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Effective weed management practices to control complex weed flora in different cultivars of hybrid and high yielding varieties of rice (*Oryza sativa* L.)

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Abstract

A field experiment was conducted during Summer and Kharif seasons of 2007-08 and 2008-09 at Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India to study the effect of hand weeding and Pretilachlor 50 EC @ 500 g a.i. ha^{-1} as pre-emergence on weed management of different varieties of hybrid and high yielding rice. The experiment was laid out in a split-plot design with three replications for both the years. It has been observed that Pretilachlor 50 EC @ 500 g a.i. ha^{-1} has a significant effect to control complex weed flora both in hybrid and high yielding varieties of rice but hand weeding twice gave the better result as expected. Among the varieties, the hybrid varieties recorded 36% and 32% more grain yield in Summer and Kharif seasons respectively than high yielding varieties (HYV). The high yielding variety 6444 (V2) showed more grain yield during Summer and Kharif seasons than that of the hybrid 6129 (V1), 97158 (V6), and 96110 (V3), respectively. Regarding weed management, hand weeding twice recorded (13% & 36%) higher grain yield during Summer than that of the chemical treatment and unweeded check, and (20% & 42%) during Kharif seasons respectively. Among the interaction, hand weeding combined with all varieties of hybrid rice recorded higher yield in comparison to other treatment combinations.

Keywords: Environment, high yielding varieties, hybrid rice, pretilachlor, weed flora

Introduction

Rice plays one of the most vital roles in food security of the world over millennia. It is grown around 114 countries across the world and contributing nearly 11 percent of the world's cultivated land (Rai, 2006). China and India are leading growers and consumers of rice and they account for 50% of the rice grown and consumed. It can grow in diverse soil and climatic conditions and so it is very popular among the farmers but in India, still its productivity level is not up to the mark. Most of the farmers in this region are small and marginal and most of them are familiar with traditional or local knowledge for farming which is a major constrains to enhance production and productivity. In 2014–15, total area of cultivation, production and productivity of rice in India was 43.86 million hectares, 104.8 million tonnes and 2390 kg ha^{-1} respectively and during this period area of cultivation and production of rice in West Bengal were 5.39 million hectares and 14.71 million tonnes respectively

(Agricultural Statistics at a Glance, 2015). The highest productivity of rice during 2014-15 was 6710 kg ha^{-1} (China) followed by 5573 kg ha^{-1} (Vietnam) (Agricultural Statistics at a Glance, 2015). Due to the increasing world's population from 7.21 billion in 2015 to 8.27 billion in 2030, the increase of rice demand will be from 680 million tonnes to 771 million tonnes in 2030 (Badawi, 2004).

It is observed that weeds take a significant amount of plant nutrients which deprive the crops as much as 47% N, 42% P, 50% K, 39% Ca, and 24% Mg of their nutrient uptake (Balasubramanian and Palaniappan, 2001). Weed management is a major problem in rice cultivation till date and it may reduce around 45-55% yield (Ghosh et al., 2013). Most of the farmer's still use hand weeding to remove weeds but in the present time scarcity of labour during the critical time of weeding is increasing continuously which enhancing cultivation cost. As a result, chemical weed management by the application of various herbicides are gaining interest among farmers but the use of agrochemicals in agricultural fields may degrade nature and may be a threat to human health (Horrigan et al., 2002). So selection of proper herbicide with an optimized dose is very important for weed control. The study aimed to evaluate the best weed management practice to control complex weed flora for enhancing yield of different hybrid and high-yielding varieties of rice during Summer and Kharif seasons.

Materials and Methods

A field experiment was conducted to study the effect of best weed management practice on different hybrid and high yielding varieties of transplanted rice during Summer and Kharif seasons of two successive years of 2007-08 and 2008-09, respectively at 'C' Block Farm (latitude: 22°57'E, longitude: 88°20'N and altitude: 9.75 m above sea level) of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India. The climate of the experimental site was a sub-tropical humid type. The soil of the experimental site was sandy loam in texture with a pH of 6.8, organic carbon 0.61%, available N 241.22 kg ha^{-1}, available P_2O_5 22.13 kg ha^{-1} and available K_2O 139.42 kg ha^{-1}. The experiment was studied in a split-plot design with three replications. Six varieties of hybrid (V1-6129, V2-6444, V3-96110, V4-97304, V5 –94024, and V6 –97158) and two high yielding varieties (HYV) of rice (V7-IET 4786 and V8-IET 4094) as a check were used in the main plot and three weed management practices were in sub-plot. In this investigation hand weeding (W1) was compared with the application of pretilachlor 50 EC @ 500 g a.i. ha^{-1} as pre-emergence (W2) at 2 DAT and unweeded control (W3). The plot size of the experimental area and spacing were 6 m x 3 m and 20 cm x 15 cm respectively.

Statistical assessment of this experiment was performed with the help of the analysis of variance (ANOVA) technique (Gomez and Gomez, 1984). The main, sub and their interaction effects of treatments were compared by critical difference (CD) at a 5% level of significance ($P \leq 0.05$).

Results and Discussion

The observations revealed that the predominant weed flora found in Summer and Kharif seasons were *Echinochloa crusgalli, Echinochloa formosensis, Echinochlo acolona, Leersia hexandra, Cyperus iria, Cyperus difformis, Fimbristylis littoralis, Eclipta alba, Stellaria media, Ammania baccifera* and *Ludwigia parviflora.*

Effect of treatments on weed density and biomass, grain yield and nutrient uptake during Summer and Kharif

The results of weed management practices on grass, sedge and broad leaf weed flora density and biomass and the interaction of weed management practices with hybrid and high yielding varieties (Table 1 & 2) showed

Table 1. Effect of variety and weed management on weed density (number m^{-2}), biomass (g m^{-2}) and grain yield (t ha^{-1}) at 30 and 60 DAT during Summer (pooled over two years)

Treat-ment	Weed density (number m^{-2})						Weed biomass (g m^{-2})						Grain Yield (t ha^{-1})
	Grass		Sedge		Broad leaf		Grass		Sedge		Broad leaf		
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
V1	19.91	25.55	13.92	23.81	20.41	26.64	2.32	2.71	1.62	2.92	2.31	2.86	6.08
V2	19.92	25.64	13.23	23.92	20.42	26.45	2.31	2.82	1.61	2.73	2.44	2.91	6.13
V3	20.72	26.12	14.71	24.50	20.86	25.92	2.33	2.81	1.63	2.62	2.34	2.85	5.90
V4	20.83	26.58	14.44	24.13	20.34	26.85	2.32	2.83	1.60	2.67	2.35	2.92	5.49
V5	20.31	25.96	14.21	24.45	21.06	26.51	2.33	2.80	1.62	2.68	2.41	2.83	5.27
V6	20.25	25.81	14.42	24.0	20.91	26.62	2.25	2.79	1.64	2.65	2.33	2.82	6.01
V7	34.14	40.44	20.73	36.09	33.62	40.06	4.22	5.16	3.12	5.26	4.34	5.55	4.41
V8	34.56	41.01	20.87	36.33	33.56	35.52	4.19	5.23	3.11	5.27	4.31	4.84	4.14
SEm(+)	1.23	1.54	1.24	2.12	1.11	2.64	0.11	0.11	0.11	0.11	0.09	0.11	0.093
CD at 5%	3.74	4.68	3.77	6.44	3.35	8.01	0.32	0.31	0.31	0.36	0.28	0.33	0.281
W1	10.62	15.01	7.45	11.53	11.75	13.36	0.93	1.84	0.92	1.66	1.33	1.61	6.22
W2	17.34	21.25	14.16	23.66	19.28	27.63	2.11	2.67	1.83	3.05	2.22	3.33	5.51
W3	43.47	52.69	25.82	46.22	40.86	47.05	5.22	5.66	3.22	5.33	5.14	5.25	4.56
SEm(+)	1.26	1.57	1.27	2.15	1.14	2.67	0.14	0.13	0.13	0.15	0.12	0.14	0.086
CD at 5%	3.65	4.54	3.68	6.21	3.28	7.69	0.40	0.38	0.39	0.43	0.36	0.41	0.248
Interaction													
V1W1	8.91	12.23	6.21	9.87	9.84	11.31	0.79	1.52	0.72	1.33	1.12	1.34	6.96
V2W1	8.13	12.64	5.78	9.16	9.86	11.59	0.81	1.53	0.69	1.32	1.16	1.29	7.05
V3W1	9.82	13.62	6.48	10.62	10.96	10.94	0.87	1.56	0.78	1.26	1.02	1.33	6.80
V4W1	9.25	14.15	6.98	9.22	9.77	11.04	0.79	1.52	0.76	1.35	1.03	1.31	6.39
V5W1	8.72	13.06	6.5	10.38	9.99	12.15	0.86	1.55	0.75	1.31	1.18	1.32	6.04
V6W1	9.48	13.13	6.72	9.82	9.68	11.5	0.81	1.54	0.78	1.35	1.08	1.23	6.88
V7W1	15.15	20.44	10.3	16.16	16.73	18.95	1.49	2.98	1.53	2.83	1.91	2.75	4.88
V8W1	15.62	21.14	10.98	16.87	17.42	19.09	1.54	3.04	1.57	2.86	1.97	2.67	4.77
V1W2	14.38	18.42	11.91	20.94	15.5	25.82	1.72	2.13	1.38	3.29	1.82	2.64	6.21
V2W2	14.26	18.67	11.16	20.62	16.01	25.41	1.66	2.2	1.45	2.68	1.78	2.53	6.19
V3W2	14.47	17.98	13.76	21.26	16.11	25.07	1.68	2.25	1.44	2.31	1.81	2.69	5.99
V4W2	14.94	18.84	13.29	21.49	15.24	25.63	1.72	2.27	1.48	2.38	1.85	2.75	5.43
V5W2	14.65	18.21	13.17	21.63	16.66	24.78	1.77	2.26	1.44	2.36	1.84	2.59	5.28
V6W2	14.42	17.95	12.81	21.16	16.71	24.6	1.68	2.14	1.39	2.38	1.82	2.61	6.11
V7W2	25.88	30.01	19.16	30.84	28.73	34.74	3.33	4.12	3.09	4.61	3.49	5.34	4.60
V8W2	25.89	29.92	18.11	31.31	28.69	35.27	3.24	4.07	3.17	4.76	3.49	5.36	4.26
V1W3	36.45	45.74	23.75	40.83	35.9	42.85	4.5	4.72	2.71	4.32	4.22	4.47	5.08
V2W3	37.47	45.66	22.94	41.82	35.34	42.25	4.47	4.7	2.73	4.28	4.27	4.57	5.16
V3W3	37.98	46.67	23.96	41.85	35.61	41.96	4.61	4.78	2.77	4.34	4.25	4.56	4.93
V4W3	38.24	46.79	22.99	41.68	35.95	43.84	4.45	4.75	2.78	4.32	4.29	4.61	4.64
V5W3	37.59	46.54	23.21	41.27	36.51	42.7	4.44	4.76	2.72	4.35	4.22	4.51	4.49
V6W3	36.85	46.62	23.85	41.14	36.43	43.71	4.39	4.72	2.75	4.26	4.23	4.57	5.04
V7W3	61.48	70.93	32.83	60.91	55.49	66.36	7.87	8.49	4.71	8.31	7.64	8.46	3.76
V8W3	61.93	72.16	33.31	60.83	55.45	52.37	7.63	8.51	4.71	8.25	7.67	6.43	3.41
SEm(+)	1.28	1.59	1.29	2.17	1.16	2.69	0.16	0.15	0.15	0.17	0.14	0.16	0.096
	1.29	1.60	1.30	2.18	1.16	2.69	0.16	0.15	0.16	0.17	0.15	0.16	0.088
CD at 5% a	3.70	4.63	3.73	6.27	3.34	7.75	0.46	0.44	0.45	0.49	0.41	0.46	0.276
CD at 5% b	2.91	3.61	2.93	4.92	2.62	6.08	0.37	0.35	0.36	0.39	0.33	0.37	0.197

N.B.: a = V1W1 vs V1W2 and b= V1W1 vs V2W1

that the hybrid varieties of rice recorded 41%, 35% lesser total grasses and 30%, 33% lesser sedges and 36%, 31% lesser broadleaf weed density than that of the HYV at 30 & 60 DAT, respectively during Summer seasons. Whereas, in Kharif seasons 31% & 37% lesser grasses, 33% & 30% lesser sedges and 31% & 29% lesser broadleaf weeds were observed at 20 & 40 DAT respectively. Hybrid varieties of rice recorded 46% & 56% less total weed biomass including grass, sedge and broadleaf in comparison to high yielding varieties at 30 & 60 DAT respectively during Summer seasons. Corresponding figures during Kharif season were 31%, 41% respectively at 20 & 40 DAT. The reason may be hybrid rice is normally a better competitor against total weed density due to its stronger tillering ability, faster leaf area expansion, higher net photosynthetic rate, more dry weight than the high yielding varieties.

Table 2. Effect of variety and weed management on weed density (number m^{-2}), biomass (g m^{-2}) and grain yield (t ha^{-1}) at 20 and 40 DAT during Kharif (pooled over two years)

Treat-ment	Weed density (number m^{-2})						Weed biomass (g m^{-2})						Grain Yield (t ha^{-1})
	Grass		Sedge		Broad leaf		Grass		Sedge		Broad leaf		
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
V1	13.66	17.69	6.35	15.21	13.74	19.52	1.81	2.69	0.83	2.48	1.61	2.45	4.94
V2	13.32	17.70	5.95	15.34	13.38	19.41	1.77	2.65	0.82	2.51	1.62	2.38	5.04
V3	13.35	17.74	5.81	15.79	13.54	19.71	1.69	2.69	0.90	2.47	1.66	2.48	4.70
V4	13.11	17.96	5.45	16.56	13.51	19.70	1.71	2.70	0.83	2.56	1.61	2.59	4.40
V5	14.17	17.27	5.54	16.13	13.78	20.24	1.73	2.70	0.89	2.57	1.69	2.62	4.09
V6	13.39	17.52	5.46	17.01	13.70	19.81	1.69	2.68	0.86	2.52	1.67	2.42	4.83
V7	19.14	27.18	9.40	23.76	19.84	26.95	2.11	4.48	1.59	4.27	2.68	4.65	3.63
V8	18.91	27.63	9.62	23.92	19.54	27.06	2.22	4.48	1.60	4.26	2.66	4.50	3.42
SEm(+)	1.27	1.41	0.451	0.45	0.98	1.63	0.09	0.09	0.05	0.09	0.08	0.09	0.086
CD at 5%	3.85	4.29	1.36	1.36	2.96	4.95	0.28	0.28	0.16	0.27	0.24	0.28	0.261
W1	4.28	6.33	2.90	4.24	6.20	5.45	0.65	1.02	0.39	0.57	0.79	1.16	5.17
W2	8.89	12.56	4.72	14.59	10.90	15.98	1.29	1.96	0.79	2.36	1.62	2.34	4.33
W3	31.46	41.37	12.47	32.54	28.29	43.22	3.58	6.42	1.94	5.93	3.29	5.55	3.64
SEm(+)	1.30	1.45	0.48	0.48	1.01	1.66	0.13	0.12	0.09	0.12	0.11	0.12	0.097
CD at 5%	3.75	4.17	1.39	1.39	2.91	4.80	0.36	0.36	0.25	0.35	0.32	0.36	0.280
Interaction													
V1W1	4.16	5.38	3.04	2.65	4.84	4.76	0.60	0.88	0.30	0.48	0.70	4.16	5.79
V2W1	3.94	5.58	2.42	2.50	5.29	3.70	0.56	0.81	0.29	0.44	0.67	3.94	6.01
V3W1	2.95	4.56	2.48	3.00	5.84	4.26	0.53	0.81	0.33	0.50	0.71	2.95	5.53
V4W1	2.72	5.68	1.96	3.84	4.94	3.70	0.62	0.92	0.33	0.50	0.71	2.72	5.16
V5W1	3.73	4.84	1.48	2.89	5.48	4.58	0.49	0.87	0.34	0.51	0.67	3.73	4.82
V6W1	3.39	4.74	1.95	3.98	5.62	4.58	0.54	0.84	0.28	0.48	0.66	3.39	5.67
V7W1	7.12	10.11	4.93	6.61	8.98	8.97	0.92	1.54	0.64	0.81	1.12	7.12	4.27
V8W1	6.45	9.76	4.93	7.20	8.61	9.05	0.93	1.55	0.62	0.85	1.12	6.45	4.14
V1W2	7.98	11.05	3.89	11.95	10.49	13.82	1.09	1.84	0.61	1.90	1.31	7.98	4.96
V2W2	7.18	11.51	4.01	12.77	9.79	13.75	1.03	1.76	0.62	1.89	1.31	7.18	4.94
V3W2	7.95	11.77	3.94	13.20	9.79	15.04	1.06	1.82	0.71	1.94	1.33	7.95	4.63
V4W2	7.87	11.70	3.41	14.10	10.44	14.33	0.96	1.82	0.63	1.94	1.33	7.87	4.31
V5W2	8.96	11.12	4.18	13.03	9.69	14.88	1.12	1.80	0.69	1.95	1.40	8.96	4.13
V6W2	8.22	11.57	3.71	13.96	10.37	14.97	0.99	1.80	0.75	1.86	1.32	8.22	4.81
V7W2	11.25	15.50	7.01	18.84	13.61	19.93	2.01	2.57	1.12	3.72	2.48	11.25	3.61
V8W2	11.98	16.24	7.63	18.99	13.02	21.14	2.04	2.29	1.17	3.72	2.49	11.98	3.27
V1W3	29.03	36.63	12.12	31.04	25.89	39.99	3.74	5.36	1.59	5.06	2.82	29.03	4.07
V2W3	29.16	36.03	11.41	30.94	25.07	40.78	3.74	5.40	1.57	5.20	2.88	29.16	4.17
V3W3	29.04	36.88	11.03	31.19	25.00	39.83	3.47	5.45	1.65	4.98	2.94	29.04	3.93
V4W3	28.61	36.51	10.98	31.78	25.16	41.06	3.55	5.38	1.54	5.24	2.80	28.61	3.73
V5W3	29.47	35.84	10.96	32.49	26.18	41.26	3.57	5.44	1.66	5.27	3.01	29.47	3.33
V6W3	28.38	36.27	10.72	33.11	25.11	39.88	3.55	5.40	1.54	5.22	3.04	28.38	4.02
V7W3	39.25	55.92	16.28	45.85	36.92	51.95	3.39	9.33	3.02	8.29	4.43	39.25	3.00
V8W3	38.42	56.91	16.30	45.60	37.00	51.00	3.69	9.60	3.00	8.22	4.39	38.42	2.85
SEm(+)	1.32	1.46	0.50	1.40	1.03	1.68	0.14	0.14	0.11	0.14	0.13	1.32	0.086
	1.32	1.47	0.50	1.41	1.03	1.69	0.15	0.15	0.11	0.14	0.13	1.32	0.085
CD at 5% a	3.80	4.23	1.44	4.04	2.92	4.85	0.42	0.42	0.31	0.41	0.38	3.80	0.248
CD at 5% b	2.99	3.32	1.14	3.17	2.33	3.81	0.34	0.34	0.25	0.33	0.31	2.99	0.192

N.B.: a = V1W1 vs V1W2 and b= V1W1 vs V2W1

Hybrid rice showed a stronger heterotic effect on depressing weeds in mixtures compared with the high yielding varieties. Regarding weed management twice hand weeding (W1) recorded (44% and 74%) & (45% and 73%) lower total weed density than that of chemical treatment and unweeded check, respectively at 30 & 60 DAT during the Summer season. The corresponding figures in Kharif season were (45% and 83%) & (63% and 87%) at 20 & 40 DAT. The use of pretilachlor resulted in (53% & 51%) lesser total weed density and (54% & 44%) lesser total weed biomass than that of the unweeded check at 30 & 60 DAT during Summer season. The corresponding figures in the Kharif season were (69% & 65%) for total weed density and (54% & 44%) lesser total weed biomass at 20 & 40 DAT.

Table 3. Benefit cost ratio during Summer (S) and Kharif (K) (pooled over two years)

Treatment		V1W1	V2W1	V3W1	V4W1	V5W1	V6W1	V7W1	V8W1	V1W2	V2W2	V3W2	V4W2	V5W2	V6W2	V7W2	V8W2	V1W3	V2W3	V3W3	V4W3	V5W3	V6W3	V7W3	V8W3
B:C	S	1.64	1.66	1.59	1.49	1.42	1.61	1.23	1.19	1.63	1.64	1.57	1.44	1.39	1.61	1.29	1.19	1.36	1.39	1.31	1.24	1.19	1.34	1.06	1.02
	K	1.51	1.57	1.45	1.36	1.27	1.47	1.19	1.16	1.47	1.48	1.38	1.29	1.24	1.43	1.16	1.06	1.24	1.27	1.18	1.13	1.08	1.21	1.02	1.01

The pooled data of grain yield of Summer and Kharif season as presented in Table (1 & 2) showed that among the varieties the hybrid varieties recorded 36% and 32% more grain yield in Summer and Kharif season respectively than HYV. The variety 6444 (V2) showed more grain yield during Summer and Kharif season than that of the hybrid 6129(V1), 97158 (V6) and 96110 (V3), respectively.

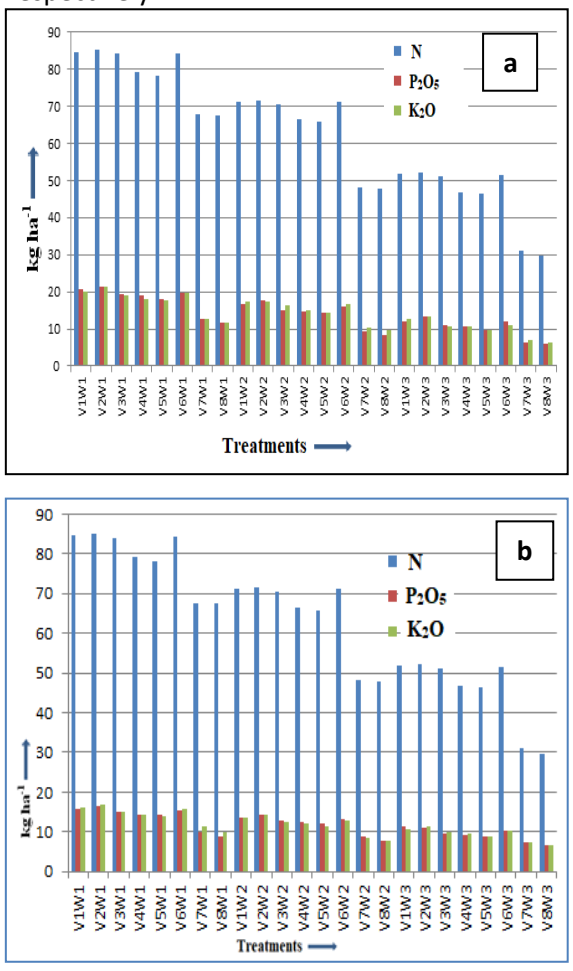

Figure 1 (a-b). Effect of interaction of variety and weed management on uptake of total Nitrogen, P_2O_5 and K_2O during (a) Summer (b) Kharif season (pooled over two years).

The reason may be that the hybrids though recorded a lesser number of tillers than that of the HYV but the number of filled grains panicle^{-1} and the panicle length were higher than that of the HYV. Regarding weed management the hand weeding twice recorded (13% &36%) and (20% & 42%) higher grain yield than that of the chemical treatment and unweeded check, during Summer and Kharif seasons respectively. The chemical treatment also recorded 20% and 19% higher grain yield over the unweeded check during Summer and Kharif seasons. Twice hand weeding though costly but can able to increase the growth environment of the paddy by managing all types of weed flora timely. Therefore, the paddy yield was higher in twice hand weeding in comparison to chemical treatment where the initial application of pretilachlor can manage the weed flora and reduced the weed competition at the initial tillering stage but later due to resurgence of the weed flora during the active tillering stage the weed competition was again increased. Among the interactions hand weeding combined with all varieties recorded higher yield in comparison to other treatment combinations because of the same reason. Moreover, twice hand weeding followed in hybrids plot recorded 38% and 30% more grain yield than that of the hand weeding followed in high yielding varieties plot during both Summer and Kharif season. Similarly, chemical treatment and unweeded control followed in hybrids plot showed better performance than that of the chemical treatment and unweeded control

practiced in the high yielding varieties plot.

Hybrids rice uptake more total nitrogen, phosphorus and potassium in grain (Fig. 1). The reason may be hybrids of rice produce more dry matter weight per hill, the total yield of dry matter per unit area, the accumulation amount of dry matter from heading to maturity and its ratio to total grain yield and the harvest index of hybrid rice were higher compared with high yielding rice. So, the demand for N, P and K especially the ratio of P and K requirements of hybrid rice plants were higher than those of high yielding rice. The nutrient efficiency ratio, nutrient harvest index and nutrient use efficiency (NUE) were also higher than those of high yielding rice. Regarding interaction, it can be clearly stated that hand weeding treated plots in combination with hybrid rice uptake more nutrients in comparison to hand-weeding practiced in high-yielding varieties of rice.

From the above findings (Table 3), it is clear that both Summer and Kharif season maximum return was obtained from V2W1 treatment i.e., hand weeding in combination with hybrid variety (6444) which was followed by V1W1, V6W1 and V3W1. Among the HYV maximum return was found from V7W1.

Conclusion

Twice hand weeding though time-consuming and costly but can able to increase the growth environment of the paddy by managing all types of weed flora timely and it results higher yield in comparison to chemical treatment. By the application of a higher dose of herbicide, weed may be controlled significantly but full dependency on agrochemicals in agricultural fields may be a threat to nature and human health. So, there should always be a balance between the use of manual labours and agrochemicals. It is hereby recommended that application of Pretilachlor 50 EC @ 500 g a.i. ha^{-1} as pre-emergence and one hand weeding at 25 DAT may be cost-effective as well as it will protect nature and human beings in a better way.

Conflict of interest

Authors declare that there is no conflict of interest.

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