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Weed management for enhancing yield and economics of wheat (*Triticum aestivum*) in Eastern India

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Wheat (*Triticum aestivum* L.) is the second most important cereal crop of India after rice, had an area of 29 mha with 88.94 million tonnes (MT) production and 2872 kg/ha average productivity in 2015-2016 (www.agricoop.nic.in). Many production factors affect yield and productivity of wheat but among them, weeds are considered a serious threat as they compete with crops for growth factors (Najwa *et al.* 2012), and in absence of an effective control measures, weeds remove a considerable quantity of applied nutrients and water which results in higher crop yield loss (Sharma and Singh 2011). The heavy infestation with complex weed flora in wheat has become a serious threat in increasing the yield and productivity. Thus a suitable combination of new herbicides like sulfosulfuron, metsulfuron, fenoxaprop, clodinafop and metribuzin, reported to be very effective against associated weed species in wheat crop (Verma *et al.* 2015), is required for effective broad-spectrum control of weeds (Pal *et al.* 2016) as continuously rely on single herbicide to a longer period not only results herbicidal resistant but also creates weed shifts. In addition to herbicides combinations, cultural practices, being economical and eco-friendly (Sharma and Singh 2011), also play a significant role in weed suppression particularly during the initial stages of crop establishment. Therefore, keeping above background in view, the present study was undertaken with the objective to understand the integration effect of tillage practices along with crop residues and weed management practices on weeds, yield and economics of wheat in eastern region of Uttar Pradesh.

An experiment involving four crop establishment methods (CEMs) (two tillage practices × two crop residue management options), viz. conventional tillage (CT)-no-residue, CT with residue, zero tillage (ZT)-no-residue and ZT with residue and six weed management practices, viz. weedy check, weed free, mesosulfuron (12g ai/ha at 30 DAS) *fb* one hand weeding at 45 DAS, metsulfuron (4g ai/ha at 30 DAS) *fb* one hand weeding at 45 DAS, clodinafop+metsulfuron (60+4g ai/ha at 30 DAS) and mesosulfuron+iodosulfuron (12+2.4g ai/ha at 30 DAS) was undertaken during winter (*rabi*) season of 2014-15 and 2015-16 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25°18´ N latitude, 83°03´ E longitude and an altitude of 129 m MSL) in a split-plot design with three replications. The crop received 76.8 and 46.3 mm rainfall during 2014-15 and 2015-16, respectively. The soil of the experimental field was sandy clay loam in texture with slightly alkaline in reaction (pH 7.8), had low organic carbon (0.43%), available nitrogen (206.2 kg/ha), phosphorus (19.2 kg/ha) and potassium (238.2 kg/ha).The recommended package and practices were followed for raising the crop. The CT plots were ploughed by tractor-drawn disc plough followed by planking, whereas ZT plots were left undisturbed. Wheat variety HUW 234 @ 120 kg/ha was sown at row distance of 22.5 cm. The previous season rice straw was applied @6 t/ha as mulch in the respective treatments. All the herbicides were applied as post-emergence (30 DAS) with the help of foot sprayer fitted with flat fan nozzle. Half amount of nitrogen and full dose of phosphorus and potash were applied as basal at the time of sowing, ¼ part of nitrogen was top dressed after first irrigation and remaining ¼ part of nitrogen was top dressed at spike initiation stage. The nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and murate of potash, respectively. For collecting weed data, an area of 0.25m^2 was selected randomly at 3 spots in each plot by placing a quadrate of 0.5×0.5m, weed species were counted from that area, and density was expressed in numbers/m^2 at 80 DAS. The collected weeds were first sun-dried and then kept in an electric oven at 60^o C till the weight become constant, and dry weight was expressed as g/m^2. As wide variation existed in the data, number and dry weight of weeds were transformed through squire-root [$\sqrt{(x+0.5)}$] methods before analysis of variance. Wheat was harvested manually, but was threshed by power operated thresher.

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Table 1 Weed density and dry weight and yield attributes of wheat as influenced by crop establishment methods and weed management practices (two years pooled data)

Treatment	Weed density at 80 DAS (No./m^2)	Weed dry weight at 80 DAS (g/m^2)	Effective tillers (running/m)	Spike length (cm)	Spikelets/ spike	Grains/ spike	Grain weight/ spike (g)	1000 grain weight (g)
Crop establishment methods								
Conventional tillage-no residue	14.11(198.7)	5.04(25.0)	93.5	7.84	17.2	45.24	1.81	38.81
Conventional tillage with residue	12.23(149.1)	4.65(21.1)	103.0	8.33	18.03	46.58	1.95	41.92
Zero tillage-no residue	13.71(187.4)	4.89(23.5)	92.2	7.77	17.04	44.70	1.73	37.15
Zero tillage with residue	11.63(134.7)	4.47(19.5)	98.1	8.19	17.96	46.37	1.91	41.09
SEm±	0.19	0.0.80	2.2	0.16	0.13	0.31	0.01	0.28
CD (P=0.05)	0.59	0.25	6.5	0.51	0.41	1.02	0.03	0.94
Weed management practices								
Weedy check	18.36(336.7)	7.23(51.8)	81.2	7.25	16.91	43.97	1.75	37.56
Weed free	0.71(0.0)	0.71(0.0)	104.9	8.46	17.99	46.76	1.96	42.13
Mesosulfuron @12 g ai/ha at 30 DAS *fb* one HW at 45 DAS	14.02(196.1)	4.96(24.1)	92.7	7.87	17.31	45.21	1.77	37.98
Metsulfuron @4 g ai/ha at 30 DAS *fb* one HW at 45 DAS	13.67(186.4)	4.83(22.9)	96.0	7.96	17.47	45.35	1.8	38.60
Clodinafop+metsulfuron @60+4 g ai/ha at 30 DAS	12.25(149.5)	4.33(18.3)	101.5	8.28	17.78	46.37	1.90	40.67
Mesosulfuron+iodosulfuron @12+2.4 g ai/ha at 30 DAS	11.69(136.1)	4.12(16.5)	103.9	8.37	17.87	46.63	1.93	41.5
SEm±	0.17	0.04	1.2	0.13	0.11	0.29	0.01	0.23
CD (P=0.05)	0.52	0.15	3.7	0.36	0.32	0.88	0.03	0.70

*Figures in parentheses are the original values which were transformed to $\sqrt{(x+0.5)}$

Yield attributes and yield were recorded as per established procedures. The economic analysis in terms of gross and net returns, and benefit: cost (B: C) ratio was done on the basis of prevailing market rate of inputs and output. The B: C ratio for each treatment was calculated separately dividing net returns by respective cost of cultivation. The recorded data were statistically analyzed by standard analysis of variance technique for split plot design described by (Gomez and Gomez 1984).

The maximum density and dry weight of weeds were recorded with CT-no residue (Table 1). However, ZT with residue recorded minimum density and dry weight of weeds followed by CT with residue. Residue-based treatments recorded significantly minimum density and dry weight of weeds than without residue treatments might be due to possible smothering effect of residues on weeds. The results are in line with the research findings of (Susha *et al.* 2014).Weed management practices reduced the density and dry weight of weeds than weedy check (Table 1). Among herbicidal treatments, mixture application of mesosulfuron+ iodosulfuron observed significant reduction in density and dry weight of weeds than metsulfuron *fb* one hand weeding at 45 DAS and mesosulfuron *fb* one hand weeding at 45 DAS but adjudged at par with clodinafop +metsulfuron.The mixture application of mesosulfuron+iodosulfuron reduced density and dry weight of weeds (36.32 and 43.01%) over weedy check. Results obtained are in congruence with the research findings of (Pal *et al.* 2016) as they have also observed effective control of complex weed flora in wheat with tank-mix application of herbicides.

Among CEMs, CT with residue performed significantly better with respect to yield and yield attributes (Table 1 and 2).The maximum and minimum values of yield attributes were recorded under CT with residue and ZT-no residue treatments, respectively. CT with residue was found to be significantly superior to ZT-no residue but remained statistically at par to ZT with residue treatment. These results corroborate the research findings of (Surin *et al.* 2012).Across weed management practices, mixture application of mesosulfuron+iodosulfuron observed significantly highest values of yield attributes than metsulfuron *fb* one hand weeding at 45 DAS and mesosulfuron *fb* one hand weeding at 45 DAS but remained statistically at par with clodinafop+metsulfuron. The combined application of mesosulfuron + iodosulfuron increased spike length (15.44%) and effective tillers (27.95%) as compared to weedy check might be due to lesser crop weed competition. Results are in conformity with the research findings of(Monsefi *et al.* 2016).Weed free treatment out-performed over all the herbicidal based treatments, recorded significantly higher values of yield attributes than mesosulfuron+iodosulfuron, which was

Table 2 Yield and economics of wheat as influenced bycrop establishment methods and weed management practices (two years pooled data)

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Crop establishment methods						
Conventional tillage-no residue	3446	5145	37992	85172	47181	1.24
Conventional tillage-with residue	3667	5425	43117	90408	47292	1.10
Zero tillage-no residue	3364	5020	35892	83128	47236	1.31
Zero tillagewith residue	3542	5260	41042	87421	46379	1.13
SEm±	27.2	29.9	-	445	445	0.01
CD (P=0.05)	81.5	97.8	-	1540	NS	0.04
Weed management practices						
Weedy check	2307	3550	34145	57487	23342	0.68
Weed free	4162	5940	48395	101634	53239	1.10
Mesosulfuron @ 12 g ai/ha at 30 DAS *fb* one HW at 45 DAS	3395	5251	39840	84728	44888	1.13
Metsulfuron @ 4 g ai/ha at 30 DAS *fb* one HW at 45 DAS	3429	5309	39745	85604	45860	1.15
Clodinafop+metsulfuron @ 60+4 g ai/ha at 30 DAS	3806	5538	36169	93425	57256	1.58
Mesosulfuron+iodosulfuron @ 12+2.4 g ai/ha at 30 DAS	3854	5592	35707	94538	58830	1.65
SEm±	20.5	27.7	-	439	437	0.01
CD (P=0.05)	58.5	79.0	-	1256	1252	0.03

Cost of cultivation= common cost + treatment cost; Price of wheat grain @ ₹ 1800/100 kg; Price of wheat straw @ ₹ 450/100 kg

found best among the herbicidal treatments. Similar results have also been reported by (Pal *et al.* 2016).

Further, CEMs showed significant influence on grain and straw yield (Table 2). CT with residue recorded significantly highest grain (3667 kg/ha) and straw yield (5425 kg/ha) over other CEMs might be due to minimal crop weed competition and production of higher yield attributing characters. CT with residue recorded higher grain (3.53%) and straw (3.14%) yield than ZT with residue treatment. The results are in agreement with the research findings of Monsefi *et al.* (2016). Among different herbicides, mesosulfuron+ iodosulfuron followed by clodinafop +metsulfuron, metsulfuron *fb* one hand weeding at 45 DAS and mesosulfuron *fb* one hand weeding at 45 DAS recorded significantly highest grain and straw yield. However, minimum grain and straw yield was observed with weedy check. The mixture application of mesosulfuron+iodosulfuron proved its superiority over all the treatments and reported higher grain (67.05%) and straw (57.52%) yield over weedy check. These results confirm the research findings of Monsefi *et al.* (2016 and Pal *et al.* 2016).

CEMs significantly influenced gross returns and B: C ratio but not net returns (Table 2). The maximum gross returns were recorded under CT with residue as compared to rest of the CEMs. Whereas, B: C ratio was reported highest with ZT no-residue. CT with residue reported 3.42% higher gross returns than ZT with residue. The results are corroborated with the research finding of (Surin *et al.* 2012). Among weed management practices, weed-free as usual reported the highest yield but indicated lower net returns and B: C ratio, considered important parameters for judging economic viability of any treatment, due to highest cost incurred in carrying out hand weeding operations. Across the herbicidal treatments, application of mesosulfuron+iodosulfuron reported highest gross returns, net returns and B:C ratio followed by clodinafop +metsulfuron, metsulfuron *fb* one hand weeding at 45 DAS and mesosulfuron *fb* one hand weeding at 45 DAS, respectively. The mixture application of mesosulfuron+iodosulfuron increased gross (64.45%) and net (152.02%) returns and B: C ratio (142.65%) over weedy check. These results are in line with the research findings of (Susha *et al.* 2014).

SUMMARY

Weed menace is very prominent in wheat sown after the harvesting of rice in rice-wheat cropping system. An experiment involving four crop establishment methods and six weed management practices was undertaken in a split-plot design with three replications at the Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The residue-based crop establishment methods were found most effective in minimising density and dry weight of weeds. Besides minimising weeds, the residue-based crop establishment methods also proved better for yield attributes, yield and gross returns. Among different herbicidal treatments, the mix application of mesosulfuron+ iodosulfuron adjudged superior recorded lowest density and dry weight of weeds with highest yield attributes, grain and straw yield (3854 and 5592 kg/ha) and economics attributes. Based on the obtained results, it is said in the conclusion that residue-based crop establishment methods

and mix application of mesosulfuron+iodosulfuron was best in managing weed and enhancing yield and economics of wheat in the eastern India.

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