

Bio-efficacy of metsulfuron methyl and carfentrazone ethyl against weed spectrum in wheat (*Triticum aestivum* L.)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2016–17 and 2017–18 at the Chandra Shekhar Azad University of Agriculture and Technology Kanpur, Uttar Pradesh, to evaluate bio-efficacy and phytotoxicity of metsulfuron methyl 10% + carfentrazone ethyl 40% against weed flora in irrigated wheat crop (*Triticum aestivum* L.). Major dominant weeds that infested the crop were lamb's quarters (*Chenopodium album* L.), scarlet pimpernel (*Anagallis arvensis* L.) and white sweet clover (*Melilotus albus* Medik.). The lowest dry weight (g/m²) and weed-control efficacy (WCE) of test weed species were found in treatments T₄ (metsulfuron methyl 10% + carfentrazone ethyl 40% @ 100 g/ha), T₃ (metsulfuron methyl 10% + carfentrazone ethyl 40% @ 75 g/ha) and T₂ (metsulfuron methane 10% + carfentrazone ethyl 40% @ 50 g/ha) respectively. Application of metsulfuron methyl 10% + carfentrazone ethyl 40% at all doses was found to be effective against all the 3 weeds and significantly increased the yield of the main crop. Application of weedicides did not show any phytotoxicity symptoms on the wheat crop in both the seasons and also on the succeeding crop of rice (*Oryza sativa* L.).

Key words: Bio-efficacy, Metsulfuron methyl 10% + Carfentrazone ethyl, Weed control

Wheat grain is considered as the staple crop worldwide. In India the total area under wheat production is about 29.8 million ha (https://farmer.gov.in/m_cropstaticswheat.aspx). Uttar Pradesh being the top-most contributor of wheat with a total production of 25.22 million tones followed by Punjab and Madhya Pradesh (https://apeda.gov.in/apedawebsite/SubHead_Products/Wheat.). Production and yield of the crop get seriously affected by weed infestation (Cheema and Farooq, 2007). Weeds damage the crop by competing not only for light, water and nutrients but also release some allelochemicals which are harmful for the growth of main crop (Reddy, 2000). Chaudhary *et al.* (2008) reported that, with the production of each kg of weed, 1 kg grains of wheat are reduced. Popular weeds of wheat in Indian subcontinent include small canary grass (*Phalaris minor* Retz.), winter white oat (*Avena sterilis* L.), lamb's quarters (*Chenopodium album* L.), pimpernel (*Anagallis arvensis* L.), field bind weed (*Convolvulus*

arvensis L.) etc. The ecological condition of crop has undergone significant changes with the introduction of high-yielding varieties of wheat, which are highly responsive to irrigation and fertilizer, promoting the manifestation of grassy weeds. The losses incurred by heavy infestation of weeds alone estimated to be 33% reduction in yield which is a serious limitation in sustaining productivity of wheat (Mukherjee *et al.*, 2011). Besides manual weeding and hand hoeing, chemical herbicides play a significant role in weed management (Ahmad and Shaikh, 2003). Herbicides like isoproturon and pendimethalin are being used since 1982 in major belt of India for effective control of grassy weeds in wheat (Walia *et al.*, 1998; Chopra *et al.*, 2001). However, its efficacy has declined during the last few years due to development of resistance (Chhokar *et al.*, 2008).

Metsulfuron methyl is a post-emergence herbicide which acts by inhibiting cell-division in the shoots and roots of the plant and carfentrazone ethyl is a contact foliar herbicide used to control broad-leaf and sedges weeds in wheat, barley (*Hordeum vulgare* L.). It acts by inhibiting the action of protoporphyrinogen oxidase, disrupting the membranes of cell, causing death. Carfentrazone ethylene has been known to cause temporary injury to wheat plants by showing cosmetic speckling on leaves; however, plants recover within 2 to 3 weeks without showing any reduction

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in yield (Howatt, 2005). Bio-efficacy of carfentrazone or metsulfuron when applied alone on weeds like yellow pea (*Lathyrus aphaca* L.), fineleaf fumitory (*Fumaria parviflora*) and Lesser swinecress (*Coronopus didymus* (L.) Sm.) was found to be unsatisfactory but would be ideal for increased spectrum of weed control when applied in combination (Singh *et al.*, 2008). Therefore, herbicides with different mode of action when mixed together, bind to different target site in weeds and prevent the probability of target-site resistance in susceptible species. The present study was designed to see the effect of most efficient post emergence herbicides combinations on weed-control efficiency of a complex weed flora leading to sustain productivity and profitability of wheat production.

MATERIALS AND METHODS

A field experiment was conducted during the winter season of 2016–17 and 2017–18 to evaluate the bio-efficacy and phytotoxicity of metsulfuron methyl 10% + carfentrazone ethyl 40% against weed flora in irrigated wheat crop at the research farm of the Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. Nine different herbicide formulations were imposed in the experiment as T₁, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 30 g/ha; T₂, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 50 g/ha; T₃, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 75 g/ha; T₄, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 100 g/ha; T₅, Lanfida (metsulfuron methyl 10% + carfentrazone ethyl 40%) @ 50 mg/ha; T₆, Affinity (carfentrazone ethyl 40%) @ 50 mg/ha; T₇, weed Free; T₈, hand weeding at 30 and 45 days after sowing (DAS), and T₉, control.

Efficacy of this formulation was compared with check Lanfida and Affinity. These herbicide treatments were compared with the untreated control treatments. The herbicide formulation of metsulfuron methyl 10%+ carfentrazone ethyl 40% was also evaluated for its phytotoxicity on wheat in the same experiment in treatments, viz, metsulfuron methyl 10%+ carfentrazone ethyl 40% @ 50, 75 and 100 g/ha and were compared with the control. The experiment was laid out in a randomized block design. A wheat variety Shatabdi was used in the study. The seeds were sown in experimental field on 10 December 2016 and on 3 December 2017. The spacing adopted was 20.0 cm × 5.0 cm.

The soil was sandy loam, low in available nitrogen (N), medium in phosphorus (P) and high in available potassium (K). A full dose of farm yard manure, phosphorus and potassium was applied basal. The nitrogen was applied in 2 splits- half at the time of sowing and half after the first irrigation (22 days after sowing). A minimum of 5 irrigations

were given at different critical stages of growth. First irrigation was given just after sowing followed by irrigation at the crown-root initiation, tillering, flowering and grain-filling stages.

The test herbicides, viz. metsulfuron methyl 10% carfentrazone ethyl 40% as well as check herbicide Affinity (carfentrazone ethyl 40%) @ 50 g/ha, were sprayed on 10 January 2017 and 2 January 2018. In plots T₇, T₈ and T₉ only water was sprayed @ 500 L/ha. In all the plots, non-ionic surfactant @ 0.2% (ISo-Octyl-phenyl-polyoxyethanol 12.5%) were added in the spray solution as per recommendation. The spray volume used was 500 L/ha. The weeds inside each quadrat for density count were uprooted, cleaned and dried. After drying, weed-control efficiency (WCE) was calculated with the following formula:

$$\text{Weed-control efficiency (WCE)} = \frac{[\text{DMC} - \text{DMT}]}{\text{DMC}} \times 100$$

where, DMC, weed dry matter in unweeded treatment; DMT, weed dry matter in weed control treatment

The crop was harvested on 28th April 2017 and 3rd May 2018 to record various yield and yield-attributing parameters. Statistical analysis of data was done using MSTAC program. The level of significance used in 'F' and 't' test was P=0.05. The critical difference values were calculated wherever the 'F' test was significant. In other cases, values of standard error means have been provided.

RESULT AND DISCUSSION

Weed population and weed dry weight

The data recorded on *Chenopodium album*, *Melilotus albus* and *Analgallis arvensis* at 30, 45 and 60 days after application of herbicides indicated that, among all the different treatments lower weed population was observed in treatment T₇ followed by T₄ T₃ and T₂ respectively. The control (T₉) recorded the highest population of 3 weeds species during both the seasons. Among standard checks, the lowest weed population was recorded in T₅ (Lanfida at 50 g/ha) followed by T₆ (Affinity) (Table 1).

Weed dry weight recorded in the first season at 30, 45 and 60 days after application indicated that, among all the treatments the lowest dry weight (g/m²) of test weed species was recorded in T₇, followed by T₄ (metsulfuron methyl 10% + carfentrazone ethyl 40% @ 100 g/ha), T₃ (metsulfuron methyl 10% + carfentrazone ethyl 40% @ 75g/ha) and T₂ (metsulfuron methane 10% + carfentrazone ethyl 40% @ 50 g/ha). The highest dry weight was recorded in the control. Similar trend for weed dry weight was recorded in the second season 30, 45 and 60 days after application (DAA) of herbicide (Table 2). The lower weed dry weight in weed-control treatments might be due to lesser number of weeds, rapid depletion of carbohydrate reserves of weeds and reduced photosynthetic activity. Khaliq *et al.*, (2013) also reported reduced weed density

Table 1. Weed density (No./m²) after spraying of metsulfuron methyl 10% + carfentrazone ethyl 40% against targeted weeds in wheat crop at 30, 45 and 60 days after application (DAA)

Treatment	<i>Chenopodium album</i>						<i>Melilotus albus</i>						<i>Anagallis arvensis</i>					
	30 DAA		45 DAA		60 DAA		30 DAA		45 DAA		60 DAA		30 DAA		45 DAA		60 DAA	
	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂
T ₁	2.55	2.61	2.86	2.92	3.14	3.19	1.96	1.78	2.20	1.96	2.41	2.12	1.96	1.96	2.20	2.20	2.41	2.41
T ₂	6.00	6.33	7.67	8.00	9.33	9.67	3.33	2.67	4.33	3.33	5.33	4.00	3.33	3.33	4.33	4.33	5.33	5.33
T ₃	2.20	2.41	2.35	2.55	2.48	2.68	1.68	1.58	1.78	1.68	1.87	1.78	1.58	1.68	1.68	1.78	1.78	1.87
T ₄	4.33	5.33	5.00	6.00	5.67	6.67	2.33	2.00	2.67	2.33	3.00	2.67	2.00	2.33	2.33	2.67	2.67	3.00
T ₅	2.04	2.20	2.20	2.35	2.41	2.55	1.58	1.58	1.68	1.68	1.87	1.87	1.47	1.58	1.58	1.68	1.78	1.87
T ₆	3.67	4.33	4.33	5.00	5.33	6.00	2.00	2.00	2.33	2.33	3.00	3.00	1.67	2.00	2.00	2.33	2.67	3.00
T ₇	1.96	2.04	2.12	2.20	2.35	2.41	1.58	1.47	1.68	1.58	1.87	1.78	1.22	1.22	1.35	1.35	1.47	1.47
T ₈	3.33	3.67	4.00	4.33	5.00	5.33	2.00	1.67	2.33	2.00	3.00	2.67	1.00	1.00	1.33	1.33	1.67	1.67
T ₉	2.61	2.86	2.92	3.19	3.19	3.49	2.12	1.96	2.35	2.20	2.55	2.41	1.78	1.87	1.96	1.96	2.12	2.12
SEM±	6.33	7.67	8.00	9.67	9.67	11.67	4.00	3.33	5.00	4.33	6.00	5.33	2.67	3.00	3.33	3.33	4.00	4.00
CD (P=0.05)	0.71	0.82	0.84	0.86	0.81	0.88	0.68	0.74	0.76	0.79	0.80	0.83	0.61	0.66	0.72	0.74	0.75	0.79
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.61	2.35	3.08	2.74	3.54	3.14	2.35	2.61	2.74	3.08	3.14	3.54	1.78	2.35	2.12	2.74	2.41	3.14
	6.33	5.00	9.00	7.00	12.00	9.33	5.00	6.33	7.00	9.00	9.33	12.00	2.67	5.00	4.00	7.00	5.33	9.33
	4.14	4.26	4.42	4.53	4.85	4.95	3.19	3.08	3.39	3.29	3.72	3.63	2.55	2.74	3.29	3.19	3.67	3.49
	16.67	17.67	19.00	20.00	23.00	24.00	9.67	9.00	11.00	10.33	13.33	12.67	6.00	7.00	10.33	9.67	13.00	11.67
	0.349	0.372	0.436	0.468	0.528	0.559	0.207	0.208	0.224	0.258	0.302	0.330	0.129	0.160	0.223	0.225	0.282	0.281
	1.056	1.124	1.018	1.415	1.597	1.691	0.626	0.29	0.737	0.781	0.913	0.999	0.389	0.483	0.647	0.680	0.851	0.850

Y₁, 2016-17; Y₂, 2017-18
 T₁, Metsulfuron methyl 10% + carfentrazone ethyl 40% @ 30 g/ha; T₂, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 50 g/ha; T₃, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 75 g/ha; T₄, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 100 g/ha; T₅, Lanfida (metsulfuron methyl 10% + carfentrazone ethyl 40%) @ 50 mg/ha; T₆, Affinity (carfentrazone ethyl 40%) @ 50 mg/ha; T₇, weed-free; T₈, hand-weeding at 30 and 45 days after sowing; and T₉, control

Table 2. Weed dry weight (g/m²) after spraying of metsulfuron methyl 10% + carfentrazone ethyl 40% against targeted weeds in wheat crop at 30, 45 and 60 days after application (DAA).

Treatment	<i>Chenopodium album</i>						<i>Melilotus albus</i>						<i>Anagallis arvensis</i>					
	30 DAA		45 DAA		60 DAA		30 DAA		45 DAA		60 DAA		30 DAA		45 DAA		60 DAA	
	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂
T ₁	2.68	2.74	3.33	3.40	4.14	4.21	2.07	1.90	2.54	2.26	3.16	2.77	2.10	2.08	2.55	2.54	3.18	3.19
T ₂	6.66	7.03	10.58	11.04	16.61	17.21	3.78	3.12	5.98	4.60	9.49	7.16	3.89	3.81	6.02	5.95	9.59	9.65
T ₃	1.99	2.18	2.47	2.69	2.92	3.16	1.55	1.45	1.87	1.76	2.18	2.07	1.47	1.52	1.75	1.86	2.30	2.44
T ₄	3.46	4.26	5.60	6.72	8.05	9.47	1.89	1.60	2.99	2.61	4.26	3.79	1.65	1.80	2.56	2.96	4.81	5.43
T ₅	1.84	1.97	2.29	2.45	2.83	2.99	1.44	1.45	1.76	1.75	2.17	2.17	1.36	1.44	1.66	1.78	2.30	2.44
T ₆	2.88	3.40	4.76	5.50	7.52	8.46	1.57	1.61	2.59	2.56	4.23	4.23	1.35	1.58	2.26	2.66	4.81	5.43
T ₇	1.76	1.83	2.20	2.28	2.73	2.81	1.44	1.34	1.74	1.64	2.16	2.05	1.14	1.15	1.42	1.12	1.87	1.88
T ₈	2.60	2.86	4.36	4.72	6.95	7.41	1.56	1.30	2.54	2.18	4.17	3.71	0.81	0.82	1.50	1.52	3.01	3.02
T ₉	2.45	2.68	3.18	3.48	3.77	4.13	1.85	1.84	2.55	2.39	2.86	2.50	1.68	1.76	2.06	2.04	2.77	2.78
T ₁₀	5.51	6.67	9.60	11.60	13.73	16.57	2.93	2.90	6.00	5.20	7.68	5.76	2.32	2.61	3.76	3.68	7.20	7.24
T ₁₁	2.64	2.85	4.18	4.46	4.95	5.28	1.99	1.69	2.96	2.56	3.00	2.84	1.77	1.93	2.09	2.10	2.92	3.02
T ₁₂	6.45	7.63	16.94	19.36	24.00	27.36	3.48	3.48	8.24	6.03	8.52	7.57	2.64	3.23	3.85	3.90	8.04	8.62
T ₁₃	0.74	0.75	0.81	0.85	0.81	0.87	0.61	0.72	0.69	0.74	0.79	0.81	0.64	0.71	0.69	0.74	0.78	0.82
T ₁₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₁₅	2.74	2.46	3.49	3.10	4.68	4.14	2.50	2.77	3.10	3.49	4.14	4.68	1.86	2.46	2.39	3.10	3.18	4.17
T ₁₆	7.03	5.55	11.70	9.10	21.36	16.61	5.75	7.15	9.10	11.70	16.61	21.36	2.96	5.55	5.20	9.10	9.59	16.89
T ₁₇	4.36	4.48	5.17	5.30	6.29	6.43	3.38	3.27	3.96	3.84	4.81	4.69	2.70	2.88	3.84	3.72	4.75	4.51
T ₁₈	18.50	19.61	26.22	27.60	39.10	40.80	10.93	10.17	15.18	14.26	22.66	21.54	6.78	7.77	14.26	13.34	22.10	19.84
SEM±	0.402	0.422	0.599	0.637	0.895	0.926	0.246	0.248	0.343	0.358	0.537	0.592	0.152	0.186	0.316	0.316	0.478	0.487
CD (P=0.05)	1.215	1.276	1.812	1.927	2.708	2.799	0.743	0.750	1.037	1.081	1.623	1.790	0.460	0.564	0.955	0.955	1.444	1.473

Y₁, 2016-17; Y₂, 2017-18
 T₁, Metsulfuron methyl 10% + carfentrazone ethyl 40% @ 30 g/ha; T₂, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 50 g/ha; T₃, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 75 g/ha; T₄, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 100 g/ha; T₅, Lanfida (metsulfuron methyl 10% + carfentrazone ethyl 40%) @ 50 mg/ha; T₆, Affinity (carfentrazone ethyl 40%) @ 50 mg/ha; T₇, weed-free; T₈, hand-weeding at 30 and 45 days after sowing; and T₉, control

and dry weight by the application of different herbicides.

Weed-control efficiency

Weed-control efficiency (WCE) was calculated at 30, 45 and 60 days after application in both seasons. The data indicated that at 30 DAA, among different treatments the highest WCE was recorded in T₇ (weed free), followed by T₄, T₃ and T₂ respectively which was par with each other, whereas standard check T₅ (*Lanfinda*) and T₆ (*Affinity*) were next to these treatments. The result was almost same for both seasons. The WCE at 45 DAA was the highest in T₇ followed by T₄, T₃ and T₂ respectively were at par with each other whereas standard check T₅ (*Lanfinda*) was best among market checks during both the season. At 60 DAA, highest WCE was recorded in T₇ followed by T₄, T₃ and T₂ respectively which was on par with each other whereas standard check T₅ (*Lanfinda*), T₁ (metsulfuron methyl 10% + carfentrazone ethyl 40% at 30 g/ha) and T₆ (*Affinity*) were next in effect and were at par with T₁ (Table 3). As the crop development increased there was decrement in weed control efficiency and herbicide combinations at all rate of application were better than the control at all rates of application. These findings are in accordance with Noor Ashiq *et al.* (2007), who reported that herbicides with broad spectrum provided better weed control efficiency than the control.

Growth and yield-contributing characters

Effect of herbicide was also studied on agronomic parameters of the crop in both seasons. The data on plant height indicated that, the maximum height was observed in T₂ (93.83 cm), followed by T₈ (92.93 cm) whereas the lowest height in T₉ (84.95 cm) at the time of harvesting during the first season. In second season, the highest plant height was recorded in T₂ (88.70 cm), followed by T₈ (88.59 cm). the lowest plant height was recorded in T₉ (77.32 cm) (Table 4). Data on number of tillers indicated that the highest number of tillers/m² was recorded in T₂, whereas the lowest number of ears/m² were recorded in T₉ in both the seasons. Number of grains/ears in the first season, it was the highest in T₂ (59.78) and the lowest in T₁ (51.64). Similarly in second season it was found highest in T₃, whereas the lowest number of filled grains/pinnacles was in T₆ (Table 4).

Data on test weight (g) indicated that, among all the herbicidal treatments, the highest test weight was recorded in T₂ during the first season and T₈ in the second season. At harvesting, the grain yield during the first season was significantly in T₇, weed-free (5.22 t/ha), followed by T₂ (5.11 t/ha), T₃ (4.91 t/ha) and T₄ (4.82 t/ha) treatments (Table 4). Significantly lowest yield was recorded in the control. In the second season, significantly maximum yield was ob-

Table 3. Weed-control efficiency (%) of metsulfuron methyl 10% + carfentrazone ethyl 40% against targeted weeds in wheat crop at 30, 45 and 60 days after application (DAA)

Treatment	Chenopodium album						Melilotus albus						Anagallis arvensis					
	30 DAA		45 DAA		60 DAA		30 DAA		45 DAA		60 DAA		30 DAA		45 DAA		60 DAA	
	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂
T ₁	64.01	64.18	59.63	60.00	57.53	57.81	65.41	69.32	60.64	67.76	58.13	66.76	42.63	50.97	57.77	55.41	56.59	51.37
T ₂	81.28	78.26	78.64	75.65	79.41	76.79	82.70	84.27	80.30	81.69	81.20	82.40	75.66	76.83	82.02	77.79	78.25	72.63
T ₃	84.43	82.67	81.83	80.07	80.78	79.26	85.63	84.17	82.96	82.02	81.33	80.36	80.09	79.67	84.15	80.10	78.25	72.63
T ₄	85.96	85.41	83.37	82.90	82.23	81.84	85.72	87.19	83.27	84.71	81.60	82.77	88.05	89.45	89.46	88.64	86.40	84.76
T ₅	70.24	65.98	63.39	57.96	64.88	59.38	73.19	71.51	60.47	63.55	66.11	73.26	65.74	66.41	73.60	72.42	67.42	63.51
T ₆	65.14	61.10	35.39	29.86	38.61	32.94	68.15	76.90	45.72	57.70	62.40	64.85	61.06	58.44	72.99	70.77	63.62	56.55
T ₇	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
T ₈	62.73	71.70	55.38	76.03	45.37	59.30	47.38	29.67	40.05	17.93	26.71	0.83	56.29	28.57	63.52	31.81	56.59	14.88
T ₉	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Y₁, 2016-17; Y₂, 2017-18

T₁, Metsulfuron methyl 10% + carfentrazone ethyl 40% @ 30 g/ha; T₂, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 50 g/ha; T₃, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 75 g/ha; T₄, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 100 g/ha; T₅, Lanfida (metsulfuron methyl 10% + carfentrazone ethyl 40%) @ 50 mg/ha; T₆, Affinity (carfentrazone ethyl 40%) @ 50 mg/ha; T₇, weed-free; T₈, hand-weeding at 30 and 45 days after sowing; and T₉, control

Table 4. Effect of application of metsulfuron methyl 10% + carfentrazone ethyl 40% on grain yield of wheat (Season: *rabi*, 2016–17 and 2017–18)

Treatment	Plant height at harvesting (cm)		Effective no. of tillers/m		No. of Grains/car		Test Weight (g)		Grain Yield (t/ha)		% increase in yield over control	
	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂	Y ₁	Y ₂
T ₁	83.09	78.00	81.72	78.01	51.64	49.78	41.02	42.43	4.43	4.34	25.04	37.10
T ₂	93.83	88.70	93.65	89.31	59.78	56.3	44.39	45.23	5.11	4.89	44.34	54.77
T ₃	91.35	87.35	93.61	88.26	58.50	56.34	43.82	45.00	4.91	4.83	38.67	52.82
T ₄	90.46	87.04	92.46	87.08	58.51	56.14	43.91	44.46	4.82	4.78	36.10	51.27
T ₅	89.54	85.56	89.19	86.19	56.18	54.31	42.98	44.04	4.53	4.35	28.08	37.46
T ₆	85.54	80.73	83.97	79.07	52.86	50.91	41.11	41.74	4.82	4.56	36.10	44.27
T ₇	84.83	80.49	82.75	79.99	53.09	50.99	41.38	41.59	5.22	5.03	47.44	59.13
T ₈	92.93	88.59	90.09	83.72	54.94	53.9	43.63	45.81	4.64	4.41	31.15	39.48
T ₉	84.95	77.32	77.05	70.33	53.42	51.51	42.42	42.57	3.54	3.16	29.20	30.45
SEm±	0.300	0.352	0.464	0.487	0.225	0.208	0.113	0.120	0.377	0.425	-	-
CD (P=0.05)	0.906	1.063	1.402	1.473	0.680	0.629	0.342	0.363	1.141	1.286	-	-

Y₁, 2016–17; Y₂, 2017–18T₁, Metsulfuron methyl 10% + carfentrazone ethyl 40% @ 30 g/ha; T₂, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 50 g/ha; T₃, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 75 g/ha; T₄, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 100 g/ha; T₅, Lanfida (metsulfuron methyl 10% + carfentrazone ethyl 40%) @ 50 mg/ha; T₆, Affinity (carfentrazone ethyl 40%) @ 50 mg/ha; T₇, weed-free; T₈, hand-weeding at 30 and 45 days after sowing; and T₉, control

served in T₇ weed free (5.03 t/ha) followed by the T₂ (4.89 t/ha), T₃ (4.83 t/ha), T₄ (4.78 t/ha) and T₅ (4.35 t/ha) treatments and the lowest grain yield was recorded in the control (3.16 t/ha). All the weed control treatments increased the grain yield. This might be owing to decrease in weed population in the plots treated with these herbicides, where there was less competition between crop and weeds for nutrition, moisture, light, space and provided congenial condition for development of its reproductive phase, resulting in the enhancement of yield-contributing characters. Our results confirm the findings of Shakya and Dixit (2017).

Phytotoxicity effect

The effect of phytotoxicity of metsulfuron methyl 10% + carfentrazone ethyl 40% on wheat crop for both season (average of 1-10 days observation) was also studied (Table 5). No visual symptoms of injury or phytotoxicity were observed in both the seasons in any of the tested dose (30, 50, 75 and 100 g/ha) during the period from first day of application to 10 days. Phytotoxic effects of metsulfuron methyl 10% + carfentrazone ethyl 40% was also studied on the succeeding crop rice. No symptoms of phytotoxicity such as epinasty, necrosis, vein clearing, wilting and leaf mortality was observed at any stage of the succeeding rice crop during the rainy (kharif) season of 2017 and 2018. Yield of the succeeding crop was also not affected by herbicide treatment in both the seasons (Table 5).

Table 5. Residual effect of different herbicides applied in wheat on succeeding paddy crop at 30 days after sowing

Treatment	Panicles/hill	Panicle length (cm)	Grain yield (t/ha)
T ₁	18.39	20.22	4.45
T ₂	19.84	21.48	4.60
T ₃	19.29	20.87	4.43
T ₄	19.20	20.78	4.31
T ₅	18.64	20.62	4.43
T ₆	18.53	20.55	4.32
T ₇	20.11	21.95	4.62
T ₈	18.14	20.10	4.04
T ₉	18.04	19.46	3.94
SEm±	0.146	0.054	3.51
CD (P=0.05)	0.210	0.211	6.45

T₁, Metsulfuron methyl 10% + carfentrazone ethyl 40% @ 30 g/ha; T₂, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 50 g/ha; T₃, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 75 g/ha; T₄, metsulfuron methyl 10% + carfentrazone ethyl 40% @ 100g/ha; T₅, Lanfida (metsulfuron methyl 10% + carfentrazone ethyl 40%) @ 50 mg/ha; T₆, Affinity (carfentrazone ethyl 40%) @ 50 mg/ha; T₇, weed-free; T₈, hand-weeding at 30 and 45 days after sowing; and T₉, control

It may be concluded that, alone herbicidal application is either ineffective or less effective against complex weed flora. However, a combination of 2 or more compatible herbicide like metsulfuron methyl + carfentrazone ethyl at all doses was quite effective against complex weed flora in wheat, resulting in higher weed-control efficiency and significantly increased the yield of the wheat and economic returns/unit area. Therefore, combining 2 compatible herbicide molecules will be a better option for managing complex weed flora in the wheat field than the sole herbicide. It also did not impose any phytotoxicity symptoms on crop, and also had no adverse effect on planting (%) and yield of succeeding crop of rice, neither it showed any phytotoxic symptoms on succeeding rice crop. Therefore, metsulfuron methyl + carfentrazone ethyl may be recommended to farmers for effective control against weed flora in wheat.

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