

# Effect of Tillage and Weed Management on Weed Dynamics in Maize-Redgram Cropping System

Tarannum<sup>1\*</sup> and J. Nambi<sup>2</sup>, A. Sundari<sup>3</sup>, A.P. Srinivasaperumal<sup>4</sup> and K.R. Sarvanan<sup>5</sup>

<sup>1,2,3,4</sup>Faculty of Agriculture, Department of Agronomy, Annamalai University, Annamalai Nagar 608 002, T.N., India

<sup>5</sup>Faculty of Agriculture, Department of Genetics and Plant Breeding, Annamalai University, Annamalai Nagar 608002, T.N., India

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## ABSTRACT

The field experiments were conducted at Annamalai University Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai Nagar, Tamil Nadu, India. The first crop of maize during rabi and the second crop redgram was sown during summer seasons of 2024 and 2025. Maize variety P3302 and VBN (Rg3) variety of red gram were taken in the experiments. Main plot includes four tillage practices viz., M<sub>1</sub>: maize- red gram(ZT- CT), M<sub>2</sub>: Maize - red gram (CT -ZT), M<sub>3</sub>:maize- red gram(ZT- ZT) and M<sub>4</sub>: maize- red gram (CT- CT) and sub plot includes Four weed management practices viz. S<sub>1</sub>- Two hand weeding on 15 and 30 DAS in both maize and redgram, pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+ hand weeding on 30 DAS in maize and Pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS in red gram (S<sub>2</sub>), Pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+post Emergence application of Halosulfuron methyl + atrazine @ 0.596 a.i kg ha<sup>-1</sup> in maize and Pre emergence of Pendimethalin 0.75 a.i kg ha<sup>-1</sup>+ post emergence application of quizalopethyl +imazethapyr @ 0.10g a.i kg ha<sup>-1</sup>(S<sub>3</sub>) and unweeded control (S<sub>4</sub>) were allocated in a split-plot design replicated thrice. The findings indicated that weed parameters and yield of maize- redgram were markedly influenced by the different tillage and weed management practices. Among the assessed tillage practices CT-CT (M<sub>4</sub>) resulted in lower weed count, higher weed control efficiency and greater values of growth and parameters in both the crops. Concerning the array of weed management practices the treatment Pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+ hand weeding on 30 DAS in maize and Pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS in red gram(S<sub>2</sub>) resulted in the lower weed count maximum weed control efficiency and higher values yield parameters in both the crops which was at par with pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+Post Emergence application of halosulfuron methyl + atrazine @ 0.596 a.i kg ha<sup>-1</sup>in maize and Pre emergence of pendimethalin 0.75 a.i kg ha<sup>-1</sup>+ post emergence application of quizalopethyl +imazethapyr @ 0.10g a.i kg ha<sup>-1</sup>(S<sub>3</sub>). In terms of interactions CT-CT with Pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+ hand weeding on 30 DAS in maize and Pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS in red gram (M<sub>4</sub>S<sub>2</sub>) was registered as best treatment which was on par with CT-CT along with Pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+post emergence application of halosulfuron methyl + atrazine @ 0.596 a.i kg ha<sup>-1</sup> in maize and pre emergence of pendimethalin 0.75 a.i kg ha<sup>-1</sup>+ post emergence application of quizalopethyl +Imazethapyr @ 0.10g a.i kg ha<sup>-1</sup>(M<sub>4</sub>S<sub>3</sub>), whereas the least values were obtained under ZT-ZT with unweeded control (M<sub>3</sub>S<sub>4</sub>) in both the crops.

**Key words:** Tillage, Metolachlor, Halosulfuron methyl + atrazine, Quizalopheyl +Imazethapyr, and Weed characters.

## Introduction

Cereal-legume cropping systems are fundamentally important for sustainable agriculture, primarily due to their complementary ecological advantages. Legumes like red gram enhance soil fertility by fixing atmospheric nitrogen, reducing the need for synthetic nitrogen fertilizers for the succeeding cereal crop like maize. This rotation also improves soil health and structure by diversifying rooting patterns and increasing soil organic matter. Furthermore, the alternation of crop families effectively disrupts the life cycles of pests, diseases, and weeds, leading to reduced infestation and stable, high yields while minimizing environmental impact. (Jha *et al.*, 2020). Despite its benefits, weed infestation remains the most significant biotic constraint in the maize-red gram sequence, competing aggressively for light, moisture, and nutrients. Uncontrolled weeds can lead to severe, yield-limiting losses, ranging from 40-70% in maize and often exceeding 80% in red gram due to its slow initial growth and prolonged duration (Nambi, 2017; Minhas *et al.*, 2023). The persistence of tough perennial weeds, such as *Cyperus rotundus* (purple nutsedge) and *Cynodon dactylon* (Bermuda grass), is exacerbated by their ability to regenerate from underground vegetative propagules (tubers/rhizomes), making conventional weeding or single-dose herbicide application largely ineffective (Rudell *et al.*, 2023). Moreover, poor canopy development in the initial stages of both crops creates a conducive environment for weed emergence and unchecked growth.

Effective and sustainable weed control necessitates an Integrated Weed Management (IWM) approach, combining cultural, mechanical, and chemical methods to keep weed populations below the economic threshold. The success of IWM is heavily dependent on the chosen Tillage system, as tillage greatly influences weed seed dynamics, soil health, and crop establishment (Minhas *et al.*, 2023). Conventional tillage reduces early weed populations by burying seeds deep into the soil and provides a clean seedbed, but it leads to accelerated soil organic matter decomposition, higher fuel consumption, and increased costs. Conversely, Zero Tillage (ZT) involves direct seeding without disturbing the soil, which significantly conserves moisture, reduces ero-

sion and lowers costs. However, ZT results in the concentration of weed seeds and residue near the surface, often increasing the germination of annual grasses and perennial weeds, necessitating a greater reliance on precise chemical control (Saravanan, 2018; Singh *et al.*, 2019). Despite the initial weed challenge, the long-term benefit of ZT includes improved soil structure, enhanced water infiltration, and better root penetration, particularly for deep-rooted crops like red gram.

The synergy between optimized tillage, the maize-red gram cropping sequence, and weed Management is vital for enhancing system productivity and mitigating weed infestation, especially in rainfed areas. Strategic tillage (like vertical/minimum tillage) improves soil structure and moisture retention, boosting red gram's deep root growth and subsequent maize performance, while IWM, combining precise herbicides with cultural practices, targets the specific weed flora promoted by the chosen tillage system. This integrated approach effectively suppresses persistent perennials and the soil seedbank, leading to increased resource-use efficiency and profitability (Singh *et al.*, 2019; Minhas *et al.*, 2023).

Therefore, this study aims to evaluate the synergistic influence of different tillage practices and integrated weed management strategies on weed dynamics *viz.*, weed count, biomass and weed control efficiency and productivity in maize - red gram cropping system.

## Materials and Methods

Field experiments were carried out during the rabi and summer seasons of 2024 and 2025 at the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Tamil Nadu, India, situated at 11°24' N latitude, 79°44' E longitude and an altitude of 5.79 m above mean sea level. The study was conducted in a split-plot design with three replications and four treatments. The main plot treatments comprised four different tillage practices, M<sub>1</sub>: Zero tillage in maize-Conventional tillage in redgram; M<sub>2</sub>: Conventional tillage in maize- Zero tillage in redgram; M<sub>3</sub>- Zero tillage in maize- Zero tillage in redgram; M<sub>4</sub>- Conventional tillage in maize- Conventional tillage in redgram,

while the four sub-plot treatments consisted of various weed management practices *viz.* Two hand weeding on 15 and 30 DAS in both maize and redgram (S<sub>1</sub>), Pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+ hand weeding on 30 DAS in maize and pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS in red gram(S<sub>2</sub>), Pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup> + post emergence application of halosulfuron methyl + atrazine @ 0.596 a.i kg ha<sup>-1</sup> in maize and pre emergence of pendimethalin 0.75 a.i kg ha<sup>-1</sup>+ post emergence application of quizalofopethyl +imazethapyr @ 0.10g ai kg ha<sup>-1</sup>(S<sub>3</sub>) and unweeded control(S<sub>4</sub>). The maize variety P3302 and the redgram variety VBN (Rg3) were used. Maize was sown at a spacing of 60 × 20 cm using 20 kg seed ha<sup>-1</sup> with a depth of 2-3 cm, while redgram seedlings, raised initially in polybags at the age of 21 days, were transplanted into the main field after the harvest of maize. Field preparation varied according to the assigned tillage treatments. Under zero tillage, seeds were dibbled into previous crop stubbles with minimal soil disturbance, whereas conventional tillage involved irrigation followed by primary tillage with a tractor-drawn cultivator and rotavator to achieve fine tilth. Fertilizer application for maize consisted of 150:75:75 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O ha<sup>-1</sup>, with 25% N and full P and K applied basally, 50% N at 25 DAS and the remaining 25% N at 45 DAS. Redgram was applied with 25:50:25 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O ha<sup>-1</sup> as basal application. Pre-emergence herbicides of metolachlor and pendimethalin were applied at 3 DAS, while post-emergence herbicides of halosulfuron-methyl + atrazine for maize and quizalofop-ethyl + imazethapyr for redgram were sprayed at 25 DAS according to treatment schedules. Hand weeding were performed as per the respective treatments. Irrigations were given immediately after sowing or transplanting, followed by life irrigations and subsequent irrigations based on crop requirement. Plant protection measures were adopted based on economic threshold levels. Maize was harvested at physiological maturity and grain yield was recorded at 12% moisture. Redgram was harvested when 80% pods turned brown, and the seed yield was recorded at 18% moisture. Weed observations included identification of dominant weed flora, total weed count and weed dry weight at 30 and 60 DAS using a 0.25 m<sup>2</sup> quadrat. Weed control efficiency was calculated fol-

lowing standard formulae of  $\frac{WDC - WDT}{WDC} \times 100$ .

## Result and Discussion

### Effect of tillage and weed management practices on weed density

Maize was infested with *Cynodon dactylon*, *Echinochloa acolonum*, *Panicum repens*, *Cyperus rotundus*, *Cyperus difformis*, *Cleome viscosa*, *Euphorbia hirta*, *Trianthema portulacastrum*, *Digeria arvensis*, *Phyllanthus niruri* and Red gram was infested with *viz.* *Echinochloa acolonum*, *Dactyloctenium aegyptium*, *Cleome viscosa*, *Euphorbia hirta*, *Phyllanthus niruri*, *Acalypha indica*, *Eclipta alba*, *Cynodon dactylon*, *Echinochloa acolonum*, and *Dactyloctenium aegyptium*, *Cyperus rotundus* and *Cyperus difformis*.

### Total weed density

The data presented in Table 1 indicates that at 60 DAS weed density was strongly influenced by tillage and weed management practices and their interactions. Conventional tillage at all the stages significantly registered lower weed density in maize I where as zero tillage recorded the higher weed density at all the stages. In second year significantly lower weed density was recorded in CT-CT at all the stages. This might be due to tillage which caused the inversion of weed seeds, bringing buried seeds to the surface soil and burying the emerged weed seeds through ploughing while ZT-ZT noticed the higher total weed density due to the deposition of weed seeds and propagules on the upper surface of the soil Upasani *et al.*, 2017.

Among the weed management treatments, pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup> + hand weeding on 30 DAS in maize recorded significantly lower weed density which was at par with pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup> + post emergence application of halosulfuron methyl + atrazine @ 0.596 a.i kg ha<sup>-1</sup> whereas the highest weed density was observed in un weeded control S<sub>4</sub> (357.19 m<sup>-2</sup>). Metolachlor is a chloroacetamide herbicide which inhibits cell division in germinating weed seedlings by suppressing shoot and root growth, thereby providing effective early- season control of grasses and certain broad leaved weeds. The post emergence application of halosulfuron methyl being a ALS inhibitor effectively controls sedges along with the atrazine which

is a photosystem II inhibitor controls the broad leaved, this ensured the control of later emerging weeds. These findings are similar with Garkhal *et al.* (2024); Joshi *et al.* (2025). The interaction effect between tillage practices and weed management practices was statistically significant. Continuous conventional tillage with Pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+ hand weeding on 30 DAS (M<sub>4</sub>S<sub>2</sub>) recorded the lowest value of total weed density by contrast continues ZT recorded significantly recorded higher weed count under unweeded control (M<sub>3</sub>S<sub>4</sub>).

In redgram the total weed density at 60DAS was significantly influenced by tillage and weed management practices. The conventional tillage in redgram recorded significantly lower weed count while zero tillage registered the higher weed density at all the stages. In second year significantly lower weed density was noticed in CT-CT as presented in (Table 2) whereas the highest weed count was observed in ZT-ZT. Improved performance under conventional tillage based cropping system can be attributed to improved soil tilth which disrupted the weed seed bank and suppressed early weed emergence when compared with zero tillage (Gosh *et al.*, 2025)

Among weed management treatments pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS in red gram (S<sub>2</sub>) registered the lowest weed count which is on par with pre emergence of pendimethalin 0.75 a.i kg ha<sup>-1</sup>+ post emergence application of quizalopethyl + imazethapyr @ 0.10g a.i kg ha<sup>-1</sup>(S<sub>3</sub>) whereas the highest weed count was observed in un weeded control (S<sub>4</sub>). This is because pendimethalin which is a dinitroaniline inhibits the cell division by disrupting microtubule formation in germinating weed seedlings, thereby effectively controlling early emerging grass and some broad leaved weeds. Subsequent hand weeding or post emergence application of quizalopethyl which is an ACCase inhibitor effective against grassy weeds combined with imazethapyr which acts as ALS inhibitor controls the broad leaved weeds and sedges. This ensured the later weed emergence (Gram *et al.*, 2024; Kaur *et al.*, 2025).

The interactions effects revealed that continues conventional tillage with Pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS (M<sub>4</sub>S<sub>2</sub>) recorded the lowest weed count whereas highest weed density was observed in zero tillage

under unweeded control (M<sub>3</sub>S<sub>4</sub>). Continuous conventional tillage combined with pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS (M<sub>4</sub>S<sub>2</sub>) resulted in the lowest weed count because soil inversion under CT buries a major portion of weed seeds deeper in the profile, reducing germination, while pre emergence application provides strong residual control of early-emerging grasses and the HW at 30 DAS eliminates escaped cohorts. In contrast, continuous zero tillage recorded the highest weed density under unweeded control S<sub>4</sub> (Nedeljkovic *et al.*, 2021).

### Group wise weed density

The occurrence of grasses, sedges and broad leaved weeds was influenced by both tillage and weed management as the data pertained in table 1. Conventional tillage received lower grassy and broad leaved weeds at all the stages in maize I and in maize II CT-CT recorded the lesser grass and broad leaved weeds at all the stages likely due to uprooting of the weeds and incorporation of the weed seeds in the soil by mechanical tillage practice. Zero tillage recorded the higher density of grassy and broad leaved weeds and as it could not cause much disturbance to vegetative propagules of grassy weeds (Maqbol *et al.*, 2022; Selvakumar and Ariraman 2023 and Adamiè and Leskovšek, 2024). The same trend was followed in redgram. The lower weed count was observed in pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+ hand weeding on 30 DAS in maize and pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS in red gram (S<sub>2</sub>), which was on par with pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup>+ post Emergence application of halosulfuron methyl + atrazine @ 0.596 a.i kg ha<sup>-1</sup> in maize and pre emergence of pendimethalin 0.75 a.i kg ha<sup>-1</sup>+ post emergence application of quizalopethyl + imazethapyr @ 0.10g a.i kg ha<sup>-1</sup> (S<sub>3</sub>) in both maize and redgram. Among weed management strategies, pre emergence application of metolachlor/ pendimethalin + HW (S<sub>2</sub>) and pre emergence application + post emergence application of combinations (S<sub>3</sub>) ensured prolonged suppression of early and late flushes, resulting in significantly lower grasses up to 60 DAS

The prevalence of sedges was influenced by both tillage and weed management treatments. Among the tillage practices higher weed count was observed in ZT-ZT whereas lower count was regis-

Table 1. Effect of tillage and weed management on weed density

Treatment	Total weed density						Grasses						Sedges						Broad leaf					
	Maize		Redgram		Maize		Redgram		Maize		Redgram		Maize		Redgram		Maize		Redgram		Maize		Redgram	
	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II		
M <sub>1</sub>	76.77 (8.79)	40.98 (6.44)	76.78 (8.79)	36.22 (6.06)	41.04 (6.44)	21.38 (4.67)	21.73 (4.71)	10.03 (3.24)	11.15 (3.41)	21.23 (4.66)	19.59 (4.48)	41.28 (6.46)	12.56 (3.61)	8.44 (2.98)	13.77 (3.77)	6.59 (2.66)								
M <sub>2</sub>	71.54 (8.48)	53.01 (7.31)	68.92 (8.33)	41.92 (6.51)	39.04 (6.28)	27.68 (5.30)	18.76 (4.38)	11.29 (3.43)	14.19 (3.83)	19.93 (4.52)	22.30 (4.77)	37.66 (6.17)	14.49 (3.87)	11.12 (3.40)	12.72 (3.67)	8.32 (2.97)								
M <sub>3</sub>	81.50 (9.05)	64.41 (8.05)	87.70 (9.39)	53.35 (7.33)	43.54 (6.63)	33.73 (5.85)	24.28 (4.97)	15.01 (3.93)	17.42 (4.23)	22.66 (4.81)	28.12 (5.35)	48.56 (7.00)	10.84 (3.36)	12.06 (3.54)	14.85 (3.91)	10.21 (3.27)								
M <sub>4</sub>	64.75 (8.07)	34.74 (5.93)	60.02 (7.77)	30.37 (5.55)	35.50 (6.00)	18.26 (4.33)	16.19 (4.08)	8.20 (2.95)	9.23 (3.12)	18.39 (4.34)	15.88 (4.04)	32.92 (5.75)	15.29 (3.97)	8.69 (3.03)	11.05 (3.39)	6.28 (2.60)								
S.Ed±	0.05	0.02	0.06	0.09	0.08	0.05	0.05	0.04	0.01	0.07	0.08	0.02	0.07	0.04	0.02	0.19								
CD(P=0.5)	0.11	0.06	0.12	0.05	0.18	0.03	0.11	0.11	0.03	0.03	0.03	0.05	0.18	0.12	0.04	0.34								
S <sub>1</sub>	54.46 (7.41)	25.51 (5.1)	39.75 (6.34)	20.43 (4.57)	29.85 (5.50)	8.84 (3.05)	11.5 (3.46)	5.57 (2.46)	8.84 (3.05)	15.56 (4.00)	11.23 (3.42)	22.91 (4.83)	9.05 (3.09)	6.41 (2.62)	5.23 (2.39)	3.62 (2.02)								
S <sub>2</sub>	29.84 (5.50)	19.10 (4.42)	24.69 (5.01)	48.39 (6.99)	17.55 (4.24)	3.96 (2.10)	7.23 (2.78)	3.55 (2.01)	3.96 (2.10)	8.48 (2.99)	6.50 (2.64)	14.23 (3.83)	3.81 (2.07)	2.55 (1.74)	3.41 (1.97)	2.03 (1.59)								
S <sub>3</sub>	31.66 (5.67)	15.49 (3.99)	26.45 (5.19)	58.45 (7.67)	18.32 (4.33)	6.23 (2.59)	7.80 (2.88)	4.08 (2.14)	6.23 (2.59)	9.06 (3.09)	7.35 (2.80)	14.79 (3.91)	4.27 (2.18)	3.59 (2.02)	3.85 (2.08)	3.17 (1.91)								
S <sub>4</sub>	178.59 (13.38)	137.6 (11.7)	202.6 (14.2)	114.7 (10.7)	93.40 (9.69)	36.97 (5.78)	54.43 (7.41)	31.33 (5.64)	36.97 (5.78)	49.12 (7.04)	60.80 (7.82)	108.4 (10.4)	36.05 (6.04)	27.77 (5.31)	39.91 (6.35)	22.59 (4.80)								
S.Ed±	0.08	0.09	0.18	0.13	0.14	0.05	0.06	0.06	0.05	0.05	0.09	0.07	0.25	0.13	0.03	0.25								
CD(p=0.5)	0.16	0.20	0.31	0.26	0.28	0.10	0.12	0.13	0.10	0.11	0.21	0.16	0.46	0.28	0.06	0.38								
M <sub>1</sub> S <sub>1</sub>	55.45 (7.33)	19.53 (4.47)	40.24 (6.38)	15.99 (4.06)	30.03 (5.25)	9.92 (3.22)	12.19 (3.56)	4.32 (2.19)	7.48 (2.82)	16.01 (4.06)	8.45 (2.99)	23.07 (4.85)	9.12 (3.10)	4.13 (2.15)	4.98 (2.33)	3.21 (1.93)								
M <sub>1</sub> S <sub>2</sub>	32.27 (5.54)	11.08 (3.40)	28.13 (5.35)	8.75 (3.04)	18.29 (4.33)	5.91 (2.53)	8.05 (2.92)	2.71 (1.79)	2.99 (1.86)	9.03 (3.08)	4.92 (2.32)	15.93 (4.05)	2.34 (1.68)	2.18 (1.63)	4.14 (2.15)	1.12 (1.27)								
M <sub>1</sub> S <sub>3</sub>	34.77 (5.75)	11.93 (3.52)	29.52 (5.47)	10.16 (3.26)	19.02 (4.41)	6.01 (2.55)	9.39 (3.14)	2.92 (1.84)	5.03 (2.35)	9.89 (3.22)	5.1 (2.36)	15.99 (4.06)	2.8 (1.81)	2.88 (1.83)	4.15 (2.16)	2.14 (1.62)								
M <sub>1</sub> S <sub>4</sub>	184.59 (13.44)	121.4 (11.0)	209.2 (14.4)	109.9 (10.5)	96.82 (9.86)	63.7 (8.01)	57.31 (7.60)	30.19 (5.53)	29.12 (5.44)	50.02 (7.10)	59.89 (7.77)	110.1 (10.5)	35.98 (6.03)	24.57 (5.00)	41.18 (6.49)	19.90 (4.51)								
M <sub>2</sub> S <sub>1</sub>	53.55 (7.35)	31.91 (5.69)	38.47 (6.24)	23.07 (4.85)	29.22 (5.45)	16.7 (4.14)	11.12 (3.40)	6.02 (2.55)	11.72 (3.49)	15.21 (3.96)	12.49 (3.60)	22.79 (4.82)	9.41 (3.14)	6.49 (2.64)	4.56 (2.24)	4.55 (2.24)								
M <sub>2</sub> S <sub>2</sub>	27.05 (5.2)	13.17 (3.69)	20.17 (4.54)	13.20 (3.70)	17.22 (4.20)	7.02 (2.74)	6.23 (2.59)	3.92 (2.10)	3.83 (2.08)	7.49 (2.82)	7.03 (2.74)	11.84 (3.51)	4.95 (2.33)	2.32 (1.67)	3.1 (1.89)	2.25 (1.65)								
M <sub>2</sub> S <sub>3</sub>	28.88 (5.42)	14.05 (3.81)	21.78 (4.72)	15.73 (4.02)	17.95 (4.29)	7.11 (2.75)	6.44 (2.63)	3.99 (2.11)	6.02 (2.55)	8.13 (2.93)	7.93 (2.90)	12.12 (3.55)	5.86 (2.52)	2.92 (1.84)	3.22 (1.92)	3.81 (2.07)								
M <sub>2</sub> S <sub>4</sub>	176.67 (13.28)	152.9 (12.3)	195.2 (13.9)	115.6 (10.7)	91.77 (9.60)	79.9 (8.96)	51.28 (7.19)	31.23 (5.63)	35.22 (5.97)	48.92 (7.02)	61.77 (7.89)	103.8 (10.2)	37.75 (6.18)	32.78 (5.76)	40.03 (6.36)	22.68 (4.81)								
M <sub>3</sub> S <sub>1</sub>	60.37 (7.80)	37.77 (6.18)	48.55 (7.00)	32.66 (5.78)	33.13 (5.79)	20.03 (4.53)	13.92 (3.79)	8.98 (3.07)	10.23 (3.27)	17.1 (4.19)	27.92 (4.29)	27.92 (5.33)	7.54 (2.83)	7.51 (2.83)	6.71 (2.68)	5.66 (2.47)								
M <sub>3</sub> S <sub>2</sub>	37.23 (6.06)	25.81 (5.12)	36.89 (6.11)	21.35 (4.67)	20.72 (4.60)	14.03 (3.81)	10.63 (3.33)	6.27 (2.60)	7.12 (2.76)	10.49 (3.31)	11.39 (3.44)	21.92 (4.73)	1.93 (1.55)	4.66 (2.27)	4.34 (2.2)	3.68 (2.04)								
M <sub>3</sub> S <sub>3</sub>	38.86 (6.27)	29.97 (5.52)	38.73 (6.26)	25.66 (5.11)	21.39 (4.67)	15.1 (3.94)	11.29 (3.43)	7.52 (2.83)	9.90 (3.22)	11.03 (3.39)	12.91 (3.65)	22.94 (4.84)	2.00 (1.58)	6.97 (2.73)	4.5 (2.23)	5.23 (2.39)								

Table 1. Continued ....

Treatment	Total weed density						Grasses						Sedges						Broad leaf						
	Maize		Redgram		Maize		Redgram		Maize		Redgram		Maize		Redgram		Maize		Redgram		Maize		Redgram		
	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II	-I	-II			
M <sub>3</sub> S <sub>4</sub>	189.54 (13.91)	226.6 (15.0)	164.0 (12.8)	133.7 (11.5)	98.92 (9.97)	85.79 (9.28)	61.28 (7.85)	37.29 (6.14)	52.03 (7.24)	42.43 (6.55)	121.4 (11.0)	70.18 (8.40)	31.91 (5.69)	29.13 (5.44)	43.87 (6.65)	26.28 (5.17)	24.12 (4.84)	15.78 (4.03)	6.89 (2.71)	14.92 (3.92)	8.13 (2.11)	8.13 (2.11)	1.59 (0.42)	3.56 (0.93)	
M <sub>4</sub> S <sub>1</sub>	48.48 (6.83)	31.74 (5.67)	12.83 (3.65)	10.02 (3.24)	27.02 (5.24)	7.84 (2.88)	8.77 (3.04)	2.99 (1.86)	13.92 (3.79)	5.94 (2.53)	17.88 (4.28)	5.98 (2.54)	10.14 (3.26)	7.51 (2.83)	4.69 (2.27)	1.05 (1.24)	163.56 (12.80)	179.25 (13.4)	112.0 (10.6)	99.52 (10.0)	51.39 (9.89)	51.39 (9.89)	24.63 (5.01)	33.92 (5.86)	
M <sub>4</sub> S <sub>2</sub>	22.83 (4.62)	13.31 (3.71)	7.25 (2.78)	5.08 (2.36)	13.97 (3.80)	3.19 (1.92)	4.02 (2.12)	1.31 (1.34)	6.93 (2.72)	1.9 (1.54)	7.23 (2.78)	2.69 (1.78)	6.02 (2.55)	1.06 (1.24)	2.06 (1.59)	1.08 (1.25)	0.10 (0.14)	0.11 (0.11)	0.12 (0.12)	0.07 (0.07)	0.08 (0.08)	0.13 (0.13)	0.24 (0.24)	0.04 (0.04)	
M <sub>4</sub> S <sub>3</sub>	24.12 (4.84)	15.78 (4.03)	6.89 (2.71)	6.89 (2.71)	14.92 (3.92)	3.77 (2.06)	4.09 (2.14)	1.89 (1.54)	7.2 (2.77)	3.98 (2.11)	8.13 (2.93)	3.48 (1.99)	6.44 (2.63)	1.59 (1.44)	3.56 (2.01)	1.52 (1.42)	0.21 (0.14)	0.25 (0.14)	0.25 (0.14)	0.23 (0.14)	0.23 (0.14)	0.29 (0.18)	0.42 (0.22)	0.09 (0.33)	
M <sub>4</sub> S <sub>4</sub>	163.56 (12.80)	179.25 (13.4)	112.0 (10.6)	99.52 (10.0)	86.12 (9.30)	58.24 (7.66)	47.88 (6.95)	26.63 (5.20)	45.53 (6.78)	25.13 (5.06)	98.44 (9.89)	51.39 (7.20)	38.59 (6.25)	24.63 (5.01)	33.92 (5.86)	21.49 (4.68)	S.Ed±	0.10	0.14	0.12	0.07	0.08	0.13	0.24	0.04
S.Ed±	0.10	0.11	0.14	0.12	0.15	0.07	0.10	0.12	0.10	0.08	0.13	0.17	0.44	0.24	0.04	0.37	CD(P=0.5)	0.21	0.25	0.23	0.14	0.23	0.29	0.42	0.09

tered in CT-CT. In ZT-ZT, sedges like *Cyperus* spp. thrive due to minimal soil disturbance, which preserves moist surface conditions and allows vegetative propagules to persist and spread in the undisturbed topsoil. Conversely, CT-CT reduces sedge density through repeated soil inversion that disrupts rhizomes, exposes them to desiccation, and buries propagules beyond their optimal germination depth (Pratibha *et al.*, 2021). Sedge count was reportedly lower in pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup> + post emergence application of halosulfuron methyl + atrazine @ 0.596 a.i kg ha<sup>-1</sup> in maize and pre emergence of pendimethalin 0.75 a.i kg ha<sup>-1</sup> + post emergence application of quizalofenyl + imazethapyr @ 0.10g a.i kg ha<sup>-1</sup> (S<sub>3</sub>) which was on par with pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup> + hand weeding on 30 DAS in maize and pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup> + hand weeding on 30 DAS in red gram (S<sub>2</sub>) whereas the higher weed count was observed in unweeded control (S<sub>4</sub>) which was unweeded control. This is because residual effect of the pre emergence herbicides metolachlor and pendimethalin suppressed early tuber/seed germination, post emergence sedge-active herbicides (halosulfuron-methyl + atrazine, quizalofenyl + Imazethapyr) controlled later escaped weeds and hand-weeding at 30 DAS removed survivors before re-establishment, producing season-long reduction in sedges (Lakshmi and Luther, 2017).

### Weed Control efficiency

Weed control efficiency was significantly influenced by tillage and weed management treatments at 60 DAS as presented in the Table 2. WCE was found significantly higher in conventional tillage in comparison to zero tillage at almost all growth stages due to difference in total weed density. Higher weed control efficiency was found in CT-CT which was followed by CT-ZT. Among weed management practices higher weed control efficiency was obtained with pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup> + hand weeding on 30 DAS in maize (S<sub>2</sub>) which was followed by pre emergence application of metolachlor @ 1.25 a.i kg ha<sup>-1</sup> + halosulfuron methyl + atrazine @ 0.596 a.i kg ha<sup>-1</sup> (S<sub>3</sub>). In redgram the effective weed control was found in CT based treatments when compared with ZT based treatments. The highest WCE was found in CT-CT which was followed by ZT-CT. Weed management showed higher weed control efficiency

**Table 2.** Effect of tillage and weed management on weed control efficiency and yield

Treatment	Weed control efficiency			
	Maize-I	Red gram-I	Maize-II	Red gram-II
M <sub>1</sub>	59.49	72.91	66.12	72.91
M <sub>2</sub>	62.25	68.65	69.58	68.65
M <sub>3</sub>	56.99	60.10	61.30	60.10
M <sub>4</sub>	65.83	76.88	73.51	76.88
S.Ed±	-	-	-	-
CD(P=0.5)	-	-	-	-
S <sub>1</sub>	71.26	84.72	82.46	84.72
S <sub>2</sub>	84.25	90.54	89.13	90.54
S <sub>3</sub>	83.29	89.07	88.32	89.07
S <sub>4</sub>	5.77	14.22	10.60	14.22
S.Ed±	-	-	-	-
CD(P=0.5)	-	-	-	-
M <sub>1</sub> S <sub>1</sub>	70.74	88.04	82.24	88.04
M <sub>1</sub> S <sub>2</sub>	82.97	93.45	87.58	93.45
M <sub>1</sub> S <sub>3</sub>	81.65	92.40	86.97	92.40
M <sub>1</sub> S <sub>4</sub>	2.61	17.77	7.67	17.77
M <sub>2</sub> S <sub>1</sub>	71.74	82.74	83.02	82.74
M <sub>2</sub> S <sub>2</sub>	85.72	90.12	91.09	90.12
M <sub>2</sub> S <sub>3</sub>	84.76	88.23	90.38	88.23
M <sub>2</sub> S <sub>4</sub>	6.78	13.51	13.84	13.51
M <sub>3</sub> S <sub>1</sub>	68.14	75.58	78.57	75.58
M <sub>3</sub> S <sub>2</sub>	80.35	84.03	83.72	84.03
M <sub>3</sub> S <sub>3</sub>	79.49	80.81	82.91	80.81
M <sub>3</sub> S <sub>4</sub>	0	0	0	0
M <sub>4</sub> S <sub>1</sub>	74.42	92.50	85.99	92.50
M <sub>4</sub> S <sub>2</sub>	87.95	94.57	94.12	94.57
M <sub>4</sub> S <sub>3</sub>	87.27	94.84	93.03	94.84
M <sub>4</sub> S <sub>4</sub>	13.70	25.59	20.91	25.59
S.Ed±	-	-	-	-
CD(P=0.5)	-	-	-	-

in pre emergence pre emergence application of pendimethalin 0.75 kg ha<sup>-1</sup>+ hand weeding on 30 DAS in red gram (S<sub>2</sub>)(87.33%) which was on par with pendimethalin 0.75 a.i kg ha<sup>-1</sup>+ post emergence application of quizalophepyl +imazethapyr @ 0.10g a.i kg ha<sup>-1</sup> (S<sub>3</sub>)and lower value was obtained in unweeded control (S<sub>4</sub>). Higher grassy-weed density under zero tillage is mainly attributed to the accumulation of viable seeds in the undisturbed 0–10 cm soil layer. In contrast, continuous conventional tillage density because repeated soil inversion by ploughing, harrowing and cross-cultivation buries seeds into deeper layers and destroys newly emerged seedlings (Stanzen *et al.*, 2017). This is because the early herbicide application effectively controlled the first weed flush, while manual weeding removed surviving and late-emerging weeds, ensur-

ing season-long suppression. This integrated approach was superior to two hand-weedings because this often allow early weed–crop interference before the first weeding (Patel *et al.*, 2016 and Debela *et al.*, 2023)

### Authors' contributions

Tarannum contributed to conceptualization, data curation and writing of the original draft. J. Nambi was involved in conceptualization, supervision, funding acquisition, writing, review and editing. A. Sundari contributed to methodology, validation and writing of the original draft. A.P. Srinivasaperumal participated in writing original draft and editing. K.R. Sarvanan contributed to resources, visualization, methodology, writing, review and editing. All authors read and approved the final manuscript.

### Compliance with ethical standards

**Conflict of interest:** On behalf of all authors, the corresponding author declares that there is no conflict of interest.

**Ethical issues:** None

### Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this article, the effects used “Quill bot” in order to improve language of readability. After that, the author carefully reviewed and edited the content as required and takes full responsibility for the content of the publications.

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