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RESEARCH ARTICLE

Evaluation of different planting methods and herbicides for weed management in maize and their residual effect on succeeding wheat crop

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ABSTRACT

Maize (*Zea mays* L.) production is affected by severe weed infestation due to frequent rainfall during wet season (*Kharif*) and inadequate interculture practices adoption by farmers. Thus, alternative integrated weed management practices need to be developed for effective management of weeds in maize. Hence, an experiment was conducted, during 2020-21 and 2021-22, using strip plot design with ten planting methods in main plots and four weed control treatments in sub plots. Greater grassy, broad-leaved and sedges density reduction along with maximum wheat and maize yield was observed with the raised bed wide bed planting with paddy residue (6 t/ha) *fb* zero till (ZT) wheat reshaping of beds, compared to sowing of maize with pneumatic planter without residues *fb* ZT wheat which had maximum density of all types of weeds. Surface mulching of paddy residue and sowing of maize on raised bed wide bed planting *fb* ZT wheat reshaping of beds reduced grassy (86.0-89.0%), broad-leaved weeds (44.8-50.8%) and sedges (80.2-83.5%) density significantly as compared to the same planting methods without surface mulching. The higher reduction in weed biomass of grassy (79.3-80.7%), broad-leaved weeds (82.4-84.1%) and sedges (82.7-87.8%), in comparison to weedy check, was recorded with tembotrione 120 g/ha. Tembotrione 120 g/ha PoE at 15 DAS recorded the highest gross returns, net returns and highest B:C ratio, due to the lowest cost of cultivation, during both years of study.

Keywords: Economics, Maize-wheat cropping system, Pneumatic planter, Ridge sowing, Tembotrione, Topramezone, Weed management

INTRODUCTION

Maize (*Zea mays* L.) is an important crop grown under wider agroecological conditions and considered as potential drivers of crop diversification. With an area of over 1.8 million ha, maize-wheat cropping system is the third most important cropping system in India, after rice-wheat and rice-rice, and contributes about 3% to the country's food basket. Maize has the largest genetic yield potential among cereal crops. It is grown on 205.9 million hectares of land worldwide, producing 1210.2 million tons of grain with an average yield of 5.88 t/ha. In India, maize is the third most significant cereal crop, after rice and wheat, with a 9.9-million-hectares area, 31.7 million tons of production, and an average grain yield of 3.12 t/ha (Anonymous 2024a). In Haryana, the *Kharif* season's maize acreage is approximately 9300 ha, with production of roughly 28000 tons and an average productivity of 3.01 t/ha (Anonymous 2024b).

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Weeds are the important limiting factor causing significant yield losses in crops. Agronomic practices, such as tillage (Wasnik *et al.* 2022), establishment methods (Khedwal *et al.* 2023), sowing time, surface mulching (Khedwal *et al.* 2017) etc. also influence the weeds infestation. The residue retention was reported to lower density and reduced biomass of all type of weeds under different methods of maize planting (Khedwal et a. 2017). Use of rice straw mulch at 9.00 t/ha produced significantly lower weed biomass as compared to 6.25 t/ha rice straw mulch and no mulch treatments (Kaur *et al.* 2020) as straw mulch alters the microclimatic conditions of the soil surface, which in turn affects the weed spectrum (Ghimire *et al.* 2017). Mulch reduces the quantity of solar radiation available, which inhibits the growth of undesirable weeds.

Among the herbicidal treatments in maize, tembotrione at 120 g/ha registered the lowest density and biomass of grassy weeds, broad-leaved weeds and sedges (Sharma *et al.* 2018). The higher weed control efficiency with post-emergence application (PoE) of topramezone + atrazine 25.2 + 250 g/ha and tembotrione + atrazine 105 + 250 g/ha was reported earlier (Swetha *et al.* 2018). However, limited studies are available on interactive effect of planting methods, surface mulching and herbicides against weeds in maize and succeeding wheat. Hence, this study was conducted with an objective to evaluate the efficacy of planting methods, paddy residue mulching and herbicides in managing weeds and improving productivity of maize and succeeding wheat.

MATERIALS AND METHODS

Experimental site and design

The experiment was conducted at Regional Research Station, Karnal of CCS Haryana Agricultural University, Hisar during 2020-21and 2021-22. The experiment was laid out in strip plot design with ten planting methods (**Table 1**) and four weed control treatments and replicated thrice. The cropping system was initiated with maize in *Kharif* 2020. The strip plot treatments were fixed in same plots for two years study. The plots were prepared as per treatments *i.e*. two harrowing + two ploughings followed by planking as preparatory tillage for the ridge sowing with dibbling method, multi crop ridge planter, pneumatic maize planter and raised bed wide bed planter whereas in zero tillage treatment, no tillage operation was carried out during the first-year crop of maize.

The herbicide treatments, in sub plots, were: weed free check, weedy check, post-emergence application (PoE) of tembotrione 120 g/ha and topramezone 25.2 g/ha PoE. The herbicides were applied by the knapsack sprayer fitted with flat fan nozzle with water volume 375 l/ha at 15 days after sowing (DAS). In wheat cropping season *i.e*., two harrowing + two ploughings followed by planking were done as preparatory tillage for conventional sowing of wheat crop in the ridge sowing with dibbling method and multi crop ridge planter, whereas in raised bed wide bed planting method the reshaping of beds done as permanent beds; in zero tillage treatment and pneumatic maize planter treatment, no tillage operations were carried out first year wheat crop season. The seed bed was prepared after applying pre-sowing irrigation as per the treatments. Single cross maize hybrid HQPM 1 and wheat variety HD 2967 was used for sowing. Ridger, multi crop ridge planter, raised bed wide bed planter, pneumatic maize planter and zero-till seed-cum-fertilizer drill was used for sowing of maize crop with row-to-row distance of 60 cm and plant to plant 20 cm. For wheat crop sowing zero-till seed-cum-fertilizer drill was used for sowing across conventional and zero tillage plots keeping row to row distance of 20 cm. The sowing of wheat crop was done on raised bed wide bed planter with reshaping of bed and keeping the row-to-row distance 20 cm on bed.

Crop management

Recommended seed rate of 25 kg/ha for maize and 100 kg/ha for wheat was used for sowing. The maize crop was sown on 3rd and 6th July during *Kharif* 2020 and 2021 and wheat crop was sown on 17th and 11th November during *Rabi* 2020-21 and 2021-22, respectively. In maize crop, recommended dose of nitrogen (150 kg N/ha), phosphorus (60 kg P_2O_5/ha) and potash (60 kg K_2O/ha were applied. The fertilizers were schedule as, 1/3rd dose of nitrogen and full dose of phosphorus and potash as basal, remaining 2/3rd nitrogen was applied as top dressing in two splits after 1st at knee height stage and 2nd at initiation of tasseling stage in both the seasons. In wheat crop, recommended dose of nitrogen (150 kg/ha), phosphorus (60 kg P/ha), potash (40 kg K/ha) and zinc sulphate 21% (25 kg/ha) were applied as per the schedule of: 1/3rd dose of nitrogen and full dose of phosphorus, potash and zinc at sowing time, remaining 2/3rd nitrogen was applied as top dressing in two splits after 1st and 2nd irrigation in both the seasons. The maize crop was harvested manually on 6th October and 8th October, during *Kharif* 2020 and 2021, respectively. The wheat crop was harvested on 19th and 15th April, during *Rabi* 2020-21 and 2021-22, respectively.

Observation recorded and data analysis

Weeds samples were taken from two randomly selected spots in each plot at 20, 40 and 60 DAS and

Table 1. Detail of the treatments

Planting methods	
M_1	Zero-tillage sowing with press wheel (with paddy residues 6 t/ha) *fb* zero till wheat (ZTW)
M_2	Zero-tillage sowing with press wheel (without residues) *fb* ZTW
M_3	Ridge sowing with dibbling method (with paddy residues 6 t/ha) *fb* conventional till wheat (CTW)
M_4	Ridge sowing with dibbling method (without residues) *fb* CTW
M_5	Multi crop ridge planter (with paddy residues 6 t/ha) *fb* CTW
M_6	Multi crop ridge planter (without residues) *fb* CTW
M_7	Raised bed wide bed planter (with paddy residues 6 t/ha) *fb* ZTW (reshaping of beds)
M_8	Raised bed wide bed planter (without residues) *f* ZTW (reshaping of beds)
M_9	Pneumatic maize planter (with paddy residues 6 t/ha) *fb* ZTW
M_{10}	Pneumatic maize planter (without residues) *fb* ZTW

in wheat crop at 30, 60 and 90 DAS using quadrat measuring 0.5 m x 0.5 m. The grassy weeds, broad-leaved weeds and sedges were collected separately. The samples were oven dried at 70^{0}C till constant weight was achieved. Then dried weed samples weighed and the dry weight was expressed as weed biomass (g/m^2) before subjecting to statistical analysis. Grain yield of maize was recorded after harvesting of cobs at physiological maturity from net plot area (4 middle rows leaving 2.0 m on each side). The harvested cobs were air dried, shelled and grains were cleaned and weighed from each plot. Grain yield/ha was computed and expressed in t/ha. Grains of wheat crop were separated with the help of plot thresher and yield was recorded from each net plot area. The grain yield thus obtained from net plot area was converted into t/ha. Data collected during the study were statistically analysed by using the technique of analysis of variance.

RESULTS AND DISCUSSION

Weed infested

In *Kharif* season, observed major broad-leaved weeds were: *Trianthema portulacastrum, Phyllanthus niruri, Commelina benghalensis, Amaranthus viridis, Convolvulus arvensis.* and *Euphorbia hirta*. Among grassy weeds, *Cynodon dactylon, Dactyloctenium aegyptium, Leptocloa chinesis, Digitaria sanguinalis, Sorghum halepense and Echinochloa crus-galli* were dominant. Among sedges, *Cyperus rotandus* was the major weed infesting in field. In *Rabi* season, broad-leaved weeds observed were: *Rumex dentatus, Medicago denticulata, Coronopus didymus, Anagallis arvensis, Cirsium arvense, Convolvulus arvensis, Fumaria parviflora, Malva parviflora*, while, grassy weeds were: *Phalaris minor* and *Avena ludoviciana*.

Weed density and biomass in maize

In present study, weed density and biomass was significantly affected by different planting methods and weed management treatments. Among planting methods, raised bed wide bed planter with paddy residues 6 t/ha *fb* zero till wheat (ZTW) reshaping of beds resulted in significantly lower density compared to rest of the treatments, but statistically at par with zero-tillage sowing with press wheel (with paddy residues 6 t/ha) *fb* ZTW at 20 and 60 DAS during both years (**Table 2**). At 60 DAS, raised bed wide bed planter with paddy residues 6 t/ha *fb* ZTW reshaping of beds reduced grassy, broad- leaved and sedges density by 94.5-94.9%, 70.6-72.4% and 89.5-91.4%, respectively during the study years as compared to sowing of maize with pneumatic planter without residues *fb* ZTW, having maximum density of all

Table 2. Effect of different planting methods and weed management treatments on weed density (no. /m^2) at 20 and 60 DAS in maize 2021 and 2022

Treatment	2021						2022					
	20 DAS			60 DAS			20 DAS			60 DAS		
	Broad-leaved	Grasses	Sedges	Broad-leaved	Grasses	Sedges	Broad-leaved	Grasses	Sedges	Broad-leaved	Grasses	Sedges
Planting methods												
M_1	2.3(3.6)	2.2 (2.2)	2.8 (4.7)	3.3 (7.5)	3.0 (6.0)	3.8 (12.5)	2.7 (4.2)	2.6 (3.5)	3.1 (6.0)	3.5 (9.2)	3.2 (7.2)	4.0 (14.5)
M_2	3.4 (8.1)	5.0 (22.5)	4.1 (13.0)	3.7 (12.0)	5.7 (34.8)	5.3 (31.7)	3.6 (9.2)	5.3 (25.7)	4.5 (6.1)	4.0 (13.8)	5.9 (37.2)	5.4 (33.5)
M_3	3.2 (6.7)	2.9 (4.8)	3.6 (9.2)	3.5 (9.3)	3.6 (10.7)	4.9 (24.2)	3.5 (8.2)	3.3 (6.5)	3.8 (10.3)	3.8 (11.0)	3.8 (12.3)	5.1 (26.2)
M_4	4.5 (16.2)	5.8(31.0)	5.4 (25.5)	4.3 (17.3)	7.0 (53.8)	6.3 (44.2)	4.6 (17.8)	6.1 (35.3)	5.7 (29.3)	4.5 (19.2)	7.3 (56.8)	6.5 (47.0)
M_5	3.5 (8.3)	3.3 (7.0)	4.0 (11.8)	4.1 (13.7)	3.9 (12.7)	5.0 (26.2)	3.7 (9.8)	3.5 (8.5)	4.1 (13.3)	4.3 (15.3)	4.2 (14.8)	5.3 (28.5)
M_6	4.9 (20.3)	6.2 (37.0)	5.7 (29.8)	4.6 (20.5)	7.3 (59.3)	6.6 (51.3)	5.2 (23.3)	6.7 (43.5)	6.1 (34.3)	4.8 (2.3)	7.5 (62.2)	6.8 (53.7)
M_7	2.6 (3.5)	2.0 (1.5)	2.5 (3.0)	3.1 (6.2)	2.6 (3.5)	2.8 (4.8)	2.5 (3.0)	2.2 (1.9)	2.6 (3.7)	3.2 (7.2)	2.8 (4.8)	3.1 (6.3)
M_8	3.2 (6.6)	4.7(18.3)	3.9 (11.2)	3.7 (11.2)	5.4 (31.8)	5.2 (29.3)	3.3 (7.7)	4.8 (20.2)	4.0 (12.0)	3.9 (14.7)	5.6 (34.5)	5.4 (31.8)
M_9	3.6(8.8)	3.5(8.3)	4.1 (13.0)	4.3 (15.3)	4.2 (14.7)	5.3 (19.2)	3.7 (10.0)	3.7 (10.0)	4.2 (14.2)	4.5 (17.0)	4.4 (16.5)	5.5 (31.2)
M_{10}	4.9(20.7)	6.4 (40.0)	4.4(16.6)	7.7 (64.1)	7.0 (56.1)	5.5 (24.2)	6.6 (42.7)	6.1 (34.1)	4.5 (19.0)	7.9 (67.3)	7.2 (60.1)	7.2 (60.1)
LSD (p=0.05)	0.4	0.3	0.4	0.4	0.5	1.0	0.4	0.4	0.5	0.5	0.4	0.97
Weed management												
W_1	1.0 (0.0)	1.0 (0.0)	1.0 (0.00)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
W_2	4.8(16.2)	6.0 (32.0)	5.7 (24.9)	6.7 (34.4)	9.0 (76.4)	10.1(91.0)	5.1 (18.3)	6.3 (35.1)	6.0 (28.3)	7.0 (37.5)	9.3 (80.4)	10.3 (95.3)
W_3	4.3(12.1)	4.8 (18.2)	4.9 (16.7)	3.9 (9.1)	4.9 (18.9)	4.6 (13.7)	4.5(13.8)	5.2 (21.4)	5.2 (19.4)	4.2 (10.9)	5.2 (21.5)	4.9 (16.7)
W_4	4.4(12.9)	4.9 (18.8)	5.2 (20.0)	4.2 (10.6)	5.2 (21.2)	5.2 (19.0)	4.6 (14.8)	5.3 (22.5)	5.4 (21.8)	4.5 (12.7)	5.5 (23.5)	5.4 (21.1)
LSD (p=0.05)	0.45	0.5	0.4	0.6	0.5	0.6	0.5	0.4	0.5	0.7	0.7	0.7

*Original figures in parentheses were subjected to square root transformation $(\sqrt{x+1})$ before statistical analysis.

ZT sowing with press wheel with (M_1) and without (M_2) paddy residues 6 t/ha *fb* ZTW; Ridge sowing with dibbling method with (M_3) and without (M_4) paddy residues 6 t/ha *fb* CTW Multi crop ridge planter with (M_5) and without (M_6) paddy residues 6 t/ha *fb* CTW; Raised bed wide bed planter with (M_7) and without (M_8) paddy residues 6 t/ha) *fb* ZTW (reshaping of beds); Pneumatic maize planter with (M_9) and without (M_{10}) paddy residues 6 t/ha) *fb* ZTW; W_1: Weed free check, W_2: Weedy check, W_3: Tembotrione 120 g/ha at 15 DAS and W_4: Topramezone 25.2 g/ha at 15 DAS

types of weeds. Moreover, maize planting with raised bed wide bed planter with paddy residues 6 t/ha *fb* ZTW reshaping of beds reduced grassy, broad-leaved and sedges biomass by 97.4-97.9%, 86.4-87.2% and 91.2-93.0%, respectively during the study years, as compared to sowing with pneumatic planter without residues *fb* ZTW, having maximum biomass of all types of weeds.

The surface mulching of paddy residue and sowing of maize on raised bed wide bed planter *fb* ZTW reshaping of beds reduced biomass of grassy (93.1-94.5%), broad-leaved (66.0-66.5) and sedges (46.6-86.7%) significantly as compared to without surface mulching for the same planting system. Zero tillage with and without surface mulching resulted in reduced weed biomass as compared to conventional ridge sowing with and without surface mulching with paddy residue. The reduction in biomass of grassy weed due to surface mulching of paddy residue was similar in ZT sowing with press wheel *fb* ZTW (80.7-82.8%) and ridge sowing with dibbling method (78.30-86.1%), while higher for sedges in former planting system (56.7-60 *vs* 44.3-45.3%) (**Table 3**). While, reduction in broad-leaved weeds was more in ridge sowing with dibbling method (42.5-46.2%) as compared to ZT sowing with press wheel (33.7-37.5%). Raised bed planting method resulted in lower weed density which increased water and nutrient use efficiency confirming findings of Fahong *et al.* (2004) and Ali and Seyedeh (2008). Govaerts *et al.* (2005) and Ortega *et al.* (2008) also reported that raised bed sowing method produced higher grain yield of maize and the minimum weeds biomass.

Among weed control treatments, tembotrione 120 g/ha PoE at 15 DAS resulted in significantly lower weed density of grassy, broad- leaved and sedges at 20 and 60 DAS and weed biomass at 60 DAS which was at par with topramezone 25.2 g/ha at 15 DAS, while maximum weed density was recorded in weedy check during both the years (**Table 2** ad **3**). The percentage reduction in weed density at 60 DAS in comparison to weedy check was recorded higher with tembotrione 120 g/ha i.e. grassy (73.3-75.2%), broad-leaved weed (70.8-73.5%) and sedges (82.4-84.9%) as compared to topramezone 25.2 g/ha (70.7-72.3, 66.2-69.2, 77.9-78.8%, respectively). Similarly, percentage reduction in biomass in comparison to weedy check was higher with tembotrione 120 g/ha i.e. grassy (79.3-80.7%), broad-leaved weed (82.4-84.1%) and sedges (82.7-87.8 %) as compared to topramezone 25.2 g/ha (76.6-77.5, 79.4-81.4, 81.3-82.8%, respectively). Better weed control, higher WCE were observed with topramezone + atrazine 25.2 + 250 g/ha followed by

Table 3. Effect of different planting methods and weed management on weeds biomass (g/m^2) of at 60 DAS in maize 2021 and 2022

Treatment	60 DAS (2021)			60 DAS (2022)		
	Broad-leaved	Grasses	Sedges	Broad-leaved	Grasses	Sedges
Planting methods						
M_1	2.6 (4.3)	2.1 (1.8)	1.7 (0.9)	2.8 (5.2)	2.2 (2.2)	1.8 (1.0)
M_2	3.4 (10.1)	4.4 (19.6)	2.2 (2.6)	3.6 (11.5)	4.6 (20.8)	2.3 (2.8)
M_3	3.0 (6.1)	2.6 (4.4)	2.0 (1.6)	3.2 (7.2)	2.8 (5.1)	2.1 (1.8)
M_4	4.1 (16.3)	5.8 (35.1)	2.5 (3.6)	4.3 (17.9)	6.0 (37.0)	2.5 (3.8)
M_5	3.3 (9.0)	2.8 (5.3)	2.1 (1.8)	3.6 (10.0)	3.0 (6.1)	2. 1 (1.9)
M_6	4.5 (20.8)	6.1 (39.3)	2.6 (4.2)	4.7 (22.5)	6.2 (41.1)	2.6 (4.4)
M_7	2.4 (3.1)	1.8 (0.9)	1.5 (0.3)	2.5 (3.6)	1.9 (1.3)	1.6 (0.4)
M_8	3.3 (9.2)	4.2 (16.8)	2.2 (2.4)	3.6 (10.8)	4.3 (18.2)	2.2 (2.6)
M_9	3.7 (12.2)	3.0 (5.9)	2.1 (2.0)	3.9 (13.4)	3.1 (6.7)	2.2 (2.1)
M_{10}	4.9 (24.5)	6.5 (45.4)	2.7 (4.6)	5.1 (26.5)	6.6 (47.6)	2.7 (4. 9)
LSD (p=0.05)	0.3	3.0	0.4	0.3	0.3	0.26
Weed management						
W_1	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.00 (0.0)	1.0 (0.0)	1.0 (0.0)
W_2	6.6 (34.3)	7.2 (49.3)	3.6 (7.4)	6.8 (37.2)	7.3 (51.6)	3.6 (7.7)
W_3	3.2 (5.5)	3.6 (9.5)	1.9 (0.9)	3.4 (6.6)	3.8 (10.7)	2.0 (1.3)
W_4	3.4 (6.4)	3.9 (11.1)	2.1 (1.3)	3.7 (7.7)	4.1 (12.1)	2.2 (1.4)
LSD (p=0.05)	0.5	0.3	0.2	0.6	0.4	0.3

*Original figures in parentheses were subjected to square root transformation ($\sqrt{x+1}$) before statistical analysis.
ZT sowing with press wheel with (M_1) and without (M_2) paddy residues 6 t/ha *fb* ZTW; Ridge sowing with dibbling method with (M_3) and without (M_4) paddy residues 6 t/ha *fb* CTW Multi crop ridge planter with (M_5) and without (M_6) paddy residues 6 t/ha *fb* CTW; Raised bed wide bed planter with (M_7) and without (M_8) paddy residues 6 t/ha) *fb* ZTW (reshaping of beds); Pneumatic maize planter with (M_9) and without (M_{10}) paddy residues 6 t/ha) *fb* ZTW; W_1: Weed free check, W_2: Weedy check, W_3: Tembotrione 120 g/ha at 15 DAS and W_4: Topramezone 25.2 g/ha at 15 DAS

tembotrione + atrazine 105 + 250 g/ha as observed by Jonathon *et al.* (2013) which might be due to higher efficacy of herbicides against complex weed flora.

Weed density and biomass in wheat

Raised bed wide bed planter (with paddy residues 6 t/ha) *fb* ZTW (reshaping of beds) resulted in maximum percentage reduction in density of grassy (69-72.3%) and broad-leaved weeds (71.5-75.3%) and biomass (72.5-75.6% of grassy weeds and 74.2-75.3% of broad-leaved weeds) as compared to sowing of maize with multi crop ridge planter (without residues) *fb* CTW, which resulted in maximum infestation of grassy and broad-leaved weeds at 60 DAS. Weed control treatment failed to affect significantly the weed density and biomass of broad-leaved and grassy weeds at 60 DAS during both the years (**Table 4**). Ghosh *et al.* (2021) also reported lesser weed infestation under conservation-based tillage system *i.e.* permanent beds (34%) and permanent narrow beds (28%) than the conventional tillage (CT) practice due to higher emergence of weeds in later one. Higher infestation of weeds in CT might be due to soil inversion caused by tillage, greater aeration and periodical irrigation application (Baghel *et al.* 2020). CA practices helped in preventing proliferation of weeds and minimized negative impact of weeds on crop productivity. Crop residue retention with zero tillage (ZT) could delay as well as suppress weed germination and emergence. It could be a multi-tactic approach for sustainable weed management in crop rotations, reducing the need for herbicides usage (Christoffoleti *et al.* 2007, Susha *et al.* 2014, Nath *et al.* 2016).

Maize and wheat grain yield

The grain yield is the principal criterion for evaluating efficiency of various treatments because ultimate effects of experimental variables are reflected in the form of final grain yield. It is a function of effective tillers, number of grains per spike and test weight. The maximum maize grain, stover and biological yield was obtained with raised bed wide bed planter (with rice residues 6 t/ha) *fb* ZTW (reshaping of beds) which was significantly higher than all the planting methods but at par with zero-tillage sowing with press wheel (with rice residues 6 t/ha) *fb* ZTW during both the years (**Table 5**). Narang *et al.* (2015) observed maximum grain yield with raised bed maize planter, multi-crop planter and manually operated planter

Grain yield of maize was significantly higher in weed free check as compared to weedy check, but at

Table 4. Effect of different planting methods, weed management on weeds density (no./m^2) and biomass (g/m^2) at 60 DAS in wheat 2020-21, 2021-22

Treatment	60 DAS (2020-21)				60 DAS (2021-22)			
	Broad-leaved		Grasses		Broad-leaved		Grasses	
	(No./m^2)	(g/m^2)	(No./m^2)	(g/m^2)	(No./m^2)	(g/m^2)	(No./m^2)	(g/m^2)
Planting methods								
M_1	4.8 (19.2)	4.0 (11.9)	3.1 (6.2)	2.6 (3.7)	4.9 (20.7)	4.1 (12.8)	3.4 (7.7)	3.4 (4.5)
M_2	5.2 (24.0)	4.2 (13.5)	3.3 (7.4)	2.9 (4.97)	5.1 (25.1)	4.3(14.4)	3.6 (8.9)	3.7 (5.8)
M_3	6.0 (33.0)	5.8 (31.0)	4.1 (13.3)	3.6 (9.4)	7.1 (49.6)	6.0 (33.0)	4.5 (16.3)	4.7 (11.2)
M_4	6.1 (34.9)	6.0 (32.9	4.4 (15.4)	3.9 (11.1)	7.25 (52.3)	6.1 (34.9)	4.7 (18.4)	5.0 (12.9)
M_5	6.1 (34.3)	5.8 (31.2)	4.3 (14.8)	3.8 10.2)	7.1 (49.8)	6.0 (33.2)	4.6 (17.8)	4.8 (12.0)
M_6	6.4 (38.8)	6.1 (34.2)	4.6 (17.4)	4.0 (11.7)	7.4 (54.3)	6.2 (36.2)	4.9 (20.4)	5.1 (13.5)
M_7	3.6 (9.6)	3.5 (8.4)	2.9 (4.8)	2.4 (2.9)	4.4 (15.5)	3.6 (9.4)	3.2 (6.3)	3.2 (3.7)
M_8	4.2 (13.9)	3.7 (9.6)	3.0 (5.4)	2.7 (4.1)	4.6 (17.4)	3.8 (10.5)	3.3 (6.9)	3.5 (4.9)
M_9	5.3 (24.7)	4.3 (15.0)	3.40 (7.8)	2.8 (4.5)	5.4 (25.8)	4.4 (16.0)	3.6 (9.3)	3.6 (5.4)
M_{10}	5.6 (27.8)	4.6(17.6)	3.6 (9.0)	3.1 (5.8)	5.7 (29.9)	4.7 (18.6)	3.8 (10.5)	3.9 (6.7)
LSD (p=0.05)	0.16	0.2	0.15	0.1	0.2	0.2	0.1	0.1
Weed management								
W_1	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
W_2	6.9 (36.6)	6.1 (28.3)	4.7 (14.4)	4.0 (9.9)	7.6 (46.7)	6.3 (30.1)	5.0 (17.2)	5.3 (11.6)
W_3	6.70 (34.2)	6.0 (26.3)	4.4 (12.6)	3.8 (8.4)	7.4 (43.7)	6.1 (28.1)	4.8 (15.4)	5.0 (10.1)
W_4	6.67 (33.6)	6.1 (27.6)	4.6 (13.6)	3.9 (9.0)	7.5 (45.1)	6.3 (29.5)	4.9 (16.4)	5.1 (10.6)
LSD (p=0.05)	0.6	0.5	0.6	0.5	0.6	0.5	0.5	0.6

*Original figures in parentheses were subjected to square root transformation ($\sqrt{x+1}$) before statistical analysis.
ZT sowing with press wheel with (M_1) and without (M_2) paddy residues 6 t/ha *fb* ZTW; Ridge sowing with dibbling method with (M_3) and without (M_4) paddy residues 6 t/ha *fb* CTW Multi crop ridge planter with (M_5) and without (M_6) paddy residues 6 t/ha *fb* CTW; Raised bed wide bed planter with (M_7) and without (M_8) paddy residues 6 t/ha) *fb* ZTW (reshaping of beds); Pneumatic maize planter with (M_9) and without (M_{10}) paddy residues 6 t/ha) *fb* ZTW; W_1: Weed free check, W_2: Weedy check, W_3: Tembotrione 120 g/ha at 15 DAS and W_4: Topramezone 25.2 g/ha at 15 DAS

par with tembotrione 120 g /ha at 15 DAS and topramezone 25.2 g /ha at 15 DAS during both the years. The interaction among planting methods and weed management was significant (**Table 6**). The maximum grain yield was found with planting method raised bed wide bed planter (with rice straw 6 t/ha) *fb* ZTW (reshaping of beds) with combination tembotrione 120 g/ha at 15 DAS, topramezone 25.2 g /ha at 15 DAS and weed free check followed by zero-tillage sowing with press wheel (with rice straw 6 t/ ha) *fb* ZTW with combination tembotrione 120 g/ha, topramezone 25.2 g /ha at 15 DAS and weed free check; and raised bed wide bed planter (without residues) *fb* ZTW (reshaping of beds) with combination tembotrione 120 g/ha at 15 DAS and topramezone 25.2 g /ha at 15 DAS. Higher yield and yield attributes raised bed wide bed planter with rice residues 6 t/ha *fb* ZTW reshaping of beds were due to significant reduction in weed density and biomass of grassy (94.5-94.9 and 97.4-97.9%), broad-leaved weeds (70.6-72.4 and 86.4-87.2%) and sedges (89.5-91.4 and 91.2-93.0%), respectively at stages of observations during both the study years, as compared to sowing of maize with pneumatic planter without residues *fb* ZTW, having maximum density and dry weight of all types of weeds. Kumar *et al.* (2018) also reported higher grain yield under bed planting over tillage practices along with zero tillage practices, while lowest grain yield was recorded under conventional tillage practice. Jat *et al.* (2013) also found significant effect of tillage practices on maize yield as higher grain yield was recorded under permanent bed compared to conventional tillage flat, which was statistically at par with zero tillage. Lower yield under CT was due to heavy rains that caused temporary flooding and adversely affected crop growth. Maize is known to be quite sensitive to excess water stress and yields poorly under water logged conditions (Dhillon *et al.* 1998, Lal *et al.* 1988). Kaur and Chhina (2019) studied that maximum plant height, leaf area index, dry matter accumulation, number of cobs/plant, number of grains/cob and grain yield was significantly higher in double row bed planting as compared to conventional tillage in spring maize.

The grain and straw yield of wheat increased irrespective of different planting methods. Among planting methods raised bed wide bed planter (with paddy residues 6 t/ha) *fb* ZTW (reshaping of beds) produced maximum grain yield as compared to all planting methods but statistically at par with raised bed wide bed planter (without residues) *fb* ZTW (reshaping of beds) and zero-tillage sowing with press wheel (with paddy residues 6 t/ha) *fb* ZTW, respectively during both the years (**Table 5**). Chandra

Table 5. Effect of tested planting methods and weed management treatments on yield and economics of maize- wheat cropping system during 2020-21 and 2021-22

Treatment	Maize grain yield (t/ha)		Wheat grain yield (t/ha)		Maize equivalent yield (t/ha)		Net returns (₹/ha)		B:C	
	2020	2021	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Planting methods										
M_1	9.03	9.26	5.74	5.97	14.94	15.25	149813	171769	1.73	1.84
M_2	7.28	7.44	5.59	5.82	13.03	13.30	110924	129991	1.55	1.65
M_3	8.04	8.25	5.43	5.62	13.63	13.90	98314	118088	1.42	1.52
M_4	6.45	6.67	5.30	5.58	11.91	12.29	63440	83287	1.28	1.37
M_5	7.62	7.90	5.29	5.46	13.07	13.39	92934	113333	1.42	1.51
M_6	5.64	5.87	5.23	5.57	11.03	11.48	49312	69976	1.23	1.32
M_7	9.43	9.66	6.16	6.21	15.78	15.92	157128	184941	1.73	1.88
M_8	7.64	7.89	5.96	6.10	13.57	14.03	112318	144752	1.53	1.71
M_9	7.83	7.96	5.63	5.90	13.63	13.90	111990	132318	1.52	1.62
M_{10}	6.11	6.25	5.45	5.77	11.72	12.06	72501	92561	1.34	1.44
LSD (p=0.05)	0.43	0.42	0.23	0.25	0.51	0.35	-	-	-	-
Weed management										
W_1	8.13	8.36	5.63	5.87	13.93	14.27	113026	136492	1.52	1.63
W_2	5.79	5.91	5.45	5.70	11.40	11.65	63065	81803	1.30	1.40
W_3	8.06	8.31	5.61	5.83	13.84	14.17	116382	139719	1.55	1.66
W_4	8.05	8.27	5.54	5799	13.76	14.11	114997	138392	1.54	1.65
LSD (p=0.05)	0.51	0.52	NS	N.S	0.85	0.62	-	-	-	-

*Original figures in parentheses were subjected to square root transformation ($\sqrt{x+1}$) before statistical analysis.

ZT sowing with press wheel with (M_1) and without (M_2) paddy residues 6 t/ha *fb* ZTW; Ridge sowing with dibbling method with (M_3) and without (M_4) paddy residues 6 t/ha *fb* CTW Multi crop ridge planter with (M_5) and without (M_6) paddy residues 6 t/ha *fb* CTW; Raised bed wide bed planter with (M_7) and without (M_8) paddy residues 6 t/ha) *fb* ZTW (reshaping of beds); Pneumatic maize planter with (M_9) and without (M_{10}) paddy residues 6 t/ha) *fb* ZTW; W_1: Weed free check, W_2: Weedy check, W_3: Tembotrione 120 g/ha at 15 DAS and W_4: Topramezone 25.2 g/ha at 15 DAS and Kumar (2019) also reported that bed planting system had its own advantage in comparison to the flat planting methods. Majeed *et al.* (2015) observed that wheat crop sown on beds produced higher grain yield and nutrient use efficiency relative to the conventional flat method. Additionally, bed planting system facilitates mechanical cultivation as an alternative method of weed control during the crop growing season and saving of irrigation water than conventional flood irrigation. Similarly, among all the planting methods the maize equivalent yield was significantly higher with raised bed wide bed planter (with paddy residues 6 t/ha) *fb* ZTW (reshaping of beds) (15.78 and 15.92 t/ha) as compared to rest of the planting methods in maize-wheat cropping system.

Weed management treatment did not influence grain yield, stover yield and biological yield and grain yield was not significantly different amongst treatments. Maximum grain yield was observed in weed free check and lower grain yield was observed in weedy check during both the of years study (**Table 5**). Among weed management treatments, maize equivalent yield was significantly higher with weed free check as compared to weedy check, but was statistically at par with tembotrione 120 g/ha and topramezone 25.2 g/ha at 15 DAS during both the study years (**Table 5**). Das *et al.* (2018) also reported higher maize equivalent yield with permanent broad and narrow bed with residue followed by zero tillage with and without residue than conventional tillage (farmers' practice).

Economics

The economics of various treatments were calculated by taking into account the current rates of inputs, labor, other expenses, and market values of the output, specifically the grain and straw yield under various treatments (**Table 5**). Zero-tillage sowing with press wheel (without residues) *fb* ZTW had the lowest cost of cultivation, while multi-crop ridge planter (with paddy residues 6 t/ha) *fb* CTW had the highest cost of cultivation in both years. Raised bed wide bed planter (with paddy residues 6 t/ha) *fb* ZTW (reshaping of beds) had the highest gross returns, net returns, and B C ratio (1.73 and 1.88, respectively) confirming Kumar *et al.* (2018). This was due to lower labour cost and mechanization, lower fertilizer application. Ahmed *et al.* (2018) opined that maize-wheat cropping system could maintain system productivity and reduce tillage cost, that would help farmers to increase profits. Further, farmers of maize-wheat system could improve productivity through adoption of mechanized bed planting for maize and mechanized wheat planting with zero till drill under tilled and no till conditions. Amongst weed management treatments, tembotrione 120 g/ha PoE at 15 DAS recorded the highest gross returns, net returns and highest B-C ratio due to the lowest cost of cultivation during both years of study (**Table 5**).

Conclusion

Raised bed wide bed planter (with paddy residues 6 t/ha) *fb* ZTW (reshaping of beds) recorded

Table 6. Interaction effect of planting methods and weed management on grain yield of maize

Treatment	Weed management Grain yield (t/ha)							
	2020				2021			
	Weed free	Weedy check	Tembotrione 120 g/ha	Topramezone 25.2 g/ha	Weed free	Weedy check	Tembotrione 120 g/ha	Topramezone 25.2 g/ha
Planting methods								
Zero-tillage sowing with press wheel (with paddy residues 6 t/ha) *fb* ZTW	9.14	9.01	9.07	9.09	9.32	9.09	9.27	9.20
Zero-tillage sowing with press wheel (without residues) *fb* ZTW	8.15	6.74	8.11	8.08	8.50	6.95	8.41	8.34
Ridge sowing with dibbling method (with paddy residues 6 t/ha) *fb* CTW)	8.29	8.16	8.25	8.24	8.35	8.17	8.31	8.29
Ridge sowing with dibbling method (without residues) *fb* CTW	7.86	2.82	7.73	7.68	7.96	2.43	7.83	7.76
Multi crop ridge planter (with paddy residues 6 t/ha) *fb* CTW	7.87	7.63	7.76	7.72	8.00	7.72	7.92	7.83
Multi crop ridge planter (without residues) *fb* CTW	7.05	2.45	7.00	6.940	7.47	2.12	7.22	7.17
Raised bed wide bed planter (with paddy residues 6 t/ha) *fb* ZTW (reshaping of beds)	9.50	9.21	9.46	9.28	9.77	9.39	9.61	9.40
Raised bed wide bed planter (without residues) *fb* ZTW (reshaping of beds)	9.05	6.20	9.01	8.93	9.20	6.67	9.14	9.03
Pneumatic maize planter (with paddy residues 6 t/ha) *fb* ZTW	8.18	7.96	8.16	8.08	8.54	8.30	8.54	8.46
Pneumatic maize planter (without residues) *fb* ZTW	7.54	2.32	7.48	7.30	7.68	2.22	7.56	7.52
Factor (B) at same level of A								
LSD (p=0.05)			1.03				0.97	
Factor (A) at same level of B								
LSD (p=0.05)			1.11				0.98	

lower weed density and biomass of all types of weeds; higher maize and wheat grain, stover and biological yield than multi crop ridge planter (without residues) *fb* CTW during both the years. Among weed management treatments, maize equivalent yield was significantly higher with weed free check which was statistically at par with tembotrione 120 g/ha and topramezone 25.2 g/ha at 15 DAS. However, tembotrione 120 g/ha PoE at 15 DAS recorded the highest B-C ratio due to the lowest cost of cultivation during both years of study.

REFERENCES

Ahmed A, Hussain I, Khalil IA, Ahmed G, Ahmad I and Imtiaz M. 2018. Effect of bed planting and zero tillage on productivity and water use of Irrigated maize-wheat cropping system in Khyber Pakhtunkhwa province of Pakistan. *Sarhad Journal of Agriculture* **34**(3): 696–704.

Anonymous. 2024a. World Food and Agriculture - Statistical Pocketbook 2024. Rome. https://doi.org/10.4060/cc2212en

Anonymous. 2024b. Statistical abstract of Haryana (2023-24), Department of economic and statistical analysis, Haryana.

Baghel JK, Das T K, Mukherjee I, Nath CP, Bhattacharyya R, Ghosh S and Raj R. 2020. Impacts of conservation agriculture and herbicides on weeds, nematodes, herbicide residue and productivity in direct-seeded rice. *Soil and Tillage Research* **201**: 104634.

Chandra S and Kumar M. 2019. Effect of different planting methods on yield and economics of cultivation of maize. *International Journal of Current Microbiology and Applied Sciences* **8**(12): 1318–1324.

Christoffoleti PJ, De Carvalho SJP, López-Ovejero RF, Nicolai M, Hidalgo E and Da Silva E. 2007. Conservation of natural resources in Brazilian agriculture: implications on weed biology and management. *Crop Protection* **26**(3): 383–389.

Das TK, Saharawat YS, Bhattacharyya R, Sudhishri S, Bandyopadhyay KK, Sharma AR, Jat ML. 2018. Conservation agriculture effects on crop and water productivity, profitability and soil organic carbon accumulation under a maize-wheat cropping system in the North-western Indo-Gangetic Plains. *Field Crops Research* **215:** 222–231.

Dhillon BS, Thind HS, Malhi NS and Sharma RK. 1998. Effect of excess water stress on grain yield and other traits in maize hybrids. *Crop Improvement India* **25**(2): 209–214.

Fahong W, Xuqing W and Sayre K. (2004). Comparison of conventional, flood irrigated, flat planting with furrow irrigated, raised bed planting for winter wheat in China. *Field Crops Research* **87**(1): 35–42.

Ghimire R, Lamichhane S, Acharya BS, Bista P and Sainju UM. 2017. Tillage, crop residue, and nutrient management effects on soil organic carbon in rice-based cropping systems: A review. *Journal of Integrative Agriculture* **16**(1): 1–15.

Ghosh S, Das TK, Shivay YS, Bhatia A, Biswas DR, Bandyopadhyay KK and Rathi N. 2021. Conservation agriculture effects on weed dynamics and maize productivity in maize-wheat-green gram system in north-western Indo-Gangetic Plains of India. *Indian Journal of Weed Science* **53**(3): 244–251.

Govaerts B, Sayre KD and Deckers J. 2005. Stable high yields with zero tillage and permanent bed planting? *Field Crops Research* **94**(1): 33–42.

Jat ML, Gathala MK, Saharawat YS, Tetarwal JP and Gupta R. 2013. Double no-till and permanent raised beds in maize–wheat rotation of north-western Indo-Gangetic plains of India: effects on crop yields, water productivity, profitability and soil physical properties. *Field Crops Research* **149**: 291–299.

Jonathon R, Kohrt, Christy L. and Sprague. 2013. Weed height and the inclusion of atrazine influence control of multiple resistant Palmer amaranth with HPPD inhibitors. *Weed Technology* **43**(2): 364–372.

Kaur A and Chhina GS. 2019. Influence of Different Planting Methods and Mulching on Growth and Yield of Spring Maize. *Journal of Krishi Vigyan* **8**(1): 149–153.

Kaur R, Kaur C and Kaur T. 2020. Zero-till sowing and residue mulching in rainy season maize: Effect on weeds, crop productivity and profitability. *Indian Journal of Weed Science* **52(1):** 82–88.

Khedwal RS, Yadav DB, Hooda VS, Dahiya S and Singh M. 2017. Zero-Tillage with Residue Mulching in Maize Hybrids: Influence on the Yield Parameters and Economics. *Indian Journal of Ecology* **44**: 650–653.

Khedwal RS, Yadav DB, Hooda VS, Dahiya S, Chaudhary A. 2023. Effect of planting methods, hybrids and weed management on weeds and productivity of rainy season maize. *Indian Journal of Weed Science* **55(1):** 99–102.

Kumar P, Kumar M, Kishor K and Kumar R. 2018. Effect of nutrient management on yield and yield attributes of Maize (*Zea mays* L.) under different tillage practices. *Journal of Pharmacognosy and Phytochemistry* **7**(2): 807–810.

Lal B, Chandra N and Yadav MS. 1988. Response of water-logged maize to planting method and time of nitrogen application. *Indian Journal of Agronomy* **33**: 191–195.

Majeed A, Muhmood A, Niaz A, Javid S, Ahmad ZA, Shah SSH and Shah AH. 2015. Bed planting of wheat (*Triticum aestivum* L.) improves nitrogen use efficiency and grain yield compared to flat planting. *The Crop Journal* **3**(2): 118–124.

Narang MK, Chandel R, Thakur SS and Mishra A. 2015. Response of Maize (*Zea Mays* L.) Crop to Different Planters. *Scientific Journal Agricultural Engineering* **2**: 61–72.

Nath CP, Das TK and Rana KS. 2016. Effects of herbicides and tillage practices on weeds and summer mungbean (*Vigna radiata*) in wheat (*Triticum aestivum*) mungbean cropping sequence. *Indian Journal of Agricultural Sciences* **86**(7): 860–864.

Ortega LA, Villaseñor-Mir E and Espitia-Rangel E. 2008. Nitrogen management and wheat genotype performance in a planting system on narrow raised beds. *Cereal Research Communications* **36**(2): 343–352.

Sharma P, Duary B and Singh R. (2018). Tank mix application of tembotrione and atrazine to reduce weed growth and increase productivity of maize. *Indian Journal of Weed Science* **50**(3): 305–308.

Susha VS, Das TK, Sharma AR and Nath, CP. 2014. Carry-over effect of weed management practices of maize (*Zea mays*) on weed dynamics and productivity of succeeding zero and conventional till wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **59**(1): 41-47.

Swetha K, Madhavi M, Pratibha G and Ramprakash T. 2018. Impact of topramezone and tembotrione tank mix application with atrazine on growth and yield of maize. *Research Journal of Agricultural Sciences* **9**(3): 607–611.