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Research Paper

Tillage and weed management in direct-seeded rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted at Ranchi, Jharkhand during 2010–11 and 2011–12, to find out the effect of tillage and weed-control methods on weed dynamics and productivity of rice (*Oryza sativa* L.)–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] cropping system. The experiment comprised of 4 tillage methods, viz. zero–zero (ZT-ZT), zero–conventional (CT-ZT), conventional–zero (CT-ZT) and conventional–conventional tillage (CT-CT), performed during rainy and winter seasons, respectively laid out under main plots, while 3 weed control methods viz., recommended herbicides in rice (butachlor 1.0 kg/ha pre-emergence + 2,4-D 0.5 kg/ha post-emergence) and wheat (isoproturon 0.75 kg/ha + 2,4-D 0.5 kg/ha post-emergence), weed free and weedy check under sub-plots**.** Continuous conventional tillage being similar to rotational tillage systems recorded the maximum rice grain (1.96 t/ha) and straw (2.86 t/ha) yield. Three hand-weedings resulted in 2.25% and 92.38% higher grain yield than recommended herbicidal use and weedy check respectively. The CT-CT tillage being similar to ZT-CT recorded 14.16% higher wheat grain yield (2.85 t/ha) than ZT-ZT tillage. Application of isoproturon @ 0.75 kg/ha + 2,4-D @ 0.5 kg/ha as post-emergence gave 22.59% and 58.75% higher grain and straw yield than hand-weeding and weedy check respectively. Continuous conventional tillage in rice and wheat recorded 22.18% higher rice-equivalent yield (5.76 t/ha) and maximum net returns (₹28,446/ha). Application of recommended herbicide in rice and wheat gave 11.8% higher rice equivalent yield (6.34 t/ha) than hand-weeding and also provided the maximum net returns (₹37,296/ha) and benefit: cost ratio (1.42).

Key words : Conventional tillage, Herbicides, Weed-management, Zero tillage

Rice–wheat cropping system accounts for about one-fourth of total foodgrain production of South-East Asia and about 31% of the total foodgrain production of India (Prasad, 2005). Transplanting of rice seedling is the major establishment practice in most parts of rice-growing areas, although this practice is labour, water and energy-intensive, as well as deteriorates the soil properties due to formation of compact hard soil surface, whereas direct-seeding of rice aids in quick establishment and early harvest than transplanted rice and consequently facilitates timely wheat sowing (Singh *et al*., 2007) and thus enhances sustainability of the rice–wheat cropping system (Farooq *et al*., 2008). Direct-seeded rice (DSR) needs only 34% of the total labour requirement and saves 27% of the total cost of transplanted crop (Mishra and Singh, 2011). However, direct-seeding is subjected to greater weed competition than transplanted rice resulting in reduced grain yield by 15–60% (Moody, 1992). Similarly, yield loss in wheat occurs due to weeds is 15–30% (Saraswat and Bhan, 1992). Tillage influences weed infestation, as under zero tillage seeds of most of the seasonal weeds remain on the soil surface, while under conventional tillage the weed seeds are inverted by plough and buried beneath the soil, thus under zero tillage the infestation of weeds are more. However, the crop establishment under zero tillage in rice–wheat system is gaining momentum in recent days as a pathway to address rising water and labour scarcity, increasing cost of fuel energy and to enhance resource-use efficiency and system sustainability. Zero tillage sowing in standing crop residues along with application of herbicides in proper combination or sequence leads to lower weed population and higher yield than conventional planting (Sharma and Singh, 2012). However, it is easier to establish a crop stand in conventionally tilled fields. Under zero tillage it is difficult to plant the seed deep enough. Tillage influences the weed-seed distribution in the soil. Presence of crop residues on soil surface in zero tillage suppresses weeds and also affects the efficacy of herbi-

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cides. Hence to evaluate the effectiveness of herbicides under combinations of conventional and zero tillage in rice–wheat system, the present investigation was undertaken.

MATERIALS AND METHODS

A field experiment was conducted on sandy loam soil of Birsa Agricultural University, Ranchi (23°17' N and 85°19' E with an altitude of 625 m above mean sea level) during 2010–11 and 2011–12 to evaluate the performance of tillage and weed-control methods on weed dynamics and productivity of rice. The soil was medium in organic carbon (0.52%), low in available nitrogen (242.23 kg/ha) and potassium (123 kg/ha) and medium in available phosphorus (14.85 kg/ha), having soil pH 5.6. The experiment was designed in split-plot having 4 tillage methods namely zero–zero (ZT-ZT), zero–conventional (ZT-CT), conventional–zero (CT-ZT) and conventional–conventional (CT-CT) tillage performed during rainy and winter seasons, respectively, under main plots. The conventional tillage was performed by mould-board plough followed by cultivator and planking. In zero tillage, furrows were opened at a spacing of 20 cm for rice and wheat with the help of dutch hoe. The seeds and fertilizers were placed in the furrows and covered manually. Three weed control methods, viz. recommended herbicides butachlor 1.0 kg/ha as pre-emergence + 2,4-D 0.5 kg/ha as post-emergence in rice and isoproturon 0.75 kg/ha + 2,4-D 0.5 kg/ha as post-emergence in wheat, weed-free [3 hand-weedings at 20, 40 and 60 days after sowing (DAS) in rice and at 25, 50 and 75 DAS in wheat] and weedy check under sub-plots, replicated 4 times. The variety of rice and wheat were 'BVD 109' and 'K 9107' respectively. The crop was fertilized with recommended 100 kg N + 25.8 kg P + 33.2 kg K in rice and wheat. Half amount of N and full of P and K were applied at the time of seeding and remaining N was applied in 2 equal splits-at mid-tillering and panicle initiation in rice and at crown-root initiation and maximum tillering in wheat respectively. Data on weeds were subjected to square-root transformation $\sqrt{(X + 0.5)}$.

RESULTS AND DISCUSSION

Weeds

The experimental field was infested with grassy weeds, viz. *Digitaria sanguinalis* (L.) Scop. (33.56%), *Dactyloctenium aegyptium* (L.) (4.60%), *Echinochloa crus-galli* (L.) P. Beauv. (2.76%), *Commelina nudifolia* (L.) (6.90%), broad-leaf weeds, viz. *Eclipta alba* (L.) Hassk (6.44%), *Ludwigia parviflora* (Jacq.) Raven (40%), while among sedges *Cyperusiria* (L.) (1.84%) and *Fimbristylis milliaceae* (L.) (3.91%) were dominant during the rainy season. During the winter season the major grassy weeds were *Avena fatua* (L.) (1.77%), *Lolium temulentum* (L.) (0.71%), *Polypogon mono speliensis* (L.) Desf. (1.06%) and C*ynodon dactylon* (L.) Pers. (5.32%) and among broad-leaf weeds, *Chenopodiun album* (L.) (26.95%), *Fumaria parviflora* Lamk. (2.13%), *Coronopus dydimus* (L.) Sm. (12.41%), *Anagalis arvensis* (L.) (5.32%) and *Melilotus indica* L. (44.33%).

Tillage methods significantly affected the population and dry matter of weeds in rice (Table 1). Conventional tillage (CT) in both rice and wheat recorded reduced weed density and weed dry matter and was on a par with CT in rice and ZT in wheat. Continuous conventional tillage in both rice and wheat recorded 65.32% and 61.26% reduction in weed population 30 and 60 days after sowing (DAS), respectively, than the continuous zero tillage. These results indicated that low soil-disturbance systems as a result of zero tillage is likely to leave a large portion of the weed seeds on the soil surface, where light stimulates seed germination, resulting in higher seedling emergence than high soil-disturbance system (Chauhan and Johnson, 2009). Among weed-control methods, application of herbicide in rice lowered total weed density by 58.55% compared to weedy check and 8.09% to hand-weeding at 30 DAS and 66.75% compared to weedy check and 9.31% to hand-weeding at 60 DAS. Similarly, corresponding reductions in dry-matter accumulation by weeds were 84.33% and 52.53% at 30 DAS and 89.32% and 75.23% at 60 DAS (Table 1). Singh *et al.* (2006) reported effective weed control in dry-seeded rice with herbicides.

In wheat, tillage system did not influence the density and dry matter of weeds, except weed dry weight at 60 DAS, where it was significantly lower with continuous CT system (Table 2). Application of recommended herbicide in rice and wheat recorded significantly reduced number of total weeds at 30 and 60 DAS and dry-matter accumulation at 30 DAS. While application of herbicides in wheat reduced 73.73% and 32.70% total weed density at 30 DAS and 73.58% and 17.51% at 60 DAS compared to weedy check and hand-weeded treatments respectively (Table 2). The reductions in dry-matter by weeds at 30 DAS were to 73.56 and 17.51 and at 60 DAS 86.36 and 51.96% as compared to weedy check and hand-weeded treatments respectively (Table 2).

Yield

Rice: Different tillage sequences and weed-control methods had a significant effect on yield and yield-attributing parameters (Table 3). Effective tillers, grains/panicle and 1,000-seed weight were maximum in CT-CT sequence in rice and wheat owing to maximum grain (1.96 t/ha) and straw (2.86 t/ha) yields and were similar to ZT-CT and CT-

Table 1. Effect of tillage and weed management in weed population and dry-matter accumulation at 30 and 60 days after sowing (DAS) in rice (pooled data of 2 years)

Treatment	Weed density (No./m^2) at 30 DAS			Weed density (No./m^2) at 60 DAS			Total weed density (No./m^2)		Dry matter weight (g/m^2)	
	Narrow leaf	Broad leaf	Sedges	Narrow leaf	Broad leaf	Sedges	30 DAS	60 DAS	30 DAS	60 DAS
Tillage										
ZT-ZT	8.9 (101.2)	9.4 (117.9)	5.7 (49.1)	11.7 (174.2)	12.9 (221.7)	7.1 (74.4)	14.4 (268.2)	19.4 (470.3)	8.3 (85.3)	11.3 (172.0)
ZT-CT	8.8 (102.4)	8.6 (107.4)	5.6 (49.3)	11.1 (163.3)	12.0 (203.5)	6.8 (73.9)	13.9 (259.1)	18.3 (440.7)	7.9 (81.0)	10.2 (143.8)
CT-ZT	6.2 (50.4)	6.2 (48.7)	3.8 (19.8)	8.1 (94.1)	8.6 (92.5)	5.1 (36.9)	9.7 (118.9)	13.2 (223.5)	5.9 (49.5)	8.0 (104.3)
CT-CT	5.4 (38.8)	5.4 (39.2)	3.26 (14.94)	7.4 (78.2)	7.6 (77.9)	4.1 (26.1)	8.4 (93.0)	11.7 (182.2)	5.2 (41.4)	7.2 (95.7)
SEm±	0.28	0.35	0.46	0.49	0.38	0.67	0.44	0.65	0.40	0.53
CD (P=0.05)	0.88	1.12	1.48	1.55	1.21	2.15	1.39	2.07	1.27	1.70
Weed management										
Hand-weeding	5.7 (45.5)	6.3 (56.6)	3.8 (21.7)	6.8 (62.1)	8.6 (104.3)	4.7 (33.5)	9.5 (128.0)	12.3 (213.1)	5.7 (42.8)	7.1 (61.0)
Herbicide	5.5 (43.9)	5.8 (52.0)	4.0 (25.9)	6.9 (68.7)	7.8 (97.6)	4.9 (40.1)	8.9 (117.6)	11.7 (193.3)	4.2 (20.3)	5.3 (31.4)
Weedy check	10.8 (130.2)	10.2 (126.3)	6.0 (52.3)	15.0 (251.5)	14.4 (244.8)	7.7 (84.9)	16.4 (308.8)	23.0 (581.2)	10.5 (129.8)	15.1 (294.4)
SEm±	0.24	0.26	0.30	0.31	0.28	0.37	0.29	0.36	0.28	0.33
CD (P=0.05)	0.69	0.77	0.89	0.91	0.80	1.07	0.86	1.05	0.82	0.95

Data in parentheses are original values

Table 2. Effect of tillage and weed management on weed population and dry matter accumulation at 30 and 60 days after sowing (DAS) in wheat (pooled data of 2 years)

Treatment	Weed density (No./m^2) at 30 DAS		Weed density (No./m^2) at 60 DAS		Total weed density (No./m^2)		Dry matter weight (g/m^2)	
	Narrow leaf	Broad leaf	Narrow leaf	Broad leaf	30 DAS	60 DAS	30 DAS	60 DAS
Tillage								
ZT-ZT	6.8 (63.9)	24.1 (734.7)	7.6 (77.0)	21.3 (600.5)	20.1 (451.5)	22.9 (677.5)	6.5 (59.1)	5.7 (46.5)
ZT-CT	8.5(109.2)	21.1 (563.1)	7.4 (78.0)	20.1 (547.3)	18.1 (381.6)	21.9 (625.3)	4.9 (38.8)	6.0 (48.2)
CT-ZT	8.1 (77.3)	21.6 (633.3)	8.5 (95.6)	20.7 (611.9)	18.0 (380.7)	23.2 (707.5)	6.0 (52.5)	6.7 (61.0)
CT-CT	7.8 (79.9)	21.2 (524.0)	7.3 (72.2)	18.7 (517.1)	16.2 (308.6)	21.0 (589.3)	5.3 (39.6)	4.9 (31.4)
SEm±	0.57	1.04	0.62	0.81	1.14	0.60	0.40	0.29
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	0.91
Weed management								
Hand-weeding	6.5 (65.0)	17.7 (329.9)	5.1 (41.7)	15.4 (258.2)	16.0 (283.3)	16.6 (299.9)	4.5 (25.4)	4.8 (28.6)
Herbicide	8.3 (90.2)	14.4 (227.6)	8.0 (73.8)	10.1 (128.1)	12.6 (178.6)	13.4 (201.8)	4.2 (21.0)	3.4 (13.4)
Weedy check	8.6 (92.5)	34.0(1283.9)	9.9(126.6)	35.2(1321.4)	25.8 (679.9)	36.8 (1448.0)	8.5 (96.1)	9.2 (98.3)
SEm±	0.34	0.46	0.35	0.40	0.69	0.47	0.27	0.37
CD (P=0.05)	0.98	1.33	1.03	1.17	2.00	1.36	0.79	1.09

Data in parentheses are original values

ZT tillage practices in rice and wheat sequences. Continuous conventional tillage sequence recorded 39.84% higher yield than continuous zero tillage in rice–wheat system.

Among weed-management practices, weed-free recorded significantly highest grain (2.09 t/ha) and straw (3.04 t/ha) yield and was 2.25% and 92.38% higher than recommended herbicidal use and weedy check respectively.

Wheat: Wheat yield was significantly affected by different tillage sequences and weed-control methods (Table 3). Continuous conventional tillage sequence in rice and wheat recorded maximum grain yield and was similar to ZT-CT tillage practices in rice and wheat sequences. CT-CT tillage sequence recorded 14.16 % higher yield than ZT-ZT tillage practice in rice and wheat. Among weed management, application of recommended herbicides resulted in significantly highest grain and straw yield and was 22.59% and 58.75% higher than hand weeding and weedy check respectively. Effective weed-control and improved grain yield of wheat with sequential application of recommended herbicides were also reported by Walia *et al*. (2005) and Punia *et al*. (2006).

Rice equivalent yield: System productivity was affected significantly by different tillage sequences and weed-control methods (Table 4). Maximum rice-equivalent yield was recorded in CT-CT sequence and was on a par with ZT-CT practices in rice and wheat sequences. Continuous conventional tillage sequence recorded 22.18% higher rice-equivalent yield than ZT-ZT practice in rice and wheat.

Among weed management, application of recommended herbicide resulted in significantly highest rice-equivalent yield (6.34 t/ha) and was 11.80% and 63.63% higher than hand weeding and weedy check respectively.

Table 4. Effect of tillage and weed management on rice–equivalent yield and economics of rice–wheat system (pooled data of 2 years)

Treatment	Rice equivalent yield (t/ha)	Cost of cultivation ($\times 10^3$ ₹/ha)	Net return ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Tillage				
ZT-ZT	4.72	27.2	20.0	0.77
ZT-CT	5.68	28.4	28.5	1.03
CT-ZT	5.04	28.0	22.4	0.80
CT-CT	5.76	29.2	28.4	1.00
SEm±	0.18		1.8	0.06
CD (P=0.05)	0.57		5.7	0.18
Weed management				
Hand weeding	5.67	35.0	21.8	0.62
Herbicide	6.34	26.1	37.3	1.42
Weedy check	3.88	23.4	15.4	0.57
SEm±	0.006		0.02	0.11
CD (P=0.05)	0.02		0.05	0.31

Price of rice grain was ₹10/kg and straw was ₹2/kg; Price of wheat grain was ₹12/kg and straw was ₹0.20/kg

Economics

Pooled data revealed that continuous conventional tillage sequence in rice and wheat recorded the maximum gross return (₹57,607/ha), net return (₹28,446 /ha) and benefit: cost ratio in rice–wheat cropping system and was similar to ZT-CT practices in rice and wheat sequences. Gangwar *et al.* (2006) also observed higher benefit: cost ratio in rotational tillage. Among weed management, application of recommended herbicide recorded significantly maximum gross returns, net returns and benefit: cost ratio.

Table 3. Effect of tillage and weed management on yield attributes and yield of rice and wheat (pooled data of 2 years)

Treatment	Total tillers/m²		Effective tillers/m²		Grains/panicle		1,000-grain weight (g)		Grain yield (t/ha)		Straw yield (t/ha)	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Tillage												
ZT-ZT	341	529	247	461	35	36	22.59	42.30	1.40	2.50	2.07	4.52
ZT-CT	318	558	223	491	40	36	23.40	41.85	1.81	2.84	2.62	5.28
CT-ZT	355	517	245	455	41	36	23.47	42.05	1.78	2.48	2.60	4.55
CT-CT	380	515	266	439	48	37	23.60	42.62	1.96	2.85	2.86	5.26
SEm±	20.2	10.8	15.3	8.4	2.4	0.6	0.37	0.24	0.08	0.06	0.12	0.14
CD (P=0.05)	NS	NS	NS	26.8	7.8	NS	NS	NS	0.25	0.20	0.38	0.45
Weed management												
Hand-weeding	402	538	274	479	48	38	23.79	42.68	2.09	2.67	3.04	5.12
Herbicide	386	536	275	465	47	37	23.57	42.19	2.04	3.27	2.98	5.54
Weedy check	257	515	186	441	27	33	22.44	41.74	1.08	2.06	1.59	4.05
SEm±	2.0	14.6	1.7	12.6	0.7	0.7	0.27	0.191	0.004	0.12	0.005	0.20
CD (P=0.05)	5.8	NS	5.1	NS	2.03	2.2	0.80	0.55	0.01	0.36	0.014	0.58

These results confirm the findings of Singh *et al*. (2010) and Mishra (2006).

Thus it can be inferred that continuous conventional tillage in rice and wheat sequences and application of butachlor 1.0 kg/ha as pre-emergence + 2,4-D 0.5 kg/ha as post-emergence in rice and isoproturon 0.75 kg/ha + 2,4-D 0.5 kg/ha post-emergence in wheat, was the most productive and remunerative approach in direct-seeded rice–wheat system.

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