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RESEARCH PAPER

Growth and yield of wheat (*Triticum aestivum* L.) as influenced by tank mix post-emergence herbicides

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Abstract: A field experiment was conducted during *rabi* (winter) season of 2020 at Main Agricultural Research Station, Dharwad, Karnataka, India to evaluate the efficacy of tank mix post emergence herbicides on growth and yield in irrigated wheat. The experiment consisted of ten treatments and was laid out in Randomised Complete Block Design. Among different weed management practices, significantly lower weed density, higher growth and yield parameters were recorded with the recommended weed management practice (RWMP) of pendimethalin 30% EC 1 kg ha^{-1} as PE + one hand weeding. Among the herbicidal treatments, significantly higher plant height, number of tillers, leaf area index and total dry matter production was recorded with post-emergence tank mix application ofmetsulfuron-methyl 20% WP + carfentrazone-ethyl 20% DF @ 4+20 g ha^{-1} followed by metsulfuron-methyl 20% WP + sulfosulfuron 75 % WG @ 4 + 25 g ha^{-1} over metsulfuron-methyl 20% WP @ 4 g ha^{-1} alone. The yield components like number of productive spikes per m^{-2}, number of grains per spike, grain weight per spike and thousand grain weight were higher in the treatment receiving post-emergence tank mix application of metsulfuron-methyl 20% WP + carfentrazone-ethyl 20% DF @ 4+20 g ha^{-1}. Significantly higher grain and straw yield were obtained with the tank mix post emergence application of metsulfuron-methyl 20% WP + carfentrazone-ethyl 20% DF @ 4+20 g ha^{-1} (4047 and 6511 kg ha^{-1}) but weed free treatment recorded superior harvest index (38.69%) and was found on par with all other treatments except weedy check (34.42%).

Key words: Carfentrazone-ethyl, Herbicide mixture, Metsulfuron-methyl, Post-emergence

Introduction

Weeds are one of the pre-dominant constraints in achieving potential yield of wheat. Weeds emerge with the emerging seedling and if not controlled in the early stages of crop, they cause reduction in yield. The wheat crop is invaded by grass and broad-leaved weeds which can reduce the grain yield up to 80 per cent (Kaur *et al*., 2015). Uncontrolled weeds were reported to cause up to 66 per cent reduction in grain yield of wheat (Angiras *et al*., 2008; Kumar *et al*., 2009 and Kumar *et al*., 2011) or even more depending upon the weed density, type of weed flora and duration of infestation. Yields are drastically reduced, if not controlled during critical period of weed crop competition. In case of severe infestation manual removal of weeds in wheat crop is laborious, time consuming and expensive due to higher rate of labour wages. As a result, chemical control of weeds is an important alternative and more over the control is more effective as the weeds even within the rows are killed. Herbicide combination offers certain advantage like broad spectrum of herbicidal action, enhance herbicide efficiency through synergistic or additive effect, needed in a lesser quantity, reduce cost of weed management, arrest weed shifts, prevent herbicide resistance in weeds and facilitate improvement in overall weed management. Keeping these points in view, a field experiment with post-emergence herbicide mixtures was conducted to achieve broad spectrum weed control and to evaluate their effect on growth and yield of wheat.

Material and methods

A field experiment was conducted during *rabi* (winter) 2020 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka. The experiment consisted of ten treatments and was laid out in randomised complete block design with three replications on *vertisols* with pH of 7.21, EC of 0.21 dS/m and available major nutrients of 134, 8 and 145 kg ha^{-1}of N, $P_2 0_5$, K_2O, respectively. Treatments were tank mixture of T_1: metsulfuron-methyl 20% WP + 2,4 – D sodium Salt 80% WP @ 4+ 500 g ha^{-1}, T_2: metsulfuron-methyl 20% WP + pinoxaden 5.1% EC @ 4 + 60 g ha^{-1}, T_3: metsulfuron-methyl 20% WP + sulfosulfuron 75% WG @ 4 + 25 g ha^{-1}, T_4: metsulfuron-methyl 20% WP + carfentrazone-ethyl 20% DF @ 4 + 20 g ha^{-1},while pre mix herbicide *i.e*., T_5: clodinofop-propargyl 15% WP + metsulfuron-methyl 1% WP @ 60 + 4 g ha^{-1}and individual application of T_6: metsulfuron-methyl 20% WP @ 4 g ha^{-1}, T_7: 2,4 – D sodium salt 80% WP @ 2.0 kg ha^{-1}and recommended weed management practice (RWMP) of T_8: pendimethalin 30% EC 1 kg ha^{-1} as PE + one hand weeding, T_9: weed free check and T_{10}: weedy check. The seeds of wheat variety UAS 304 at the rate of 150 kg ha^{-1} after treating with *Azospirillium* (1250 g ha^{-1}) were drilled evenly in the furrows at 22.5 cm row spacing and covered with soil manually. Recommended doses of nitrogen, phosphorus and potassium were given in the form of urea, di-ammonium phosphate and muriate of potash, respectively. Half of the recommended dose of N (50 kg ha^{-1}) and full dose of $P_2 0_5$ (75 kg ha^{-1}) and K_2O (50 kg ha^{-1}) were applied as basal and the remaining nitrogen (50 kg ha^{-1}) was applied 30 DAS. Experimental site was uniformly irrigated prior to sowing of seeds and application of fertilizers. Then subsequent irrigations were given at an interval of 10-15 days till the crop reaches physiological maturity so as to maintain adequate soil moisture in root zone. All the herbicides were applied at 28 days after sowing with the help of knapsack

sprayer with a spray volume of 500 lit ha^{-1} with minimum trampling. In T_8, pre-emergence herbicide was sprayed a day after sowing. The weed free plot was maintained by repeated manual weeding. The crop was harvested at maturity leaving the border row plants and then the produce from net plots were collected and sun dried for two days. The weed density was recorded at pre-treatment, 20 DAHA and 40 DAHA (days after herbicide application) with the help of 1 m^2 quadrate and data on weed density were subjected to square root transformation before statistical analysis. Data obtained were statistically analysed using the F-test procedure as given by Gomez and Gomez (1984). The level of significance used in "F" test was P=0.05.

Results and discussion

Effect of herbicides on weed control

The predominant weed spectrum found in the experimental field of wheat crop consisted of grasses *viz*., *Cynodon dactylon* L., *Brachiaria eruciformis* and *Digitaria sanguinalis*. Among BLWs, *Euphorbia geniculata*, *Euphorbia hirta*, *Parthenium hysterophorus*, *Commelina benghalensis* L., *Cyanotis* sp., *Alternanthera sessilis*, *Digera arvensis*, *Amaranthus viridis*, *Trianthema portulacastrum* and *Ageratum conyzoides*. Among sedges, *Cyperus rotundus* was noticed. Similar weed spectrum was noticed by Saha *et al*. (2006), Singh *et al*. (2011) and Sudha *et al*. (2016) in wheat.

The weed count per 1.0 m^2 area were recorded at pre-treatment (before the application of post-emergence herbicides), at 20 and 40 DAHA are presented in Table 1. At all the stages weed free treatment recorded the lowest weed count and in contrast weedy check recorded the highest weed count compared to other treatments. Before the application of post-emergence herbicides, the recommended weed management practice (RWMP) of pendimethalin (PE) + one hand weeding recorded lower total weed density. There is no significant difference in the total weed density of other treatments. Lowest number of weeds was noticed in weed free check (0.00 m^{-2}).

Among the post-emergence herbicide tank mixtures, Metsulfuron-methyl 20% WP + Carfentrazone-ethyl 20% DF @ 4 +20 g ha^{-1} (3.16 and 4.46 m^{-2}, respectively) recorded lower total weed count followed by Metsulfuron-methyl 20% WP + Sulfosulfuron 75% WG @ 4 + 25 g ha^{-1} (7.53 and 10.33 m^{-2}, respectively), Metsulfuron-methyl 20 % WP + 2,4-D Sodium salt 80% WP @ 4 +500 g ha^{-1} (8.16 and 14.86 m^{-2}, respectively), Metsulfuron-methyl 20% WP + Pinoxaden 5.1% EC @ 4 + 60 g ha^{-1} (16.33 and 19.90 m^{-2}, respectively) and pre mix Clodinofop-propargyl 15% WP + Metsulfuron-methyl 1%WP @ 60 + 4 g ha^{-1} (10.16 and 14.00 m^{-2}, respectively) (Table 1). Whereas, Metsulfuron-methyl 20% WP @ 4 g ha^{-1} (16.53 and 20.00 m^{-2}, respectively) alone recorded higher total number of weeds at both 20 and 40 DAHA. Weedy check recorded markedly higher weed density (50.00 and 69.33 m^{-2}, respectively) compared to all other treatments.

Carfentrazone-ethyl belonging to aryl triazolinone family, found effective in controlling broad leaved and sedge weeds in cereals by inhibiting the activity of protoporphyrinogen oxidase in chlorophyll biosynthetic pathway causing cell death. Whereas, metsulfuron-methyl belonging to sulfonylurea herbicide and it acts as acetolactate synthesis inhibitor thereby

Table 1. Weed density as influenced by weed management practices in wheat

Treatments		Number of weeds m^{-2}		
		Before application	20 DAHA	40 DAHA
T_1 :	Metsulfuron-methyl 20% WP + 2,4 – D Sodium salt 80% WP (Tank Mix) @ 4 + 500 g ha^{-1} PoE at 25-30 DAS	*5.40 (28.66)	2.94 (8.16)	3.91 (14.86)
T_2 :	Metsulfuron-methyl 20% WP + Pinoxaden 5.1% EC (Tank Mix) @ 4 + 60 g ha^{-1} PoE at 25-30 DAS	5.27 (27.33)	4.10 (16.33)	4.51 (19.90)
T_3 :	Metsulfuron-methyl 20% WP + Sulfosulfuron 75% WG (Tank Mix) @ 4 + 25 g ha^{-1} PoE at 25-30 DAS	5.40 (28.66)	2.83 (7.53)	3.29 (10.33)
T_4 :	Metsulfuron-methyl 20% WP + Carfentrazone-ethyl 20% DF (Tank Mix) @ 4 + 20 g ha^{-1} at 25-30 DAS	5.32 (27.90)	1.91 (3.16)	2.22 (4.46)
T_5 :	Clodinofop-propargyl 15% WP + Metsulfuron-methyl 1% WP (Pre mix) @ 60 + 4 g ha^{-1} PoE at 25-30 DAS	5.59 (30.80)	3.26 (10.16)	3.80 (14.00)
T_6 :	Metsulfuron-methyl 20% WP @ 4 g ha^{-1} PoE at 25-30 DAS	5.51 (29.90)	4.12 (16.53)	4.52 (20.00)
T_7 :	2,4 – D Sodium salt 80% WP @ 2.0 kg ha^{-1} PoE at 25-30 DAS	5.87 (34.00)	4.24 (17.50)	4.56 (20.33)
T_8 :	Pendimethalin 30% EC 1 kg ha^{-1} as Pre emergence + one hand weeding (RWMP)	1.95 (3.33)	1.58 (2.00)	1.65 (2.23)
T_9 :	Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{10} :	Weedy check	6.12 (37.00)	7.10 (50.00)	8.35 (69.33)
	S. Em. ±	0.21	0.15	0.19
	C. D. at 5%	0.63	0.44	0.57

PE : Pre-emergence herbicide
PoE : Post- emergence herbicide
DAS: Days after sowing
* : (x+0.5) ½ transformed data
Original figures are given in parenthesis
DAHA: Days after herbicide application

Table 2. Growth attributes of wheat as influenced by weed management practices

Treatments	Plant height (cm)	Number of tillers / m row length	Leaf area index	Dry matter production (g m^{-1} row length)
T_1: Metsulfuron-methyl 20% WP + 2,4 – D Sodium salt 80% WP (Tank Mix) @ 4 + 500 g ha^{-1} PoE at 25-30 DAS	73.00	95.00	1.36	251.67
T_2: Metsulfuron-methyl 20% WP + Pinoxaden 5.1% EC (Tank Mix) @ 4 + 60 g ha^{-1} PoE at 25-30 DAS	72.33	90.33	1.14	244.33
T_3: Metsulfuron-methyl 20% WP + Sulfosulfuron 75% WG (Tank Mix) @ 4 + 25 g ha^{-1} PoE at 25-30 DAS	75.00	97.33	1.32	255.00
T_4: Metsulfuron-methyl 20% WP + Carfentrazone -ethyl 20% DF (Tank Mix) @ 4 + 20 g ha^{-1} at 25-30 DAS	82.33	107.33	1.56	275.00
T_5: Clodinofop-propargyl 15% WP + Metsulfuron- methyl 1% WP (Pre mix) @ 60 + 4 g ha^{-1} PoE at 25-30 DAS	73.33	93.67	1.32	248.33
T_6: Metsulfuron-methyl 20% WP @ 4 g ha^{-1} PoE at 25-30 DAS	70.67	87.00	1.09	243.33
T_7: 2,4 - D Sodium salt 80% WP @ 2.0 kg ha^{-1} PoE at 25-30 DAS	66.67	85.00	1.04	246.67
T_8: Pendimethalin 30% EC 1 kg ha^{-1} as (PE) + one hand weeding (RWMP)	83.33	109.00	1.61	277.00
T_9: Weed free check	85.37	112.37	1.69	280.00
T_{10}: Weedy check	63.00	80.33	0.90	228.00
S. Em. ±	1.96	3.24	0.07	4.80
C. D. at 5%	5.83	9.63	0.19	14.25

PE : Pre-emergence herbicide PoE : Post- emergence herbicide DAS: Days after sowing

inhibiting cell division in roots and shoots of broadleaf weeds and some annual grasses. Tank mix application of herbicides, Carfentrazone-ethyl and Metsulfuron-methyl was comparable with each other and controlled all the BLWs more effectively than their separate application (Paswan *et al*., 2012).

Effect of herbicides on growth parameters of wheat

Maximum crop growth rate was observed in weed free plot. Significantly higher plant height and leaf area index at harvest was recorded with the treatment receiving metsulfuron-methyl 20% WP + carfentrazone-ethyl 20% DF @ 4+ 20 g ha^{-1} (82.33 cm and 1.56, respectively), followed by Metsulfuron-methyl 20% WP + Sulfosulfuron 75% WG @ 4 + 25 g ha^{-1} (75.00 cm and 1.32, respectively), Metsulfuron-methyl 20% WP + 2,4-D Sodium salt 80% WP @ 4 +500 g ha^{-1} (73.00 cm and 1.36, respectively), Metsulfuron-methyl 20% WP + Pinoxaden 5.1 % EC @ 4 + 60 g ha^{-1} (72.33 cm and 1.14, respectively) and pre mix Clodinofop-propargyl 15% WP + Metsulfuron-methyl 1% WP @ 60 + 4 g ha^{-1} (73.33 and 1.32, respectively) (Table 2). This might be due to effective control of weeds, thus resulted in minimum weed-crop competition.

Similar trends were observed for dry matter accumulation and number of tillers per meter row length recorded at harvest. The dry matter accumulation is largely a function of photosynthetic surface, resulted in increased biological productivity. Similar results were obtained by Hooda *et al*. (2007), where he reported that among the herbicide treatments, metsulfuron-methyl 20% WP + carfentrazone-ethyl 20% DF @ 4+20 g ha^{-1}recorded higher dry matter production and number of tillers per meter row length. Singh *et al*. (2011) reported that pre-mix of carfentrazone + metsulfuron @ 25 g ha^{-1} with 0.2 per cent NIS, achieved good weed control thereby producing 25 per cent higher tillers per metre row length recorded at harvest as compared to weedy plots.

Effect of herbicides on yield attributes of wheat

All the weed control measures recorded significantly higher yield attributes over control. The maximum number of productive spikes m^{-2} (233.33), grains $spike^{-1}$ (42.13), grain weight per spike (1.48 g) and 1000-grain weight (39.67 g) was recorded in metsulfuron-methyl 20 % WP + carfentrazone-ethyl 20 % DF @ 4 + 20 g ha^{-1} followed by metsulfuron-methyl 20 % WP + sulfosulfuron 75% WG @ 4 + 25 g ha^{-1}compared to metsulfuron-methyl alone 20% WP @ 4 g ha^{-1} (Table 3). This was because of significant reduction in weed population and biomass, which enhanced N uptake over weedy check (Bharat *et al*., 2012). Due to effective control of weeds which resulted in minimum weed-crop competition, which in turn provide the favourable environment for growth and development of crop, thereby increasing the wheat yield and yield components. Weed free check recorded significantly higher yield attributes and in contrast weedy check was found to be inferior compared to all other treatments.

Effect of herbicides on grain and straw yield of wheat

Grain yield and straw yield of wheat differed notably among the different weed management practices (Table 4). The highest grain yield of wheat was obtained with weed free check (4286 kg ha^{-1}) and was in line with RWMP of pendimethalin 30% EC 1 kg ha^{-1} as PE + one hand weeding (4147 kg ha^{-1}) among different weed management practices. The higher grain

Table 3. Yield attributes of wheat as influenced by weed management practices

Treatments		Productive spikes (m^{-2})	Number of grains per spike	Grain weight per spike (g)	Thousand grain weight (g)
T_1 :	Metsulfuron-methyl 20% WP + 2,4 – D Sodium salt 80% WP (Tank Mix) @ 4 + 500 g ha^{-1} PoE at 25-30 DAS	212.67	34.33	1.40	32.55
T_2 :	Metsulfuron-methyl 20% WP + Pinoxaden 5.1% EC (Tank Mix) @ 4 + 60 g ha^{-1} PoE at 25-30 DAS	209.67	32.67	1.32	30.67
T_3 :	Metsulfuron-methyl 20% WP + Sulfosulfuron 75% WG (Tank Mix) @ 4 + 25 g ha^{-1} PoE at 25-30 DAS	215.67	35.67	1.44	34.93
T_4 :	Metsulfuron-methyl 20% WP + Carfentrazone -ethyl 20% DF (Tank Mix) @ 4 + 20 g ha^{-1} at 25-30 DAS	233.33	42.13	1.58	39.67
T_5 :	Clodinofop-propargyl 15% WP + Metsulfuron- methyl 1% WP (Pre mix) @ 60 + 4 g ha^{-1} PoE at 25-30 DAS	212.33	34.00	1.39	33.67
T_6 :	Metsulfuron-methyl 20% WP @ 4 g ha^{-1} PoE at 25-30 DAS	203.33	30.67	1.30	28.00
T_7 :	2,4 – D Sodium salt 80% WP @ 2.0 kg ha^{-1} PoE at 25-30 DAS	199.33	28.67	1.27	29.67
T_8 :	Pendimethalin 30% EC 1 kg ha^{-1} as (PE) + one hand weeding (RWMP)	237.33	44.33	1.59	40.67
T_9 :	Weed free check	240.00	45.00	1.61	41.67
T_{10} :	Weedy check	193.67	25.00	1.21	25.67
	S. Em. ±	5.45	1.97	0.04	1.29
	C. D. at 5%	16.18	5.86	0.12	3.84

PE : Pre-emergence herbicide PoE : Post- emergence herbicide DAS: Days after sowing

Table 4. Grain yield, straw yield and harvest index of wheat as influenced by weed management practices

Treatments		Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1 :	Metsulfuron-methyl 20 % WP + 2,4 – D Sodium salt 80 % WP (Tank Mix) @ 4 + 500 g ha^{-1} PoE at 25-30 DAS	3579	5835	38.02
T_2 :	Metsulfuron-methyl 20 % WP + Pinoxaden 5.1 % EC (Tank Mix) @ 4 + 60 g ha^{-1} PoE at 25-30 DAS	3566	5742	38.31
T_3 :	Metsulfuron-methyl 20% WP + Sulfosulfuron 75% WG (Tank Mix) @ 4 + 25 g ha^{-1} PoE at 25-30 DAS	3706	5990	38.25
T_4 :	Metsulfuron-methyl 20 % WP + Carfentrazone -ethyl 20 % DF (Tank Mix) @ 4 + 20 g ha^{-1} at 25-30 DAS	4047	6511	38.32
T_5 :	Clodinofop-propargyl 15 % WP + Metsulfuron -methyl 1 % WP (Pre mix) @ 60 + 4 g ha^{-1} PoE at 25-30 DAS	3588	5782	38.31
T_6 :	Metsulfuron-methyl 20 % WP @ 4 g ha^{-1} PoE at 25 - 30 DAS	3238	5451	37.30
T_7 :	2,4 - D Sodium salt 80 % WP @ 2.0 kg ha^{-1} PoE at 25 - 30 DAS	3128	5289	37.15
T_8 :	Pendimethalin 30 % EC 1 kg ha^{-1} as (PE) + one hand weeding (RWMP)	4147	6625	38.50
T_9 :	Weed free check	4286	6793	38.69
T_{10} :	Weedy check	2624	4970	34.42
	S. Em. ±	109.68	153.32	0.80
	C. D. at 5%	325.89	455.53	2.37

PE : Pre-emergence herbicide PoE : Post- emergence herbicide DAS: Days after sowing

yield was mainly due to minimum crop-weed competition throughout the crop growth period and resulted in the maximum utilization of nutrients, moisture, light and space which influenced the better growth and yield of the crop. Similar trends were observed by Pisal and Sagarka (2013). These findings were in close conformity with Singh and Singh (2004) who reported highest grain yield with pendimethalin 0.9 kg ha^{-1} pre-emergence supplemented by one hand weeding. Among the herbicide treated plots, higher grain and straw yield were recorded with post-emergence tank mix application of Metsulfuron-methyl 20% WP + Carfentrazone-ethyl 40% DF @ 4 + 20 g ha^{-1}(4047 and 6511 kg ha^{-1}, respectively). Similar results were obtained by (Paswan *et al*., 2012). Singh *et al*., 2011 reported highest grain yield of wheat (4966 kg ha^{-1}) with pre mix of Carfentrazone+ Metsulfuron @ 25 g ha^{-1} tank mixed with 0.2 per cent NIS which was 31 per cent higher over untreated weedy plot. Reduction in crop weed competition under weed control treatments led to enhanced crop growth and finally biomass yield (Sudha *et al*., 2016).

Conclusion

It was inferred that among the chemical treatments, tank mix post emergence application of metsulfuron-methyl 20% WP + carfentrazone-ethyl 20% DF @ 4 + 20 g ha^{-1} was found effective in controlling weeds and resulted in increased the grain yield by 54% as compared to weedy check under irrigated situation.

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