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Role of herbicides and tillage on weeds and wheat (*Triticum aestivum)* yield in northern region of Madhya Pradesh

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ABSTRACT

The present study was carried out during winter (*rabi)* season of 2019–20 and 2020–21 at College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh to study the role of herbicides and tillage on weeds and wheat (*Triticum aestivum* L.) yield in the northern region of Madhya Pradesh. The experiment was laid out in a split-plot design (SPD) with three replications. The treatments comprise 21 combinations with tillage systems, namely conventional tillage (CT), minimal tillage (MT) and zero tillage (ZT), as main plots and seven weed control practices, viz. sulfosulfuron (30 g/ha); metsulfuron-methyl (4 g/ha); clodinafop (60 g/ha); sulfosulfuron + metsulfuron-methyl (30 + 2 g/ha); clodinafop + metsulfuron-methyl (60 + 4 g/ha), two hand weeding at 30 and 60 days after sowing (DAS), as a sub plot. Both biomass and weed density were reduced by 45% in ZT and 19% in MT and grain yield was increased by 20% in ZT and 14% in MT compared to CT at 60 days after sowing. Two-hand weeding with ZT produced the maximum grain production (5.2 t/ha), which was statistically comparable to applying clodinafop + metsulfuron (60 + 4) g/ha under the ZT. ZT practice coupled with two-hand weeding (30 and 60 DAS) provided 43.7% higher gross profit than CT with two-hand weeding (30 and 60 DAS); however, net profit increased by 18%, B:C (3.11) under ZT with clodinafop + metsulfuron (60 + 4) g/ha than CT with clodinafop + metsulfuron-methyl. Because of the increased production costs, the B:C was lower in all herbicidal treatments using CT and MT. Consequently, ZT in conjunction with clodinafop + metsulfuron (60 + 4 g/ha) in wheat can be suggested for effective control of weeds, enhanced yield and profitable production.

Keywords: Conventional tillage, Minimum tillage, Weed density, Weed control efficiency, Yield, Zero tillage

Wheat (*Triticum aestivum* L.) is a significant winter season crop in north-west India, it not only offers calories but also adaptable to a variety of agro-climatic situations. According to Khan and Haq (2002), weed reduce the productivity of wheat by 48% because they compete with crops for resources. Herbicide use is inevitable in present scenario because of scarcity of labour and higher wages, at the same time herbicides provides cost-effective solutions to many weed problems (Khaliq *et al.* 2012). In addition to altering the structure and behaviour of weed populations, herbicides help in declining species diversity in an agro-ecosystem (Mahajan *et al.* 2011). Integrated weed control strategy, detrimental effects of herbicide use can also be reduced up to significant level (Mushtaq *et al.* 2010).

Researchers today are aware that tillage can alter the physico-chemical characteristics of seedbeds, hence influencing the emergence of weeds and crops (Arif *et al.* 2007). Weeds' vertical seed dispersal in the soil profile (Buhler 1995), survival (Mohler and Calloway 1992), dormancy and seed bank dynamics (Chahal *et al.* 2002) can be impacted by tillage. Herbicide adsorption, translocation, prominence and efficacy can be affected by tillage-induced changes in soil properties, including organic material, microbial colonies, moisture content in the soil, temperature, and *p*H (Blevins *et al.* 1983). Herbicide-assisted tillage and weed interaction, can significantly affect crop productivity and growth (Acciaresi *et al.* 2003). ZT planting is an integrated weed management technique (Mehla *et al.* 2000). ZT breaks dormancy and causes decreased weed levels (Yenish 1992). ZT is an option for the Indo-Gangetic Plains region because of its ability to suppress herbicide-

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resistant canary grass (*Phalaris minor* Retz) by reducing soil mobility (Mehta and Singh 2005). Hence, the aim of the current investigation was to find out the effect of tillage and herbicides on weeds, economics, and the productivity of wheat in the northern part of Madhya Pradesh

MATERIALS AND METHODS

The present study was carried out during winter (*rabi)* season of 2019–20 and 2020–21 at College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh. The soil of the experimental site was sandy clay loam in texture, with a *p*H of 8.3, organic carbon 0.40%, cation exchange capacity of 16.20, electrical conductivity of 0.40 dS/m at 25°C, bulk density of 1.34 g/cm, particle density of 2.52 g/cm, porosity of 48.3% and available N, P, K was 164.5 kg/ha, 19.3 kg/ha and 235.5 kg/ha. The experiment was laid out in a split-plot design (SPD) in three replications. The treatments comprise 21 combinations having three tillage, viz. zero tillage (ZT); minimum (MT) and conventional tillage (CT) as main plots and seven weed control practices, viz. sulfosulfuron (30 g/ha); metsulfuron-methyl (4 g/ha); clodinafop (60 g/ha); sulfosulfuron + metsulfuron-methyl (30 + 2 g/ha); clodinafop + metsulfuron-methyl (60 + 4 g/ha) and two hand weeding at 30 and 60 DAS, as a sub plot. Wheat cultivar RVW-4106 was sown in ZT plots on 11 November in 2019 and 06 November in 2020. Similarly, sowing was done in MT and CT plots on 5 December 2019 and 30 November 2020. 100 kg of seeds/ha was placed at a row spacing of 22.5 cm. The crop was nourished with 100 kg N, 60 kg P and 40 kg K per hectare through fertilizers. After the pearl millet was harvested, the field was set up in accordance with the experiment. Following pearl millet, no-tillage operations were carried out in ZT. After pearl millet was harvested, ZT plots were watered to promote the germination of wheat seeds that had been showed, and after four weeks, the plot was treated with post-emergence herbicides to manage weeds. The corresponding plots were prepared for the MT with one disc harrowing and one pass of rotavator. Contrarily, CT plots required one-disc plough pass, two passes with a cultivator, and one pass with a planker to level the field. Following the first watering, post-emergence herbicides were sprayed at a rate of 500 l/ha at the 28 DAS stage of the crop using a combination of the appropriate amount of their commercial products. Herbicides were sprayed date in ZT plot on 08 December 2019 and 04 December 2020. Similarly, in MT and CT plots herbicides were applied on 02 January 2020 and 28 December 2020, respectively. After 30 and 60 days of sowing (DAS), hand weeding was carried out in ZT, MT and CT.

Observations on broad and narrow leaved weed density were made by using the quadrate count method, from each plot at 20, 40 and 60 DAS as well as at harvest. Each plot had 1 m^2 quadrate randomly set in four locations before the species-wise weed density was conducted. The information was then converted as No.s/m^2. The weedy check plot was used to evaluate the percentage composition of weed flora. The formula published by (Mishra 1968) was used to calculate the relative weed density. To normalize the distribution of the total weed density, square root transformation was applied (Gomez and Gomez 1984).

$$\text{Relative density (\%)} = \frac{\text{Number of individuals of the same}}{\text{Total number of individuals of all species}} \times 100$$

At 20, 40, 60 DAS and harvest, the biomass of broad and narrow-leaved weeds was recorded. Using quadrate, species wise associated weeds were removed from four different locations within each plot to record the dry weight of broad-leaved weeds. After being sun-dried, the weeds were put in paper bags and dried for 48 h at 60°C in an oven. Biomass measurements were carried out until stable weight was reached. The information was later converted to g/m^2. After the net plots' harvest was threshed, the grains that were left over were weighed. The yield recorded in kg/plot was stabilized to 12% moisture and then weight was converted into (kg/ha) by using the appropriate factor. The dry weight of straw collected from the net plot was recorded after sun drying for 5–6 days and expressed in kg/ha by using the appropriate factor. The harvest index was calculated under each treatment as per the formula suggested by (Donald and Hamblin 1976):

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biologicals yield}} \times 100$$

Various yield attribute, viz. spike/m^2, ear length, grains/ear, weight of grains/ear and test weight were recorded to assess the real causes of yield differences among different treatments investigated.

Statistical analysis: The tests were statistically analyzed as per the method provided by (Panse and Sukhatme 1954) to determine the significance of differences. Wherever the "F" test was significant at 5% significance level, significant differences were calculated to evaluate the significance of treatment means. There was no significant (P<0.05) effect of years on various parameters, therefore, pooled analysis was performed for the two years mean and interpreted accordingly.

RESULTS AND DISCUSSION

Weed density and biomass: In pearl millet-wheat cropping system, *Phalaris minor* and *Avena fatua* were the major narrow-leaved while *Chenopodium album*, *Rumex dentatus*, *Fumaria parviflora*, *Convolvulus arvensis* and *Anagallis arvensis* were the major broad-leaved observed during 2019–20 and 2020–21. Weed density and biomass were significantly (P<0.05) reduced by herbicides under various tillage (Table 1 and 2). At every stage of crop growth, the relative contribution of narrow leaf weeds to the overall weed population in terms of density was larger. *Phalaris minor* was the most dominant weed at harvest, contributed 31% of total weed population. Among broad-leaved weeds, *Chenpodium album* was the most dominant 29% followed by

Table 1 Effects of tillage and herbicides on weed density (pooled basis)

Treatment	Narrow-leaved				Broad-leaved				Total			
Tillage	20 DAS	40 DAS	60 DAS	Harvest	20 DAS	40 DAS	60 DAS	Harvest	20 DAS	40 DAS	60 DAS	Harvest
Weed density (no./m^2)												
Zero tillage	1.86 (73.3)	1.12 (30.2)	1.05 (27.1)	0.98 (22.5)	2.10 (130.0)	1.36 (52.4)	1.34 (46.86)	1.195 (34.0)	2.30 (202)	1.63 (86.4)	1.58 (75.5)	1.48 (61.1)
Minimum tillage	2.19 (157.3)	1.28 (66.1)	1.21 (48.7)	1.14 (39.7)	2.15 (144.1)	1.44 (67.8)	1.42 (60)	1.31 (47.4)	2.48 (304)	1.76 (136.8)	1.71 (112.1)	1.62 (87.4)
Conventional tillage	2.25 (179.6)	1.35 (73.8)	1.28 (62.9)	1.21 (49.9)	2.19 (158.2)	1.51 (82.4)	1.49 (76.28)	1.37 (60.4)	2.53 (337)	1.83 (147.3)	1.78 (137.5)	1.68 (106.7)
SEM (d)	0.01	0.01	0.02	0.04	0.01	0.01	0.01	0.028	0.01	0.01	0.01	0.03
CD (*P*=0.05)	0.4	0.03	0.07	NS	0.04	0.02	0.02	NS	0.03	0.05	0.04	0.10
Weed Management												
Sulfosulfuron (25 g/ha)	2.09 (132.6)	0.84 (7.3)	0.82 (6.9)	0.74 (5.9)	2.14 (139.7)	1.88 (77.2)	1.80 (64.30)	1.66 (49.7)	2.42 (272)	1.92 (85.5)	1.85 (72.5)	1.71 (54.7)
Metsulfouron–methyl (4 g/ha)	2.09 (134.3)	2.18 (163.5)	2.05 (131.3)	1.93 (103.4)	2.16 (149.4)	1.19 (15.9)	1.21 (16.41)	1.148 (14.9)	2.44 (282)	2.19 (180.8)	2.15 (154.2)	2.04 (122.3)
Clodinafop (60 g/ha)	2.10 (137.0)	1.64 (45.5)	1.58 (39.8)	1.48 (32.7)	2.15 (143.4)	2.22 (170.9)	2.17 (150.39)	2.024 (115.4)	2.43 (279)	2.32 (218.4)	2.28 (193.6)	2.13 (143.6)
Sulfosulfuron + metsulfouron-methyl (30 + 2) g/ha	2.09 (134.2)	0.78 (6.3)	0.72 (5.4)	0.67 (5.0)	2.14 (140.1)	1.08 (12.2)	1.10 (12.78)	1.051 (11.9)	2.42 (274)	1.31 (26.01)	1.25 (18.1)	1.20 (16.5)
Clodinafop + metsulfuron (60 + 4) g/ha	2.11 (139.2)	0.69 (5.01)	0.59 (4.1)	0.56 (3.9)	2.14 (140.5)	0.99 (9.8)	0.98 (9.72)	0.925 (8.7)	2.44 (286)	1.17 (14.95)	1.14 (13.8)	1.08 (12.4)
Two hand weeding (30 and 60 DAS)	2.09 (133.0)	0.41 (2.61)	0.71 (0.0)	0.71 (0.0)	2.11 (132.3)	0.43 (2.7)	0.71 (0.0)	0.71 (0.0)	2.41 (263)	0.72 (5.35)	0.74 (5.5)	0.62 (4.3)
Weedy check	2.14 (146.7)	2.21 (167)	2.09 (133.5	1.99 (108.3)	2.20 (163.9)	2.26 (184.3)	2.20 (163.88)	2.070 (128.6)	2.48 (308)	2.53 (357.1)	2.46 (300.7)	2.36 (241.5)
SEM (d)	0.01	0.02	0.03	0.04	0.02	0.01	0.01	0.037	0.01	0.03	0.02	0.03
CD (*P*=0.05)	NS	0.05	0.07	0.11	NS	0.03	0.03	0.105	0.04	0.09	0.05	0.08

DAS, Days after sowing.

Table 2 Effects of tillage and herbicides on weed biomass (pooled basis)

Treatment	Weed biomass (g/m^2)					
Tillage	Narrow-leaved		Broad-leaved		Total	
	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest
Zero tillage	18.74	25.07	9.53	14.16	28.32	38.27
Minimum tillage	23.95	34.55	17.96	26.69	41.91	59.55
Conventional tillage	28.95	42.80	22.10	32.18	51.06	72.73
SEM (d)	0.52	0.96	1.45	1.95	1.68	3.23
CD (*P*=0.05)	1.69	3.14	4.72	6.37	5.49	10.54
Weed management						
Sulfosulfuron (25 g/ha)	26.95	41.94	2.43	3.8	29.51	45.85
Metsulfouron-methyl (4 g/ha),	6.54	11.52	48.33	69.5	54.87	81.15
Clodinafop (60 g/ha)	58.97	38.34	11.80	16.0	70.77	90.56
Sulfosulfuron + Metsulfouron-methyl (30 + 2) g/ha	4.88	9.02	1.89	3.1	6.77	11.94
Clodinafop + metsulfuron (60 + 4) g/ha	3.72	6.18	1.41	2.4	5.13	9.01
Two hand weeding (30 and 60 DAS),	0.00	0.00	0.00	0.00	0.00	0.00
Weedy check	66.12	68.78	49.84	75.6	115.96	159.45
SEM (d)	0.70	0.94	1.77	3.7	2.07	3.54
CD (*P*=0.05)	1.98	2.65	4.99	10.5	5.82	9.97

DAS, Days after sowing.

Rumex dentatus. In the pearl millet-wheat cropping system, *Phalaris minor*, *Rumex* spp. and *Chenopodium album* are major weeds in wheat were also reported earlier by (Mishra and Singh 2005). At 20, 40, 60 DAS and at harvest, the density of total weeds was lower with ZT (40, 41.34, 45.01 and 42.7% respectively) and MT (9.7, 7.12, 19 and 18%) than under CT (337, 147.3, 137.5 and 106.7/m^2) while the lowest weed biomass was recorded in ZT (45 and 47.3%) and MT (17.9 and 18.12%) as compared to CT (51.06 and 72.73 g/m^2) at 60 DAS and harvest respectively. In this context, Sinha and Singh (2005) also observed a similar pattern. Prasad *et al.* (2005) also reported that lower total weed density under ZT over CT which supports our findings. Following the harvest of pearl millet, *Phalaris minor* density was much lower when wheat was sown with ZT over CT in wheat. During all the stages, weed density and biomass of each weeds were higher in CT. This may be attributed to its pulverized soil which provided congenial growth environment such as optimum moisture and nutrients in the root zone of the crop (Yadav and Malik 2005). While, CT brings the weed seeds from deeper depths and also scarify and breaks the dormancy of weed seeds resulting in enhanced germination and emergence (Barros *et al.* 2007). Thus, it ultimately leads to 52% lower weed density in ZT over CT (Mann *et al.* 2004). Similarly, Mishra and Singh (2005) in Jabalpur corroborated that decline in *Phalaris minor* and *Chenopodium album* density under ZT. These decline was mainly due to absence of sunlight and loss of viable seeds buried deep in the soil profile. In absence of tillage, they could not come up, while it was almost twice and thrice under MT and CT (Table 1 and 2).

Among herbicides, the highest weed density was recorded under weedy check (308, 357.1, 300.7 and 241.5/m^2) while it was lowest in two hand weeding [30 and 60 DAS (14.6, 98.5, 98.1 and 98.21%)] followed by clodinafop + metsulfuron-methyl [(60 + 4) g/ha] (7.14, 95.81, 95.4 and 94.8%) at 20, 40, 60 DAS and at harvest, respectively. The highest biomass was recorded in weedy check (115.96 and 159.45 g/m^2) and the lowest in two hand weeding at 30 and 60 DAS, while it was comparable with clodinafop propargyl 15% WP + metsulfuron methyl 20% WP (60 + 4) g/ha at 60 DAS and harvest (95.5% and 94.34%, respectively). Increase in WCE is a result of improved weed management, which reduced the accumulation of biomass. Additionally, uniform placement of previous crop residues also inhibited the emergence and growth of weeds. Comparable findings were also supported by (Khaliq *et al.* 2013). The broad-spectrum control of weeds in herbicide-applied plots may be the reason of this. Chopra and Chopra (2005) further confirmed that clodinafop is more effective than sulfosulfuron-methyl in controlling grasses, especially resistant biotypes of *Phalaris minor*. Metsulfuron-methyl was shown to be more effective against dicot weeds as suggested by Walia and Singh (2005). The application of clodinafop propargyl 15% WP + metsulfuron methyl 20% WP (60 + 4) g/ha as 28 DAS provided broad-spectrum weed control controlling 97.3% of grasses and 96.5% of BLWs (Singh *et al.* 2012).

Yield attributes and yield: Based on pooled analysis, attributes and yield of wheat was influenced by tillage and herbicides (Table 3). The productive spikes/unit area was comparable among tillage, while there was significantly ($P \leq 0.05$) increase in number of grains/spike, test weight and spike length under ZT plots. The effect of herbicides

Table 3 Effect of tillage and herbicides on attributes and yield of wheat (pooled basis)

Treatment	Yield attribute						
Tillage	Tiller/m-row	Spike/m^2	Spike length (cm)	Grains/ spike	Test weight (g)	Grain yield (t/ha)	HI (%)
Zero tillage	132.2	313.9	9.29	39.9	40.61	4.81	40.1
Minimum tillage	130.3	301.3	8.41	38.9	39.59	4.56	40.0
Conventional tillage	128.2	287.9	7.54	38.0	38.56	4.26	39.8
SEM (d)	1.21	3.04	0.08	0.21	0.18	0.04	0.1
CD (*P*=0.05)	NS	9.90	0.27	0.68	0.59	0.13	0.2
Weed management							
Sulfosulfuron (25 g/ha)	128.6	285.1	8.08	39.0	39.08	4.2	40.7
Metsulfouron-methyl (4 g/ha),	129.3	276.8	7.78	38.6	39.52	4.4	39.8
Clodinafop (60 g/ha)	130.1	295.4	7.38	37.5	39.90	4.6	39.6
Sulfosulfuron + Metsulfouron–methyl (30 + 2) g/ha	131.2	307.4	8.62	39.6	40.42	4.7	40.0
Clodinafop + metsulfuron (60 + 4) g/ha	132.9	330.4	9.87	40.2	40.67	5.0	40.3
Two hand weeding (30 and 60 DAS),	134.3	345.8	10.32	40.8	41.64	5.2	40.9
Weedy check	124.9	266.4	6.85	36.6	35.87	3.8	38.7
SEM (d)	1.85	5.36	0.18	0.39	0.39	0.07	0.2
CD (*P*=0.05)	NS	15.11	0.51	1.10	1.10	0.19	0.6

HI, Harvest index; DAS, Days after sowing.

treatments was significant ($P \leq 0.05$) for grains/spike and test weight regardless of tillage opted. The higher tillers, productive spikes and grains/spike were recorded with ZT (3.02, 8.28 and 4.76%) followed by MT (1.61, 4.45 and 2.3%) compared to CT (128.2/m row, 287.9/m² and 38.0 grain/spike). Under the herbicides, the greater tillers, productive spike, and grain/spike were observed with two hand weeding at 30 and 60 DAS (134.3/m row, 345.8/m^2, and 40.8/spike), which was comparable to clodinafop propargyl 15% WP + metsulfuron methyl 20% WP (60 + 4) g/ha at 60 DAS (132.9/m row, 330.4/m^2 and 40.2/spike, respectively). It may be due to efficient weed control, resulting in less crop weed competition. ZT has been recorded significantly ($P \leq 0.05$) higher test weight (5.04%) followed by MT (2.60%) compared to CT (38.56 g). Among herbicidal treatments, two hand weeding 30 and 60 DAS resulted in the highest grain production (5.2 t/ha), equivalent to clodinafop + metsulfuron-methyl (60 + 4) g/ha (5.0 t/ha). The decreased yield under the CT system might be attributed to increased weed density, nitrogen leaching and immobilization due to crop residue incorporation. In contrast, ZT has been shown to decrease weed growth, especially *P. minor* and all weeds, which increased yield by reduced crop-weed competition, nitrogen loss and moisture loss thereby increasing the productivity of wheat tillers and ears. Similar findings were also supported by **(**Mann *et al.* 2004, Chhokar *et al.* 2007**)**. Higher grain yields in herbicide-treated plots may be due to effective weed control. These results corroborate the findings of (Singh *et al.* 2007, Baghestani *et al.* 2008), where herbicides increased crop productivity based on weed control efficacy.

Economic analysis: On the basis of pooled analysis, noticeable differences between the all interactions of tillage with herbicides treatments are showed (Supplementary Table 1). Savings in terms of cultivation cost was ₹5,250/ha under ZT, ₹3,000/ha with MT in comparison to CT (₹44,678/ha). ZT significantly reduced production costs by reducing cost of tillage and weed control treatments. The savings trend in the cost of production of the systems was in order, ZT>MT>CT. Similarly, net returns were significantly higher with ZT compared with MT and CT (Supplementary Table 1). Additionally, the maximum net return was recorded in the interactions of ZT with clodinafop + metsulfuron-methyl (₹1,05,474/ha), followed by the other interactions, whereas the minimum net monetary return was recorded in CT with weedy check (₹61,912/ha) due to higher net returns, reduction in cost of cultivation and higher yield with ZT and MT consistency was observed (Singh *et al.* 2016, Singh *et al.* 2018). The maximum B:C ratio was recorded in interactions of CT with clodinafop + metsulfuron-methyl (3.11) followed by the other interactions, while the lowest B:C ratio was found in CT with weed check (1.61). However, the largest cultivation costs and lower wheat yield were the reasons for the lowest net income and B:C ratio with CT. Due to lower expenses and greater economic returns, the economic analysis showed that net benefits increased as tillage intensity decreased. Because of the increased yield, wheat had a greater financial advantage following the harvest of pearl millet. Treatments with herbicides and tillage also had a positive impact on the B:C of different systems. In contrast to gross return, a similar trend was seen in net return and B: C. The overall cost effectiveness of ZT in wheat observed, conforms with Streit *et al.* (2002).

In central India, most farmers use intense tillage to develop fine seedbeds for wheat establishment following *kharif* season harvests. According to the current study, ZT was shown to have reduced weed pressure when combined with clodinafop + metsulfuron-methyl, which improved development of crops and economic yield. Better weed control, higher grain yield, and economic benefits of wheat can be achieved with ZT. Conservation tillage technique, zero tillage in wheat improved soil properties and maximum cost of production savings as compared to minimum and conventional tillage. Among various treatment combinations, zero tillage with clodinafop + metsulfuron also gave maximum net return and B:C ratio. In the alluvial plains of central India, ZT is seen as a viable choice for late-sown conditions and for the prompt establishment of wheat. Different climatic variables must be used to assess the conservation tillage strategies. Additionally, the zero drill machine needs to be modified in order to directly drill seeds and fertilizer under crop residue. Thus, without losing wheat yields, this approach offers conserving resources and minimizes production costs for sustainable weed control.

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