444' was transplanted at thirty days old with 20 x15 cm apart and one seedling hill^{-1}. The crop received uniform doses of plant nutrients @ 120: 60: 60 kg ha^{-1} of N, P_2O_5 and K_2O through urea, single super phosphate and muriate of potash respectively. Full dose of P and K were applied as basal, 1/4th N was top dressed at 10 days after transplanting, ½ N was top dressed at 25 days after transplanting (active tillering stage) and the rest 1/4th N was top dressed at 60 days after transplanting (panicle initiation stage). The duration of the crop was 150 days. Observations on yield attributes and yield were recorded after harvest of the crop. Water-use efficiency was computed on the basis of water use and grain yield. Economics of treatments was calculated on present market price of yields and inputs. The selling price of paddy grain and straw was Rs.6000 t^{-1} and Rs.500 t^{-1} respectively. The cost of cultivation was as follows: common cost for all treatments = Rs.14883 ha^{-1}; cost of weed control treatments (Rs. ha^{-1})- W_0 = 540, W_1 = 7452, W_2 = 499, W_3 = 524 and W_4 = 3726; irrigation cost (Rs. ha^{-1} $season^{-1}$) = 540.

RESULTS AND DISCUSSION

The predominant weed flora associated with the crop was grasses (*Echinochloa crusgalli*, *Cynodon dactylon*, *Leersia hexandra*), sedges (*Cyperus rotundus*, *Cyperus difformis*, *Fimbristylis littoralis*) and broad leaves (*Ludwigia octovalvis*, *Monochoria vaginalis*, *Marsilea minuta*). Dry weight of weeds $unit^{-1}$ area was lowest when continuous submergence of 5±2 cm condition (I_1) was maintained in the field, followed by irrigation (5 cm) at 1 day after disappearance of ponded water (I_2) (Table 1). This might be due to lack of oxygen under continuous submergence results lower emergence of weeds. With the increase in degree of dryness dry weight of weeds was also increased, might be due to increased number of total weeds $unit^{-1}$ area. Compared to unweeded check, substantial reduction in dry matter production of weed was observed under different weed control treatments at all the stages of observation. Such effects were more pronounced under weed free check (W_1), followed by hand weeding twice (25 and 45 DAT). Among the herbicidal treatments, Pyrazosulfuron ethyl (W_2) @ 25 a.i.g ha^{-1} were equally effective and significantly superior to Pretilachlor (W_3) for controlling population and dry matter production of weed. Halder (2000) reported that Pyrazosulfuron ethyl @ 15 a.i. g ha^{-1} when applied as pre-emergence provided an excellent performance in lowering down both the weed population and weed dry matter weight throughout the growing period duo to its effectiveness against a broad spectrum of rice weed specially sedges and broad leaved weeds. Weed control efficiency was also the highest (81.55%) in weed free check (W_1) treatment, followed by hand weeding twice (W_4), Pyrazosulfuron ethyl (W_2) and Pretilachlor (W_3) respectively (Table 1).

Different levels of irrigations and methods of weed control significantly influenced yield and yield attributes (Table 2). Among the different levels of irrigation schedules, the continuous submergence of 5 ± 2 cm irrigation water (I_1) showed the maximum number of effective tiller m^{-2} (324), length of panicle (25 cm), filled grains $panicle^{-1}$ (72.81) and 1000-grain weight (22.25 g) than other levels, resulting in the highest grain yield (7.04 t ha^{-1}). Increased days of dryness substantially decreased the yield attributes and grain yield. This might be due to cyclic submergence with differential depth of water as well as moisture stress not favoured the growth of the crop. The results are in agreement with Singh *et al.* (1997).

Crop under weed free check (W_1) produced the highest grain yield (7.54 t ha^{-1}), followed by hand weeding twice at 25 and 45 DAT (W_4). This could be attributed to less weed infestation favoured to produce higher yield components. Among the herbicidal treatments, pre-emergence application of PSE @ 25 g ha^{-1} at 7 DAT (W_2) was better than pre-emergence application of Pretilachlor @ 400 g a.i. ha^{-1} at 3 DAT (W_3) in respect of yield attributes and grain yield (Table 2). This might be due to that pre-emergence application of PSE in transplanted hybrid rice gave higher efficacy in controlling weeds, which in turn increased the yield attributes that ultimately reflected in higher yield of grains. However, minimum values were observed under unweeded control (W_0), might be owing to high weed infestation as well as competition during the growth period of the crop hindered to produce optimum number of yield attributes, resulting in lower grain yield. Similar results were also observed by Bhattacharya and Kumbhakar (1998) and Halder (2000).

Interaction between levels of irrigation and methods of weed control on yield attributes was significant (Table 3). Within the same method of weed control, continuous submergence of 5 ± 2 cm depth of water (I_1) recorded maximum number of effective tillers m^{-2}, longest panicle, maximum filled grains $panicle^{-1}$ and highest value of 1000-grain weight than other irrigation treatments. Similarly, within a same level of irrigation, weed free check (W_1) produced the highest value of yield attributes. These interaction effects were reflected in the grain yield of rice, which was the maximum (8.22 t ha^{-1}) under I_1W_1 treatment (Table 4).

Mean data of two years showed that continuous submergence coupled with unweeded

Table 1. Effect of levels of irrigation and weed management practices on dry weight of weeds (g m^{-2}) and weed control efficiency (%)

Treatments	Dry weight of weeds (g m^{-2})														
	30 DAT			60 DAT			90 DAT			Harvest			WCE (%) at harvest		
	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled
Levels of irrigation															
I_1	5.33	5.51	5.42	7.15	7.09	7.12	12.79	12.76	12.78	14.12	15.46	14.79			
I_2	5.53	5.57	5.55	7.14	7.19	7.17	12.42	13.22	12.82	14.24	15.69	14.96			
I_3	5.79	5.75	5.77	7.16	7.12	7.15	12.91	12.88	12.89	14.79	15.78	15.29			
I_4	5.87	5.89	5.88	7.52	7.28	7.40	12.59	13.47	13.17	15.63	16.01	15.82			
CD (P= 0.05)	0.225	0.292	0.249	0.360	NS	NS	NS	NS	NS	0.421	0.417	0.365			
Weed management															
W_0	12.85	13.14	12.99	17.88	18.01	17.95	28.15	20.09	28.62	32.81	35.04	33.93	-	-	-
W_1	2.87	3.15	3.01	3.46	3.53	3.49	6.04	6.25	6.15	6.05	6.46	6.26	81.53	81.57	81.55
W_2	3.92	3.89	3.90	4.03	4.23	4.13	8.36	9.41	8.88	12.49	13.47	12.98	61.94	51.53	61.73
W_3	4.90	4.81	4.86	7.33	6.19	6.76	13.75	13.65	13.70	14.63	16.36	15.49	55.42	53.31	54.33
W_4	3.61	3.42	3.51	3.51	3.91	3.71	7.41	7.02	7.22	7.49	7.32	7.41	77.15	79.11	78.16
CD (P= 0.05)	0.382	0.403	0.387	0.403	0.362	0.378	0.619	0.516	0.631	0.572	0.548	0.524			

DAT = Days after transplanting; S_1= 1st year (2002-03); S_2= 2nd year (2003-04); NS= Not significant; Details of the treatments are given under Materials and Methods

Table 2. Effect of levels of irrigation and weed management practices on yield components and grain yield of hybrid rice

Treatments	Yield components														
	Effective tiller m^{-2}			Length of panicle (cm)			Filled grains panicle^{-1}			1000-grain weight (g)			Grain yield (t ha^{-1})		
	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled	S_1	S_2	Pooled
Levels of irrigation															
I_1	328.35	319.67	324.01	25.89	24.10	24.99	74.18	71.44	72.81	22.33	22.18	22.25	7.44	6.64	7.04
I_2	327.28	318.26	322.77	25.67	23.79	24.73	72.62	70.82	71.72	22.28	22.16	22.22	6.90	6.76	6.83
I_3	324.02	317.70	320.86	25.06	23.30	24.18	72.23	69.30	70.76	22.08	22.12	22.09	6.63	6.49	6.56
I_4	325.20	316.93	321.06	24.96	23.18	24.07	71.28	68.27	69.77	22.00	22.05	22.03	6.28	6.20	6.24
CD (P= 0.05)	2.065	1.078	1.165	NS	0.194	0.425	0.799	0.798	0.578	0.055	0.026	0.031	1.615	0.751	0.948
Weed management															
W_0	286.95	278.31	282.63	24.49	22.88	23.68	62.37	60.62	61.49	21.28	21.16	21.22	5.89	5.56	5.73
W_1	344.88	336.52	340.70	26.17	24.80	25.48	80.80	77.30	79.05	22.78	22.66	22.72	7.59	7.48	7.54
W_2	336.13	326.30	331.21	25.29	22.89	24.09	73.21	70.81	72.01	22.56	22.53	22.54	6.97	6.32	6.65
W_3	322.22	316.98	319.60	24.99	22.68	23.83	70.01	67.37	68.69	21.59	21.66	21.63	6.20	6.14	6.17
W_4	340.88	332.58	336.73	26.04	24.70	25.37	76.51	73.70	75.09	22.66	22.61	22.64	7.46	7.02	7.24
CD (P= 0.05)	1.654	1.436	1.095	0.767	0.204	0.396	0.778	0.784	0.578	0.068	0.026	0.037	1.565	0.696	0.923

S_1= 1st year (2002-03); S_2= 2nd year (2003-04); NS= Not significant; Details of the treatments are given under Materials and Methods

Table 3. Interaction effect of levels of irrigation and weed management practices on yield components of hybrid rice (pooled data of two years)

Treatments	Effective tiller m^{-2}					Length of panicle (cm)					Filled grains $panicle^{-1}$					1000-grain weight (g)				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
W_0	287.65	283.67	279.80	279.40	282.63	24.45	23.93	23.06	23.31	23.68	65.99	62.28	60.13	57.56	61.49	21.28	21.33	21.15	21.11	21.22
W_1	341.97	341.28	338.93	340.63	340.70	25.72	25.63	25.45	25.14	25.48	79.93	78.97	78.92	78.38	79.05	22.82	22.78	22.67	22.62	22.72
W_2	331.82	331.17	331.10	330.77	331.21	24.69	24.50	23.67	23.50	24.09	72.28	1.94	71.92	71.90	72.01	22.64	22.54	22.52	22.48	22.54
W_3	320.79	320.67	318.78	318.15	319.59	24.58	24.08	23.36	23.33	23.83	69.65	69.54	68.55	67.02	68.69	21.79	21.75	21.57	21.39	21.63
W_4	337.82	337.07	335.68	336.37	336.73	25.54	25.51	25.36	25.07	25.37	76.20	75.87	74.28	73.99	75.09	22.72	22.71	22.58	22.54	22.64
Mean	324.01	322.77	320.86	321.06		24.99	24.73	24.18	24.07		72.81	71.72	70.76	69.77		22.25	22.22	22.09	22.03	
CD (P= 0.05)		I x W		W x I			I x W		W x I			I x W		W x I			I xW		W x I	
		2.190		2.275			0.409		0.413			1.618		1.721			0.073		0.074	

I= Levels of irrigation; W= Weed management practices; Details of the treatments are given under Materials and Methods

control (I_1W_0) received 37.5 number of irrigations and recorded the maximum water use (153 cm) (Table 4). This might be due to higher rate of evapo-transpiration both by hybrid rice as well as heavily infested weed population resulting in higher water use. In other irrigation treatments, the maximum number of irrigation (18.5) was received by irrigation (5 cm) at 1 day after disappearance of ponded water in combination with unweeded control (I_2W_0), which consumed 92.5 cm of water. However, irrigation (5 cm) at 3 days after disappearance of ponded water along with weed free check (I_4W_1) recorded 8.5 number of irrigations and utilized 42.5 cm of water. Increased gap of cyclic submergence with intensity of weed infestation utilized less water as evapo-transpiration resulting in lower value of water use. The results corroborated the findings of Mastan and Vijaykumar (1993).

The mean data of two years revealed that water-use efficiency (WUE) was influenced by levels of irrigation and methods of weed control treament combinations (Table 4). The highest value of WUE (16.30 kg $ha^{-1}mm^{-1}$) was recorded under irrigation (5 cm) at 3 days after disappearance of ponded water along with weed free check (I_4W_1), indicating that under the same treatment combinations, the highest yield was recorded with minimum water use. Similar trend of results was reported by Prasad *et al*. (1997). However, the lowest value of WUE (4.02 kg $ha^{-1}mm^{-1}$) was noticed under continuous submergence along with unweeded control (I_1W_0).

The mean data of two years showed that the levels of irrigation in combination with different methods of weed control directly influenced the production economics of hybrid rice (Table 4). The maximum net return (Rs.33,565 ha^{-1}) was obtained under continuous submergence along with weed free check treatment (I_1W_1), followed by continuous submergence along with hand weeding twice at 25 and 45 days after transplanting (I_1W_4), which might be due to maximum grain and straw yields. The lowest net return (Rs.20,642 ha^{-1}) was found under irrigation (5 cm) at 3 days after disappearance of ponded water along with unweeded control treatment (I_4W_0). However, the highest benefit: cost ratio (1.94) was obtained under continuous submergence along with pre-emergence application of pyrazosulfuron ethyl 10% WP @ 25 g a.i. ha^{-1} at 7 days after transplanting treatment (I_1W_2), closely

Table 4. Effect of irrigation and weed management treatment combinations on water use, water-use efficiency and economics of hybrid rice (mean data of two years)

Treatment combinations	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	No. of irrigation	Water use (cm)	Water-use efficiency (kg ha^{-1} mm^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit: costratio
I_1W_0	6.15	9.56	37.5	153	4.02	41680	26259	1.71
I_1W_1	8.22	14.24	30	123	6.68	56440	33565	1.57
I_1W_2	6.78	14.47	32.5	133	5.62	46915	30923	1.94
I_1W_3	6.49	11.22	35	143	4.54	44550	28603	1.79
I_1W_4	7.57	13.22	31	127	5.96	52030	32881	1.72
I_2W_0	5.79	9.70	18.5	92.5	6.26	39590	24167	1.57
I_2W_1	7.84	13.90	13.5	67.5	11.62	53990	31115	1.46
I_2W_2	6.70	12.56	16	80	8.38	46480	30558	1.92
I_2W_3	6.30	10.89	17.5	87.5	7.20	43245	27298	1.71
I_2W_4	7.50	12.57	14.5	72.5	10.35	51285	32136	1.68
I_3W_0	5.73	9.37	15.5	77.5	7.39	39065	23642	1.53
I_3W_1	7.19	12.65	10	50	14.38	49465	26590	1.26
I_3W_2	6.67	11.39	12.5	62.5	10.67	45715	29793	1.87
I_3W_3	6.14	10.85	14.5	72.5	8.47	42265	26318	1.65
I_3W_4	7.09	11.68	11	55	12.89	48380	29231	1.53
I_4W_0	5.25	9.13	14	70	7.50	36065	20642	1.34
I_4W_1	6.93	12.39	8.5	42.5	16.31	47775	24900	1.19
I_4W_2	6.44	10.90	12	60	10.73	44090	28168	1.77
I_4W_3	5.77	9.01	13	65	8.88	39125	23178	1.45
I_4W_4	6.79	11.48	10	50	13.58	46480	27331	1.43
CD (P= 0.05)	Ix W 0.998	WxI 0.982	IxW 1.02	WxI 0.997				

I= Levels of irrigation; W= Weed management practices; Details of the treatments are given under Materials and Methods followed by irrigation (5 cm) at 1 day after disappearance of ponded water along with pre-emergence application of the same herbicide (I_2W_2). The lowest benefit: cost ratio (1.19) was recorded with the application of irrigation (5 cm) at 3 days after disappearance of ponded water along with weed free check treatment (I_4W_1) combination. Hence, with the same level of irrigation when herbicides were combined, it was found to be more remunerative than manual weeding as the cost of manual weeding had become expensive than chemicals towards controlling the weeds.

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