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Influence of Tillage and Weed Management Practices on Growth, Yield and Weed Control Efficiency of Aromatic Rice (*Oryza sativa*)

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ABSTRACT

To study the influence of tillage and weed management practices on growth, yield and weed control efficiency of aromatic black rice (*Oryza sativa*), a field experiment was conducted during *kharif* of 2019-20 and 2020-21 at research farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal. The experiment was laid out in a split plot design with four main plots and three sub plots replicated thrice. Results revealed that rice was infested with three categories of weeds viz., grasses, broadleaved and sedges. Treatment receiving conventional tillage (transplanted) with Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT + mechanical weeding at 50 DAT showed the lowest density and dry weight of weeds throughout the crop growth period and highest grain yield of rice. Thus, conventional tillage with recommended herbicide plus one hand weeding appeared to be a promising technique with respect to weed suppression and crop yield.

Keywords Black rice, Tillage, Weed management, Growth, Yield.

INTRODUCTION

Rice (*Oryza sativa*) is one of the most important food crops in India, making India one of the world's largest producers of rice, including white rice and brown rice, grown mostly in the eastern and southern parts of the country. In India, rice is grown over 42.4 million ha area, as a major staple food for over 3 billion people world-wide, with the production of 104.4 million tons and a productivity of 2.46 tons ha^{-1} (Gill and Walia 2013, Thirunavukkarasu and Vinoth 2013). Black rice is actually more purplish in color than black. It is rich in iron and high in fiber, high in nutritional value. It provides several health benefits such as, prevention of cancer, diabetes, heart diseases, alzheimer's diseases and heart attacks. Growing rice in a more profitable and environmentally sound manner by following

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conservation agriculture (CA) will quickly address the rising vagaries of climatic change eventually confirming farmers with a sustainable output. CA aims to improve the soil structure, water retention, reduce the need for chemical fertilizers and reduced labor requirement, while at the same time improving crop yield. Weed could be considered as the major constraint to the adoption of conservation agriculture due to changes in patterns of tillage, planting systems and other management strategies. Yield losses due to weed infestation may vary with system of rice culture, variety, plant population, fertilizer applied, duration and time of application of fertilizer; weed species, amount of weed growth, season, ecology and climatic conditions. Weeds are a major hindrance to rice production, through their ability to compete for resources and their impact on product quality, irrespective of the method of rice establishment. According to Rao (2011), weed competition would be less severe under transplanting than those under direct-seeding. In case of direct seeded rice weed competition is higher, additionally, competition from weeds is greater when rice is seeded into dry soil than when it is wet seeded or transplanted. However, in direct seeded rice, seedling of rice establishes rapidly. Direct seeding in rice serves several advantages like labor saving, faster and easier planting, helps in timely sowing and early maturity by 7-10 days, less water requirement, high tolerance to water deficit, often high yield, low production cost, and more profit, better soil physical condition, less methane emission (Balasubramanian and Hill 2002, Singh *et al*. 2005). In CA, at least 30% of crop residue is maintained which may be beneficial in improving soil quality but may not necessarily reduce weed germination and emergence (Liebman and Mohler 2001, Jena *et al*. 2017). The practice of retention of previous crops residues also helps in suppressing the weed growth by influencing light transmittance, soil temperature, soil moisture and enhancing weed seed predation (Nichols *et al.*2015 and Taje and Duray 2018). Minimum tillage plus crop residue has been found to be beneficial for conserving water and improving crop productivity (Jat *et al.* 2012). Keeping all these in view the present investigation regarding the influence of tillage and weed management practices on growth, yield and weed control efficiency of aromatic rice (*Oryza sativa*) was carried out.

MATERIALS AND METHODS

Field experiments were conducted during *kharif* of 2019-20 and 2020-21 at research farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal. This experiment was year round system based and conducted to know the effect of tillage, mulch on rice followed by rapeseed and chickpea. The experiment was laid out in split plot design with three replications. Four tillage practices comprising of M_1- Conventional Tillage (CT) (Transplanted), M_2- Conventional Tillage (CT) (Transplanted) for rice *kharif* season and Minimum Tillage (MT) for rapeseed *rabi* season, M_3- Conventional Tillage(CT) (Direct-seeded)-(CT) (rapeseed), M_4- Minimum Tillage (MT) (Direct -seeded), M_5 – MT (Direct seeded rice) + Residue (R) - (MT) (rapeseed) + R and 3 subplots, (S_1- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT*(kharif*) and Pendimethalin 1.0 kg/ha PRE (*rabi*), S_2- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT + hand weeding at 50 DAT (*kharif*) and Pendimethalin 1.0 kg/ha PRE + hand weeding at 30 DAT (*rabi*), S_3-hand weeding at 30 DAT (rice) and at 30 DAS (rapeseed). About 30 % of crop residue of previous crop, from respective treatments of conservation tillage was retained in the plot itself. Rice variety 'Kalabhat' (black rice) was used for rice. The row to row and plant to plant spacing was adjusted at 20 cm for direct seeded rice and transplanted rice. Seed rate was not fixed by adjusting the lever at 80 kg/ha for direct seeded rice, and 40 kg/ha for line sowing in transplanted rice. Recommended NPK at 80:40:40 kg/ha in rice were applied as per recommended practice. In direct seeded rice half dose of N and full dose of P_2O_5 and K_2O were applied as basal at the time of sowing. Remaining half dose of N was applied as top-dressing through urea in two equal splits at 30 and 50 days after sowing. Hand operated knapsack sprayer fitted with a flat fan type nozzle was used for spraying the herbicides in combination with a spray volume of 600 liters/ha. All other recommended agronomic practices were followed and plant protection measures were adopted as per need. The density of total weeds was recorded at 30, 60, 90 and140 DAS by placing a quadrat of 1m × 1m from the marked sampling area of 1.0 m^2 in each plot. For recording their biomass, weed samples were oven dried at 70^{o}C until constant

Table 1. Effect of tillage, residue and weed management practices on total weed density in rice during 2019-2020 and 2020-2021.

Treatments	Total weed density (No/m^2)							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
Main plot: Tillage and residue management								
T_1 CT-TR	4.12 (17.66)	5.38 (29.01)	5.02(26.00)	6.58(43.33)	5.84(34.66)	6.48 (42.0)	4.24(20.06)	438 (19.221)
T_2 CT-TR	4.24 (18.66)	4.56 (20.77)	5.10(26.22)	5.98 (35.78)	5.49(31.00)	5.72 (32.666)	4.54(21.22)	390 (15.222)
T_3 CT-DSR	5.23 (27.89)	6.55 (42.88)	5.77(33.78)	7.42 (55.01)	6.31(40.22)	7.56 (57.111)	5.65(31.55)	5.25(27.555)
T_4 MT-DSR	6.90 (49.56)	7.67 (58.88)	7.77(62.22)	8.93 (79.67)	8.16 (67.77)	9.18 (84.333)	6.71(45.33)	6.94(48.111)
T_5 MT-DSR + R	5.53 (31.11)	6.9 (47.55)	6.18(38.66)	7.62 (58.0)	6.74 (45.89)	7.82 (61.223)	5.79(34.00)	5.75 (33.11)
LSD (P=0.05)	0.004	0.583	0.3	0.193	0.28	0.247	0.05	0.247
Sub plot: Weed management								
W_1	4.92(25.07)	5.02 (25.2)	5.87(35.07)	6.36 (40.4)	6.35(41.13)	6.37 (40.533)	5.27(28.23)	97 (24.734)
W_2	3.57(15.89)	5.06 (25.6)	4.09(20.44)	5.72 (32.733)	4.65(26.55)	5.83 (34.0)	3.79(18.61)	4.38 (19.2)
W_3	6.42(42.80)	8.29 (68.66)	7.13(52.53)	9.48 (89.93)	7.59(58.73)	9.58 (91.867)	6.35(40.73)	6.48 (42.0)
LSD (P=0.05)	4.94	0.292	5.66	0.204	6.17	0.126	5.11	0.162

Abbreviations: CT- Conventional tillage (3-4 cultivation followed by planking), MT- Minimum tillage (Use of 1 pass rotovator), R-Residue of previous crop retained *in-situ* on soil surface, TR- Transplanted rice, DSR- Direct seeded rice, W_1- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT, W_2- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT, W_3- One hand weeding at 30 DAS.
*Square root transformed data are presented; original data are in parenthesis.

weight was attained. The data was subjected to square root transformation to normalize their distribution. Grain yield of direct seeded rice and transplanted rice were recorded at harvest and statistically analyzed at 5% level of significance.

RESULTS AND DISCUSSION

The total number of weed species, out of which *Echinochloa colona, Eleusine indica* and *Digitaria sanguinalis* among the grasses; *Commelina benghalensis, Sphenoclea zeylanica, Eclipta alba, ludwigia perviflora* and *Fimbristylis milliacea* among the broadleaved weeds and *Cyperus iria, Cyperus difformis* and *Chloris barbata* among the sedges were the most predominant weeds in experimental field of rice. Duary *et al.* (2005, 2016), Kumar and Ladha (2011), Duary and Mukherjee (2013) and Singh *et al.* (2015) also reported similar weed flora in direct seeded rice.

During both the years of study, different tillage and residue management practices had significant effect on weed density and weed biomass at 30, 60, 90 and 120 DAS (Tables 1- 2). Among tillage and residue management, transplanted rice receiving conventional tillage (CT-TR) recorded lower weed population and biomass and remained at par as compared with minimum tilled direct seeded rice along with previous crop residue (MT-DSR+R) and minimum tilled direct seeded rice (MT-DSR) at 30, 60, 90 and 120 DAS. Among direct seeded rice (DSR), conventionally tilled direct seeded rice (CT-DSR) recorded lower weed density and biomass as compared to minimum tilled direct seeded rice (MT-DSR). Treatment receiving MT-DSR + R showed better performance with less weed flora and biomass compared to MT-DSR at all three dates of observation. Apart from various benefits, crop residue acts as mulch and thus conserves soil moisture, reduces weed growth and enhances crop yield. The beneficial effect of Minimum tillage + crop residue for conserving water and improving crop productivity was also found by Jat *et al.* (2012). At 120 DAS, MT-DSR recorded highest total weed density (45.33, 48.11 plants/m^2) and biomass (16.25, 9.22 g/ m^2) in both the consecutive years, respectively and was followed by MT-DSR + R. Duary *et al.* (2016) also opined alike.

Table 2. Effect of tillage, residue and weed management practices on total weed biomass in rice during 2019-2020 and 2020-2021.

Treatments	Total weed biomass (g/m^2)							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
Main plot: Tillage and residue management								
T_1 CT-TR	2.29(4.61)	3.11 (9.66)	2.66(7.14)	3.51(11.815)	2.84(8.12)	2.85 (8.15)	2.27(5.39)	2.38 (5.66)
T_2 CT-TR	2.45(5.54)	2.67 (7.12)	2.52(6.48)	3.39(10.788)	2.69(7.31)	2.87 (8.22)	2.41(5.83)	2.30 (5.27)
T_3 CT-DSR	3.04(7.20)	3.99 (15.97)	2.83(8.01)	3.72(13.37)	2.90(8.44)	3.37 (11.37)	2.71(7.35)	2.60 (6.74)
T_4 MT-DSR	3.96(17.57)	4.4 (19.33)	4.08(18.54)	4.26(17.606)	4.14(18.67)	3.86 (14.88)	3.78(16.25)	3.04 (9.22)
T_5 MT-DSR + R	2.86(7.71)	3.95(15.61)	2.96(8.77)	3.76(13.61)	2.99(8.99)	3.86 (12.02)	2.79(7.81)	2.65 (7.03)
LSD (P=0.05)	0.4	0.423	0.01	0.117	0.07	0.112	0.13	0.068
Sub plot: Weed management								
W_1	2.66(6.51)	2.9 (8.41)	2.84(8.17)	3.38(10.935)	2.94(8.73)	2.97 (8.81)	2.61(6.94)	2.47 (6.12)
W_2	2.17(4.64)	3.02 (9.10)	2.13(5.54)	3.21(9.80)	2.28(6.28)	2.81 (7.87)	1.99(4.84)	2.41 (5.82)
W_3	3.50(13.51)	4.81 (23.11)	3.63(14.55)	4.48(19.58)	3.66(14.65)	4.01 (16.10)	3.38(12.84)	2.90 (8.42)
LSD (P=0.05)	2.78	0.254	2.85	0.115	2.95	0.49	2.65	0.034

Abbreviations: CT- Conventional tillage (3-4 cultivation followed by planking), MT- Minimum tillage (Use of 1 pass rotovator), R- Residue of previous crop retained *in situ* on soil surface, TR- Transplanted rice, DSR- Direct seeded rice, W_1- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT, W_2- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT, W3- One hand weeding at 30 DAS

*Square root transformed data are presented; original data are in parenthesis.

Among weed management practices, weed density and weed biomass was lowest with the pre emergence application of Pretilachlor @ 0.75 kg/ha followed by bispyribac-Na 25 g/ha at 25 DAT +

Table 3. Interaction effect of tillage, residue and weed management practices on total weed density in rice during 2019-2020 and 2020-2021

Treatments	Total weed density (No/m^2)							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
$T_1 W_1$	3.79(14.33)	4.58 (21.00)	4.97 (24.67)	5.77 (33.333)	5.80(33.66)	5.45 (29.67)	4.02(16.18)	3.79 (14.333)
$T_1 W_2$	3.32(11.00)	4.47 (20.00)	3.92 (15.34)	5.13 (26.333)	4.90 (24)	4.76 (22.67)	3.65(13.33)	3.21 (10.334)
$T_1 W_3$	5.26(27.66)	6.78 (46.00)	6.16 (38)	8.39 (70.333)	6.81(46.33)	8.58 (73.67)	5.54(30.66)	5.74 (33.0)
$T_2 W_1$	3.92(15.34)	3.61 (13.00)	5.39 (29)	5.16 (26.667)	5.23(27.34)	5.00 (25.00)	4.28(18.33)	3.37 (11.333)
$T_2 W_2$	3.41(11.66)	3.37 (11.33)	3.41 (11.66)	4.36 (18.999)	4.47(20)	4.51 (20.33)	3.70(13.67)	2.52 (6.333)
$T_2 W_3$	5.39(29.00)	6.16 (38.00)	6.16 (38)	7.85 (61.667)	6.76(45.66)	7.26 (52.67)	5.63(31.66)	5.29 (28.0)
$T_3 W_1$	5.10(26.00)	4.83 (23.33)	5.69 (32.34)	5.77 (33.334)	6.19(38.33)	5.83 (34.00)	5.71(30.33)	4.80 (23.0)
$T_3 W_2$	4.44(19.67)	5.03 (25.33)	4.97 (24.66)	5.42 (29.333)	5.54(30.67)	5.60 (31.33)	4.87(23.67)	4.28 (18.333)
$T_3 W_3$	6.16(38.00)	8.94 (80.00)	6.66 (44.33)	10.12 (102.333)	7.19(51.67)	10.3 (106.00)	6.38(40.66)	6.43 (41.333)
$T_4 W_1$	6.35(40.33)	6.35 (40.33)	7.30 (53.33)	8.14 (66.334)	7.87(62)	8.52 (72.67)	6.63(44)	6.73 (45.333)
$T_4 W_2$	5.57(31.00)	6.30 (39.67)	6.40(41)	7.48 (56.0)	7.00(48.99)	7.79 (60.67)	5.97(35.66)	6.14 (37.667)
$T_4 W_3$	8.79(77.33)	9.83 (96.67)	9.61(92.33)	10.80 (116.666)	9.61(92.33)	10.94 (119.67)	7.53(56.66)	7.83 (61.333)
$T_5 W_1$	5.42(29.33)	5.32 (28.33)	6 (36)	6.51 (42.333)	6.66(44.34)	6.43 (41.33)	5.69(32.33)	5.45 (29.667)
$T_5 W_2$	4.69(22.00)	5.63 (31.67)	5.48(30)	5.74 (33.0)	5.97(35.66)	5.92 (35.00)	5.03(25.33)	4.83 (23.333)
$T_5 W3$	6.48(42.00)	9.09 (82.67)	7.07 (49.99)	9.93 (98.667)	7.59(57.66)	10.36 (107.33)	6.66(44.33)	6.81 (46.333)
LSD (P=0.05)	11.04	0.731	12.66	0.483	13.8	0.452	11.42	0.464
LSD (P=0.05)	10.24	0.646	10.34	0.563	11.27	0.392	9.32	0.42

Abbreviations:- T_1: CT-TR, T_2: CT-TR, T_3: CT-DSR, T_4: MT-DSR, T_5: MT-DSR + R, W_1- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT, W_2- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT, W_3- One hand weeding at 30 DAS.

CT- Conventional tillage (3-4 cultivation followed by planking), MT- Minimum tillage (Use of 1 pass rotovator), R- Residue of previous crop retained *insitu* on soil surface, TR- Transplanted rice, DSR- Direct seeded rice.

*Square root transformed data are presented; original data are in parenthesis.

Table 4. Interaction effect of tillage, residue and weed management practices on total weed biomass in rice during 2019-2020 and 2020-2021.

Treatments	Total weed biomass (g/m^2)							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
$T_1 W_1$	2.30(4.81)	2.77 (7.68)	2.60(6.78)	3.11 (9.67)	2.84(8.05)	2.67 (7.14)	2.32(5.69)	2.26 (5.11)
$T_1 W_2$	1.97(3.37)	2.66 (7.06)	2.34(5.47)	2.92 (8.55)	2.57(6.58)	2.52 (6.35)	1.85(3.43)	2.15 (4.62)
$T_1 W_3$	2.61(6.29)	3.77 (14.25)	3.03(9.18)	4.15 (17.23)	3.12(9.72)	3.31 (10.94)	2.65(7.04)	2.69 (7.26)
$T_2 W_1$	2.39(5.22)	2.29 (5.25)	2.53(6.4)	2.96 (8.79)	2.59(6.72)	2.61 (6.80)	2.36(5.57)	2.13 (4.55)
$T_2 W_2$	2.22(4.44)	2.29(5.24)	2.11(4.47)	2.58 (6.65)	2.47(6.11)	2.57 (6.60)	2.20(4.82)	2.13 (4.29)
$T_2 W_3$	2.73(6.97)	3.30 (10.88)	2.93(8.56)	4.11 (16.92)	3.02(9.1)	3.36 (11.26)	2.67(7.11)	2.64 (6.97)
$T_3 W_1$	2.79(7.26)	2.81 (7.92)	2.85(8.12)	3.07 (9.44)	2.91(8.49)	2.76 (7.63)	2.70(7.28)	2.38 (5.66)
$T_3 W_2$	2.55(6.01)	3.14 (9.89)	2.60(6.74)	3.05 (9.28)	2.74(7.51)	2.69 (7.22)	2.58(6.66)	2. 73 (5.60)
$T_3 W_3$	2.97(8.33)	5.37(28.88)	3.03(9.17)	4.62(21.39)	3.05(9.31)	4.39 (19.25)	2.85(8.12)	3.00 (8.98)
$T_4 W_1$	2.94(8.15)	3.54 (12.52)	3.32(11.02)	4.01 (16.09)	3.40(11.54)	3.72 (13.85)	2.9(8.41)	3.03 (9.15)
$T_4 W_2$	2.80(7.35)	3.56 (12.65)	2.94(8.67)	3.85 (14.85)	3.10(9.58)	3.31 (10.92)	2.71(7.37)	2.96 (8.77)
$T_4 W_3$	6.14(37.22)	5.73 (32.81)	5.99 (35.93)	6.73 (44.87)	5.91(34.88)	7.37 (53.85)	5.74(32.98)	5.68(31.75)
$T_5 W_1$	2.87(7.74)	2.95 (8.676)	2.92(8.53)	3.27 (10.68)	2.98(8.86)	2.93 (8.61)	2.78(7.74)	2.47 (6.11)
$T_5 W_2$	2.68(6.66)	3.26 (10.66)	2.80(7.86)	3.11 (9.67)	2.80(7.87)	2.88 (8.26)	2.60(6.74)	2.42 (5.83)
$T_5 W_3$	3.04(8.72)	5.24 (27.49)	3.15 (9.92)	4.52 (20.47)	3.20 (10.23)	4.38 (19.17)	2.99(8.94)	3.03 (9.16)
LSD (P=0.05)	6.22	0.342	6.38	0.158	6.6	0.112	5.92	0.112
LSD (P=0.05)	6.07	0.373	5.21	0.146	5.39	0.131	4.84	0.094

Abbreviations:- T_1: CT-TR, T_2: CT-TR, T_3: CT-DSR, T_4: MT-DSR, T_5: MT-DSR + R;W_1- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT, W_2- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT, W_3- One hand weeding at 30 DAS.
CT- Conventional tillage (3-4 cultivation followed by planking), MT- Minimum tillage (Use of 1 pass rotovator), R- Residue of previous crop retained *in situ* on soil surface, TR- Transplanted rice, DSR- Direct seeded rice,
*Square root transformed data are presented, original data are in parenthesis.

mechanical weeding at 50 DAT and was followed by Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT whereas treatment receiving one hand weeding at 30 DAS recorded highest values of the said parameters throughout the crop growth period. Among the weed management practices, pre emergence application of pendimethalin at1.0 kg/ha fb bispyribac sodium at 25 g/ha at 20 DAS fb one hand weeding at 35 DAS recorded the lowest density and dry weight of total weeds (Taja and Duary 2018). Application of Bispyribac sodium @30 g a.i ha^{-1} applied at 25 days after transplanting is most effective to check all types of weed population and their growth (Das *et al.* 2017). Similarly, Kumar *et al.* (2013) and Chakraborti *et al.* (2015 and 2017) also suggested pendimethalin + bispyribac Na + 1 HW as the best integrated weed management strategy to control weeds in DSR (Tables 1-2).

Tillage and weed management practices showed significant interaction effects of tillage, residue and weed management practices on total weed density and biomass (Tables 3-4). Results showed that CT-transplanted in combination with the application of Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT + mechanical weeding at 50 DAT showed best performance in controlling weed with least weed density and weed biomass throughout the crop growth period. As compared to the treatment combination receiving MT-DSR and one hand weeding at 30 DAS, WCE was calculated. Treatment combination receiving conventionally tilled transplanted rice (CT-TR) along with Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT recorded highest WCE to the tune of 90.95 % in first year of the study at 30 DAS and about 84.78, 80.95; 81.14, 88.20, 89.6 and 85.46 % during 60, 90 and 120 DAS in the first and second year, respectively (Table 5). Similar findings were also observed by Duary and Mukherjee (2013), Chakraborti *et. al.* (2017).

Table 5. Interaction effect of tillage, residue and weed management practices on weed control efficiency in rice during 2019-2020 and 2020-2021.

Treatments	WCE (%)							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
$T_1 W_1$	88.77	76.58	81.13	78.45	76.92	86.74	82.75	83.91
$T_1 W_2$	90.95	78.49	84.78	80.95	81.14	88.2	89.6	85.46
$T_1 W_3$	83.1	56.58	74.45	61.61	72.13	79.68	78.65	77.13
$T_2 W_1$	85.98	84	82.19	80.41	80.73	87.37	83.11	85.66
$T_2 W_2$	88.07	84.03	87.56	85.18	82.48	87.74	85.39	86.47
$T_2 W_3$	81.27	66.84	76.18	62.28	73.91	79.08	78.44	78.05
$T_3 W_1$	80.49	75.86	77.4	78.97	75.66	85.83	77.93	82.18
$T_3 W_2$	83.85	69.87	81.24	79.31	78.47	86.59	79.81	82.36
$T_3 W_3$	77.62	72.94	74.48	52.33	73.31	64.25	75.38	71.72
$T_4 W_1$	78.1	61.84	69.33	64.13	66.92	74.27	74.5	71.17
$T_4 W_2$	80.25	61.44	75.87	66.9	72.53	79.71	77.65	72.38
$T_4 W_3$	0	0	0	0	0	0	0	0
$T_5 W_1$	79.2	73.56	76.26	76.19	74.6	84.01	76.53	80.77
$T_5 W_2$	82.11	67.51	78.12	78.44	77.44	84.65	79.55	81.63
$T_5 W_3$	76.57	16.21	81.13	54.38	76.92	64.39	72.89	71.16

Abbreviations:- T_1: CT-TR, T_2: CT-TR, T_3: CT-DSR, T_4: MT-DSR, T_5: MT-DSR + R, W_1- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT, W_2- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT, W_3- One hand weeding at 30 DAS.
CT- Conventional tillage (3-4 cultivation followed by planking), MT- Minimum tillage (Use of 1 pass rotovator), R- Residue of previous crop retained *in situ* on soil surface, TR- Transplanted rice, DSR- Direct seeded rice.

Tillage and weed management practices significantly influenced yield parameters and yield of rice in both the years under study (Tables 6 -7). Conventionally tilled transplanted rice (CT-TR) recorded highest grains/panicle (65.52), grain (2.46 t/ha) and straw yield (5.35 t/ha) in 2nd year of the experiment over other treatments. Conventionally tilled direct seeded rice (CT-DSR) recorded better responses with higher grains/panicle, grain and straw yield as compared to the treatment receiving minimum tilled

Table 6. Effect of tillage, residue and weed management practices on yield parameters in rice during 2019-2020 and 2020-2021.

Treatments	Yield parameters							
	Grains/panicle		Test wt.(g)		Grain yield (t/ha)		Straw yield (t/ha)	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
Main plot: Tillage and residue management								
T_1 CT-TR	57.63	62.578	16.60	16.59	2.37	2.422	5.33	5.348
T_2 CT-TR	57.98	65.522	16.58	16.56	2.31	2.459	5.33	5.334
T_3 CT-DSR	53.14	57.611	16.28	16.49	2.34	2.411	5.27	5.326
T_4 MT-DSR	43.13	47.000	15.72	16.54	2.18	2.320	5.02	5.019
T_5 MT-DSR + R	51.50	55.189	16.17	16.60	2.31	2.373	5.16	5.276
LSD (P=0.05)	1.89	0.895	0.02	0.16	0.05	0.060	0.26	0.052
Sub plot: Weed management								
W_1	47.33	59.147	13.73	16.55	2.03	2.494	4.55	5.418
W_2	54.14	61.400	16.27	16.57	2.40	2.517	5.40	5.471
W_3	47.09	52.193	16.06	16.55	2.08	2.181	4.81	4.893
LSD (P=0.05)	49.96	0.557	15.43	0.14	2.18	0.043	4.95	0.042

Abbreviations: CT- Conventional tillage (3-4 cultivation followed by planking), MT- Minimum tillage (Use of 1 pass rotovator), R- Residue of previous crop retained *in situ* on soil surface, TR- Transplanted rice, DSR- Direct seeded rice, W_1- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT, W_2- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT, W_3- One hand weeding at 30 DAS.

Table 7. Interaction effect of tillage, residue and weed management practices on yield parameters in rice during 2019-2020 and 2020-2021.

Treatments	Yield parameter							
	Grains/panicle		Test wt.(g)		Grain yield (t/ha)		Straw yield (t/ha)	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
$T_1 W_1$	60.83	63.000	16.62	16.61	2.43	2.530	5.52	5.533
$T_1 W_2$	62.83	66.167	16.68	16.63	2.47	2.547	5.56	5.570
$T_1 W_3$	49.23	58.567	16.51	16.54	2.21	2.190	4.91	4.940
$T_2 W_1$	61.00	66.667	16.61	16.53	2.44	2.557	5.53	5.563
$T_2 W_2$	62.63	69.500	16.65	16.65	2.48	2.570	5.55	5.577
$T_2 W_3$	50.30	60.400	16.47	16.51	2.02	2.250	4.93	4.863
$T_3 W_1$	54.00	60.900	16.33	16.52	2.41	2.497	5.49	5.507
$T_3 W_2$	57.67	61.833	16.46	16.48	2.44	2.523	5.52	5.547
$T_3 W_3$	47.77	50.100	16.07	16.46	2.18	2.213	4.81	4.923
$T_4 W_1$	42.67	46.667	15.55	16.52	2.31	2.427	5.16	5.007
$T_4 W_2$	45.10	50.167	16.18	16.49	2.37	2.440	5.29	5.150
$T_4 W_3$	41.63	44.167	15.42	16.60	1.85	2.093	4.60	4.900
$T_5 W_1$	52.20	58.500	16.27	16.55	2.39	2.460	5.31	5.480
$T_5 W_2$	55.77	59.333	16.42	16.62	2.42	2.503	5.39	5.510
$T_5 W_3$	46.53	47.733	15.83	16.64	2.13	2.157	4.79	4.837
LSD (P=0.05)	111.71	1.299	34.50	NS	4.89	0.096	11.08	0.096
LSD (P=0.05)	111.71	1.352	28.17	NS	3.99	0.106	9.05	0.092

direct seeded rice with residue (MT-DSR + R). Application of Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT recorded highest grains/panicle (61.40), grain (2.52 t/ha) and straw yield (5.48 t/ha) in 2nd year of the experiment over other two weed management treatments. Among tillage practices, minimum tilled direct seeded rice with residue (MT-DSR + R) showed highest benefit cost ratio of about 2.07 and 1.96 in the successive years, respectively while among weed management practices Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT recorded highest B:C ratio of about 1.98 in 2019-20 and about 2.12 in 2020-21 was recorded highest by the treatment Pretilachlor @ 0.75 kg/ha PRE followed by bispyri-

Table 8. Effect of tillage, residue and weed management practices on economics of rice during 2019-2020 and 2020-2021.

Treatments	Economics							
	Total cost of cultivation (Rs/ha)		Gross return (Rs/ha)		Net return (Rs/ha)		B:C ratio	
	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021	2019-2020	2020-2021
Main plot: Tillage and residue management								
T_1 CT-TR	120776.33	126931	244027.77	248839	123251.43	121908	2.02	1.96
T_2 CT-TR	123735.67	129589	238433.33	252275	114697.67	122686	1.93	1.95
T_3 CT-DSR	123529.33	129986	240963.77	247685	117434.53	117699	1.95	1.91
T_4 MT-DSR	114602.67	120952	224552.77	237967	109950	117015	1.96	1.97
T_5 MT-DSR + R	116302.33	123240	237936.13	243932	121633.8	120691	2.07	1.98
Sub plot: Weed management								
W_1	113026.2	120566	208775.00	255912	95748.8	135346	1.85	2.12
W_2	124485.2	129511	246900.66	258225	122414.8	128714	1.98	2.00
W_3	121856.4	128342	214435.00	224281	92578.60	95939	1.76	1.75

Abbreviations: CT- Conventional tillage (3-4 cultivation followed by planking), MT- Minimum tillage (Use of 1 pass rotovator), R-Residue of previous crop retained *in situ* on soil surface, TR- Transplanted rice, DSR- Direct seeded rice, W_1- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT, W_2- Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT, W_3- One hand weeding at 30 DAS.

bac-Na 25 g/ha at 25 DAT (Table 8).

CONCLUSION

From the two years experiment it can be concluded that both tillage and weed management practices are essential for achieving higher black rice yield. Transplanted rice receiving conventional tillage performed best in controlling weed and producing yield as compared to direct seeded minimum tilled one. Application of crop residue was found effective in managing weed population in the crop field. Conventionally tilled transplanted rice (CT-TR) treated with Pretilachlor @ 0.75 kg/ha PRE followed by bispyribac-Na 25 g/ha at 25 DAT +mechanical weeding at 50 DAT proved as the best treatment combination with highest yield and WCE.

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