Indian Journal of Weed Science 52(4): 326–330, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Tillage and weed management effects on productivity of wheat under dry seeded rice–wheat system on lateritic soils of West Bengal

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Article information

DOI: 10.5958/0974-8164.2020.00065.9

Type of article: Research article

Received : 8 September 2020
Revised : 9 December 2020
Accepted : 13 December 2020

Key words
Conventional tillage
Dry seeded rice
Recommended herbicides
Weed management
Wheat
Zero tillage

ABSTRACT

A field study was conducted during 2016-17and 2017-18 to evaluate the impact of four tillage systems, *viz.* zero tillage (ZT) both in rice and wheat, conventional tillage (CT) both in rice and wheat, ZT in rice – CT in wheat and CT in rice –ZT in wheat with four weed management practices (recommended herbicide, recommended herbicide + one hand weeding, weed free and weedy check) in dry seeded rice–wheat cropping system on a lateritic soil of West Bengal. Among weed management practices, application of sulfosulfuron + metsulfuron at 0.032 kg/ha at 20 DAS followed by one hand weeding at 40 DAS in wheat was found to be the most effective. The yield of wheat under ZT-ZT was found to be the highest (3.78 t/ha), which was at par with CT-ZT. Advantages in ZT-ZT were to the extent of 23.6 and 21.8% over CT-CT in first and second year, respectively. Among weed management practices, recommended herbicide followed by one hand weeding registered higher yield (3.78 t/ha) and was comparable with the weed free treatment. The highest B:C ratio was recorded in zero tillage in wheat (ZT-ZT and CT-ZT) in combination with the sole application of recommended herbicide. The continuous ZT, especially in wheat with recommended herbicide alone was promising for higher productivity and profitability under dry-seeded rice–wheat system on lateritic soils of Eastern India.

INTRODUCTION

Rice-wheat cropping system (RWCS) is called as Indian Food Security System which occupies the highest area in India. Globally RWCS occupies about 24 million (M) ha area, and in India it is the most popular and prevalent sequence covering ~10.5 Mha mainly in the Indo-Gangetic Plains (IGP) (Jat *et al.* 2014). Rice and wheat crops contribute 76% of the total food grain production in India (Economic Survey 2018-19).

Yield losses due to weeds in wheat have been estimated up to 33-47% (Meena *et al.* 2019). Whereas, Kumar *et al.* (2013) reported that reduction in wheat grain yield due to the uncontrolled weeds is up to 66%. Composition of weed flora and their competition with crop plants not only depend upon cropping system but also change dynamically with the soil, climate and management practices.

Tillage operations can have a major impact on the distribution of weed flora and weed seeds in the soil. In traditional RWCS, puddled transplanted rice is followed by the conventional till wheat, which requires large amount of water, labour and energy. Puddling deteriorates soil health, leads to compaction of sub soil, and lessens the soil porosity. However, accumulation of nutrient in surface soil, soil penetration resistance and increased weed competition by leaving most of the weed seeds on or close to the top layer of the soil surface are the negative impacts of long-term zero tillage cultivation.

Along with the tillage operation, use of effective herbicide can give the yield advantage by minimising the weed infestation in rice-based cropping system (Teja and Duary 2018). The ZT has been the function of weed management, not just in wheat but in rice as well (Malik *et al.* 2018). With ZT, the early emergence of wheat and the absence of soil disturbance in uncropped area resulted in less and late emergence of weeds. Therefore, crop-weed competition in wheat crop is greatly reduced. Thus, the present study was conducted to see the effect of tillage and weed management practices on weed growth and yield of wheat under direct-seeded rice-wheat cropping system.

MATERIALS AND METHODS

Field experiment was carried out during 2016-17 and 2017-18 at the Institute of Agriculture, Visva-Bharati, Sriniketan ($23^0$39′ North latitude and $87^0$42′ East longitude with an average altitude of 58.9 m above MSL), West Bengal. Experimental plot was having red and lateritic type of soil association group with sandy loam in texture (sand: 70.4, silt: 17.1 and clay: 12.5%) and acidic in soil reaction (6.10 pH). The top-soil (0-15 cm layer) at the beginning of the experiment was low (0.41%) in organic carbon, available nitrogen (135.0 kg/ha) and extractable K (124.4 kg/ha) whereas, medium (10.7 kg/ha) in available phosphorous.

The experiment was laid out in a split-plot design in three replications with four tillage practices in main plot and four weed management practices in sub-plot. Four tillage systems consisted of zero tillage (ZT) both in dry direct-seeded rice (DSR) and wheat (ZT-ZT), conventional tillage (CT) both in DSR and wheat (CT-CT), zero tillage (ZT) in DSR – conventional tillage (CT) in wheat (ZT-CT) and conventional tillage (CT) in DSR – zero tillage (ZT) in wheat (CT-ZT). Four weed management practices were: recommended herbicide *i.e.* pendimethalin at 1.0 kg/ha followed by bispyribac-sodium at 0.025 kg/ha in rice and sulfosulfuron + metsulfuron at 0.032 kg/ha in wheat, recommended herbicide + one hand weeding at 40 days after sowing (DAS), weed free and weedy check. Herbicide spraying was done by using knapsack sprayer with flat fan nozzle. In zero tilled plots, glyphosate at 1.0 kg/ha was sprayed well ahead before sowing.

Crop varieties '*MTU 1010*' and '*PBW 343*' were used for rice and wheat under the experimentation, respectively. Sowing was done mechanically by using zero till ferti-cum-seed drill machine (National Zero Till Ferti-cum-Seed Drill, Ludhiana). To accomplish the sowing, the row to row spacing of 20 cm was maintained. Seed rate was fixed by adjusting the zero till drill machine at 40 kg for rice and 100 kg/ha for wheat. The fertilizer was applied in the form of urea and 10-26-26 whereas the recommended dose of N, P and K for rice and wheat was 80:40:40 and 120:60:60 kg/ha, respectively. Zinc sulphate 25 kg/ha was also applied at final land preparation. The field was surface-irrigated and kept moist throughout the season and irrigation was stopped 2 weeks before crop harvest. Observations of the parameters were recorded at 60 DAS and at the time of harvest by following standard procedure. The density of the weeds was recorded at 60 DAS by placing a quadrate of 50 × 50 cm from the marked sampling area of 1.0 m^2 in each plot. For recording their biomass, weed samples were sun-dried and later oven dried at 70^oC until constant weight was attained. Grain yield was taken from undisturbed net plot area in the center of each plot at 14% moisture and statistically analyzed at a 5% level of significance. The cost of cultivation, gross return, net return and B:C ratio of wheat under different treatments were calculated by considering the cost of various inputs like seeds, fertilizers, herbicides and all other inputs including labour charges as per the local market price. The value of products like grain and straw was also calculated on the basis of Govt. of India Minimum Support Price (MSP) and available price at the local market. The weed data were subjected to a square root transformation to normalize their distribution.

RESULTS AND DISCUSSION

Digitaria sanguinalis was the most dominant grasses and *Gnaphalium indicum* and *Polygonum plebeium* were the predominant broad-leaved weeds under all the tillage practices in both the years in wheat. However, in second year, *Spilanthes acmella* and *Anagalis arvensis* were the broad-leaved weeds found under CT-CT and CT-ZT tillage practices along with the infestation of *G. indicum* and *P. plebeium*. Mitra *et al.* (2019) observed various species of *Polygonum* as dominant in all the stages of crop growth.

Irrespective of weed management practices, density and biomass of *D. sanguinalis* was significantly the lowest under CT-CT, whilst, it was significantly at par under ZT-CT in both the years (**Table 1** and **2**). Opposite trend was observed for *G. indicum* and *P. plebeium*, where continuous zero tilled plot registered the lowest biomass, which was statistically at par with CT-ZT for both the year. Likewise, CT-ZT tillage practice was found to be significantly superior over the others in reducing density of *P. plebeium*, followed by the ZT-ZT tillage practice in the second year (**Table 1**). The effect of tillage practice was found to be non-significant for density of *P. plebeium* for first year and other weed species densities in both the year (**Table 1**). Unlike densities of other weed species, the highest biomass was recorded under continuous conventionally tilled plot in the first year, whilst there was no significant difference among the tillage practices for other weeds in the second year (**Table 2**). In continuously conventional tilled plot (CT-CT) and zero tillage in rice *fb* conventional tillage in wheat (ZT-CT) registered significantly higher density and biomass of total weeds as compared to zero tilled wheat (ZT-ZT and/or CT-ZT) during both the years (**Table 1** and **2**).

The lowest weed density, biomass and weed growth rate across all the growth stages under zero tillage of maize as compared to other conventional tillage practices have been reported earlier (Khedwal *et al.* 2017). The biomass of *D. sanguinalis* under CT-CT was 31.16 and 24.16% lowered than ZT-ZT in first and second year, respectively. Total weed biomass in ZT-ZT had 18.96 and 12.53% less than CT-CT in first and second year, respectively.

The weed free check attained least weed count and biomass, which was closely followed by recommended herbicide with one hand weeding (**Table 1** and **2**). Application of recommended herbicide with one hand weeding registered similar result as that of weed free plot with respect to *P. plebeium* for both the years and *G. indicum* for the first year. All the weed management practices were found to be effective in total control of the *P. plebeium* population during second year of experimentation. The application of only recommended herbicide in wheat had 63.88 and 57.85% less total weed biomass than weedy check in first and second year, respectively (**Table 2**).

Mishra and Singh (2012) observed that ZT wheat sowing (either continuous or rotated with conventional) significantly increased population of grassy weeds like *A. ludoviciana* than conventional tillage (CT-CT or ZT-CT). Zero (ZT-ZT) and conventional tillage in rice *fb* zero tillage in wheat (CT-ZT) remained at par with each other in both the years. The lower emergence of weeds under ZT may be due to higher soil strength in ZT because of crust development in the absence of tillage after rice harvest, which can mechanically impede seedling emergence (Duary *et al.* 2016), and higher weed seed predation under ZT (Kumar *et al.* 2013).

Table 1. Species wise and total weed density at 60 DAS of wheat under rice-wheat system under different tillage and weed management practices

Treatment	Weed density (no./m^2)									
	2016-17					2017-18				
	D. sanguinalis	*G. indicum*	*P. plebeium*	Others	Total	*D. sanguinalis*	*G. indicum*	*P. plebeium*	Others	Total
Tillage										
ZT-ZT	2.58(6.1)	4.18(17.0)	4.39(18.7)	1.94(3.3)	7.01(48.6)	3.57(12.2)	2.96(8.3)	3.04(8.7)	4.32(18.2)	7.20(51.3)
CT-CT	1.99(3.5)	5.78(32.9)	5.09(25.4)	2.45(5.5)	8.43(70.5)	2.87(7.7)	3.99(15.4)	3.83(14.2)	3.88(14.5)	7.68(58.4)
ZT-CT	2.32(4.9)	5.05(25.0)	4.83(22.8)	2.21(4.4)	7.73(59.2)	2.95(8.2)	3.85(14.3)	3.80(13.9)	3.76(13.7)	7.57(56.8)
CT-ZT	2.52(5.8)	4.34(18.4)	4.46(19.4)	2.06(3.7)	7.27(52.3)	3.35(10.7)	3.41(11.1)	3.04(8.7)	3.57(12.3)	6.93(47.5)
LSD(p=0.05)	0.34	0.67	NS	NS	0.54	0.32	0.67	0.31	NS	0.54
Weed management										
RH	3.26(10.1)	4.67(21.3)	6.58(42.8)	3.36(10.8)	9.51(90.0)	3.92(14.9)	6.35(39.8)	0.71(0.0)	4.18(17.0)	8.58(73.1)
RH+HW	1.47(1.6)	4.04(15.8)	0.71(0.0)	0.71(0.0)	4.40(18.9)	2.55(6.0)	0.71(0.0)	0.71(0.0)	2.17(4.2)	3.27(10.2)
Weed free	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)
Weedy	3.97(15.3)	9.93(98.1)	10.8(115.5)	3.88(14.6)	15.8(249.5)	5.58(30.6)	6.45(41.1)	11.6(133.7)	8.48(71.4)	16.8(282.2)
LSD(p=0.05)	0.28	0.52	0.37	0.33	0.45	0.27	0.63	0.37	0.47	0.52

Figures within parentheses indicate original values. Data were transformed to $\sqrt{x+0.5}$ before analysis
CT: Conventional tillage, ZT: Zero tillage, RH: Recommended herbicides, HW: Hand weeding

Table 2. Species wise and total weed biomass at 60 DAS of wheat under rice-wheat system under different tillage and weed management practices

Treatment	Weed biomass (g/m^2)									
	2016-17					2017-18				
	D. sanguinalis	*G. indicum*	*P. plebeium*	Others	Total	*D. sanguinalis*	*G. indicum*	*P. plebeium*	Others	Total
Tillage										
ZT-ZT	1.81(2.8)	1.87(3.0)	1.81(2.8)	1.43(1.5)	3.27(10.2)	1.85(2.9)	1.93(3.2)	1.43(1.5)	2.41(5.3)	3.67(13.0)
CT-CT	1.38(1.4)	2.51(5.8)	2.35(5.0)	2.01(3.5)	3.89(14.6)	1.49(1.7)	2.81(7.4)	1.79(2.7)	2.21(4.4)	4.13(16.5)
ZT-CT	1.61(2.1)	2.25(4.5)	2.25(4.6)	1.56(1.9)	3.57(12.3)	1.49(1.7)	2.59(6.2)	1.75(2.6)	2.32(4.9)	4.01(15.5)
CT-ZT	1.73(2.5)	2.01(3.5)	1.94(3.3)	1.39(1.4)	3.28(10.2)	1.69(2.3)	2.08(3.8)	1.46(1.6)	1.99(3.5)	3.41(11.1)
LSD(p=0.05)	0.30	0.25	0.32	0.31	0.27	0.17	0.38	0.19	NS	0.33
Weed management										
RH	2.21(4.4)	1.98(3.4)	2.53(5.9)	2.23(4.5)	4.43(19.1)	1.86(3.0)	4.02(15.7)	0.71(0.0)	2.48(5.6)	5.03(24.7)
RH+HW	1.08(0.7)	1.43(1.5)	0.71(0.0)	0.71(0.0)	1.62(2.1)	1.26(1.1)	0.71(0.0)	0.71(0.0)	1.13(0.8)	1.54(1.9)
Weed free	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)
Weedy	2.53(5.9)	4.52(19.9)	4.41(18.9)	2.74(7.0)	7.26(52.2)	2.69(6.7)	3.98(15.3)	4.30(18.0)	4.61(20.8)	7.94(62.5)
LSD(p=0.05)	0.19	0.28	0.25	0.23	0.34	0.11	0.40	0.15	0.31	0.36

Figures within parentheses indicate original values. Data were transformed to $\sqrt{x+0.5}$ before analysis; CT: Conventional tillage, ZT: Zero tillage, RH: Recommended herbicides, HW: Hand weeding

Effect on yield of wheat

The yield levels of grain (3.48 and 3.78 t/ha) and straw (5.23 and 5.70 t/ha) were significantly the highest under ZT-ZT, in first and second year, respectively, compared with the others during *Rabi* season (**Table 3**). With respect to grain yield, advantages in ZT-ZT were to the extent of 23.59 and 21.75% over CT-CT in first and second year, respectively (**Table 3**). Although the ZT-ZT crop yielded the highest, then CT-ZT tillage practice, they did not differ from each other in respect of grain (3.34 and 3.62 t/ha) and straw (5.15 and 5.57 t/ha) yield, in first and second year, respectively. Irrespective of tillage practices, the highest productivity of grain (3.72 and 3.78 t/ha) and straw (5.56 and 6.31 t/ha) was significantly recorded with the weed free treatment, which, however, was found to maintain statistically similar yield levels with recommended herbicide with one hand weeding (grain yield 3.58 and 3.68 t/ha, straw yield 5.06 and 5.60 t/ha) in first and second year, respectively (**Table 3**). Compared with weedy check, yield advantages under these treatments ranged from 44.23 to 30.67% and 32.58 to 29.33%, on grain and straw yield, respectively (**Table 3**). Weed management treatments did not differ significantly in both the years in respect of harvest index.

Interaction amongst tillage and weed management practices on grain yield of wheat was significant in both the years. Weed free registered significantly the highest grain yield under all the tillage practices (**Figure 1** and **2**). After completion of two rounds of tillage practices in rice-wheat system, sole application of recommended herbicide remained at par with the weed free treatment under ZT-ZT and CT-ZT tillage practices. However, weed free under CT-ZT was comparable with sole application of recommended herbicide in ZT-ZT (**Figure 1** and **2**). Singh *et al.* (2017) also proved that metsulfuron + clodinafop applied in wheat with ZT preceding soybean resulted in higher grain and straw yields, than other combinations.Similarly, in CT-ZT, application of recommended herbicide was at par with weed free treatment under ZT-CT with respect to grain yield of wheat. ZT sowing of maize with recommended herbicide *fb* one HW resulted in lower weed infestation, higher productivity and economics returns (Khedwal *et al.* 2017).

Economics

The tillage cost was recorded highest in CT-CT, CT-ZT followed by ZT-CT and least in ZT-ZT. The tillage cost in ZT-ZT was lower by 7.13% and 7.14% than CT-CT during 2016-17 and 2017-18, respectively (**Table 3**). Similarly, the cost of weed management was recorded highest in weed free treatment. The cost of production was lower by 30.85 to 28.91% in ZT-ZT than CT-CT in 2016-17 and 2017-18, respectively. The gross return, net return and B:C ratio of wheat was highest in ZT-ZT which was closely followed by CT-ZT during both the year of investigation (**Table 3**). Among the weed management practices, sole application of recommended herbicide registered the highest net return as well as B:C ratio in the second year of experimentation (**Table 3**). Therefore, the highest B:C ratio was recorded in zero tillage in wheat (ZT-ZT and CT-ZT) in combination with the recommended herbicide alone (**Table 4**).

The cost of cultivation was significantly affected by the tillage and weed management practices. Consistent with our results, savings in

Table 3. Grain, straw yield and economics of wheat in rice-wheat cropping system under different tillage and weed management practices

Treatment	2016-17				2017-18				2016-17		2017-18	
	Cost of cultivation (×10³ ₹/ha)	Gross return (×10³ ₹/ha)	Netreturn (×10³ ₹/ha)	B:C ratio	Cost of cultivation (×10³₹/ha)	Gross return (×10³ ₹/ha)	Net return (×10³ ₹/ha)	B:C ratio	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
Tillage												
ZT-ZT	34.15	61.80	27.65	0.81	35.23	67.11	31.89	0.94	3.48	5.23	3.78	570
CT-CT	36.77	47.23	10.46	0.28	37.94	52.06	14.12	0.37	2.66	4.00	2.96	3.99
ZT-CT	36.77	52.58	15.81	0.42	37.94	57.88	19.94	0.53	2.97	4.34	3.25	5.11
CT-ZT	34.15	59.42	25.27	0.74	35.23	64.48	29.25	0.86	3.34	5.15	3.62	5.57
LSD(p=0.05)	-	6.67	6.67	0.19	-	4.38	4.38	0.11	0.38	0.78	0.29	0.64
Weed management												
RH	31.58	56.00	24.42	0.79	32.38	62.77	30.39	0.95	3.16	4.67	3.59	4.48
RH+HW	35.83	63.23	27.40	0.77	36.88	65.47	28.59	0.78	3.58	5.06	3.68	5.60
Weed free	44.76	65.96	21.20	0.48	46.64	67.82	21.18	0.46	3.72	5.56	3.78	6.31
Weedy	29.68	35.85	6.17	0.21	30.44	45.47	15.03	0.51	2.00	3.41	2.55	3.96
LSD(p=0.05)	-	2.58	2.58	0.08	-	2.52	2.52	0.07	0.15	0.53	0.14	0.76

CT: Conventional tillage, ZT: Zero tillage, RH: Recommended herbicides, HW: Hand weeding

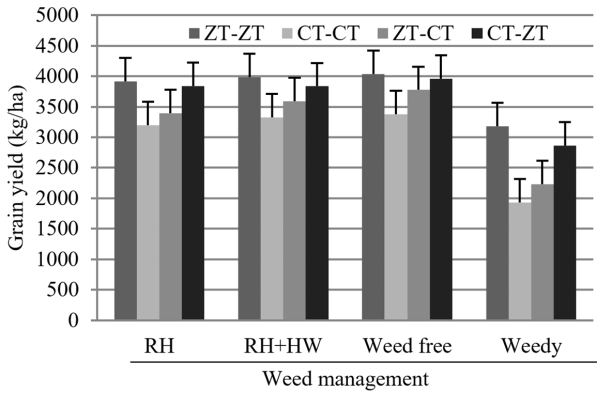

Figure 1. Interaction effect of tillage and weed management practices on grain yield of wheat under rice-wheat cropping system in second year

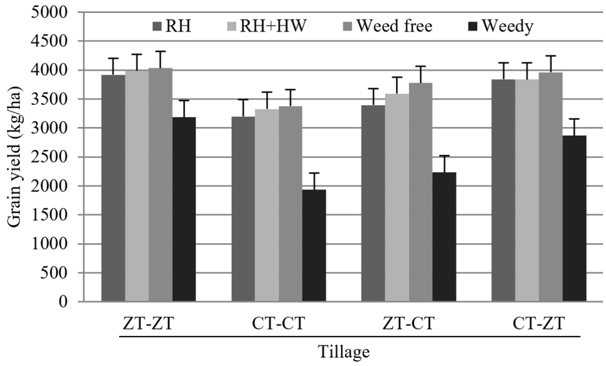

Figure 2. Interaction effect of weed management and tillage practices on grain yield of wheat under rice-wheat cropping system in second year

labor and production costs and higher net economic returns have been reported in zero tilled wheat (Stanzen *et al.* 2017). The results demonstrate that ZT in wheat seeding technology can play an important role in saving inputs and improving farmer's income.

Thus, after two cycles of rice-wheat system, ZT in wheat (ZT-ZT and/or CT-ZT) with recommended herbicide alone may be recommended for effective weed management and higher productivity and profitability of wheat in direct-seeded rice-wheat system on lateritic soils of Eastern India.

Table 4. Interaction effect of tillage and weed management practices on B:C ratio of wheat under rice-wheat cropping system in second year

Treatment	B:C ratio			
	Zero tillage-zero tillage	Conventional tillage-conventional tillage	Zero tillage-conventional tillage	Conventional tillage-zero tillage
RH	1.21	0.64	0.77	1.17
RH + HW	1.01	0.54	0.67	0.91
Weed free	0.60	0.26	0.41	0.57
Weedy	0.93	0.06	0.28	0.77
LSD (p=0.05)	T×W 0.14		W×T 0.16	

RH: Recommended herbicides; HW: hand weeding

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