Indian Journal of Weed Science **52**(4): 331–335, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Weed management in wheat by pre-emergence and pre-mix post-emergence combinations of herbicides

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Article information

DOI: 10.5958/0974-8164.2020.00066.0

Type of article: Research article

Received : 19 July 2020
Revised : 26 November 2020
Accepted : 28 November 2020

Key words
Clodinafop-propargyl
Metsulfuron-methyl
Post-emergence
Pre-mix
Wheat

ABSTRACT

Field investigation was carried out at Akola, Maharashtra during three consecutive *Rabi* season of 2016-2017, 2017-18 and 2018-19 to assess the efficacy of herbicide combinations in wheat. Treatments comprised of twelve different pre-emergence and pre-mix combinations of post-emergence herbicides. Results revealed that pre-mix post-emergence application (PoE) of clodinafop propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha at 35 DAS and sulfosulfuron + metsulfuron-methyl 0.03 + 0.002 kg/ha at 35 DAS gave higher weed control efficiency (90 and 80%) and lower weed index (2.85 and 2.98%). These proved as effective as weed free treatment and recorded significantly higher grain yield of 4.37 and 4.36 t/ha, respectively over rest of the treatments. The highest net monetory returns and B:C ratio (₹ 64356/ha, 3.69) were registered with application clodinafop-propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha at 35 DAS followed by sulfosulfuron + metsulfuron-methyl 0.03 + 0.002 kg/ha at 35 DAS. (₹ 62162/ha and 3.40).

INTRODUCTION

Wheat (*Triticum aestivum*. L.) is the most widely cultivated as staple food crop of world playing crucial role in global food security by providing food to billions of people and half of the dietary protein and more than half of the calories (Meena *et al*. 2017). It is the second important food crop consumed next to rice and contributes to the extent of 25% of total food grain production of country.

In era of climate change and increasing biotic and abiotic stresses, maintaining yield up to required level is going to be formidable challenge in coming future. Productivity of the wheat depends upon several factors like crop establishment techniques, irrigation, weed management, fertilizers management and other cultural practices.Weeds are the major deterrent to the development of sustainable wheat crop production and causes enormous losses (37.0 to 57.1%) due to their interference. (Verma *et al*. 2015). Wheat in *Rabi* season is generally sown after pre-sowing irrigation to obtain the uniform stand of the crop, but at the same time irrigation favours germination of weed seeds. Under such a situation, it is very essential to control weeds during the first 35 to 45 days after sowing. Weed competiton for longer period results into reduction of surviving tillers and the tillers bear short ears, less number of grains in comparison to crop tillers produced in weed free situation. (Rathod and Vadodaria 2004).

In wheat, chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding. Nowadays there are many good ready-mix combinations of herbicides used for weed control in wheat and they were found effective in controlling broad spectrum weeds in wheat. Combination of sulfosulfuron + metsulfuron, clodinafop + metsulfuron and mesosulfuron + iodosulfuron has been found promising against complex weed flora. Under such situation, a suitable combination of some broad-spectrum herbicides are needed. To control diverse weed flora, application of two or more herbicides and pre-mix combination is advantageous. Hence, an attempt was made to assess the efficancy of different post-emergence herbicide combinations on weed flora, growth and yield of wheat.

MATERIALS AND METHODS

The study was conducted at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during three consecutive *Rabi* season of the year 2016-2017, 2017-18 and 2018-19. The experiment was laid out in a randomized block design with twelve treatments replicated thrice. Treatments include pendimethalin

1.0 kg/ha, sulfosulfuron 0.025 kg/ha, metribuzin 0.21 kg/ha, clodinafop 0.06 kg/ha, pendimethalin + metribuzin 1.0 + 0.175 kg/ha, pendimethalin *fb* sulfosulfuron 1.0 + 0.018 kg/ha, sulfosulfuron + metsulfuron 0.3 + 0.002 kg/ha, pinoxaden + metsulfuron-methyl 0.6 + 0.004 kg/ha, mesosulfuron + iodosulfuron 0.012+ 0.0024 kg/ha, clodinafop-propargyl + metsulfuron 0.06 + 0.004 kg/ha, 2 hand weeding at 30 and 60 DAS and unweeded control. The soil was low in nitrogen, medium in available phosphorus and high in potassium content. Wheat variety '*AKAW-4627*' was sown on 20th November, 17th November and 26th November during the year 2016-17, 2017-18 and 2018-19, respectively at 22.5 spacing with 120:60:60 NPK kg/ha. After sowing, a light irrigation was given to the crop for uniform germination and next day pre-emergence herbicides were applied. The application of herbicide was done as per the treatments with manually operated knapsack sprayer attached with a flat fan nozzle. After calibrating the sprayer, water volume used was 700 L/ha for PE and 500 L/ha for PoE.

The observations on weed density and weed biomass were taken at 30 days interval upto harvest from four randomly selected spots by using a quadrate of 50 x 50 cm from net plot area. The entire weeds inside the quadrat were uprooted and cut close to the transition of root and shoot in each plot and collected for dry matter accumulation. Then weeds were grouped as monocot species and dicot species. The samples were first dried in sun and kept in oven at 70 $\pm$ 2^{0}C. The dried samples were weighed and expressed as dry biomass (g/m^2). Square root transformation was done for weed density and weed biomass by using the formula ($\sqrt{x+1}$). Weed control efficiency (WCE) and weed index was calculated by using standard formula suggested by Mani *et al*. (1973). Phytotoxicity symptoms due to herbicides on crop was recorded by using a visual score scale of 0-10 scale method as proposed by Rao (2000). Visual assessment of herbicide toxicity on crop was monitored 10 days after application of herbicide in respective treatment. Cost of cultivation, gross returns and benefit cost ratio for each treatment were calculated by taking into consideration of total costs incurred and returns obtained. Data on various growth and yield attributing characters were analysed as per standard procedure.

RESULTS AND DISCUSSION

Weed flora

The experimental field was absolutely invaded with mixed population of weed flora consisting of both dicots and monocots. Among the total weeds, dicots (82%) were more prominent than monocot weeds (18%). Major dicot weed flora during *Rabi* season in wheat crop was dominated by *Amaranthus polygamus, Euphorbia geniculata, Phyllanthus niruri, Parthenium hysterophorus, Argemone mexicana, Amaranthus viridis, Chenopodium album, Chenopodium murale, Melilotus indica, Portulaca oleracae, Mimosa pudica, Alternanthera triandra* and among the monocots weeds *Cyperus rotundus, Cynodon dactylon, Dinebra Arabica, Poa annua, Digitaria sanguinalis, Dinebra retroflexa and Commelina benghalensis* were the weeds observed in the experimental field. Similar observations on weed flora in wheat was also reported by Khobragade and Sathawane (2014).

Crop phytotoxicity

The herbicide toxicity on crop stand and growth was recorded at 10 days after application of herbicide in respective treatment by using visual score scale of 0-10. Phytotoxicity rating revealed that, at 10 DAS pre-emergence application metribuzin 0.21 kg/ha gave setback to wheat crop by causing stunting and discolouration of crop, but recovered after some days. Similar symptoms of phytotoxicity was observed in case of pendimethalin + metribuzin 1.0 + 0.175 kg/ha as a pre-emergence application (**Table 1**). However,among the post-emergence herbicide combination of mesosulfuron-methyl + iodosulfuron-methyl showed phytotoxic effect (score 2) on wheat crop where stunting and discolouration of leaves was observed for a limited period and recovered thereafter without any effect on final yield of wheat.Similar results with regards to phytotoxicity was reported earlier by Chaudhari *et al*. (2017).

Effect on weed density and dry weight of weeds

Pooled analysis of data revealed significant reduction in all weed control treatments with respect to weed density and dry weed biomass over unweeded control as indicated in (**Table 1**). Highest reduction in weed density and dry matter of weeds were recorded under two hand weeding at 30 and 60 DAS (13.98 no./m^2 and 15.40 g/m^2) due to complete removal of the weeds among the herbicides, clodinafop-propargyl + metsulfuron-methyl was found to be more superior in curtailing the weed population and dry weight of weeds (18.89 no./m^2, 24.66 g/m^2) followed by sulfosulfuron + metsulfuron-methyl (31.01 no./m^2, 47.14 g/m^2) as compared to unweeded control (**Table 1**). Sole application of a single herbicide was less effective in controlling weeds as compared to their pre-mix application. The tank mixtures of broad-leaf and

grassy weed killing herbicides provided higher order of performance in terms of weed density and intensity of total weeds as observed by Meena *et al*. (2017). Pre-mix combination of clodinafop-propargyl + metsulfuron-methyl provided excellent control of weeds. Total weed population was reduced significantly due to various weed control treatments. This might be due to the herbicidal application alone and in combination which were effective in timely reducing total weed population. Lekh Chand and Punia (2017) and Chaudhary *et al*. (2017) also reported similar results.

Effect on weed control efficiency and weed index

Weed control efficiency in wheat was significantly influenced by weed management treatments, where all the treatments resulted in increase of weed control efficiency over the weedy check. Highest value of weed control efficiency (92.4%) was obtained from hand weeding treatment. Amongst herbicides, maximum value of WCE was achieved by clodinafop-propargyl + metsulfuron-methyl (89.7%) followed by sulfosulfuron + metsulfuron-methyl (79.9%) application of pre-emergence herbicides while sole application of single herbicides registered low weed control efficiency (**Table 1**). This indicate that pre-mix herbicides have significant effect on minimizing the weed population, which resulted increased yield over control treatment. Similar results were also reported by Kumar *et al*. (2012) with clodinafop-propargyl + metsulfuron in wheat. The lowest weed index (2.85%) was obtained with clodinafop-propargyl + metsulfuron-methyl followed by sulfosulfuron + metsulfuron-ethyl (2.98%). Whereas yield reduction varied from 2.85% to 29.05% in the herbicide applied plots as compared to weed free treatment. Weed index was lower in all the treatments as compared to weedy check. which provided favourable conditions for crop growth which ultimately increased the grain yield of wheat crop as compared to weedy check treatment. Similar trends in weed control efficiency and weed index were also recorded.

Effect on growth and yield

Significant reduction in plant height was noticed in unweeded control treatment which might be due to competition between crop and weeds for soil moisture, plant nutrients, solar radiation and space during active growth period (**Table 2**). These results were in accordance with the results reported by Pradhan and Chakraborti (2010) and Kaur *et al.* (2017). Significantly the highest number of effective tillers/meter row length was recorded in two hand

Table 1. Phytotoxicity rating, weed count, weed dry matter, weed control efficiency and weed index as influenced by different weed control treatments (pooled of three years)

Treatment	Crop phytotoxicity visual rating score		Weed density/m^2				Weed dry matter (g/m^2)				WCE (%)	Weed index (%)
	Score	Effect on crop	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled		
Pendimethalin 1.0 kg/ha PE	0	No injury	7.15 (50.7)	7.18 (51.0)	7.08 (49.6)	7.14 (50.4)	8.34 (69.1)	9.65 (92.7)	9.73 (94.2)	9.24 (85.3)	63.22	29.05
Sulfosulfuron 0.025 kg/ha PoE at 35 DAS	0	No injury	6.05 (36.2)	6.04 (36.0)	5.91 (34.4)	6.00 (35.5)	7.02 (48.8)	6.98 (48.3)	8.12 (65.5)	7.37 (54.2)	76.88	14.83
Metribuzin 0.21 kg/ha PE	1	Slight stunting, discoloration	7.45 (55.0)	7.45 (55.0)	7.24 (51.9)	7.38 (54.0)	8.54 (72.5)	8.51 (72.0)	9.95 (98.6)	9.00 (81.0)	65.46	18.97
Clodinafop 0.06 kg/ha PoE at 35 DAS	0	No injury	6.52 (42.0)	6.52 (42.0)	6.42 (40.7)	6.49 (41.5)	7.83 (60.8)	7.82 (60.7)	8.82 (77.3)	8.16 (66.3)	71.61	15.37
Pendimethalin + metribuzin 1.0 + 0.175 kg/ha (tank mix) PE	1	Slight stunting, discoloration	7.29 (52.7)	7.29 (52.7)	7.07 (49.5)	7.22 (51.6)	8.49 (71.7)	8.63 (74.0)	9.72 (94.0)	8.95 (79.9)	65.80	21.34
Pendimethalin *fb* sulfosulfuron 1.0 + 0.018 kg/ha PE and PoE	0	No injury	6.65 (43.8)	6.67 (44.0)	6.55 (42.4)	6.62 (43.4)	7.44 (54.8)	7.47 (55.3)	9.01 (80.7)	7.97 (63.6)	73.03	6.30
Sulfosulfuron + metsulfuron-methyl 0.03 + 0.002 kg/ha PM at 35 DAS as PoE	0	No injury	5.68 (31.8)	5.64 (31.3)	5.51 (29.9)	5.61 (31.0)	6.56 (42.6)	6.51 (42.0)	7.57 (56.8)	6.88 (47.1)	79.88	2.98
Pinoxaden + metsulfuron-methyl 0.06 + 0.004 kg/ha PM at 35 DAS as PoE	0	No injury	6.60 (43.1)	6.59 (43.0)	6.50 (41.7)	6.56 (42.6)	7.47 (55.3)	6.66 (44.3)	8.93 (79.3)	7.69 (59.7)	74.85	10.29
Mesosulfuron-methyl + iodosulfuron-methyl 0.012 + 0.0024 kg/ha PM at 35 DAS as PoE	2	Stunting & discoloration	6.25 (36.6)	6.23 (38.3)	6.01 (35.7)	6.16 (36.9)	7.05 (49.2)	7.03 (49.0)	8.26 (67.8)	7.45 (55.3)	76.44	7.89
Clodinafop-propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha PM at 35 DAS as PoE	0	No injury	4.47 (19.5)	4.45 (19.3)	4.29 (17.9)	4.40 (18.9)	4.52 (20.0)	4.52 (20.0)	5.87 (34.0)	4.97 (24.7)	89.66	2.85
Two hand weeding – (30 and 60 DAS)	-	-	3.87 (14.6)	3.80 (14.0)	3.72 (13.3)	3.80 (14.0)	3.37 (10.9)	3.23 (10.0)	5.08 (25.3)	3.89 (15.4)	92.41	0.00
Un-weeded control	-	-	12.52 (156)	12.51 (156)	12.25 (150)	12.43 (154)	14.49 (210)	14.48 (209)	16.88 (284)	15.28 (234)	0.00	47.54
LSD (p=0.05)			0.48	0.44	0.37	0.49	0.43	0.48	0.47	0.46		

Figures in parentheses are original values; PE- Pre-emergence; PoE- Post-emergence; PM- Pre-mix

weeding treatment (102.17 no./m) but remained at par with all treatments where pre-mix combination of post-emergence herbicides were sprayed *i.e.* sulfosulfuron + metsulfuron-methyl, pinoxaden + metsulfuron-methyl, mesosulfuron-methyl + iodosulfuron-methyl and clodinafop-propargyl + metsulfuron-methyl. Data on grain per spike at harvest showed significant differences among treatments and showed the similar trends as in case of other growth attributes (**Table 2**). These results in accordance with the results reported by Amare *et al.* (2014) and Kaur *et al.* (2017).

Pooled analysis of different weed control treatments registered significant increase in grain yield of wheat compared to unweeded control during all the three years of study. Two hand weeding at 30 and 60 DAS recorded highest grain yield of 4.49 t/ha. Further data explicated that collective application of herbicides either as pre-mix, tank mix or sequentially gave significantly higher yield over single applied herbicides. Among the herbicides, higher value of grain yield in individual years and in pooled data was obtained with clodinafop-propargyl + metsulfuron-methyl 0.012 + 0.0024 kg/ha at 35 DAS (4.37 t/ha.) closely followed by sulfosulfuron + metsulfuron-methyl 0.03+0.002 kg/ha at 35 DAS (4.36 t/ha). Pooled data showed that both these treatments recorded 48.74% increase in grain yield over unweeded control was due to higher growth and yield attributes due to reduced weed infestation by these treatments, which helped the crop plants to accumulate more dry matter through more nutrient uptake that might have provided more quantity of photosynthates to developing sink in crop plants resulted in more yield. Similar results of improvement grain yield and weed control has been reported by Walia *et al.* (2010) and Chaudhari *et al.* (2017) with different herbicides combinations. Next best treatments in order of merit regarding the grain yield were pinoxaden + metsulfuron-methyland mesosulfuron-methyl + iodosulfuron-methyl, which brought about 46.66 and 45.78% increase in pooled grain yield over unweeded control. The solitary application of single herbicide resulted in lesser grain yield compared to pre-mix combination of post-emergence herbicides.

Economics of weed control

Although, hand weeding twice at 30 and 60 DAS recorded the maximum yield and gross returns (₹ 90920/ha), but the net returns (₹ 64356/ha,) and B:C ratio (3.69) was registered in clodinafop propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha at 35 DAS followed by sulfosulfuron + metsulfuron-methyl 0.03 + 0.002 kg/ha at 35 DAS. (₹ 62162 /ha and 3.40), which was about 61.36 and 59.99% of net returns over unweeded control (**Table 3**). Thus, results clearly endorsed to better economic feasibility of treatment linked with higher production potential over unweeded control as reported earlier by Meena *et al.* (2017), Punia *et al.* (2017) and Chauhan *et al.* (2017).

It was concluded that in wheat, weeds should be controlled by the pre-mix combination of post-emergence application of either clodinafop-propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha or sulfosulfuron + metsulfuron-methyl 0.03 + 0.002

Table 2. Growth and yield attributes of wheat as influenced by weed control treatments (pooled of three years)

Treatment	Plant height at harvest (cm)				No. of effective tillers (no./m)				No. of grains per spike			
	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled
Pendimethalin 1.0 kg/ha PE	88.98	89.43	90.80	89.74	66.43	70.00	60.10	65.51	52.92	45.73	48.13	48.17
Sulfosulfuron 0.025 kg/ha PoE at 35 DAS	91.98	93.06	92.50	92.51	78.10	79.00	82.70	79.93	53.98	49.60	52.00	51.10
Metribuzin 0.21 kg/ha PE	90.38	90.77	91.20	90.78	68.80	72.00	70.10	70.30	50.85	45.67	48.07	47.44
Clodinafop 0.06 kg/ha PoE at 35 DAS	91.25	92.42	91.90	91.86	76.73	78.00	77.90	77.54	51.33	48.40	50.80	49.42
Pendimethalin + metribuzin 1.0 + 0.175 kg/ha (tank mix) PE	89.92	90.39	89.50	89.94	68.03	76.00	67.40	70.48	51.77	45.83	48.23	47.85
Pendimethalin *fb* sulfosulfuron 1.0 + 0.018 kg/ha PE and PoE	92.98	93.76	92.80	93.18	85.73	85.00	85.80	85.51	53.53	48.43	50.83	50.17
Sulfosulfuron + metsulfuron-methyl 0.03 + 0.002 kg/ha PM at 35 DAS as PoE	93.15	94.16	93.30	93.54	88.90	91.00	95.30	91.73	51.73	49.93	52.33	50.57
Pinoxaden + metsulfuron-methyl 0.06 + 0.004 kg/ha PM at 35 DAS as PoE	92.55	92.91	91.90	92.45	89.93	80.00	96.50	88.81	52.15	48.47	50.87	49.74
Mesosulfuron-methyl + iodosulfuron-methyl 0.012 + 0.0024 kg/ha PM at 35 DAS as PoE	91.98	91.65	91.50	91.71	83.88	82.00	84.40	83.43	51.17	48.20	50.60	49.23
Clodinafop-propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha PM at 35 DAS as PoE	94.52	94.75	92.80	94.02	91.03	102.00	92.10	95.04	56.23	50.20	52.60	52.25
Two hand weeding – (30 and 60 DAS)	96.05	96.97	93.90	95.64	94.52	110.00	102.00	102.17	57.77	52.47	54.87	54.28
Un-weeded control	84.35	84.33	88.40	85.69	57.10	50.00	55.90	54.33	47.32	38.13	40.53	41.24
LSD (p= 0.05)	3.45	3.20	3.88	1.70	10.17	8.76	10.74	7.79	3.77	4.28	3.36	1.98

Table 3. Grain yield, gross monetary returns, net monetary returns and B:C ratio as influenced by weed control treatments in wheat (pooled of 3 years)

Treatment	Grain yield (t/ha)				GMR (x10³₹/ha)				NMR (x10³₹/ha)				B:C ratio
	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled	
Pendimethalin 1.0 kg/ha PE	3.42	3.25	2.84	3.17	67.40	62.77	62.37	64.18	45.96	37.38	36.98	40.11	2.69
Sulfosulfuron 0.025 kg/ha PoE at 35 DAS	3.78	3.61	4.04	3.81	74.50	69.59	88.77	77.62	50.89	45.98	60.16	52.34	3.07
Metribuzin 0.21 kg/ha PE	3.60	3.43	3.83	3.62	70.77	66.02	84.33	73.71	47.96	41.21	55.52	48.23	2.90
Clodinafop 0.06 kg/ha PoE at 35 DAS	3.75	3.58	4.03	3.79	73.74	68.79	88.62	77.05	53.23	44.28	60.11	52.54	3.17
Pendimethalin + metribuzin 1.0 + 0.175 kg/ha (tank mix) PE	3.57	3.40	3.57	3.52	70.29	65.59	78.63	71.50	45.35	39.54	52.59	45.83	2.79
Pendimethalin *fb* sulfosulfuron 1.0 + 0.018 kg/ha PE and PoE	4.09	3.91	4.06	4.02	80.69	75.26	89.21	81.72	56.68	50.25	60.20	55.71	3.15
Sulfosulfuron + metsulfuron-methyl 0.03 + 0.002 kg/ha PM at 35 DAS as PoE	4.48	4.31	4.28	4.36	88.32	82.29	94.14	88.25	64.90	54.87	66.72	62.16	3.40
Pinoxaden + metsulfuron-methyl 0.06 + 0.004 kg/ha PM at 35 DAS as PoE	4.32	4.15	4.13	4.20	85.04	79.30	90.77	85.04	63.63	53.89	59.36	58.96	3.33
Mesosulfuron-methyl + iodosulfuron-methyl 0.012 + 0.0024 kg/ha PM at 35 DAS as PoE	4.27	4.09	4.02	4.13	84.00	78.29	88.42	83.57	62.39	52.68	58.81	57.96	3.31
Clodinafop-propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha PM at 35 DAS as PoE	4.45	4.28	4.38	4.37	87.45	81.53	96.32	88.43	66.04	56.12	70.91	64.36	3.69
Two hand weeding – (30 and 60 DAS)	4.59	4.41	4.45	4.49	90.72	84.05	97.99	90.92	65.05	54.44	68.38	62.62	3.23
Un-weeded control	2.58	2.15	2.00	2.24	50.60	43.06	44.00	45.89	32.13	20.77	21.71	24.87	2.21
LSD (p= 0.05)	0.64	0.58	0.60	0.51	12.66	10.08	13.38	6.42	12.66	10.08	13.38	6.42	-

kg/ha at 35 DAS for getting higher yield and monetary benefits. Use of pre-mix herbicides may help in effective and eco-freindly weed management in wheat.

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