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Weed dynamics and productivity of wheat (*Triticum aestivum*) under various tillage and weed management practices

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Wheat (*Triticum aestivum* L.) is a crucial staple food for millions of people worldwide, belonging to family Poaceae. It holds significant importance as the primary cereal crop and plays a vital role in ensuring food security in many nations. In spite of this, extensive weed infestations significantly reduce the productivity of wheat. Both grassy and broad-leaved weeds pose a serious challenge, particularly in Eastern India, and are detrimental to wheat cultivation. Thus, it is necessary to find some herbicides that are suitable for treating mixed weed flora. Herbicide resistance has been found in various weeds like *Avena* sp., *Rumex* sp. (Punia *et al.* 2017). Integrated weed management approaches are required to address resistance in weeds, such as crop and herbicide rotation, and herbicide mixtures with cultural and mechanical techniques.

In wheat, tillage plays an essential role; however, intensive tillage affects soil structure adversely, resulting in soil erosion and carbon loss. Moreover, the burning of rice residues is increasing the concentration of greenhouse gases in the atmosphere, which contributes to global warming. Consequently, many countries are switching to conservation agriculture, in which soil disturbance is minimal or zero, crop residues are retained on the surface of the soil, and legumes are rotated among the crops. The use of conservation tillage practices, such as no-till farming, combined with previous crop residues, may offset the cost of soil preparation and other constraints associated with it (Singh *et al.* 2008). In zero-tillage conditions, less energy is needed for tillage, but fertilizers and weed control, whether done manually or with herbicides, affect crop growth (Ghosh *et al.* 2020). Controlling weeds in conservation agriculture presents a significant challenge due to the limitations of conventional methods. The practice of burying weed seeds through tillage operations and applying herbicides to the soil does not integrate effectively, leading to a reduced efficiency of herbicides (Cordeau *et al.* 2020, Duary *et al.* 2021). Additionally, crops may intercept herbicides from reaching the soil surface by binding to their residues. Considering the aforementioned facts, this study examines how tillage and weed management practices impact weed dynamics, herbicide phytotoxicity, and wheat yield.

The present study was carried out at the research farm of Bihar Agricultural University, Sabour, Bihar during winter (*rabi*) season 2021–22. The experimental field soil was sandy loam with Walkley-Black C (oxidizable–SOC) 0.58%, alkaline $KMnO_4$ oxidizable–N 173.45 kg/ha, 0.5 M $NaHCO_3$ extractable–P 22.43 kg/ha and 1 N NH_4OAc extractable–K 148.82 kg/ha. A semiarid climate with hot, dry summers, moderate rainfall, and extremely chilly winters is characteristic of the experimental sites. The treatment details of the experiment are two tillage practices, viz. T_1, zero tillage (ZT) and; T_2, conventional tillage (CT) in the main plot and nine weed management practices in sub-plots, i.e. W_1, weedy; W_2, weed free; W_3, pinoxaden 5.1% EC 20 g a.i./ha; W_4, carfentrazone ethyl 40% DF 20 g a.i./ha; W_5, clodinafop propargyl 15% WP EC 60 g a.i./ha; W_6, carfentrazone ethyl 20% DF 20 g a.i./ha + pinoxaden 5.1% EC 20 g a.i./ha; W_7, carfentrazone ethyl 20% DF EC 20 g a.i./ha + pinoxaden 5.1% EC 20 g a.i./ha; W_8, metsulfuron methyl 20% WP 4 g a.i./ha + clodinafop propargyl 15% WP 60 g a.i./ha; W_9, metsulfuron methyl 20% WP 4 g a.i./ha + pinoxaden 5.1% EC 20 g a.i./ha. All the herbicides were applied at 30 days after sowing (DAS). A zero-till ferti-cum-seed drill was used to seed wheat variety HD2967 at a seed rate of 125 kg/ha for conventionally and zero-till tilled plots with a row-to-row spacing of 20 cm.

At 30 DAS, 60 DAS, and 90 DAS, weed density per meter square area was calculated from two-three randomly

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selected data points located within a quadrate of 50 cm by 50 cm. A square root transformation $(\sqrt{x+0.5})$ was used to normalize the distribution of the data in order to determine the density of weeds in the wheat crop. Likewise, the same procedure was followed for weed biomass and the samples were sun-dried and then oven dried. These were weighed and expressed in g/m^2 of weed biomass. On a scale of 0–10, phytotoxicity effects were observed and rated. Zero rating represents no injury to crop and 10 represents complete destruction, i.e. highest injury to the crop. Weed index and wheat yield were worked out as per standard procedures. Then, the grain yield was calculated and expressed as q/ha. The statistical analysis was conducted using Analysis of Variance (Gomez and Gomez 1984) and mean comparisons were based on the least significant difference (LSD) at 0.05 probability.

Tillage as well as herbicidal combination affected total weed density and biomass significantly at all the stages except 30 DAS (Table 1). Amongst tillage, the lowest total weed counts, i.e. 91.76 and 76.02/m^2 respectively at 60 and 90 DAS was observed under zero tillage. It can be observed that the total weed counts decreased in all the treatments as the crop growth advanced except in W_1, where it was enhanced at 60 DAS and thereafter it decreased. At 60 and 90 DAS, metsulfuron methyl 20% WP 4 g a.i./ha + clodinafop propargyl 15% WP 60 g a.i./ha (W_8) recorded minimum total weed counts, i.e. 58.60 and 44.45/m^2 respectively. At all stages except 30 DAS, tillage and weed management practices significantly affected weed biomass. At 60 and 90 DAS zero tillage recorded 8.7 and 10.3% respectively lower total weed biomass as compared to conventional tillage. From the data, it can be concluded that the total weed biomass enhanced as the crop growth advanced at 60 DAS and thereafter it decreased at 90 DAS.

It was found that tillage and weed management practices significantly affected total weed density. Under conventional tillage, total weed density was highest, while under zero tillage, it was lowest. The reduction in weed density under zero tillage might be due to reduced soil disturbance and the mulching of soil surface with preceding crop residues. All these factors influenced seed germination, dormancy and mortality (Barla *et al.* 2017 and Kushwah *et al.* 2020). Application of metsulfuron methyl 20% WP 4 g a.i./ha + clodinafop propargyl 15% WP 60 g a.i./ha resulted in better control of weeds in comparison to the rest of the herbicides. This was largely due to broad-spectrum activity of both the herbicides which have the ability to control both grassy and broad leaf weeds effectively (Bharat *et al.* 2012).

Weed index differed significantly with tillage and weed management practices (Table 2). The highest weed index was recorded under conventional tillage (24.13%) and lowest under zero tillage (18.04%). A major contributor to this may be the fact that tillage brought deeply buried weed seeds up to the surface, which facilitated their germination and growth (maximum weed seeds were found at a depth of 5–10 cm under conventional tillage) (Mitra *et al.* 2014). As a result, conventional tillage produces less yield than zero tillage. Furthermore, no weed control measures were

Table 1 Effect of tillage and weed management practices on total weed density and biomass

Treatment	Total weed density (no./m^2)			Total weed biomass (g/m^2)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Tillage practices						
T_1	10.43(121.84)	9.82(113.13)	8.74(89.44)	8.49(80.49)	11.93(171.64)	10.99(149.94)
T_2	10.05(113.18)	8.86(91.76)	8.00(76.02)	8.14(73.78)	10.89(148.62)	9.85(124.40)
SEm±	0.07	0.02	0.04	0.05	0.04	0.04
CD (P=0.05)	NS	0.11	0.23	NS	0.23	0.27
Weed management practices						
W_1	10.80(117.05)	16.64(277.62)	15.44(238.03)	9.32(87.15)	23.61(557.44)	22.91(524.68)
W_2	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
W_3	12.33(153.12)	11.21(125.82)	9.97(99.08)	9.89(98.95)	12.48(155.36)	11.23(126.17)
W_4	11.80(141.73)	10.69(114.48	9.26(85.78)	9.05(82.17)	11.75(138.11)	10.67(114.52)
W_5	11.59(135.10)	10.18(103.67)	9.12(82.92)	9.64(95.14)	12.05(144.95)	10.63(112.89)
W_6	11.66(136.57)	9.47(89.65)	8.51(72.73)	8.92(80.51)	10.67(114.50)	10.23(104.55)
W_7	11.22(127.40)	9.03(81.20)	8.12(65.67)	9.17(84.06)	11.13(123.74)	9.89(97.73)
W_8	10.80(118.00)	7.67(58.60)	6.70(44.45)	9.01(82.75)	9.84(97.50)	8.29(68.81)
W_9	11.26(128.00)	8.44(70.98)	7.49(55.90)	9.12(83.50)	10.45(109.55)	9.23(85.20)
SEm±	0.60	0.19	0.15	0.48	0.18	0.15
CD (P=0.05)	NS	0.54	0.44	NS	0.53	0.43

*Refer to the methodology for treatment details. Original values given in parentheses was subjected to square root transformation $(\sqrt{x+0.5})$ before analysis; DAS, days after sowing; NS, Non-significant.

Table 2 Effect of tillage and weed management practices on weed index and phytotoxicity of herbicides

Treatment	Weed index (%)	Phytotoxicity effect (0–10) by visual observation		
		5 DAA	10 DAA	15 DAA
T_1	24.13	-	-	-
T_2	18.04	-	-	-
SEm±	3.12	-	-	-
CD (P=0.05)	19.00	-	-	-
W_1	46.78	0	0	0
W_2	0.00	0	0	0
W_3	33.94	0	0	0
W_4	31.43	4.0	2.9	1.5
W_5	26.89	0	0	0
W_6	16.26	3.0	2.3	1.2
W_7	13.99	0	0	0
W_8	8.74	0	0	0
W_9	11.73	0	0	0
SEm±	2.87	-	-	-
CD (P=0.05)	8.27	-	-	-

*Refer to the methodology for treatment details. DAA, days after application; DAS, days after sowing; NS, Non-significant.

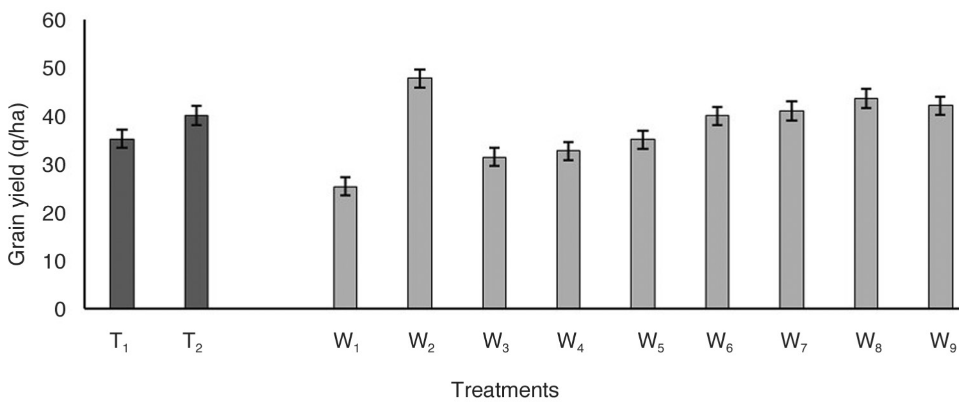

Fig 1 Effect of tillage and weed management practices on grain yield of wheat. Refer to methodology for treatment details.

adopted in weedy check plots, resulting in the lowest yield and weed index. Among the weed management practices, weedy plots showed the highest weed index (46.78%) and application of metsulfuron methyl 20% WP 4 g a.i./ha + clodinafop propargyl 15% WP 60 g a.i./ha resulted in significantly lowest weed index (8.74%). This might be attributed to the broad-spectrum activity and persistence of the herbicide which controlled the weeds more effectively than other herbicides which resulted in higher yield (Chopra *et al.* 2015, Chaudhari *et al.* 2017).

The phytotoxic effect of different herbicidal treatments is presented in Table 2. Moderate injury in the form of light-yellow discoloration in upper leaves of wheat plant was observed at 5 days after application (DAA) of herbicide with application of carfentrazone ethyl 40% DF 20 g a.i./ha and carfentrazone ethyl 20% DF 20 g a.i./ha + pinoxaden 5.1% EC 20 g a.i./ha. There was slight reduction in plant population at 10 DAA of herbicide with application of carfentrazone ethyl 40% DF 20 g a.i./ha and carfentrazone ethyl 20% DF 20 g a.i./ha + pinoxaden 5.1% EC 20 g a.i./ha but the crop recovered after 15 DAA. Hence, the data revealed that all herbicides were safe for application in wheat. In agreement with these results, Thirumalai *et al.* (2017) reported reduced weed density by applying flumioxazin pre-emergence without causing phytotoxicity to soybeans and with residual effects on subsequent crops. Zero tillage produced a maximum yield of 40.08 q/ha and weed free treatment produced a maximum yield of 47.77 q/ha, which was significantly higher than the rest of the treatments (Fig 1). Application of metsulfuron methyl 20% WP 4 g a.i./ha + clodinafop propargyl 15% WP 60 g a.i./ha recorded the highest grain yield (43.60 q/ha) when compared to application of carfentrazone ethyl 20% DF 20 g a.i./ha + pinoxaden 5.1% EC 20 g a.i./ha, carfentrazone ethyl 20% DF EC 20 g a.i./ha + pinoxaden 5.1% EC 20 g a.i./ha and, metsulfuron methyl 20% WP 4 g a.i./ha + pinoxaden 5.1% EC 20 g a.i./ha.

SUMMARY

The reduced yield under conventional tillage is due to more crop-weed competition and more dry matter accumulation by the weeds (Kumar *et al.* 2018). Due to zero weed competition, weed-free treatments yielded the highest grain yield of all weed management practices. In contrast to this, the lowest grain yield was obtained in weedy treatment due to season-long weed competition. Maximum yield under W_8 is due to broad-spectrum activity of these herbicides (Sharma *et al.* 2014, Sunil *et al.* 2021). The use of zero tillage reduced weed incidence and suppression, leading to higher grain yields. Therefore, zero tillage and metsulfuron 20% WP 4 g a.i./ha + clodinafop propargyl 15% WP 60 g a.i./ha should be practiced for minimizing weed growth and maximizing the yield.

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