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RESEARCH ARTICLE

Tillage and weed management practice influences on weed dynamics and yield of greengram in maize-wheat-greengram cropping system

Narendra Kumar[1,2], V.K. Choudhary[1*], D.S. Sasode[2], Mrinali Gajbhiye[3], M.P. Sahu[1], Vikash Singh[1], Alpana Kumhare[1,2] and Sonali Singh[1,2]

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ABSTRACT

Weed management plays an important role in the success of conservation agriculture (CA) and help in gaining optimum crop yields. The knowledge of CA and weed management practices in a particular area allows to study, ecological interaction between crops and weeds to develop sustainable management strategies. A field study was conducted at research farm at ICAR-Directorate of Weed Research, Jabalpur (M.P.) between 2021-23 with an objective to study the influence of tillage and weed management practices on weed dynamics, and yield of greengram [*Vigna radiata* (L.) Wilczek] under long-term maize-wheat-greengram cropping system. The experiment was laid out in a split-plot design and replicated thrice. The main plots was assigned to two crop establishment methods [conventional tillage (CT) and zero tillage with retention of previous crop residues (ZT+R) in system] and four weed management practices [weedy check, recommended herbicide (RH), integrated weed management (IWM), herbicide rotations (HR)] in sub-plot. Results revealed that the lowest total broad leaved weeds density (11.8 and 10.2 no./m^2) and total sedges (22.1 and 11.8 no./m^2) were obtained with ZT+R. Similarly, total biomass of total broad-leaved weeds (13.6 and 11.0 g/m^2), total sedges (16.8 and 8.9 g/m^2) and more weed control efficiency (56.55% and 59.10%) with ZT+R in the year 2021-22 and 2022-23, respectively. Integrated weed management obtained lowest weed density of total broad-leaved weeds (8.5 and 6.5 no./m^2), total grassy weeds (9.7 and 10.8 no./m^2) and total sedges (10.7 and 7.0 no./m^2). The total biomass of broad-leaved weeds (5.3 and 4.7 g/m^2), grassy weeds (4.9 and 5.3 g/m^2), sedges (7.5 and 2.2 g/m^2) with highest WCE 84.80% and 85.28% during 2021-22 and 2022-23, respectively. Lower weed parameters under ZT+R noted with higher seed yield of 908 and 994 kg/ha, respectively) In IWM, seed yield was highest with 1129 and 1203 kg/ha during 2021-22 and 2022-23, respectively. Phytosociological analysis revealed the dominance of *Cyperus rotundus* (L.) and *Echinochloa colona* (L.) with the highest importance value index.

Keywords: Conservation tillage, Relative density, Relative abundance, Relative frequency and Importance value index

INTRODUCTION

Greengram [*Vigna radiata* (L.) Wilczek] is one of the important pulses that occupies 3% of the gross cropped area (Annual Report 2021-22) It provides about 24-28% protein and 60% carbohydrate thus plays an important role in ensuring nutritional security (Nath *et al.* 2017). In Central India, three cropping systems, *viz.* rice-wheat, maize-wheat and soybean-wheat are mostly followed by the farmers as per the land suitability and water adequacy. Cereal crops exhaust a large amount of nutrients without returning to the soil and nutrition depletion adversely affects soil quality (Tan *et al*. 2008). The inclusion of leguminous crop in the cropping system could help to improve soil fertility by fixing atmospheric nitrogen (Page *et al.* 2020). Incorporation of greengram crop residue helps to add organic matter to the soil thereby improving soil quality for succeeding crop. Furthermore, greengram is a good option for the farmers leaving fallow during summer season, greengram as a summer crop provides some extra income during this period (Ghosh *et al.* 2021). With the increase in minimum support price (MSP) of greengram, farmers raised their interest in taking greengram that resulted in an increase in its area and production. With the advancement in agriculture technology, farmers are moving more towards mechanizations and time-saving technology that drifted farmers economic conditions but excessive mechanization like continuous tillage and clean cultivation has increased soil compactness and organic matter decomposition in soil. Conservation agriculture (CA) based technology such as zero tillage (ZT), stubble mulch tillage, raised bed planting, and crop diversification are used as an alternative for

[1] ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh 482004, India

[2] Rajmata Vijayraje Scindia Krishi Vishwavidyalaya, Gwalior, Madhya Pradesh 474002, India

[3] Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, Madhya Pradesh 482004, India

* Corresponding author email: ind_vc@rediffmail.com

machine intensive tillage practices in India as it minimises the labour and machinery while enhancing profitability (Das *et al.* 2014, Bhattacharyya *et al.* 2015, Jat *et al.* 2020). Adoption of CA along with greengram can be a restorative measure with less C: N promote rapid mineralization of nutrient in maize-wheat cropping system (Hazra *et al.* 2019). It enhances soil health, reduces soil erosion by engaging farm round the year, hence, utilises all the resources efficiently, thereby, providing extra income to the farmer.

Weeds are one of the major problems in CA as it provides favourable conditions for perennial weeds in most of the cropping system. Depending upon the infestation of weeds, yield reduction of about 30-80% in summer and rainy and 70-80% during *Rabi* seasons in greengram was observed (Algotar *et al.* 2015). Adoption of ZT with crop residue retention can reduce biomass of weeds and enhance yield than conventional tillage (CT) in various crops (Ghosh *et al.* 2022). Under ZT conditions viable weed seeds remains near the soil surface that provides favourable condition for their germination and emergence but also susceptible for herbicide, weather variability and predation (Nichols *et al.* 2015). Presence of crop residue on soil surface, hinders the germination, growth, light interception and also releases allelo-chemicals on weeds (Franke *et al.* 2007). Crop diversification could be an effective option to minimise weed density and dry weight due to change in production strategies caused by various cropping system (Buhler *et al.* 2001, Kaur *et al.* 2015). Moreover, phyto-sociological parameters enable to study co-existence between the crops and weeds as it is helpful determining weed species prevalence in the different periods of crop growth (Silva *et al.* 2018) also in identification of particular weed species distribution in an ecosystem. The weed which are frequent and dominant in a particular environment are more important in that area. Different weed management practices are being followed in order to minimize the weed pressure, among them, cultural and chemical weed management are most common and widely used. Moreover, weeds are susceptible to herbicide and when used repetitively leaves tolerant weed species that often thrive reduced competition (Tuessca *et al.* 2001, Suresha 2014). In summer greengram, pre-emergence (PE) application of pendimethalin at 0.45 kg/ha followed by (*fb)* one hand weeding had the lowest weed dry matter. Imazethapyr has been reported to provide effective control of weeds in greengram (Singh *et al.* 2014). Similarly, application of pendimethalin at 1.0 kg/ha (PE) *fb* imazethapyr at 55 g/ha at 15-20 DAS considerably reduced weed density and biomass resulting in higher seed yield (Bahar *et al.* 2017). CA along with different weed management practices to control various weed flora reduced herbicide retention in soil thereby protect the environment from pollutions by opting integrated weed management. Keeping all the above facts in view, the present study seeks to compare the effect of CT and ZT with weed management practices to assess the influence of conservation tillage and weed management practices on weed dynamics, and yield of greengram [*Vigna radiata* (L.) Wilczek] under maize-wheat-greengram cropping system.

MATERIAL AND METHODS

The field experiment was carried out at ICAR-Directorate of Weed Research, Jabalpur (M.P.) during the summer seasons of 2021-22 and 2022-23. The experiment was laid out in a split-plot design with three replications. The main plot consists of two crop establishment methods, conventional tillage [CT (greengram residue; GR)-CT(Maize residue; MR)-CT (Wheat residue; WR)] and conservation tillage [ZT+R(GR)-ZT+R(MR)-ZT+R(WR)] in the system and four weed management practices [weedy check, recommended herbicide [RH; pendimethalin 678 g/ha (pre-emergence, PE) *fb* imazethapyr at 100 g/ha (post-emergence, PoE)], integrated weed management [IWM; pendimethalin 678 g/ha (PE) *fb* hand weeding at 30 DAS], herbicide rotations [HR; pendimethalin 678 g/ha (PE) *fb* imazethapyr at 100 g/ ha (PoE) during first year, pendimethalin 678 g/ha (PE) *fb* quizalofop 60 g/ha during second year] in the sub-plot. The soil of the experimental field was clayey in texture with neutral pH, medium organic carbon (OC; 0.76%) and available nitrogen (256.5 kg/ha) and potassium (342.6 kg/ha), and high in phosphorus (62.5 kg/ha). The greengram variety '*Virat*' was selected for the experiment. The field was prepared by ploughing with two pass of tractor drawn cultivator followed by one pass rotavator in CT. Water management was done as per the need of the crop. The seed of greengram was sown in line at 30 cm apart using normal seed drill in CT and happy seed drill in ZT+R with the seed rate of 25 kg/ha. Entire residues of wheat crop were left in the field before sowing of greengram. The recommended dose of nutrient N:P:K of 22.5:60:00 kg/ha was applied as basal. For spraying herbicide, knapsack sprayer fitted with a flat fan nozzle was used for spraying herbicide of 500 L/ha for PE and 375 L/ha at 20 DAS as PoE. Weed density and weed dry weight were recorded at 60 days after sowing by placing 0.25 m^2 (0.5 m x 0.5 m) quadrat at two places in each plot and the mean was converted to 1 m^2. The collected weeds were initially shade-dried and then placed in an oven for drying at 65±2 ÚC until constant weight was achieved. The data was then subjected to square root transformations to normalize the variations. The original values of weed dry weight were used for the calculation of weed control efficiency. Similarly, weed phytosociology parameters (density, frequency and abundance, important value index) were worked out by using formula suggested by Hetta *et al.* (2022).

$$\text{Density} = \frac{\text{Total number of individuals of species in all quadrates}}{\text{Total number of quadrates studied}}$$

$$\text{Frequency (\%)} = \frac{\text{Total number of quadrates in which the species occurred}}{\text{Total number of quadrates studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates in which the species occurred}}$$

Importance value index (IVI) = Relative density + Relative frequency + Relative abundance

Statistical analysis

The data obtained over two years were subjected to statistical analysis of variance (ANOVA) using F-test as suggested by Gomez and Gomez (1984). The significant difference between treatment means were compared with critical differences at 5% levels of significance.

RESULTS AND DISCUSSION

Weed flora

Mean data revealed that greengram crop was mainly infested with *Echinochloa colona* (L.) (22.3%), *Dinebra retroflexa* (Vahl.) (17.0%), *Cyperus rotundus* (L.) (17.4%) and *Digitaria sanguinalis* (L.) (14.2%). However, *Convolvulus arvensis* (L.) (4.7%), *Alternanthera sessilis* (L.) (3.9%) and *Eleusine indica* (L.) (3.3%) also recorded as minor weeds during the study.

Weed density and dry weight

The field was infested with complex weed flora comprising of broad-leaved, grasses and sedges (**Table 1**). Among the crop establishment methods, significantly minimum total broad-leaved weeds (11.8 and 10.2 no./m^2) and sedges (22.1 and 11.8 no./m^2) were recorded in ZT+R over CT except, total grassy weeds (43.5 and 37.7 no./m^2), which was significantly minimum in CT during both the years of experimentations. This might be because of residue retention in ZT that significantly supressed the weed seed germination and emergence in ZT+R. The density of grassy weeds was more in ZT+R may be due to the well established grassy weeds of previous crop. As also observed by Suryawanshi *et al.* 2018a, Choudhary and Sharma (2023). Among the weed management practices, the minimum density of total broad-leaved weeds (8.5 and 6.5 no./m^2), total grasses (9.7 and 10.8 no./m^2) and total sedges (10.7 and 7.0 no./m^2) in IWM during both the years of experimentation. This might be because of effective weed controlled by pendimethalin *fb* HW during early stages that favoured better crop growth which ultimately supressed weeds. As also reported by Shilurenla *et al.* (2022) that maximum reduction in weed density was observed in pendimethalin *fb* HW.

Among the crop establishment methods, significantly minimum weed dry weight of total broad-leaved weeds (13.6 and 11.0 g/m^2) and sedges (16.8 and 8.9 g/m^2) was recorded in ZT+R over CT except total grassy weeds (40.5 and 33.4 g/m^2), which was more in CT during both the years of experimentation. This might be due to lower weed density in ZT+R, which ultimately resulted in lower weed biomass, however grassy weeds were higher in ZT which resulted in more weed dry weight. Ghosh *et al.* (2022a) also observed reduction in total weed density and biomass under CA-based practices. IWM practices recorded significantly minimum weed dry weight of total broad leaved weeds (5.3 and 4.7 g/m^2), total grassy weeds (4.9 and 5.3 g/m^2) and total sedges (7.5 and 2.2 g/m^2) over the others during both the years of experimentations. This might be due to better weed control by pendimethalin *fb* HW that favoured crop growth, which resulted in quick coverage of ground and more shading affect by crop thereby reducing growth of weeds. Singh *et al.* (2015), lower dry matter of weeds by application of pendimethalin + 1 HW.

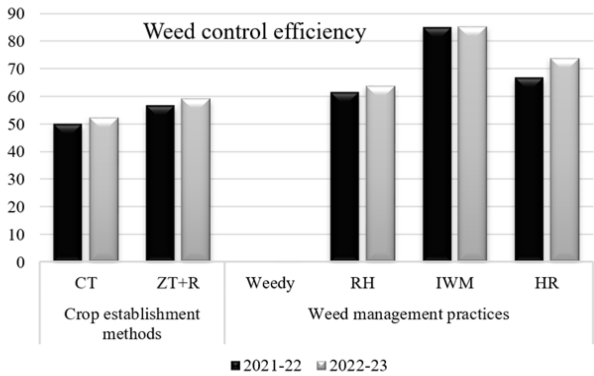
The interaction effect of crop establishment methods and weed management practices during both the years was found to be significant for total broad-leaved weeds. The combination of ZT+R with IWM recorded minimum weed density and biomass over the other treatment combinations. However, the interaction effects for total grassy weeds and total sadges was non-significant during both the years of experiments.

Weed control efficiency (WCE)

The WCE were recorded under different crop establishment methods and weed management practices at 60 DAS and is presented in **Figure 1**. The maximum weed control efficiency was recorded under ZT+R than CT during both the year. This may be because of crop residue in ZT+R that might have hindered weed seed germination and emergence. The fewer weeds those got germinated were controlled by applying herbicides. Choudhary and Sharma (2023) also noted the highest weed control efficiency in ZT+R than CT. Among the weed management practices, maximum weed control was recorded under IWM and HR. This was due to application of pendimethalin *fb* hand weed weeding at 30 DAS that completely removed weeds resulted in higher WCE in IWM. The result are in accordance with Shilurenla *et al.* (2022) that the highest WCE in pendimethalin *fb* hand weeding. In general, the weed control efficiency was more in second year of the experiment. This might be due to better control of weeds that resulted in fewer weeds and lesser dry weight.

Phytosociological parameters

Phytosociology is the study of various communities of weeds which reflect the pattern of particular species present in an agro-ecosystem. Weed phytosociology is useful in identifying weed species that are more important during the various growth stages of the crop and make sure for efficient methods that can be used for weeds control (Concenco *et al*. 2017). Phytosociological parameters, *viz*. relative density (RD), relative frequency (RF), relative abundance (RA), and important value index (IVI) were estimated based on seasonal observation for two years **Tables 2 to 5**. These parameters were used to determine frequently occurring, abundant, and more important weed species in a particular area.



CT; Conventional tillage, ZT+R; Zero tillage with crop residue, RH; Recommended herbicide, IWM; Integrated weed management, HR; Herbicide rotation

Figure 1. Conservation tillage and weed management practice influences weed control efficiency in greengram under maize-wheat-greengram cropping system

Relative density

The relative density reflects the density of a particular species in relation to all the species and is expressed in percentage. It shows the extent of the species in that particular community **Table 2**. It is clear that among the crop establishment methods, *Cyperus rotundas* (L.), was most dominant in CT (35.9% and 33.9%) than ZT+R (27.3% and 27.7% during both the years, respectively). However, *Echinochloa colona* (L.) (21.8%) and *Dinebra retroflexa* (Vahl.) (17.3%) were more dominant in ZT+R than CT during 2021-22. Contrarily to this, the foresaid weeds were more dominant in CT over

Table 1. Effect of conservation tillage and weed management practices on density and dry weight of total broad leaved, total grassy weeds and total sedges in greengram under maize-wheat-greengram cropping system

Treatment	Total broad-leaf weeds				Total grassy weeds				Total sedges			
	Total density		Total dry weight		Total density		Total dry weight		Total Density		Total dry weight	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Crop establishment method (M)												
CT	4.57	3.91	4.63	4.00	6.14	5.46	5.50	4.93	5.35	4.63	4.44	3.78
	(22.2)	(16.5)	(24.4)	(18.3)	(43.5)	(37.7)	(40.5)	(33.4)	(29.7)	(22.1)	(20.9)	(15.5)
ZT+R	3.41	3.19	3.57	3.24	6.44	5.84	5.72	5.32	4.61	3.39	4.02	2.85
	(11.8)	(10.2)	(13.6)	(11.0)	(49.3)	(43.7)	(43.2)	(40.0)	(22.1)	(11.8)	(16.8)	(8.9)
p=0.05	0.48	0.68	0.62	NS	0.19	0.33	0.21	0.35	0.69	0.29	0.39	0.80
Weed management practice (S)												
Weedy check	5.68	5.10	6.43	5.67	10.94	10.31	11.07	10.57	6.41	5.20	5.96	4.56
	(33.2)	(26.5)	(42.5)	(32.8)	(118.5)	(107.2)	(122.2)	(111.8)	(41.2)	(27.3)	(35.3)	(21.2)
RH	3.75	3.11	3.84	3.11	5.66	5.63	4.74	4.80	5.31	3.79	4.05	2.92
	(13.8)	(9.3)	(14.5)	(9.3)	(30.7)	(32.3)	(22.1)	(22.7)	(27.8)	(14.3)	(16.1)	(8.3)
IWM	2.97	2.63	2.40	2.25	3.26	3.21	2.32	2.39	3.30	2.66	2.82	1.59
	(8.5)	(6.5)	(5.3)	(4.7)	(9.7)	(10.8)	(4.9)	(5.3)	(10.7)	(7.0)	(7.5)	(2.2)
HR	3.55	3.35	3.73	3.45	5.31	3.44	4.31	2.73	4.92	4.41	4.09	4.19
	(12.3)	(11.0)	(13.6)	(11.8)	(26.8)	(12.3)	(18.2)	(6.9)	(23.8)	(19.2)	(16.4)	(17.2)
p=0.05	0.46	0.46	0.68	0.46	0.48	0.71	0.37	0.58	0.53	0.50	0.56	0.45
M×S												
p=0.05	0.65	0.65	0.96	0.66	NS	NS	NS	NS	NS	NS	NS	NS

ZT+R in 2022-23. Similar to our findings, Kumar *et al.* (2022) also observed the dominance of *Cyperus* spp. in CT. Chhokar *et al.* (2021) observed more density of *Dinebra retroflexa* (Vahl.) and *Digitaria sanguinalis* (L.) in ZT+R. Among the weed management practices, thick population of *Cyperus rotundus* (L.) was present in IWM (38.0%) than other weed management practices during the year of 2021-22. However, *Echinochloa colona* (L.) (25.4%), *Dinebra retroflexa* (Vahl.) (17.0%) and *Digitaria sanguinalis* (12.6%) were more in weedy check plot than other weed management practices. *Dinebra retroflexa* (Vahl.) followed significant (p<0.05) trend with the highest in weedy check > HR > RH > IWM. In 2022-23, density of *Cyperus rotundus* (L.) (53.7%) was more than other weed management practices, whereas *Echinochloa colona* (L.) (29.5%), *Dinebra retroflexa* (Vahl.) (20.6%) and *Digitaria sanguinalis* (22.2%) were higher in weedy check plots.

Relative frequency

It is a useful index to monitor and compare plant community changes over a time (Bonham 2013). It reflects either presence or absence of a species and it is distributed within a community. It is clear from **Table 3**, that among the crop establishment methods, during both the year *Echinochloa colona* (L.) (15.2% and 15.4%, respectively) and *Cyperus rotundus* (L.) (15.2% and 15.4%, respectively) were the most frequently occurring weeds in ZT+R (12.9% and 13.1%, respectively) than CT (13.9% and 14.4%, during 2021 and 2022, respectively). Among the weed management practices during both the years, *Echinochloa colona* (17.8% and 17.1%, respectively) and *Cyperus rotundus* (17.8% and 17.1%, respectively) were most frequent in IWM than other weed management practices during 2021 and 2022, respectively. In 2021-22, *Cyperus rotundus* was significantly more frequent in IWM followed by HR and RH. However, *Cyperus rotundus* was more frequent in IWM followed by HR in 2022-23.

Relative abundance

It is the measure of weed species occurrence in a particular area. The data on relative abundance is presented in **Table 4**. Among the crop establishment methods, *Cyperus rotundus* (L.) was the most abundant weed in CT (35.1% and 31.9%) than ZT+R

Table 2. Effect of conservation tillage and weed management practices on relative density in greengram under maize-wheat-greengram cropping system

Weed species	Crop establishment method				p=0.05		Weed management practice								p=0.05	
	CT		ZT+R				Weedy check		RH		IWM		RH			
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Echinochloa colona (L.)	19.5	22.6	21.8	21.7	NS	NS	25.4	29.5	18.6	25.2	19.5	23.3	19.3	10.9	NS	6.05
Dinebra retroflexa (Vahl.)	11.0	11.1	17.3	8.1	1.86	NS	17.0	20.6	15.3	19.0	7.7	11.1	16.6	7.7	6.81	5.78
Digitaria sanguinalis (L.)	10.2	10.8	10.2	13.8	NS	NS	12.6	22.2	11.0	13.2	8.3	10.4	8.9	3.4	NS	5.60
Alternanthera sessilis (L.)	6.0	4.4	4.9	2.8	NS	NS	7.9	2.1	5.3	2.0	4.8	4.9	3.7	5.3	NS	NS
Phyllanthus niruri (L.)	8.0	5.5	4.3	2.9	NS	NS	8.6	4.7	4.7	2.6	5.8	3.0	5.5	6.6	NS	NS
Cyperus rotundus (L.)	35.9	33.9	27.3	27.7	NS	NS	22.6	14.5	28.5	22.0	38.0	33.0	37.2	53.7	NS	1.91
Convolvulus arvensis (L.)	8.1	8.1	7.1	5.9	NS	NS	6.8	5.3	6.4	5.8	10.7	6.6	6.4	10.7	NS	NS
Eleusine indica (L.)	3.5	4.9	3.6	4.4	NS	NS	3.1	3.8	3.3	4.7	5.2	8.3	2.6	1.9	NS	2.66

CT; Conventional tillage, ZT+R; Zero tillage with crop residues, RH; Recommended herbicide, IWM; Integrated weed management, HR; Herbicide rotation

Table 3. Effect of conservation tillage and weed management practices on relative frequency in greengram under maize-wheat-greengram cropping system

Weed species	Crop establishment method				p=0.05		Weed management practice								p=0.05	
	CT		ZT+R				Weedy check		RH		IWM		RH			
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Echinochloa colona (L.)	12.9	13.1	15.2	15.4	NS	NS	12.5	12.6	13.3	14.6	17.8	17.1	12.6	12.6	NS	NS
Dinebra retroflexa (Vahl.)	10.9	10.8	13.5	14.7	NS	NS	12.5	12.6	13.3	14.6	8.3	11.3	14.7	12.7	NS	NS
Digitaria sanguinalis (L.)	13.3	12.4	11.4	13.2	NS	NS	12.5	12.6	13.3	14.6	12.3	15.6	11.3	8.6	NS	4.66
Alternanthera sessilis (L.)	12.1	11.9	9.6	9.0	1.39	NS	12.5	11.5	12.0	8.4	8.7	9.6	10.1	12.4	NS	NS
Phyllanthus niruri (L.)	12.7	11.7	11.9	9.5	NS	NS	12.5	12.6	13.3	9.3	11.1	6.7	12.4	13.9	NS	NS
Cyperus rotundus (L.)	13.9	14.4	15.2	15.4	NS	NS	12.5	12.6	13.3	14.6	17.8	17.1	14.7	15.4	3.63	1.71
Convolvulus arvensis (L.)	13.0	12.5	13.7	11.2	NS	NS	12.5	12.6	13.3	10.8	14.6	8.6	13.0	15.4	NS	NS
Eleusine indica (L.)	10.3	11.7	9.5	11.5	NS	NS	12.2	12.6	8.5	13.3	9.4	14.2	9.3	6.4	NS	NS

CT; Conventional tillage, ZT+R; Zero tillage with crop residues, RH; Recommended herbicide, IWM; Integrated weed management, HR; Herbicide rotation during 2021 and 2022, respectively. In 2021-22, abundance of *Echinochloa colona* (20.6%) and *Dinebra retroflexa* (Vahl.) (18.0%) was more in ZT+R but in 2022-23, the abundance of *Dinebra retroflexa* (Vahl.) (18.0%) and *Digitaria sanguinalis* (13.8%) was more as compared to CT. Among the weed management practices, *Cyperus rotundus* (36.4 and 51.7% during 2021 and 2022, respectively) was most abundant weed among all the weed species in HR and *Echinochloa colona* was the second most abundant species in weedy check during both the year of experiment.

Important value index

It is a standard tool for estimating overall importance of a species in a particular area. It is sum of the percentage value of relative density, relative frequency and relative abundance. Among the crop establishment methods, *Cyperus rotundas* registered highest IVI (84.9 and 80.3%) in CT than ZT+R (75.3 and 75.5%) during 2021 and 2022, respectively. *Echinochloa colona* registered the second most important weed among all the species during both the years. Among the weed management practices, *Cyperus rotundus* registered the highest IVI in HR among all the weed species during both the year and *Echinochloa colona* registered second weed species in weedy check during both the years (**Table 5**).

Seed and stover yield

Seed yield varied significantly among crop establishment methods and weed management practices (**Table 6**). The highest seed yield 908 kg/ha in 2021-22 and 994 kg/ha in 2022-23 was recorded in ZT+R than CT (715 and 869 kg/ha during 2021 and 2022, respectively). The higher seed yield in ZT+R was mainly due to reduction in weed density that favoured utilization of light, space, and nutrients, which helped in synthesizing higher growth and yield attributing characters and ultimately, resulted in higher seed yield than CT. The results were in agreement with Ghosh *et al.* (2022a). Among the weed management practices, the highest seed yield was recorded in IWM practices (1129 and 1203 kg/ha, respectively) than other weed management practices. The lowest seed yield (323 and 462 kg/haduring 2021 and 2022, respectively) was obtained in weedy check. Application of pendimethalin *fb* hand

Table 4. Effect of conservation tillage and weed management practices on relative abundance in greengram under maize-wheat-greengram cropping system

Weed species	Crop establishment method				p=0.05		Weed management practice								p=0.05	
	CT		ZT+R				Weedy check		RH		IWM		RH			
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Echinochloa colona (L.)	19.3	21.6	20.6	21.2	NS	NS	25.4	29.5	18.5	24.5	17.2	21.2	18.8	10.5	NS	5.67
Dinebra retroflexa (Vahl.)	10.8	11.0	18.0	18.0	4.14	NS	17.0	20.5	15.1	18.6	9.2	10.6	16.1	8.4	NS	5.49
Digitaria sanguinalis (L.)	10.4	11.3	9.9	13.8	NS	NS	12.6	22.2	10.9	13.0	8.4	10.4	8.8	4.7	NS	5.31
Alternanthera sessilis (L.)	5.9	5.2	5.4	3.4	NS	NS	7.9	2.2	5.6	2.8	4.9	6.9	4.0	5.9	NS	3.5
Phyllanthus niruri (L.)	6.3	4.6	4.6	3.4	NS	0.8	4.6	2.2	2.6	3.2	6.6	3.7	6.1	7.0	NS	NS
Cyperus rotundus (L.)	35.1	31.9	29.3	29.7	NS	NS	22.6	14.4	35.1	26.9	34.7	30.2	36.4	51.7	8.17	7.23
Convolvulus arvensis (L.)	8.3	9.0	7.3	5.6	NS	NS	6.8	5.3	6.4	6.1	11.3	7.6	6.7	10.3	3.15	NS
Eleusine indica (L.)	4.1	5.4	4.9	4.9	NS	NS	3.1	3.6	3.8	5.0	7.6	9.6	3.3	2.3	NS	3.07

CT; Conventional tillage, ZT+R; Zero tillage with crop residues, RH; Recommended herbicide, IWM; Integrated weed management, HR; Herbicide rotation

Table 5. Influence of conservation tillage and weed management practices on important value index in greengram under maize-wheat-greengram cropping system

Weed species	Crop establishment method				p=0.05		Weed management practice								p=0.05	
	CT		ZT+R				Weedy check		RH		IWM		RH			
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Echinochloa colona (L.)	52.7	58.7	57.6	58.3	NS	NS	63.2	71.6	50.3	64.2	54.4	61.5	52.7	36.7	NS	11.37
Dinebra retroflexa (Vahl.)	32.6	32.9	48.8	50.9	7.30	NS	46.5	53.7	43.6	52.1	25.2	32.9	47.3	28.8	16.92	13.23
Digitaria sanguinalis (L.)	33.9	34.5	31.6	40.8	NS	NS	37.7	57.0	35.1	40.8	29.1	36.4	29.0	16.6	NS	12.80
Alternanthera sessilis (L.)	23.9	21.5	19.8	15.1	NS	NS	28.4	15.9	23.0	13.2	18.5	21.4	17.7	22.7	NS	NS
Phyllanthus niruri (L.)	24.9	20.6	20.9	15.8	NS	NS	21.6	17.0	22.5	15.1	23.5	13.4	24.0	27.5	NS	NS
Cyperus rotundus (L.)	84.9	80.3	75.3	75.5	NS	NS	57.8	41.5	83.9	69.0	90.5	80.2	88.2	120.8	14.35	13.88
Convolvulus arvensis (L.)	29.4	29.5	28.1	22.7	NS	NS	26.1	23.2	26.5	22.7	36.6	22.2	26.1	36.3	NS	NS
Eleusine indica (L.)	17.8	22.1	18.0	20.8	NS	NS	18.8	20.2	15.5	23.0	22.2	32.1	15.1	10.6	NS	8.82

CT; Conventional tillage, ZT+R; Zero tillage with crop residues, RH; Recommended herbicide, IWM; Integrated weed management, HR; herbicide rotatio

Table 6. Effect of conservation tillage and weed management practices on seed and stover yield of greengram under maize-wheat-greengram cropping system

Treatment	Seed yield (kg/ha)		Stover yield (kg/ha)	
	2021-22	2022-23	2021-22	2022-23
Crop establishment method (M)				
CT	714	869	1869	1925
ZT+R	908	994	2223	1950
p=0.05	76.24	64.73	317.20	NS
Weed management practice (S)				
Weedy check	323	462	1141	1352
RH	790	939	2194	1984
IWM	1129	1203	2273	2253
HR	1000	1121	2577	2201
p=0.05	91.43	45.46	228.43	193.95
M×S				
p=0.05	NS	64.30	NS	NS

weeding at 30 DAS efficiently controlled weeds during the initial as well as later stages of the crop which offered lesser competition for the available resources at sites resulted in better growth and development of the crop thereby enhancing seed yield. Similar to this, Ghosh *et al.* (2022b) also stated that the application of pendimethalin *fb* hoeing obtained higher seed yield over herbicide alone.

After the critical review of data of both the years, it was observed that ZT+R recorded significantly higher stover yield (2223 kg/ha) than CT (1869 kg/ha) during the first year of the experiment. However, it was non-significant in the second year. It might be due to favourable conditions provided by ZT+R that resulted in better crop-establishment hence, more stover yield. Among the weed management practices, in the first year of experiment, the highest stover yield (2527 kg/ha) was harvested in HR whereas in second year, IWM harvested the highest yield (2253 kg/ha) although it was at par to HR. This might be due to the application of PoE herbicide in HR that extended the vegetative growth phase but shortened the reproductive stage that ultimately helped in higher stover yield in HR than IWM. Suryavanshi *et al.* (2018b) also found significant effect of crop establishment methods and weed management practices on seed and stover yield of greengram. Lower weed density and dry weight with higher weed control efficiency helped in obtaining higher seed and stover yield.

The interaction effect among crop establishment and weed management was found to be significant for the second year of experimentation with treatment combination of ZT+R with IWM, which recorded maximum grain yield over the others treatment combinations.

Conclusion

Based on the study it was be concluded that ZT with retention of entire crop residues of wheat crop resulted in a noticeable reduction in density and dry weight of weeds. Similarly, application of pendimethalin 678 g/ha *fb* hand weeding at 30 DAS outperformed than herbicides alone. In greengram, under long-term maize-wheat-greengram cropping system, greater weed flora diversity with eight species during both the years of experiment was observed. Weed importance value varied greatly due to the crop establishment methods and weed management practices in greengram. Therefore, ZT+R with IWM (pendimethalin *fb* hand weeding) practices had significant importance in achieving higher seed yield and weed control in greengram under maize-wheat-greengram cropping system.

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