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Research Article

Effect of Tillage and Weed Management Practices on Weed Dynamics of Rice (*Oryza sativa*) under Conservation Agriculture

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Abstract

The Present study aimed to evaluate the effect of different tillage methods and weed management practices on weed dynamics of rice in rice-maize-green manure system of conservation agriculture. This research is part of a long-term experiment in its fifth year. A field experiment was conducted during kharif-2018, at AICRP on Weed Management, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Hyderabad. The experiment was laid out in split plot design with five main plots, three sub-plots and three replications. The main plots included five tillage practices such as i) conventional tillage transplanted rice fb conventional tillage maize, ii) Conventional tillage transplanted rice fb zero tillage maize, iii) conventional tillage direct seeded rice fb conventional tillage maize, iv) zero tillage direct seeded rice fb zero tillage maize with residue cover and v) zero tillage direct seeded rice with residue cover fb zero tillage maize with residue cover and sub plots including three weed management practices i.e., chemical weed management with recommended herbicides, Integrated Weed Management (IWM) and unweeded control. Transplanted rice reduced the density and dry weight of all the major weed species at all the stages of crop growth. In direct seeded rice, conventional tillage direct seeded rice fb conventional tillage maize recorded lower weed density and dry matter. Maximum suppression of weeds was reported in IWM with higher weed control efficiency.

Keywords: Rice; Tillage; Weed Management; Conservation Agriculture; Direct Seeded Rice; Weed Dynamics; Weed Seed Bank Studies

Abbreviations

TPR: Transplanted Rice; DSR: Direct Seeded Rice; CT: Conventional Tillage; ZT: Zero Tillage; PE: Pre-Emergence; PoE: Post-Emergence; IWM: Integrated Weed Management; HW: Hand Weeding, +R: Residue Cover; *fb*: Followed By

Introduction

The area under rice cultivation in India spans approximately 47.6 million hectares [4], yielding an average production of about 205.52 million tonnes and a productivity rate of 4.3 tonnes per hectare [9]. Notably, 85% of this area is dedicated to transplanted rice, while 12% is cultivated using upland direct seeding techniques. In Telangana, rice covers around 2.31 million hectares, producing 7.7 million tonnes with a productivity of 3.32 tonnes per hectare for the 2020-21 period [1]. Traditionally, rice is cultivated by transplanting seedlings that are 25-30 days old into puddled fields. This method offers several advantages, including effective weed control, reduced percolation, improved nutrient availability due to anaerobic conditions, and easier seedling establishment. However, the drawbacks include increased labor and water requirements, contributing to higher production costs [16].

These challenges have led researchers to explore alternative methods, such as irrigated dry rice cultivation, to enhance efficiency and sustainability in rice production.

Direct Seeded Rice (DSR) can be sown under conventional tillage or under zero-till conditions. The main advantage is it requires less labor and fuel compared to conventional tillage systems. When rainfall at planting time is highly variable, direct seeding may help reduce the production risk [13]. Weed control is a challenge in DSR systems because of the diversity and severity of weed infestation.

Shifting from conventional tillage transplanted rice to zero tillage direct seeded rice resulted in significantly higher evenness, species richness indicating the reduction in tillage intensity with increased weed diversity [12]. Due to continuous use of herbicides, there is a shift in dominance of grassy weeds from dicotyledonous weeds under direct seeding conditions [2].

The conventional tillage with or without residue retention recorded the emergence of a high percentage of grassy weeds, especially *Phalaris minor*, *Avena ludoviciana*, and *Cynodan dactylon* in wheat when compared to their establishment in zero-till system with or without residue retention in Uttar Pradesh [18]. Lowest weed density and weed biomass was recorded under conventional system of transplanted rice whereas zero tillage direct seeded rice recorded higher weed density and weed biomass [15]. In central Punjab observations from farmer fields revealed that the population of weeds was significantly more in direct seeded rice than puddled transplanted rice [16].

Studies have indicated that the application of bispyribac sodium followed by manual weeding results in lower weed density compared to the combination of pendimethalin followed by manual weeding in aerobic rice systems [19]. Specifically, the use of bispyribac sodium has been associated with a significant reduction in weed density (over 80%) and a decrease in weed dry matter (up to 78%) in dry direct-seeded rice [10]. Pendimethalin *fb* hand weeding, penoxsulam plus cyhalofop and bispyribac-sodium achieved good control of *Echinocloa colona* with reduction of 85%, 85% and 72% respectively compared with the weedy treatment in both zero tillage as well as conventional tillage direct seeded rice [17]. These findings highlight the effectiveness of bispyribac sodium in managing weed populations, contributing to improved crop health and yields in rice cultivation.

"Conservation Agriculture (CA) is a resource saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving environment" [5]. The main principles of conservation agriculture include reduced tillage systems, permanent soil cover, effective use of crop rotations including intercrops and cover crops and reducing the fallow period. In low intensity tillage or no tillage associated with conservation agriculture weeds are the major biological constraints towards the large-scale adoption of it [20].

The present investigation is carried out to know effect of different tillage and weed management practices on weed dynamics and weed seed bank of rice in rice-maize-greenmanure system of conservation agriculture.

Materials and Methods

Site description

A field experiment was conducted during *kharif*-2018, at AICRP on Weed Management, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India (17°19' N and 78°24' E). The field was under conservation agriculture with rice-maize-greenmanure system since 2014 (5 years). The present study was in fifth year of experimentation in rice.

Treatment details

The experiment was laid out in split plot design with three replications. Main plot treatments were five tillage practices and sub-plot treatments were three weed management practices. Five tillage practices consists of conventional tillage transplanted rice *fb* conventional tillage maize in rabi and fallow in summer (CT-CT of TPR) (T_1), conventional tillage transplanted rice *fb* zero tillage maize in rabi and green manure (*Sesbania*) in summer(CT-ZT of TPR) (T_2), conventional tillage direct seeded rice *fb* conventional tillage maize in *rabi* and green manure in summer(CT-CT of DSR)

(T_3), zero tillage direct seeded rice *fb* zero tillage maize in *rabi* and green manure in summer (ZT-ZT of DSR) (T_4) and zero tillage direct seeded rice with residue cover *fb* zero tillage maize with residue cover in *rabi* and green manure in summer (ZT+R - ZT+R of DSR) (T_5). Weed management practices included chemical weed management *i.e.,* Bensulfuron methyl (0.6%) + pretilachlor (6%) 0.66 kg ha^{-1} as PE at 3-5 DAT *fb*bispyribac sodium 10% SC 25g ha^{-1} as PoE at 2-3 weed leaf stage for transplanted rice whereas Pendimethalin 30% EC 1000g ha^{-1} as PE *fb*bispyribac sodium 10% SC 25g ha^{-1} as PoE at 2-3 weed leaf stage for direct seeded rice (W_1), Integrated weed management (IWM) *i.e.,*Bispyribac sodium 10% SC 25 g ha^{-1} as early PoE at 2-3 weed leaf stage *fb* HW at 40 DAT (W_2) and Unweeded control (W_3). For residue cover treatments previous season green manure was spread as mulch in between rows of current season crop.

Crop management

Rice variety MTU-1010 was sown with a seed rate of 50 kg ha^{-1} for transplanted rice and 70 kg ha^{-1} for dry direct seeded rice, spacing of 20 X 10 cm was followed. 30 days old rice seedlings were transplanted in the main field for transplanted rice. For dry direct seeded rice, seeds were directly sown in plots by following line sowing on the same day of nursery raising for transplanted rice.

Recommended fertilizer dose 120 kg N + 60 kg P + 40 kg K to transplanted rice and 100 kg N + 50 kg P + 50 kg K to direct seeded rice was applied. Remaining agronomic practices were carried out as per the recommendations.

Observations on weeds

The weed flora observed in experimental plots were recorded species wise (grasses, sedges and broadleaved weeds) at 30, 60, 90 DAS/T and at harvest. Weed count was taken from each plot at randomly selected place with the help of quadrate of 0.25 m^2 at 30, 60, 90 DAS/T and at harvest.

The dry weight of weeds was recorded at 30, 60, 90 DAS/T and at harvest stage. Weeds which were present within the area of quadrate of 0.25 m^2 were cut close to the ground and air dried for 4-5 days. Then it was oven dried at 65 ± 5 ^oC until constant weight was achieved. After completion of oven drying, dry weight was recorded as per treatment and expressed as g m^{-2}. The weed count and weed dry matter data was subjected to square root transformation $X = \sqrt{x+0.5}$ before statistical analysis. Where, X = transformed value x = original value Weed control efficiency was calculated at 30, 60, 90 DAS/T and at harvest stages of crop on the basis of reduction in weed dry weight in treated plots in comparison to unweeded control.

Results and Discussion

Weed flora present

Dominant weed flora in transplanted rice were *Panicum repens, Echinocloa colona* among grasses, *Cyperus iria* and *Scirpus lacustris* among sedges, *Ammania baccifera* among broadleaved weeds. In direct seeded rice, dominant weed flora observed were *Cynodon dactylon*, *Dinebra retroflexa, Digitaria sanguinalis, Dactyloctenium aegyptium*, *Eleucine indica* among grasses, *Cyperus rotundus* among sedges, *Alternanthera sessilis, Trianthema portulacastrum, Euphorbia geniculata, Digera arvensis* among broad leaved weeds.

Total weed density

Total weed density was significantly influenced by tillage and weed management practices presented in table 1 and depicted in figure 1. In general, higher weed density was recorded in direct seeded rice compared to transplanted rice.

At 30 DAS/T, lower weed density was recorded in transplanted rice under CT-CT system (47.4 m^{-2}) and CT-ZT system (52.2 m^{-2}) and both were on par with each other and significantly superior to other tillage methods. In direct seeded rice, CT-CT system recorded significantly lower weed density (125.8 m^{-2}) than zero tillage systems with and without residue cover. Similar trend was observed at 60, 90 DAS/T and at harvest stages. With respect to weed management practices at 30 DAS/T, significantly lowest weed density was recorded in IWM involving bispyribac sodium as early POE fb hand weeding (83.8 m^{-2}) which was followed by chemical weed management (106.7 m^{-2}). Significantly higher weed density was recorded in unweeded control. Similar trend was recorded at 60, 90 DAS/T and at harvest stages also.

Interaction effect of tillage and weed management practices on weed density was also significant. At 30 DAS/T, significantly lower weed density was recorded with IWM under CT-CT system in transplanted rice which was comparable to IWM in CT-ZT system. At later stages lowest weed density was recorded under IWM in CT-CT which was on par with IWM in CT-ZT and chemical weed management in CT-CT of TPR. Higher weed density was recorded under unweeded control of zero tillage DSR systems with and without residue cover.

Treatments		Total weed density (m^{-2})			
Tillage	**Weed Management**	**30 DAS/T**	**60 DAS/T**	**90 DAS/T**	**HARVEST**
T_1- CT (TPR) - CT (maize)	W_1	5.75 (32.7)	7.62 (57.7)	7.38 (54.0)	7.63 (57.7)
	W_2	5.37 (28.3)	7.27 (52.3)	7.03 (49.0)	7.01 (48.7)
	W_3	9.04 (81.3)	11.01 (120.7)	11.13 (123.3)	11.30 (127.3)
T_2- CT (TPR) - ZT (maize) - GM	W_1	5.95 (35.0)	7.92 (62.3)	7.79 (60.3)	7.91 (62.0)
	W_2	5.70 (32.0)	7.56 (56.7)	7.31 (53.0)	7.22 (51.7)
	W_3	9.49 (89.7)	11.59 (134.0)	11.32 (127.7)	11.45 (130.7)
T_3- CT (DSR) - CT (maize) - GM	W_1	10.15 (102.7)	12.48 (155.3)	12.14 (147.0)	12.18 (148.0)
	W_2	9.37 (87.3)	11.39 (129.3)	10.66 (113.3)	10.60 (112.0)
	W_3	13.70 (187.3)	15.59 (242.7)	14.93 (189.3)	14.45 (208.7)
T_4- ZT (DSR) - ZT (maize) - GM	W_1	13.72 (187.7)	15.31 (234.0)	15.11 (228.0)	14.99 (224.7)
	W_2	12.05 (144.7)	14.18 (200.7)	12.98 (168.0)	12.37 (152.7)
	W_3	16.04 (256.7)	17.06 (290.7)	16.83 (282.7)	16.66 (277.0)
T_5- ZT+R (DSR)-ZT+R (maize)-GM	W_1	13.26 (175.3)	14.14 (199.3)	13.73 (188.0)	13.56 (183.7)
	W_2	11.28 (126.7)	12.74 (162.0)	12.55 (157.3)	12.07 (145.3)
	W_3	15.83 (250.3)	16.32 (266.0)	16.22 (262.7)	16.18 (261.3)
Mean					
Tillage (Main plots)					
T_1 - CT (TPR) – CT		6.72 (47.4)	8.63 (76.9)	8.51 (75.4)	8.65 (77.9)
T_2 - CT (TPR) - ZT - GM		7.05 (52.2)	9.03 (84.3)	8.81 (80.3)	8.86 (81.4)
T_3 - CT (DSR) – CT - GM		11.07 (125.8)	13.16 (175.8)	12.58 (149.9)	12.41 (156.2)
T_4 - ZT (DSR) – ZT - GM		13.93 (196.3)	15.52 (241.8)	14.97 (226.2)	14.67 (218.1)
T_5 - ZT+R (DSR) – ZT+R - GM		13.45 (184.1)	14.40 (209.1)	14.17 (202.7)	13.94 (196.8)
Weed Management (Sub plots)					
W_1 – Chemical management		9.77 (106.7)	11.49 (141.7)	11.23 (135.5)	11.25 (135.2)
W_2 - IWM		8.75 (83.8)	10.63 (120.2)	10.10 (108.1)	9.86 (102.1)
W_3 – Unweeded control		12.82 (173.1)	14.32 (210.8)	14.08 (197.1)	14.01 (201.0)

	SE (m) ±	CD (P = 0.05)	SE (m) ±	CD (P = 0.05)	SE (m)±	CD (P = 0.05)	SE (m) ±	CD (P = 0.05)
Tillage	0.14	0.45	0.07	0.23	0.13	0.44	0.09	0.28
Weed management	0.10	0.29	0.09	0.27	0.10	0.29	0.12	0.36
SUB AT SAME LEVEL OF MAIN	0.24	0.68	0.12	0.61	0.23	0.68	0.15	0.82
MAIN AT SAME LEVEL OF SUB	0.22	0.70	0.18	0.54	0.22	0.69	0.24	0.72

Table 1: Total weed density (m^{-2}) as influenced by tillage and weed management in rice under conservation agriculture (*kharif,* 2018).

*Figures in parentheses are original values and data is subjected √x + 0.5 transformation

CT: Conventional Tillage; TPR: Transplanted Rice; DSR: Direct Seeded Rice; ZT: Zero Tillage; R: Residue Cover; GM: Green Manure (*Sesbania*)

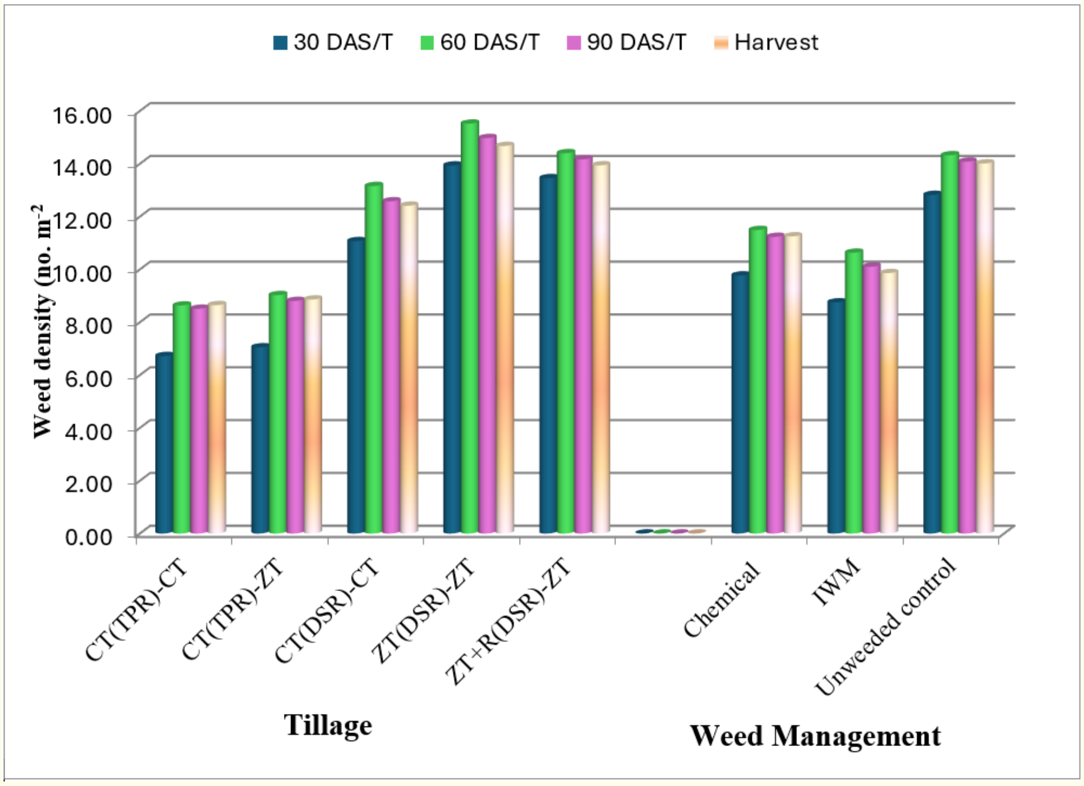

Figure 1: Total weed density (no. m^{-2}) as influenced by tillage and weed management.

Weed density under IWM and chemical weed management was comparable in both the transplanted rice treatments at all stages.

Higher density of grasses was recorded under zero tillage DSR which might be due to no tillage system over years encouraged development of small seeded grasses on the soil surface rather than broad leaved weeds and sedges. Sedges dominated more in transplanted rice than under direct seeded rice. Continuous submerged conditions might have suppressed emergence of BLW's and grasses and only sedges were able to overcome the anaerobic conditions and increased in density over time. BLW's dominated under conventional tillage DSR which might be due to tillage practice which could bring deeply placed weed seeds to surface during tillage and favored their establishment due to presence of aerobic environment. These results are in confirmation with the findings [3,6].

Lowest weed density in conventional tillage TPR might be due to thorough land preparation and puddling which destroyed weed seeds and smothering effect of larger canopy and early ground cover of transplanted rice compared to direct seeded rice. Lower weed density under conventional tillage DSR than zero tillage DSR could be due to tillage operation which buried weed seeds to deeper depths in soil and also destroyed propagation of perennial weeds. Zero tillage reported higher weed density mainly due to deposition of weed seeds near soil surface and their easy propagation. These results are in accordance with the findings of [7,15,16].

Weed dry matter (g m^{-2})

Weed dry matter is a better parameter to measure weed competition than weed density as it measures more precisely the weed growth and the resources utilized by weeds. Dry weight of weeds at different stages presented in table 2 and figure 2.

At 30 DAS, transplanted rice under CT-CT (24.5 g m^{-2}) and CT-ZT systems (27.7 g m^{-2}) recorded significantly lower weed dry matter compared to direct seeded rice under different tillage methods. In direct seeded rice, CT-CT system (89.6 g m^{-2}) reported significantly lower weed dry matter compared to zero tillage system with or without residue cover. Similar trend was observed at 60, 90 DAS/T and at harvest stages. At 30 DAS/T zero tillage direct seeded rice

<table>
<tr><th colspan="2">Treatments</th><th colspan="8">Weed dry matter (m^{-2})</th></tr>
<tr><th>Tillage</th><th>Weed Management</th><th colspan="2">30 DAS/T</th><th colspan="2">60 DAS/T</th><th colspan="2">90 DAS/T</th><th colspan="2">HARVEST</th></tr>
<tr><td rowspan="3">T_1- CT (TPR) - CT (maize)</td><td>W_1</td><td colspan="2">3.54 (12.1)</td><td colspan="2">4.55 (20.3)</td><td colspan="2">5.20 (26.6)</td><td colspan="2">5.32 (27.8)</td></tr>
<tr><td>W_2</td><td colspan="2">3.24 (10.0)</td><td colspan="2">4.23 (17.5)</td><td colspan="2">4.66 (21.4)</td><td colspan="2">5.16 (26.5)</td></tr>
<tr><td>W_3</td><td colspan="2">7.20 (51.4)</td><td colspan="2">8.94 (79.5)</td><td colspan="2">9.81 (95.9)</td><td colspan="2">9.95 (98.6)</td></tr>
<tr><td rowspan="3">T_2- CT (TPR) - ZT (maize) - GM</td><td>W_1</td><td colspan="2">3.84 (14.3)</td><td colspan="2">4.72 (21.8)</td><td colspan="2">5.29 (27.5)</td><td colspan="2">5.50 (29.8)</td></tr>
<tr><td>W_2</td><td colspan="2">3.50 (11.8)</td><td colspan="2">4.31 (18.1)</td><td colspan="2">4.90 (23.6)</td><td colspan="2">5.54 (30.2)</td></tr>
<tr><td>W_3</td><td colspan="2">7.58 (57.0)</td><td colspan="2">9.08 (82.0)</td><td colspan="2">9.91 (97.9)</td><td colspan="2">10.00 (99.5)</td></tr>
<tr><td rowspan="3">T_3- CT (DSR) - CT (maize) - GM</td><td>W_1</td><td colspan="2">7.51 (56.1)</td><td colspan="2">8.79 (76.7)</td><td colspan="2">10.43 (108.5)</td><td colspan="2">12.51 (156.3)</td></tr>
<tr><td>W_2</td><td colspan="2">6.88 (47.0)</td><td colspan="2">8.29 (68.5)</td><td colspan="2">9.08 (82.1)</td><td colspan="2">11.52 (132.3)</td></tr>
<tr><td>W_3</td><td colspan="2">12.89 (165)</td><td colspan="2">15.95 (254.1)</td><td colspan="2">17.13 (292.9)</td><td colspan="2">17.85 (319.1)</td></tr>
<tr><td rowspan="3">T_4- ZT (DSR) - ZT (maize) - GM</td><td>W_1</td><td colspan="2">8.90 (78.7)</td><td colspan="2">11.50 (131.7)</td><td colspan="2">12.27 (150.0)</td><td colspan="2">16.50 (271.9)</td></tr>
<tr><td>W_2</td><td colspan="2">8.19 (66.7)</td><td colspan="2">10.62 (112.4)</td><td colspan="2">11.39 (129.4)</td><td colspan="2">15.77 (248.4)</td></tr>
<tr><td>W_3</td><td colspan="2">14.07 (197)</td><td colspan="2">17.18 (294.7)</td><td colspan="2">17.95 (321.6)</td><td colspan="2">23.22 (538.9)</td></tr>
<tr><td rowspan="3">T_5- ZT+R (DSR)-ZT+R (maize)-GM</td><td>W_1</td><td colspan="2">8.32 (68.8)</td><td colspan="2">10.60 (112.0)</td><td colspan="2">11.70 (136.8)</td><td colspan="2">15.92 (253.0)</td></tr>
<tr><td>W_2</td><td colspan="2">7.65 (58.1)</td><td colspan="2">9.71 (94.1)</td><td colspan="2">10.69 (114.0)</td><td colspan="2">14.57 (212.2)</td></tr>
<tr><td>W_3</td><td colspan="2">14.04 (196)</td><td colspan="2">16.83 (282.7)</td><td colspan="2">17.65 (311.1)</td><td colspan="2">22.50 (505.9)</td></tr>
<tr><td colspan="10">Mean</td></tr>
<tr><td colspan="10">Tillage (Main plots)</td></tr>
<tr><td colspan="2">T_1 - CT (TPR) – CT</td><td colspan="2">4.66 (24.5)</td><td colspan="2">5.90 (39.1)</td><td colspan="2">6.56 (48.0)</td><td colspan="2">6.81 (51.0)</td></tr>
<tr><td colspan="2">T_2 - CT (TPR) - ZT - GM</td><td colspan="2">4.97 (27.7)</td><td colspan="2">6.04 (40.7)</td><td colspan="2">6.70 (49.7)</td><td colspan="2">7.01 (53.2)</td></tr>
<tr><td colspan="2">T_3 - CT (DSR) – CT - GM</td><td colspan="2">9.09 (89.6)</td><td colspan="2">11.01 (133.1)</td><td colspan="2">12.21 (161.2)</td><td colspan="2">13.96 (202.6)</td></tr>
<tr><td colspan="2">T_4 - ZT (DSR) – ZT - GM</td><td colspan="2">10.39 (114)</td><td colspan="2">13.10 (179.6)</td><td colspan="2">13.87 (200.3)</td><td colspan="2">18.50 (353.1)</td></tr>
<tr><td colspan="2">T_5 - ZT+R (DSR) – ZT+R - GM</td><td colspan="2">10.01 (107)</td><td colspan="2">12.38 (162.9)</td><td colspan="2">13.35 (187.3)</td><td colspan="2">17.66 (323.7)</td></tr>
<tr><td colspan="10">Weed Management (Sub plots)</td></tr>
<tr><td colspan="2">W_1 – Chemical management</td><td colspan="2">6.42 (46.0)</td><td colspan="2">8.03 (72.5)</td><td colspan="2">8.98 (89.9)</td><td colspan="2">11.15 (147.8)</td></tr>
<tr><td colspan="2">W_2 - IWM</td><td colspan="2">5.89 (38.7)</td><td colspan="2">7.43 (62.1)</td><td colspan="2">8.15 (74.1)</td><td colspan="2">10.51 (129.9)</td></tr>
<tr><td colspan="2">W_3 – Unweeded control</td><td colspan="2">11.16 (133)</td><td colspan="2">13.59 (198.6)</td><td colspan="2">14.49 (223.9)</td><td colspan="2">16.70 (312.4)</td></tr>
<tr><td colspan="2"></td><td>SE (m) ±</td><td>CD (P = 0.05)</td><td>SE (m) ±</td><td>CD (P = 0.05)</td><td>SE (m)±</td><td>CD (P = 0.05)</td><td>SE (m) ±</td><td>CD (P = 0.05)</td></tr>
<tr><td colspan="2">Tillage</td><td>0.12</td><td>0.41</td><td>0.18</td><td>0.60</td><td>0.17</td><td>0.57</td><td>0.17</td><td>0.58</td></tr>
<tr><td colspan="2">Weed Management</td><td>0.08</td><td>0.24</td><td>0.10</td><td>0.30</td><td>0.11</td><td>0.33</td><td>0.15</td><td>0.44</td></tr>
<tr><td colspan="2">SUB AT SAME LEVEL OF MAIN</td><td>0.21</td><td>0.56</td><td>0.31</td><td>0.71</td><td>0.30</td><td>0.77</td><td>0.30</td><td>1.02</td></tr>
<tr><td colspan="2">MAIN AT SAME LEVEL OF SUB</td><td>0.19</td><td>0.60</td><td>0.26</td><td>0.81</td><td>0.26</td><td>0.82</td><td>0.32</td><td>0.99</td></tr>
</table>

Table 2: Weed dry matter (m^{-2}) as influenced by tillage and weed management in rice under conservation agriculture (*kharif,* 2018).

*Figures in parentheses are original values and data is subjected $\sqrt{x}$ + 0.5 transformation

CT: Conventional Tillage; TPR: Transplanted Rice; DSR: Direct Seeded Rice; ZT: Zero Tillage; R: Residue Cover; GM: Green Manure (*Sesbania*)

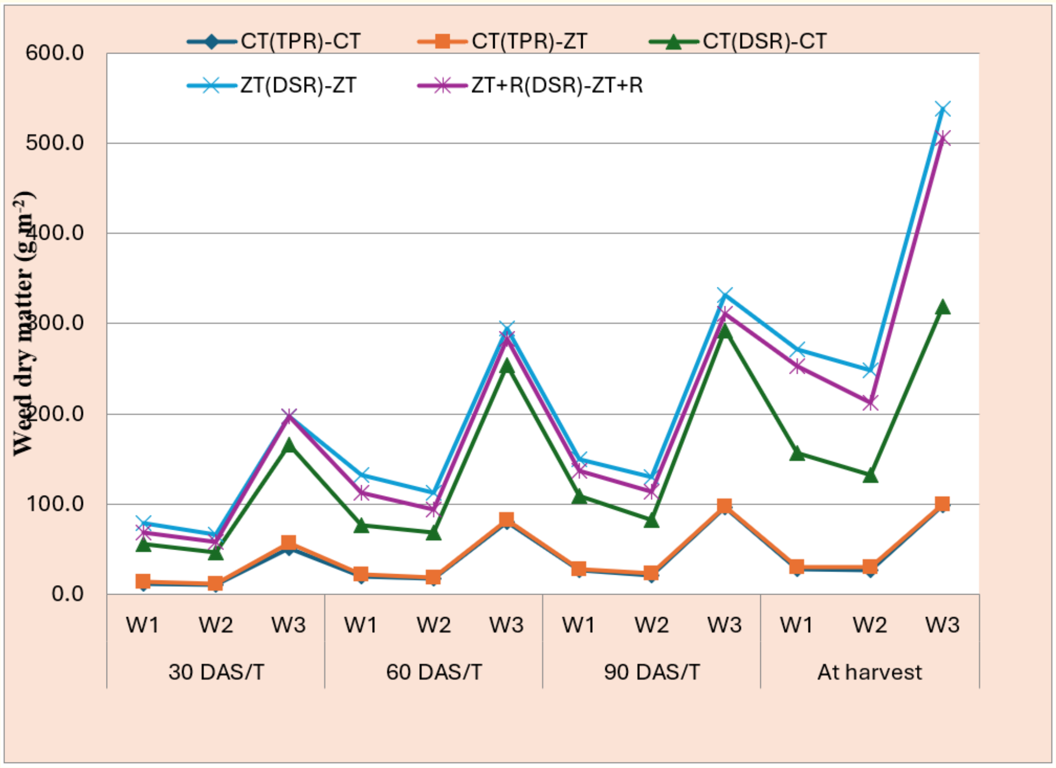

Figure 2: Weed dry matter (g m^{-2}) as influenced by tillage and weed management.

with and without residue cover recorded weed dry matter on par with each other. At 60 DAS/T, highest weed dry matter was recorded in zero tillage DSR without residues and it was significantly superior to other tillage practices. At 90 DAS/T and at harvest stages zero tillage direct seeded rice with and without residue cover recorded weed dry matter on par with each other.

With respect to weed management practices at 30 DAS/T, significantly lowest weed dry matter was recorded in IWM involving bispyribac sodium as early PoE fb hand weeding (38.7 g m^{-2}) and it was comparable to chemical weed management (46.0 g m^{-2}). At later stages, IWM recorded significantly lower weed dry matter followed by chemical weed management. Unweeded control recorded highest weed dry matter at all the stages.

Interaction effect of tillage and weed management practices on weed dry matter was significant at all the stages. Significantly lower weed dry matter was recorded with the adoption of IWM and chemical weed management in TPR under CT - CT and CT-ZT systems. Significantly higher weed dry matter was recorded under unweeded control in DSR under zero tillage with and without residue cover at all the stages of observation.

At 30 DAS/T, IWM and chemical weed management were on par with each other in both transplanted rice treatments but in DSR, IWM recorded significantly lower weed dry matter. At 60 DAS/T, IWM and chemical weed management were on par with each other under CT-CT and CT-ZT in TPR and CT-CT in DSR whereas IWM was significantly superior to chemical weed management in zero tillage DSR. At 90 DAS, IWM and chemical weed management were on par with each other in TPR and at harvest IWM and chemical weed management were comparable to each other in all the tillage practices except under ZT+R-ZT+R. Unweeded control recorded significantly higher weed dry matter at all the stages.

Comparable weed dry matter was recorded in both transplanted rice treatments in their respective weed management treatments at all the stages. In DSR, CT-CT system recorded significantly lower weed dry matter in all weed management practices at all the stages. Zero tillage DSR with and without residue cover was comparable in their respective chemical, IWM and unweeded control at 30 and 90 DAS. At 60 DAS, DSR under ZT-ZT recorded significantly higher weed dry matter than ZT+R-ZT+R in chemical and IWM. At harvest, DSR under ZT-ZT recorded significantly higher weed dry matter than ZT+R-ZT+R in IWM. Transplanted rice recorded lowest weed dry matter mainly due to thorough land preparation and puddling which could have avoided burial of weed seeds and preserve inside the soil unlike direct seeded rice with conventional tillage and zero tillage systems. Direct seeded rice under conventional tillage reported lower weed dry matter than zero tillage as the tillage generally suppresses weeds and in addition zero tillage favor the germination and establishment of small seeded weeds. Similar findings were reported by [11]. Lowest weed dry matter in IWM could be due to broad spectrum of weed control with IWM involving bispyribac sodium and hand weeding which help in reducing weed growth effectively. Weed dry matter was effectively reduced under transplanted conditions.

Weed control efficiency (%)

Weed control efficiency exhibited variation among different weed management practices which is an index of reduction in weed dry matter at different growth stages was computed and presented in table 3. At all the stages of crop growth, IWM involving bispyribac sodium as early PoE *fb* hand weeding has recorded maximum weed control efficiency (71.05%, 68.76%, 66.91% and 58.41% at 30, 60, 90 and at harvest stages respectively) followed by chemical weed management (65.6%, 63.51%, 59.85% and 52.7% at 30, 60, 90 and at harvest stages respectively). These results are in accordance with findings of [8,14]

Treatments	Weed Control Efficiency (%)			
	30 DAS/T	60 DAS/T	90 DAS/T	Harvest
Weed Management (Sub plots)				
W_1- Chemical weed management	65.60	63.51	59.85	52.70
W_2 - Integrated weed management	71.05	68.76	66.91	58.41
W_3- Unweeded control	--	--	--	--

Table 3: Weed control efficiency (%) as influenced as influenced by tillage and weed management in rice (*kharif,* 2018).

Conclusion

The study indicates that transplanted rice effectively reduces the density and dry weight of major weed species throughout different growth stages. Notably, the lowest weed density was observed in transplanted rice under both conventional tillage-conventional tillage (CT - CT) and conventional tillage-zero tillage (CT - ZT) systems. In contrast, direct-seeded rice showed lower weed density and dry matter only in the CT - CT system. Among the various weed management strategies, Integrated Weed Management (IWM) proved most effective, achieving the lowest weed density and dry matter across all crop growth stages, with the highest weed control efficiency. Chemical weed management followed closely but was less effective than IWM. This suggests that IWM may be a more sustainable approach for managing weeds in rice cultivation.

In future we may integrate various herbicides into Integrated Weed Management (IWM) which is crucial for understanding their impacts on soil health, particularly soil enzymes that play a key role in nutrient cycling and soil fertility. Herbicides can alter the microbial community structure and enzyme activities, which may affect the overall ecosystem. Conduct long-term studies to monitor soil enzyme changes and assess the sustainability of proposed practices.

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