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Kazi Aliza Ahmed
Department of Agronomy, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India

B Duary
Department of Agronomy, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India

Wasim Iftikar4
Department of Agronomy, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India

Corresponding Author:
B Duary
Department of Agronomy, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India

Effect of tillage and weed management practices on weed growth and productivity of maize-greengram cropping sequence

Kazi Aliza Ahmed, B Duary and Wasim Iftikar

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Abstract
A field experiment was conducted during *rabi* 2017-18 and summer 2018 at farmer's field of Muluk village, Birbhum, West Bengal to evaluate the effect of tillage and weed management practices on weed growth and yield of *rabi* maize and greengram. Maize hybrid DKC 9081 and Samrat (PDM 139) variety of greengram were taken in the experiment. Four tillage practices *viz,* conventional tillage (CT) in maize - CT in greengram, CT (Maize) - Zero tillage (ZT) (greengram), ZT (maize) - CT (greengram) and ZT (maize) - ZT (greengram), and three weed management practices *viz.* recommended herbicide (atrazine at 0.625 kg ha^{-1} in maize and pendimethalin at 0.75 kg ha^{-1} in greengram), herbicide combination (tembotrione at 90 g ha^{-1} + atrazine at 500 g ha^{-1} at 20 DAS in maize and pendimethalin at 0.75 kg ha^{-1} followed by imazethapyr at 75 g ha^{-1} in greengram at 20 DAS) and unweeded control were allocated in a strip-plot design replicated thrice. *Rabi* maize was infested with six weed species *viz. Cynodon dactylon*, *Digitaria sanguinalis, Croton bonplandianum*, *Polygonum plebeium* and *Grangea maderaspatana* and *Cyperus iria* whereas *C. dactylon*, *Echinochloa colona*, *Murdania nudiflora*, *Fimbristylis miliacea* and *C. rotundus* were present in greengram. Zero tillage (ZT) based practices were observed to have higher weed pressure compared to conventional tillage (CT) based practices both in maize and greengram. Conventional tillage registered significantly lower total weed density (17.66 m^{-2} - in CT-CT and 17.76m^{-2} in CT-ZT) than ZT based practices (24.93 m^{-2} in ZT-CT and 24.60 m^{-2} in ZT-ZT). CT-CT also registered significantly the lowest total weed biomass (11.07 g m^{-2}) at 45 DAS. In greengram also, CT-based systems recorded significantly lower total weed density and dry weight than ZT-based systems. In maize, herbicide combination recorded significantly higher yield (9062 kg ha^{-1}) than that of recommended herbicide (8202 kg ha^{-1}) and weedy check (6259 kg ha^{-1}), while tillage practices did not differ significantly. CT-CT produced the highest yield (1034 kg ha^{-1}) of greengram, whereas ZT-ZT recorded significantly the lowest (761 kg ha^{-1}). Herbicide combination (1128 kg ha^{-1}) and recommended herbicide (1058 kg ha^{-1}) both were at par and outperformed the weedy check (584 kg ha^{-1}) regarding seed yield of greengram.

Keywords: Conventional tillage, greengram, herbicide combination, imazethapyr, pendimethalin, *rabi* maize, tembotrione, weed management, zero tillage

Introduction
The maize-green gram cropping sequence exemplifies an efficient and sustainable cereal-legume rotation, delivering multiple agronomic and ecological advantages. The contrasting rooting patterns and crop residues disrupt the life cycles of soil-borne pests and pathogens, aiding in natural pest and disease management. Additionally, when properly managed, the sequence helps suppress weeds by altering weed flora and depleting the weed seedbank over time. Green gram further contributes to soil health by boosting microbial activity, enhancing nutrient cycling, and enriching soil organic matter, which in turn improves the growth and yield potential of subsequent maize crops. Weed infestation is a major yield-limiting factor in both *rabi* maize and summer green gram in India. In maize, wide row spacing and open canopies during early growth favor weed emergence, causing 27-90% yield losses if unmanaged (Dalley *et al*., 2006 [1]; Kumar *et al*., 2015[2]). In green gram, yield losses range from 31-75% under irrigated conditions (Kaur *et al*., 2016) [3]. Persistent perennials like *Cyperus rotundus* and *Cynodon dactylon* survive conventional weeding, while gaps in herbicide timing or dosage lead to escapes that replenish the soil seedbank, affecting the succeeding crop.

Effective weed control in maize reduces seedbank carryover and weed pressure in green gram. An integrated weed management approach combining timely pre- and post-emergence herbicides, mechanical methods and cultural practices is essential to improve establishment, productivity, and profitability of the maize-green gram sequence.

Tillage strongly affects weed dynamics, soil health, and productivity in the maize-green gram sequence. Conventional tillage reduces weed populations by burying seeds and improving seedbed conditions (Jaiswal *et al*., 2024) [4], while conservation tillage conserves moisture, reduces erosion, and lowers costs but may increase surface weed seed germination, requiring adapted management (Jat *et al*., 2012) [5]. Well-planned tillage enhances maize establishment, residue incorporation, and moisture conservation for summer green gram, ultimately improving resource-use efficiency, reducing costs, and supporting the long-term sustainability of the system. A single herbicide application can reduce early weed pressure but often fails to provide season-long control, especially for perennials (e.g., *Cyperus rotundus*, C*ynodon dactylon*) and late-germinating weeds. Tank mixes of herbicides in maize provide broad-spectrum weed control, enhance efficacy against tough weeds, aid resistance management, and reduce labor and costs. Integrating optimized herbicide strategies with suitable tillage is the key to sustaining productivity in the maize-green gram system. In conventional tillage, weed seed burial allows reduced herbicide use without losing control. Combining tillage choice with site-specific herbicide programs suppresses weeds, conserves moisture, recycles nutrients, and lowers costs, enhancing both crops' performance. This study evaluates weed growth and crop productivity of maize- green gram cropping sequence as influenced by tillage and weed management practices.

Materials and Methods

Experimental period and location

A field study was conducted in maize-greengram cropping sequence during *rabi* and summer season of the year 2027- 18 at farmers' fields in Muluk village, located approximately at 23.6544° N latitude, 87.7197° E longitude with an elevation of about 59 m above mean sea level within Bolpur-Sriniketan Block of Birbhum district, West Bengal, India. The soil in the experimental field was a sandy loam (*Ultisol*) with low organic carbon (0.42%), low available N (289.4 kg ha^{-1}), medium available P (27.16 kg ha^{-1}) and medium available K (193.21 kg ha^{-1}). The pH of soil was 6.12 (acidic), measured in a 1:2.5 soil to water ratio.

Experimental design and treatments details

The experiment was conducted in a strip-plot design, with four tillage practices *viz.*, Conventional tillage (CT) in *rabi* maize and CT in greengram (CT-CT), Conventional tillage (CT) in maize and zero tillage (ZT) in greengram (CT-ZT), ZT in maize and CT in greengram (ZT-CT) and ZT in maize ZT in greengram (ZT-ZT) in horizontal strip and three weed management practices in the vertical strips, which were replicated thrice. Three weed management practices were recommended herbicide (atrazine at 0.625 kg ha^{-1} in maize and pendimethalin at 0.75 kg ha^{-1} in greengram) (W_1), herbicide combination (tembotrione at 90 g ha^{-1} + atrazine at 500 g ha^{-1} at 20 DAS in maize and pendimethalin at 0.75 kg ha^{-1} followed by imazethapyr at 75 g ha^{-1} in greengram at 20 DAS) (W_2) and unweeded control (W_3).

Crop management and recording of observations

Maize hybrid DKC 9081 and Samrat (PDM 139) variety of greengram were taken in the experiment. The row spacing in maize was 60 cm for maize and 30 cm for greengram. A uniform fertilizer dose of 160 kg N, 80 kg P_2O_5, and 80 kg K_2O per hectare was applied to maize. One-third of the nitrogen, the full dose of phosphorus (P_2O_5) and half the dose of potassium (K_2O) were applied as a basal application at sowing. At 25 days after sowing (DAS), half of the remaining K_2O along with one-third of the nitrogen was applied as the first top-dressing, and the final one-third of nitrogen was applied at 45 DAS as the second top-dressing. For greengram, the recommended dose of 20:40:40 kg ha^{-1} of N, P_2O_5, and K_2O was followed. The entire dose of P_2O_5 and K_2O was applied at sowing, while the remaining nitrogen, accounting for the N content not supplied by DAP (which contains 18% N), was applied as basal through urea. Weed density and biomass were measured by counting and removing all weeds that were inside 50 cm × 50 cm quadrat from the designated sampling area in each plot. The collected weeds were then dried in a hot air oven at 72ºC to determine weed biomass and expressed in g m^{-2}. The yield of both grain/seed and straw/stover was recorded and expressed in kg ha^{-1}.

Methods of statistical analysis

The square root [$\sqrt{X+0.5}$] transformation was made applicable to the weed data, and the resulting data was then used for analysis. The data was statistically analyzed at a 5% level of significance, following the procedure as described by Gomez and Gomez (1984) [6]. The table on weed data includes both the transformed values and the original data in parenthesis.

Results and Discussion

Effect on weeds

The experimental field was infested with 3 categories of weeds comprising six species in maize and five in greengram. Major weeds present in the experimental field were *Cynodon dactylon, Digitaria sanguinalis, Croton bonplandianum, Grangea maderaspatana, Polygonum plebeium* and *Cyperus iria* in maize and *Cynodon dactylon, Echinocloa colona, Murdania nudiflora*, *Fimbristylis miliacea* and *Cyperus rotundus* in greengram. Similar patterns of weed flora have also been reported by Singh *et al*. (2017) [7], Barla *et al*. (2016) [8] and Kumar and Singh (2020) [9] in maize and Duary *et al.* (2014) [10], Ghosh *et al*. (2023) [11] and Kumar *et al*. (2023) [12] in greengram.

Total weed density and biomass at 45 DAS

The total weed density at 45 DAS in maize was significantly influenced by tillage, weed management practices and their interactions (Table 1). Zero tillage (ZT) based practices were observed to have higher weed pressure compared to conventional tillage (CT) based practices. Conventional tillage registered significantly lower weed density (17.66 m^{-2} - in CT-CT and 17.76m^{-2} in CT-ZT) than ZT based practices (24.93 m^{-2} in ZT-CT and 24.60 m^{-2} in ZT-ZT). The improved practice *i.e.* herbicide combination (W_2) provided complete control of total weeds, whereas the weedy check (W_3) recorded the highest infestations (59.51m^{-2}). Under the recommended herbicide treatment (W_1), total weed density was significantly reduced to 29.6 m^{-2}. Relative to W_3, W_2 achieved 100% reduction, while W_1 suppressed weed populations by 50% only. The interaction effects revealed that under W_1 and W_3, ZT-ZT and ZT-CT recorded significantly higher total weed density when compared with CT-based systems. By contrast improved herbicide combination (W_2) ensured complete control across tillage systems, emphasizing its reliability in total weed management at later crop stages.

In greengram also the total weed density at 45 DAS was significantly influenced by tillage and weed management practices. The conventional tillage in greengram registered significantly lower weed infestation (CT-CT- 10.89 m^{-2} and ZT-CT- 11.94 m^{-2}) than the zero tillage (CT-ZT- 12.69 m^{-2} and ZT-ZT- 13.07 m^{-2}) (Table 2). Conventional tillage based system (CT-CT) registered the lowest weed infestation (10.89 m^{-2}) than those of remaining treatments and ZT-ZT registered the highest weed pressure (13.07 m^{-2}). The herbicide combination treatment (W_2) showed complete control of weeds (0.00 m^{-2}), whereas the weedy check treatment (W_3) recorded the highest infestations (55.54 m^{-2}). Also, the sole application of recommended herbicide (W_1) drastically reduced the weed density (5.60 m^{-2}) in greengram. As compared with weedy check treatment (W_3), W_2 recorded 100% weed suppression whereas W_1 was able to suppress the weeds by 89%. The interaction effects revealed that under W_1, CT-CT and ZT-CT registered significantly lower weed infestation as compared with remaining two treatments. Whereas, under W_3 only the treatment CT-CT recorded significantly the lowest weed infestation than rest of the treatments and reduced the weed density by 16.6% from ZT-ZT.

Like density the total weed biomass was also significantly influenced by tillage, weed management, and their interactions at 45 DAS. Among the tillage practices, ZT-CT recorded the highest mean value (86.23 g m^{-2}), followed by ZT-ZT (80.64 g m^{-2}), and both were significantly higher than CT-CT (61.23 g m^{-2}) and CT-ZT (57.66 g m^{-2}), indicating a tendency for greater total weed biomass accumulation under zero tillage systems. Improved weed management (W_2) exhibited complete suppression of total weeds across all tillage practices, recording no biomass and was significantly lower than W_1 (91.44 g m^{-2}) and W_3 (226.22 g m^{-2}). Recommended herbicide (W_1) also recorded significantly lower biomass than W_3, with a weed control efficiency of nearly 60%. The interactions were statistically significant, confirming that weed biomass varied across tillage and weed management combinations. The combination of ZT-CT under W_3 produced the highest biomass (288.84 g m^{-2}), closely followed by ZT-ZT (275.95 g m^{-2}), while CT-based systems recorded significantly lower values (176.02-176.55 g m^{-2}), reflecting better weed control. The W×T interaction further emphasized that CT-based tillage combined with weed management was more effective in suppressing weed growth. Recommended herbicide (W_1) provided intermediate control compared to W_2 and W_3, demonstrating partial efficacy of the recommended herbicide in reducing total weed biomass, while W_2 completely suppressed total weeds and recorded zero biomass at 45 DAS, indicating the efficiency of improved weed management practices to control weeds and increase productivity. Lowest weed density and biomass was observed in continuous conventional tillage (CT-CT) in maize wheat cropping system by earlier workers (Stanzen *et al.*, 2017) [13]. Repeated inversions of soil destroy the establishment of weed propagules in the plow zone, while reduction in an inversion of soil shifts weed communities from annual dicots to small-seeded annual and perennial grasses (Choudhary *et al*., 2015) [14], and minimizes the weed seed bank. Tillage works as primary cause of the vertical distribution of weeds by uprooting, destruction of food storage organs, burying deep and mixing in the soil (Sherestha *et al.*, 2002) [15].

In greengram total weed biomass at 45 DAS was significantly affected by tillage and weed management practices and their interaction. Among the tillage practices CT-CT resulted with significantly the lowest (11.07 g m^{-2}) total weed biomass. Whereas ZT-ZT recorded the highest total weed biomass (14.51 g m^{-2}) at 45 DAS. The treatment CT-CT registered 23.7% lower dry weight as compared to ZT-ZT. As the improved practice of herbicide combination (W_2) recorded no weed population the dry biomass of weed under the treatment was also nil, whereas the unweeded control (W_3) resulted with the highest total weed biomass (59.06 g m^{-2}). The recommended herbicide (W_1) was also able to reduce the total weed dry weight (6.37 g m^{-2}) to a good extent, which was 89.2% lower as compared with weedy check treatment (W_3). The interactions among treatments revealed that under W_1 and W_3 the treatment CT-CT recorded significantly the lowest total weed biomass (4.59 g m^{-2} and 51.93 g m^{-2}, respectively) as compared with other treatments.

Yield of maize and greengram

Maize

The seed yield of maize was significantly influenced by weed management practices whereas the effect of tillage practices and interaction effects remained statistically non-significant. During the study year, seed yield ranged from 6,170 to 9,169 kg ha^{-1} across the treatments (Table 3). Among tillage systems, the mean yields were fairly comparable, ranging from 7,799 to 7,882 kg ha^{-1}, suggesting that the effect of tillage alone was negligible in the initial year. However, weed management exerted a pronounced influence on yield of maize. The improved weed management (W_2) recorded the highest mean grain yield (9,062 kg ha^{-1}) of maize which was significantly higher over recommended practice (8,202 kg ha^{-1} in W_1) and weedy check (6,295 kg ha^{-1} in W_3), reflecting substantial yield loss due to unchecked weed competition. The difference between W_2 and W_1 was statistically significant and 11.4% yield advantage indicating the superiority of improved weed management in realizing higher productivity.

It was evident that weed management, rather than tillage, was the decisive factor governing maize productivity in the initial year. Continuous adoption of zero tillage exhibited a tendency to reduce maize yield, whereas a rotational tillage approach appeared more effective and convincing in sustaining higher productivity. The results indicated that yield optimization in maize is governed more by the extent of weed suppression than by the tillage regime itself. Therefore, the adoption of improved weed management practices is crucial for minimizing yield losses and ensuring higher productivity of maize under different tillage-based cropping sequences in the initial year.

Greengram

Seed yield of greengram was significantly influenced by both tillage and weed management practices, while their interaction effects were found to be non-significant. Among tillage practices, the highest mean seed yield was obtained under CT-CT (1034 kg ha^{-1}) which was significantly higher than ZT-CT (761 kg ha^{-1}) and ZT-ZT (915 kg ha^{-1}) and at par with CT-ZT (982 kg ha^{-1}), whereas ZT-CT produced significantly lower yield than rest of the tillage practices. Weed management practices also showed a significant effect, with W_1 (1058 kg ha^{-1}) and W_2 (1128 kg ha^{-1}) being statistically at par and both significantly superior over W_3 (584 kg ha^{-1}) (Table 3). This clearly indicates that adoption of either recommended (W_1) or improved (W_2) weed control practices substantially enhanced seed yield over weedy check. The combined effects of tillage and weed management did not show any significant difference, suggesting that the influence of weed management was consistent across all tillage systems in the initial year of the cropping sequence. The data also revealed that maintaining an effective weed control regime is more crucial than tillage choice in achieving higher greengram productivity. Conventional tillage and weed management practices that promote weed suppression and efficient resource utilization contribute to higher seed yield, biological yield, and harvest index, ultimately enhancing the overall productivity of green gram cultivation. In conventional tillage practice the combination of herbicide, specifically pendimethalin (pre-emergence) followed by imazethapyr (post-emergence), resulted in higher pod yield in greengram (Indra *et al.*, 2024) [16].

Table 1: Effect of tillage and weed management practices on total weed density and biomass in maize at 45 DAS

Treatments	Total weed density (No.m^{-2}) at 45 DAS				Total weed biomass (gm^{-2}) at 45 DAS			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
CT-CT	5.16	0.71	6.91	4.26	9.56	0.71	13.31	7.86
	(26.17)*	(0.00)	(47.26)	(17.66)	(90.86)	(0.00)	(176.55)	(61.23)
CT-ZT	5.05	0.71	7.07	4.27	8.89	0.71	13.29	7.63
	(24.96)	(0.00)	(49.45)	(17.76)	(78.46)	(0.00)	(176.02)	(57.66)
ZT-CT	5.92	0.71	8.50	5.04	10.22	0.71	17.01	9.31
	(34.57)	(0.00)	(71.73)	(24.93)	(103.98)	(0.00)	(288.84)	(86.23)
ZT-ZT	5.81	0.71	8.51	5.01	9.69	0.71	16.63	9.01
	(33.30)	(0.00)	(71.92)	(24.60)	(93.37)	(0.00)	(275.95)	(80.64)
Mean	5.49	0.71	7.75		9.59	0.71	15.06	
	(29.60)	(0.00)	(59.51)		(91.44)	(0.00)	(226.22)	
	T	W	T×W	W×T	T	W	T×W	W×T
S.Em (±)	0.07	0.04	0.10	0.09	0.20	0.12	0.25	0.21
LSD (P=0.05)	0.23	0.15	0.40	0.30	0.68	1.00	0.99	0.64

*Figures within parentheses indicate original values and the data were transformed to $\sqrt{(X + 0.5)}$ before analysis; DAS = Day after sowing: CT-Conventional tillage: ZT- Zero tillage

Table 2: Effect of tillage and weed management practices on total weed density and biomass in greengram at 45 DAS

Treatments	Total weed density (No.m^{-2}) at 45 DAS				Total weed biomass (gm^{-2}) at 45 DAS			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
CT-CT	2.18	0.71	7.24	3.37	2.26	0.71	7.24	3.40
	(4.26)	(0.00)	(51.85)	(10.89)	(4.59)	(0.00)	(51.93)	(11.07)
CT-ZT	2.63	0.71	7.56	3.63	2.76	0.71	7.91	3.79
	(6.40)	(0.00)	(56.66)	(12.69)	(7.14)	(0.00)	(62.01)	(13.88)
ZT-CT	2.27	0.71	7.60	3.53	2.51	0.71	7.76	3.66
	(4.65)	(0.00)	(57.32)	(11.94)	(5.82)	(0.00)	(59.73)	(12.90)
ZT-ZT	2.80	0.71	7.54	3.68	2.95	0.71	7.96	3.87
	(7.33)	(0.00)	(56.41)	(13.07)	(8.23)	(0.00)	(62.88)	(14.51)
Mean	2.47	0.71	7.49		2.62	0.71	7.72	
	(5.60)	(0.00)	(55.54)		(6.37)	(0.00)	(59.06)	
	T	W	T×W	W×T	T	W	T×W	W×T
S.Em (±)	0.05	0.03	0.07	0.06	0.06	0.06	0.09	0.09
LSD (P=0.05)	0.18	0.13	0.28	0.19	0.21	0.22	0.34	0.26

*Figures within parentheses indicate original values and the data were transformed to $\sqrt{(X + 0.5)}$ before analysis; DAS = Day after sowing: CT-Conventional tillage: ZT- Zero tillage

Table 3: Effect of tillage and weed management practices on grain yield of maize and seed yield of greengram

Treatments	Grain yield (kg ha^{-1}) of maize				Seed yield (kg ha^{-1}) of greengram			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
CT-CT	8133	9013	6251	7799	1206	1190	706	1034
CT-ZT	8321	9141	6252	7905	1145	1222	580	982
ZT-CT	8047	8925	6508	7827	900	856	528	761
ZT-ZT	8307	9169	6170	7882	979	1245	523	915
Mean	8202	9062	6295		1058	1128	584	
	T	W	T×W	W×T	T	W	T×W	W×T
S.Em (±)	147.82	110.69	247.85	238.28	29	22	57	58
LSD (P=0.05)	NS	434.60	NS	NS	102	85	NS	NS

CT-Conventional tillage: ZT- Zero tillage

Conclusion

The study highlights the significant impact of tillage and weed management practices on yield of both *rabi* maize and greengram. Across various tillage practices, significant improvements in yield were observed under weed management with herbicides compared to unweeded check. Thus, it can be concluded that the conventional tillage in *rabi* maize along with herbicide combination of tembotrione at 90 g ha^{-1} + atrazine at 500 g ha^{-1} at 20 DAS and conventional or zero tillage with pre-emergence herbicide pendimethalin at 0.75 kg ha^{-1} alone or sequential application of pre-emergence followed by post emergence imazethapyr at 75 g ha^{-1} in greengram appeared to be promising for effective weed management and higher productivity of maize and greengram in lateritic soil of West Bengal in the initial year.

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