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Integrated weed management in dry-seeded irrigated rice (*Oryza sativa*)

J.S. MISHRA* AND V.P. SINGH

National Research Centre for Weed Science, Jabalpur, Madhya Pradesh 482 004

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ABSTRACT

A field experiment was conducted during rainy seasons of 2006 and 2007 on clay-loam soil at Jabalpur, Madhya Pradesh to find out the effect of tillage (zero and conventional), time of sowing (before and after monsoon) and weed-control measures (integration of hand weeding and *Sesbania* with herbicides and rotational use of herbicides) on weeds, yield, nutrient uptake and economics of dry-seeded irrigated rice (*Oryza sativa* L.). The major weeds associated with dry-seeded rice were: *Echinochloa colona* (31.5%), *Phyllanthus* spp. (26.5%), *Commelina communis* (17.8%), *Cyperus iria* (9.9%), *Alternanthera sessilis* (5.9%), *Dinebra retrolexa* (5.1%), *Physalis minima* (1.8%) and *Caesulia axillaris* (1.2%). Zero tillage significantly reduced the total population and dry matter of weeds compared with conventional tillage, but the difference in yield was not significant. Dry seeding before monsoon resulted in lower grain yield due to higher population and dry matter of weeds. Infestation of weeds reduced the grain yield of dry-seeded rice by 60% compared with hand-weeding twice and removed 10.99 kg N, 2.78 kg P and 7.22 kg K/ha. The maximum rice yield (3.41 t/ha) was obtained from 2 hand-weeding. Integration of pendimethalin 1.0 kg/ha or pretilachlor 0.75 kg/ha with 1 hand-weeding at 30 days after sowing or sequential application of pre-emergence herbicides followed by post-emergence application of 2, 4-D (0.5 kg/ha) and fenoxaprop (0.07 kg/ha), being on a par with each other, proved quite effective against weeds and gave significantly higher grain yields and benefits than weedy check.

Key words: Dry-seeded rice, Economics, Grain yield, Herbicides, Nutrient uptake, Weeds

The technology of direct-seeded rice (*Oryza sativa* L.) is gradually finding favour with the farmers, as it saves irrigation water and reduces the production costs. Direct-seeded rice needs only 34% of the total labour requirement and saves 29% of the total cost of the transplanted crop (Ho and Romli, 2000). Direct seeding of rice also allows early establishment of the succeeding wheat crop, reduces methane emissions and ensures higher profit in areas with assured water supply (Balasubramanian and Hill, 2000). In India, dry-seeding is extensively practised in rainfed lowlands, uplands, and flood-prone areas. Weeds are one of the major concerns in dry-seeded rice. Aerobic soil conditions and dry-tillage practices, besides alternate wetting and drying conditions are conducive for germination and growth of highly competitive weeds, which cause 40-100% loss in grain yield (Choubey *et al*., 2001; Bahar and Singh, 2004). With the availability of proper weed management technology, it is possible to raise the productivity of dry-seeded rice. As weeds in direct-seeded rice emerge in different flushes, single method of weed control may not be successful for raising a good crop. Hence, different methods such as cultural, manual and chemical need to be adopted in an integrated manner for effective weed management. Keeping this in view, a field experiment was conducted to study the effect of tillage, time of sowing and weed-control measures on weeds, yield and economics of dry-seeded irrigated rice.

MATERIALS AND METHODS

A field experiment was conducted during rainy season of 2006 and 2007 at National Research Centre for Weed Science, Jabalpur (23^0 9’ N, 79^0 58 E, 412 m above mean sea level). The soil was clay loam (Typic chromusterts), low in available N (245 kg/ha), and medium in available P (19.5 kg/ha) and K (318 kg/ha), with organic C 0.53% and neutral pH (6.9). The experiment was laid out in split-plot design with 3 replications. The main-plot treatments comprised combination of 2 tillage practices, viz. zero and conventional; and 2 dates of sowing viz. dry seeding before monsoon and seeding after receipt of first flush of monsoon. In sub-plots there were weed-control methods, *viz*. pretilachlor 0.75 kg/ha + 1 hand-weeding (HW);

***Corresponding author** (Email: jsmishra31@gmail.com)

Present address: Project Directorate of Sorghum Research, Hyderabad

pendimethalin 1.0 kg/ha + 1 HW; pretilachlor 0.75 kg/ha followed by *(fb)* 2,4-D 0.50 kg/ha at 30 Days After Sowing (DAS) and fenoxaprop (0.070 kg/ha at 35 DAS); pendimethalin 1.0 kg/ha *fb* 2,4-D (0.50 kg/ha) at 30 DAS and fenoxaprop (0.070 kg/ha.) at 35 DAS; *Sesbania* (broadcast at the time of sowing) + pretilachlor 0.75 kg/ha *fb* 2,4-D (0.50 kg/ha) at 30 DAS and fenoxaprop (0.070 kg/ha) at 35 DAS; *Sesbania* + pendimethalin 1.0 kg/ha *fb* 2,4-D (0.50 kg/ha) at 30 DAS and fenoxaprop (0.070 kg /ha) at 35 DAS; *Sesbania fb* 2,4-D (0.50 kg/ha) at 30 DAS and fenoxaprop (0.070 kg/ha) at 35 DAS; 2 hand-weedings at 20 and 45 DAS; and weedy check.

Rice variety 'Kranti' was sown in the third week of June as pre-monsoon and in the first week of July as post-monsoon crop in 20 cm row spacing with 100 kg/ha seeding rate. *Sesbania* was broadcast @ 50 kg/ha along with rice seeding and it was killed by spraying 2,4-D (0.5 kg/ha) at 30 DAS. Glyphosate at 1.0 kg/ha was applied 1 week before seeding in all the zero-till plots to kill the existing vegetation. Herbicides were applied as per the treatment with 500 litres/ha water with knapsack sprayer, fitted with flat-fan nozzle. The crop was raised under irrigated conditions as per recommended package of practice. Density and dry matter of weeds were recorded at 60 DAS by placing a quadrate of 50 cm x 50 cm randomly at 4 places in each plot. These were subjected to square-root transformation before analysis. The treatments by year interactions were not significant, and so the data for both the years were pooled for all the variables and the averages of two seasons were analysed by the analysis of variance technique. Economics was calculated by considering the prevailing sale price of rice and the cost of cultivation.

RESULTS AND DISCUSSION

Weed population

The major weeds associated with dry-seeded rice were: *Echinochloa colona* (31.5%), *Phyllanthus* spp. (26.5%), *Commelina communis* (17.8%), *Cyperus iria* (9.9%), *Alternanthera sessilis* (5.9%), *Dinebra retroflexa* (5.1%), *Physalis minima* (1.8%) and *Caesulia axillaris* (1.2%). Zero tillage significantly reduced the population of all the weed species (except *A. sessilis*) as well as total population compared with the conventional tillage (Table 1). Dry seeding before monsoon resulted in higher population of all the weed species except *C. iria, A. sessilis, C. axillaris* and *D. retroflexa*, which were significantly higher when rice was seeded after receipt of first flush of monsoon. Application of herbicides + 1 hand-weeding or sequential application of herbicides or integration of *Sesbania* with herbicides significantly reduced the population of *E. colona*, *C. iria* and *C. communis* as well as total weed population compared with the weedy check. However, none of the treatments, except herbicide+ 1 hand-weeding and 2 hand-weeding, provided effective control of *Physalis minima* and *Phyllanthus* spp. Sequential application of herbicides and integration of *Sesbania* with herbicides effectively reduced the population of *C. axillaris* and *D. retroflexa* compared with hand-weeding twice and integration of hand-weeding with pre-emergence application of pretilachlor and pendimethalin. The lowest weed population was recorded with pre-emergence application of pendimethalin *fb* 1 HW at 30 DAS. Integration of pretilachlor with HW and sequential application of pretilachlor *fb* 2,4-D and fenoxaprop were equally effective in reducing the total weed density. Brommer *et al*. (2000) also reported the use of a mixture of herbicides to control multiple weed problems. Integration of *Sesbania* with post-emergence application of 2, 4-D and fenoxaprop but without application of pre-emergence herbicides was less effective in reducing the total weed density compared with the inclusion of pre-emergence herbicides.

Weight of weeds

Variation in tillage system did not influence the dry weight of *E. colona*, *C. iria* and *C. communis* (Table 2). However, zero tillage significantly reduced the dry weight of *P. minima*, *Phyllanthus* spp., *C. axillaries* and *D. retroflexa* compared with the conventional tillage. Total dry weight of weeds was significantly lower (27.9%) in zero tillage due to lower weed population. Dry-seeding before onset of monsoon significantly reduced the dry-matter accumulation of *E. colona*, *C. iria*, *A. sessilis* and *D. retroflexa*, but increased the dry weight of *P. minima*, *Phyllanthus* spp. and *C. communis* compared with seeding after monsoon. Total dry weight of weeds was significantly lower (42.2%) in dry-seeding after monsoon due to lower total weed population. All the weed-control treatments significantly reduced the total dry weight of weeds compared with weedy check, but their effects varied on individual weed species. Integration of 1 HW with pre-emergence application of pendimethalin or pretilachlor, sequential application of pre- and post-emergence herbicides and integration of *Sesbania* with herbicides significantly reduced the dry weight of *E. colona* and *C. iria* compared with the weedy check. Pendimethalin was more effective against *E. colona* and pretilachlor against *C. iria*. Sequential application of herbicides and integration of *Sesbania* with herbicides were less effective against *P. minima* and *Phyllanthus* spp. due to poor efficacy of 2,4-D against these weeds. However, these treatments significantly reduced the dry weight of *A. sessilis, C. communis, C. axillaries* and *D. retroflexa*. Integration of 1 HW with pre-emergence application of pendimethalin or pretilachlor was as effective as 2 HW in reducing the to-

Table 1. Effect of tillage, sowing time and weed management on weed population (no./m²) at 60 DAS in direct seeded rice (mean data of 2 years)

Treatment	*E. colona*	*C. iria*	*P. minima*	*Phyllanthus* spp.	*A. sessilis*	*C. communis*	*C. axillaris*	*D. retroflexa*	Total
Tillage									
Zero	2.2 (4.3)	1.8 (2.7)	1.2 (0.9)	2.7 (6.8)	1.5 (1.6)	1.4 (1.3)	0.8 (0.3)	1.2 (0.9)	4.7 (17.7)
Conventional	3.2 (9.6)	1.9 (3.2)	1.8 (2.9)	4.4 (18.4)	1.1 (0.7)	2.2 (4.2)	1.1 (0.7)	1.5 (1.8)	6.3 (39.4)
SEm±	0.06	0.07	0.05	0.09	0.04	0.04	0.03	0.02	0.08
CD (P=0.05)	0.21	NS	0.17	0.30	0.13	0.14	0.1	0.06	0.29
Time of sowing									
Before monsoon	2.9 (7.9)	1.7 (2.3)	1.7 (2.4)	4.7 (22)	1.0 (0.5)	1.9 (3.0)	0.9 (0.3)	1.1 (0.7)	5.5 (29.5)
After monsoon	2.4 (5.4)	2.0 (3.6)	1.3 (1.3)	2.3 (4.9)	1.6 (2.0)	1.6 (2.2)	1.1 (0.6)	1.6 (2.0)	4.9 (23.8)
SEm±	0.06	0.07	0.05	0.09	0.04	0.04	0.03	0.02	0.08
CD (P=0.05)	0.21	0.23	0.17	0.30	0.13	0.14	0.10	0.06	0.29
Weed control									
Pretilachlor (P) 0.75 + 1 HW	2.4 (5.3)	1.6 (1.9)	1.1 (0.7)	2.2 (4.5)	2.0 (3.4)	1.6 (2.1)	1.3 (1.2)	1.9 (3.1)	5.0 (24.3)
Pendimethalin (Pm) 1.0 + 1 HW	2.2 (4.4)	1.6 (2.0)	0.9 (0.4)	2.8 (7.1)	1.6 (2.0)	1.7 (2.2)	1.6 (2.1)	1.2 (0.9)	4.1 (15.9)
P *fb* 2,4-D (0.5) *fb* fenoxaprop (F) 0.07	2.1 (3.9)	1.4 (1.5)	1.9 (3.1)	3.8 (14.2)	1.2 (1.0)	1.4 (1.3)	0.7 (0)	0.8 (0.2)	4.7 (21.4)
Pm 1.0 *fb* 2,4-D *fb* F	2.1 (4.1)	1.7 (2.3)	2.0 (3.4)	4.2 (17.4)	0.8 (0.1)	1.4 (1.5)	0.7 (0)	0.8 (0.1)	5.1 (25.7)
Sesbania + *fb* P 2,4-D *fb* F	2.7 (6.6)	1.7 (2.3)	2.0 (3.6)	3.5 (11.6)	0.9 (0.3)	1.4 (1.4)	0.8 (0.1)	0.8 (0.1)	5.1 (25.0)
Sesbania + Pm *fb* 2,4-D *fb* F	2.5 (5.7)	2.0 (3.4)	1.4 (1.3)	3.5 (11.6)	0.9 (0.3)	1.7 (2.5)	0.8 (0.1)	0.8 (0.2)	5.1 (25.5)
Sesbaniaa *fb* 2,4-D (0.5) *fb* F	3.0 (8.7)	2.3 (4.6)	1.9 (3.0)	5.1 (25.6)	0.9 (0.3)	1.6 (2.2)	0.7 (0)	1.0 (0.5)	7.1 (49.2)
Hand weeding at 20 & 45 DAS	2.1 (3.8)	1.7 (2.2)	1.4 (1.6)	2.3 (4.7)	1.0 (0.4)	1.4 (1.5)	1.0 (0.6)	2.7 (6.9)	4.6 (20.2)
Weedy check	4.8 (22.3)	2.8 (7.2)	1.5 (1.3)	4.4 (18.6)	2.2 (4.3)	3.6 (12.6)	1.2 (0.9)	2.1 (3.5)	8.6 (73.5)
SEm±	0.13	0.10	0.08	0.14	0.07	0.08	0.05	0.07	0.13
CD (P=0.05)	0.38	0.29	0.24	0.38	0.20	0.23	0.15	0.19	0.35

*Data subjected to square root transformation; Values in parentheses are original

Table 2. Effect of tillage, sowing time and weed management on weed dry weight (g/m^2) at 60 days after sowing in direct seeded rice (mean data of 2 years)

Treatment	*E. colona*	*C. iria*	*P. minima*	*Phyllanthus* spp.	*A. sessilis*	*C. communis*	*C. axillaris*	*D. retroflexa*	Total
Tillage									
Zero	3.3 (10.3)	1.9 (3.2)	2.3 (4.8)	2.5 (6.0)	1.6 (1.9)	1.4 (1.5)	0.8 (0.2)	1.2 (0.9)	5.4 (29.0)
Conventional	3.2 (9.5)	2.0 (3.5)	3.2 (9.8)	3.0 (8.5)	1.3 (1.1)	1.5 (1.6)	1.1 (0.6)	1.7 (2.4)	6.4 (40.2)
SEm±	0.05	0.08	0.06	0.06	0.04	0.02	0.04	0.06	0.16
CD (P=0.05)	NS	NS	0.22	0.2	0.13	NS	0.12	0.22	0.55
Time of sowing									
Before monsoon	2.2 (4.4)	1.3 (1.1)	4.1 (16.5)	3.9 (14.3)	1.2 (0.9)	1.6 (2.2)	0.9 (0.3)	1.2 (1.0)	6.7 (44.5)
After monsoon	4.2 (17.4)	2.7 (6.6)	1.4 (1.4)	1.6 (2.2)	1.6 (2.1)	1.2 (1.0)	1.0 (0.5)	1.7 (2.3)	5.1 (25.7)
SEm±	0.05	0.08	0.06	0.06	0.04	0.02	0.04	0.06	0.16
CD (P=0.05)	0.17	0.27	0.22	0.2	0.13	0.06	0.12	0.22	0.55
Weed control									
Pretilachlor (P) 0.75 + 1 HW	3.1 (9.0)	1.2 (0.9)	0.9 (0.4)	1.6 (1.9)	1.8 (2.7)	1.7 (2.3)	1.2 (0.9)	1.7 (2.2)	4.7 (21.4)
Pendimethalin (Pm) 1.0 + 1 HW	2.3 (4.9)	2.3 (4.9)	1.0 (0.5)	1.9 (3.2)	1.2 (0.8)	1.5 (1.8)	1.5 (1.6)	1.0 (0.6)	4.5 (19.8)
P *fb* 2,4-D (0.5) *fb* fenoxaprop (F) 0.07	3.3 (10.3)	1.6 (2.0)	4.1 (16.6)	4.0 (15.6)	1.9 (3.1)	1.3 (1.2)	0.7 (0)	0.8 (0.2)	5.6 (30.7)
Pm 1.0 *fb* 2,4-D *fb* F	3.3 (10.3)	2.2 (4.5)	4.1 (16.1)	3.5 (11.9)	0.8 (0.1)	0.7 (0)	0.7 (0)	0.8 (0.1)	6.1 (36.2)
Sesbania + *fb* P 2,4-D *fb* F	2.7 (6.6)	1.5 (1.6)	3.7 (13.3)	2.5 (5.7)	0.9 (0.2)	0.7 (0)	1.0 (0.6)	0.8 (0.1)	5.9 (34.1)
Sesbania + Pm *fb* 2,4-D *fb* F	2.0 (3.5)	2.0 (3.6)	2.6 (6.1)	2.4 (5.0)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.9 (0.3)	5.2 (26.4)
Sesbania *fb* 2,4-D (0.5) *fb* F	2.3 (4.6)	2.4 (5.1)	4.1 (16.2)	3.2 (9.9)	0.8 (0.1)	0.7 (0)	0.7 (0)	1.0 (0.4)	6.4 (39.8)
Hand weeding at 20 & 45 DAS	2.1 (3.7)	1.5 (1.8)	1.2 (1.0)	1.7 (2.4)	0.9 (0.2)	1.0 (0.5)	0.9 (0.2)	3.3 (10.3)	4.4 (18.6)
Weedy check	8.1 (64.0)	3.0 (8.5)	3.1 (9.4)	3.9 (14.7)	3.8 (13.9)	4.6 (20.3)	1.1 (0.7)	2.9 (8.1)	10.6 (111.0)
SEm±	0.12	0.12	0.16	0.16	0.06	0.05	0.06	0.1	0.18
CD (P=0.05)	0.33	0.34	0.46	0.44	0.18	0.15	0.16	0.28	0.51

*Data subjected to square root transformation; values in parentheses are original

Table 3. Effect of tillage, sowing time and weed management on plant population, yield attributes and grain yield (t/ha) and economis of direct seeded rice (mean data of 2 years)

Treatment	Plant population (no./m row)	Plant height (cm)	Panicles (no./m^2)	Panicle length (cm)	Grains/ panicle	1000-grains weight (g)	Grain yield	Cost of cultivation (x 10^3 Rs/ha)	Net returns (x 10^3 Rs/ha)	B:C ratio
Tillage										
Zero	45.2	56.3	221	19.7	140	28.4	2.73	11.95	8.53	1.71
Conventional	42.9	59.6	213	19.2	132	28.7	2.84	15.00	6.29	1.42
SEm±	1.7	0.4	6	0.13	5	0.40	0.05			
CD (P=0.05)	NS	1.4	NS	0.44	NS	NS	NS			
Time of sowing										
Before monsoon	42.2	61.9	220	18.4	118	28.1	2.30	12.87	4.42	1.34
After monsoon	45.5	54.0	214	20.6	154	29.2	3.26	14.09	10.39	1.74
SEm±	1.7	0.4	6	0.13	5	0.40	0.05			
CD (P=0.05)	NS	1.4	NS	0.44	18	NS	0.18			
Weed control										
Pretilachlor (P) 0.75 + 1 HW	45.7	56.7	232	19.6	133	28.6	3.07	13.13	9.91	1.75
Pendimethalin (Pm) 1.0 + 1 HW	45.9	56.5	253	19.2	144	29.6	3.25	13.89	10.46	1.75
P *fb* 2,4-D (0.5) *fb* fenoxaprop (F) 0.07	45.3	60.9	225	20.0	146	29.4	3.23	13.01	11.25	1.86
Pm 1.0 *fb* 2,4-D *fb* F	47.3	58.7	222	19.6	140	29.5	3.14	13.77	9.76	1.71
Sesbania + *fb* P 2,4-D *fb* F	40.8	58.4	212	19.9	136	27.8	2.58	14.12	5.61	1.40
Sesbania + Pm *fb* 2,4-D *fb* F	38.9	58.8	207	19.9	139	28.0	2.67	14.87	5.19	1.35
Sesbania *fb* 2,4-D (0.5) *fb* F	40.7	57.5	208	20.0	137	28.3	2.37	13.30	4.47	1.34
Hand weeding at 20 & 45 DAS	44.4	58.1	262	19.6	138	29.0	3.41	14.43	11.15	1.77
Weedy check	45.2	56.1	132	18.5	112	27.4	1.36	10.78	-0.58	0.95
SEm±	1.4	1.0	14	0.3	5	0.6	0.08			
CD (P=0.05)	4.0	2.9	39	0.9	14	1.9	0.23			

tal dry matter of weeds.

Growth and yield

Variation in tillage and time of sowing did not cause significant effect on plant population at 30 DAS and number of panicles/m^2; however, inclusion of *Sesbania* with sequential application of herbicides significantly reduced the number of rice plants/m row length and number of panicles compared with the weedy check due to smothering effect of *Sesbania* on rice plants (Table 3). Grains/panicle were not affected significantly due to variation in tillage, however, dry-seeding of rice after monsoon produced significantly higher number of grains than seeding before monsoon, primarily due to increased panicle length. Different weed-control treatments, being on a par with each other, significantly increased the number of grains/panicle and 1,000-grain weight compared with the weedy check. Variation in tillage did not influence the rice grain yield. Dry-seeding after receipt of first flush of monsoon produced significantly higher grain yield (3.26 t/ha) compared with seeding before monsoon (2.30 t/ha). Infestation of weeds caused 60 % reduction in grain yield of dry-seeded rice compared with HW twice. The maximum rice yield (3.41 t/ha) was obtained from 2 HW (Table 3). Integration of pendimethalin and pretilachlor with 1 HW or sequential application of pre-emergence herbicides *fb* post-emergence application of 2, 4-D (0.5 kg/ha) and fenoxaprop (0.07 kg/ha), being on a par with each other, produced significantly higher grain yield compared with weedy check (1.36 t/ha). Integration of *Sesbania* with post-emergence application of 2,4-D and fenoxaprop produced lower grain yields (2.37-2.67 t/ha) compared with other weed-control treatments, mainly due to significant reduction in the number of panicles. However, these yield levels were significantly higher compared with that of the weedy check.

Nutrient uptake

Zero tillage significantly reduced the N, P and K depletion by weeds compared with the conventional tillage (Table 4). Dry-seeding after monsoon minimized the nutrient drain by weeds compared with seeding before monsoon. The lower depletion of nutrients by weeds in these treatments was due to lower weed population and biomass production. Among weed-control treatments, minimum removal of nutrients by weeds was recorded with HW twice. Pendimethalin 1.0 kg/ha and pretilachlor 0.75 kg/ha, each supplemented with 1 HW at 30 DAS, recorded significantly lower removal of N, P, and K by weeds compared with highest nutrient removal from unweeded check. Singh and Tripathi (2007) also reported similar results.

Variation in tillage systems did not influence the nutrient uptake by rice. Seeding after monsoon utilized more

Table 4. Effect of tillage, sowing time and weed management on nutrient uptake by weeds and rice (mean data of 2 years)

Treatment	Nutrients removal by weeds (kg/ha)			Nutrients uptake by rice grains (kg/ha)		
	N	P	K	N	P	K
Tillage						
Zero	2.81	0.73	1.88	36.85	9.88	9.01
Conventional	3.93	1.04	2.64	38.50	10.31	9.43
SEm±	0.07	0.04	0.08	0.80	0.20	0.21
CD (P=0.05)	0.22	0.12	0.25	NS	NS	NS
Time of sowing						
Before monsoon	4.36	1.11	2.90	31.13	8.36	7.67
After monsoon	2.54	0.68	1.70	44.15	11.88	10.89
SEm±	0.07	0.04	0.08	0.80	0.20	0.21
CD (P=0.05)	0.22	0.12	0.25	2.50	0.60	NS
Weed control						
Pretilachlor (P) 0.75 + 1 HW	2.1	0.56	1.41	41.72	11.15	10.20
Pendimethalin (Pm) 1.0 + 1 HW	1.96	0.50	1.29	44.08	11.75	10.87
P *fb* 2,4-D (0.5) *fb* fenoxaprop (F) 0.07	3.04	0.79	2.04	43.92	11.74	10.83
Pm 1.0 *fb* 2,4-D *fb* F	3.61	0.92	2.38	42.57	11.42	10.45
Sesbania + *fb* P 2,4-D *fb* F	3.40	0.89	2.25	34.78	9.30	8.50
Sesbania + Pm *fb* 2,4-D *fb* F	2.58	0.68	1.74	36.13	9.68	8.85
Sesbania fb 2,4-D (0.5) *fb* F	3.92	1.07	2.67	32.03	8.58	7.82
Hand weeding at 20 & 45 DAS	1.80	0.47	1.23	46.38	12.45	11.46
Weedy check	10.99	2.78	7.22	18.33	4.90	4.48
SEm±	0.17	0.07	0.14	1.32	0.41	0.30
CD (P=0.05)	0.50	0.20	0.50	4.21	1.30	1.00

nutrients compared with seeding before monsoon. The best weed-management practices, viz. HW twice at 20 and 45 DAS, pendimethalin 1.0 kg/ha or pretilachlor 0.75 kg/ha, each supplemented with 1 HW at 30 DAS or sequential use of pre- and post-emergence herbicides gave maximum nutrient uptake by the crop. The better nutrients removal by the crop was associated with its better growth and development, resulting in higher yield. The lowest nutrients uptake by the crop was recorded with unweeded check due to poor yield.

Economics

A cost and return analysis (Table 3) indicated that zero tillage provided higher net returns (Rs 8,526/ha) and benefit: cost (B:C ratio) (1.71) than conventional tillage (Rs 6,291 and 1.42) due to lower cost of cultivation. Dry-seeding after monsoon was more economical than seeding before monsoon due to higher rice yield. Among weed-control treatments, sequential application of pretilachlor (pre-emer) *fb* 2,4-D and fenoxaprop gave the highest net returns (Rs 11,247/ha) and B:C ratio (1.86), followed by HW twice. Singh *et al*. (2006) also obtained higher yields and benefits from dry-seeded rice with herbicide mixtures and sequential application of herbicides. Weedy check recorded a net loss of Rs 577/ha due to poor crop yield.

It may be concluded that zero-till seeding of rice after receipt of first flush of monsoon and effective control of weeds by sequential application of pretilachlor at 0.75 kg/ha as pre-emergence followed by 2,4-D at 0.50 kg/ha and fenoxaprop at 0.07 kg/ha as post-emergence should be adopted for obtaining higher yield and benefit from dry-seeded rice.

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