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Herbicide combinations for broad-spectrum weed control in wheat

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ABSTRACT

Ten treatments, *viz.* clodinafop 60 g/ha, sulfosulfuron 25 g/ha, metribuzin 175 g/ha, pinoxaden 50 g/ha, clodinafop 60 + metribuzin 105 and 122.5 g/ha, sulfosulfuron 25 + metribuzin 105 g/ha, sulfosulfuron 25 + pinoxaden + 40 g/ha, weed free and unweeded check were tested during the *Rabi* season of 2010-11 and 2011-12 at Palampur. Grassy weeds (*Phalaris minor*, *Avena ludoviciana*, *Poa annua* and *Lolium temulentum*) constituted 90% of the total weed flora. All the weed control treatments were significantly superior to weedy check in curtailing dry weight of *Phalaris*, *Avena* and *Vicia sativa*. Metribuzin remaining at par with sulfosulfuron effectively reduced the dry weight of *Poa annua*. Clodinafop alone was least effective against *Poa annua*. Weed free, clodinafop, pinoxaden, clodinafop + metribuzin resulted in significant reduction in the dry weight of *L. temulentum*. Clodinafop 60 g/ha + metribuzin 122.5 g/ha, clodinafop 60 g/ha + metribuzin 105 g/ha, pinoxaden 50 g/ha and weed free resulted in significantly higher grain yield of wheat. Weeds reduced grain yield of wheat by 59.3%. Grain yield was negatively associated with weed count and weed biomass and positively associated with plant height, spike length, spikelets/spike and effective tillers. With every 1 g/m^2 increase in weed dry weight, the grain yield of wheat was expected to fall by 41.55 kg/ha. The economic threshold levels (number of weeds/unit area) with weed management practices varied between 2.6-45.4/m^2. Clodinafop 60 g/ha + metribuzin 122.5 g/ha resulted in highest weed control efficiency, crop resistance index and efficiency index. It gave lowest weed persistence index and weed index. Clodinafop 60 g/ha + metribuzin 122.5 g/ha resulted in highest net return due to weed control. Metribuzin 175 g/ha resulted in the highest marginal benefit: cost ratio.

Key words: Clodinafop, Combinations, Metribuzin, Pinoxaden, Sulfosulfuron, Weeds, Wheat

Wheat is an important winter cereal of Himachal Pradesh. Weeds are the major bottlenecks in realizing potential yield of wheat. Uncontrolled weeds are reported to cause upto 66% reduction in wheat grain yield (Angiras *et al.* 2008, Kumar *et al.* 2009, Kumar *et al.* 2011) or even more depending upon the weed densities, type of weed flora and duration of infestation. Chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding especially in broadcast wheat. Combination of isoproturon and 2,4-D as tank mixture have been recommended against complex weed flora. This combination has been found promising in the situation where isoproturon was effective against *Phalaris minor*. But against complex weed flora dominated by *Avena ludoviciana*, *Lolium temulentum* and *Poa annua,* this combination was not so effective. Under such situation, a suitable combination of clodinafop or pinoxaden with some broad-spectrum herbicides like sulfosulfuron and metribuzin was needed. Hence, the present investigation was carried out to evaluate the efficacy of metribuzin in combination with recommended post-emergence herbicides clodinafop, sulfosulfuron and pinoxaden against mixed weed flora in wheat.

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MATERIALS AND METHODS

A field experiment was conducted during *Rabi* season of 2010-11 and 2011-12 at Palampur. The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.6) and medium in available N (310 kg N/ha), P (18.2 kg/ha) and K (266.2 kg/ha). The experiment comprised of 10 treatments, *viz.* clodinafop 60 g/ha, sulfosulfuron 25 g/ha, metribuzin 175 g/ha, pinoxaden 50 g/ha, clodinafop 60 g + metribuzin 105 and 122.5 g/ha, sulfosulfuron 25 g + metribuzin 105 g/ha, sulfosulfuron 25 + pinoxaden + 40 g/ha, weed free (three hand weedings) and unweeded check were tested in randomized block design with three replications. Wheat variety *'HPW 155'* was sown on 12 November. Except weed control, the crop was raised in accordance with the recommended package of practices. The crop was fertilized with 60 kg

N, 60 kg P_2O_5 and 40 kg K_2O/ha as basal dose. Remaining half dose of nitrogen (60 kg/ha) was applied in two equal splits. The herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using 700 liter of water per hectare after 40-45 days of sowing. Weed count and dry weight were recorded at 90 DAS and at harvest from two randomly selected spots (0.25 m^2) in each plot and expressed as no./m^2 and g/m^2, respectively. The data on count and dry weight of weeds were subjected to $\sqrt{x+1}$ (square root transformation). Yields were harvested from net plot. Economics of treatments was computed based upon prevalent market prices. The economic threshold (=economic injury levels), the weed density at which the cost of treatment equals the economic benefit obtained from that treatment, was calculated after modifying the formula presented by Uygur and Mennan (1995) as well as those given by Stone and Pedigo (1972) as below

Uygur and Mennan:

$Y= [\{(100/He \times Hc) + A_C\}/(Gp \times Yg)] \times 100$

Where, Y is per cent yield losses at a different weed density; He, herbicide efficiency; Hc, herbicide cost; Ac, application cost of herbicide; Gp, grain price and Yg, yield of weed free.

Stone and Pedigo:

Economic threshold = Gain threshold/Regression coefficient

Where, gain threshold = Cost of weed control (Hc+Ac)/Price of produce (Gp), and regression coefficient (b) is the outcome of simple linear relationship between yield (Y) and weed density/biomass (x), Y = a + bx.

The different impact indices were worked out after Walia (2003).

RESULTS AND DISCUSSION

Effect on weeds

The weed flora of the experimental field was mainly composed of grassy weeds. They constituted 88.9 and 91.2% of the total weed flora at 90 DAS and at harvest, respectively. *Phalaris minor* (25.8 and 31% at 90 DAS and at harvest, respectively), *Avena ludoviciana* (31.4 and 18.6 at 90 DAS and harvest, respectively), *Lolium temulentum (*14.3 and 22.1%) and *Poa annua* (17.4 and

Table 1. Effect of treatments on species-wise weed dry weight (g/m²) at maximum dry matter stage in wheat

Treatment	Dosage (g/ha)	*Phalaris* at 90 DAS		*Avena* at 90 DAS		*Poa* at harvest		*Lolium* at harvest		*Vicia* at harvest	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1 - Clodinafop	60	2.2	2.2	2.2	1.0	2.9	2.5	1.0	1.7	1.3	1.4
		(4.0)	(6.7)	(3.7)	(0.0)	(7.7)	(5.3)	(0.0)	(2.3)	(1.0)	(1.3)
T_2 - Sulfosulfuron	25	2.2	3.6	2.0	2.6	1.8	1.5	2.1	3.4	1.3	1.0
		(3.7)	(12.0)	(3.0)	(5.9)	(2.7)	(1.3)	(4.0)	(11.9)	(1.0)	(0.0)
T_3 - Metribuzin	175	2.0	2.9	2.1	2.6	1.4	1.6	2.1	2.7	1.0	1.2
		(3.0)	(9.6)	(3.3)	(6.0)	(1.3)	(2.4)	(4.0)	(7.6)	(0.0)	(0.7)
T_4 - Pinoxaden	50	1.7	1.5	1.7	1.0	2.5	2.1	2.0	1.0	1.3	1.6
		(2.0)	(2.0)	(2.0)	(0.0)	(5.3)	(3.5)	(3.3)	(0.0)	(1.0)	(1.7)
T_5 - Clodinafop + metribuzin	60+105	1.3	1.4	1.7	1.5	2.2	1.5	1.4	1.2	1.3	1.8
		(1.0)	(1.3)	(2.0)	(1.9)	(4.0)	(1.3)	(1.3)	(0.5)	(1.0)	(2.5)
T_6 - Clodinafop + metribuzin	60+122.5	2.0	1.0	1.4	1.4	2.2	1.5	1.0	1.4	1.3	1.7
		(3.0)	(0.0)	(1.3)	(1.2)	(4.0)	(1.2)	(0.0)	(1.2)	(1.0)	(1.9)
T_7 - Sulfosulfuron + metribuzin	25+105	2.0	1.4	2.0	2.4	2.2	1.3	1.8	2.8	1.0	1.0
		(3.0)	(1.2)	(3.0)	(4.5)	(4.0)	(0.8)	(2.7)	(6.8)	(0.0)	(0.0)
T_8 - Sulfosulfuron + pinoxaden	25 + 40	2.0	2.5	1.3	3.4	2.2	1.4	2.3	1.6	2.0	1.0
		(3.0)	(5.6)	(1.0)	(13.3)	(4.0)	(1.2)	(4.3)	(1.5)	(3.0)	(0.0)
T_9 - Weed free	-	1.3	1.6	1.3	1.8	2.2	1.0	1.8	1.0	2.5	1.0
		(1.0)	(1.9)	(1.0)	(3.3)	(4.0)	(0.0)	(2.7)	(0.0)	(5.3)	(0.0)
T_{10} - Weedy check	-	4.2	3.7	4.1	4.5	4.8	2.5	3.1	3.3	3.7	1.6
		(17.3)	(12.6)	(16.0)	(19.1)	(22.3)	(5.7)	(8.7)	(10.1)	(12.7)	(1.5)
LSD (P=0.05)	-	0.8	1.5	0.9	1.6	0.6	NS	1.1	1.2	0.7	NS

Values given in the parentheses are the original means, DAS= Days after sowing

19.5%) were the important grassy weeds. *Vicia sativa* (5.5 and 8.8%) and *Coronopus didymus* (5.5% at 90 DAS) were important broad-leaved weeds. *Spergulla arvensis, Stellaria media* and *Alopecurous myosuriodes* also showed their presence but their occurrence was negligible in the experimental field.

Weed control treatments brought about significant variation in the dry weight of *Phalaris minor* and *Avena luduviciana* at maximum weed dry weight stage (Table 1). All the weed control treatments were significantly superior to weedy check in curtailing their dry weight during 2011. However, sulfosulfuron and sulfosulfuron + pinoxaden did not significantly influence their dry weight over weedy check during 2012. The effectiveness of sulfosulfuron against *Phalaris minor* and *Avena ludoviciana* has been well documented (Chhokar and Malik 2002, Chhokar *et al.* 2008, Chhokar *et al.* 2011). Dry weight of *Phalaris* and *Avena* was effectively reduced under weed free treatment. However, except sulfosulfuron 25 g/ha, clodinafop 60 g/ha and sulfosulfuron + pinoxaden, all other treatments were comparable to weed free in influencing the dry weight of *Phalaris* and *Avena*.

All treatments brought about significant reduction in the dry weight of *Poa annua* at harvest during 2011 (Table 1). Metribuzin remaining at par with sulfosulfuron effectively reduced the dry weight of *Poa annua* at harvest. Clodinafop alone was least effective against *Poa annua*. Weed free, clodinafop, pinoxaden, clodinafop + metribuzin resulted in significant reduction in the dry weight of *Lolium temulentum* at harvest during both the years. There was significant reduction in the dry weight of *Vicia sativa* under all the treatments at harvest during 2011. All the weed control treatments except sulfosulfuron + pinoxaden resulted in significantly lower dry weight of *Vicia sativa* over weed free.

Owing to species-wise reduction in the count and dry weight, all treatments resulted in significantly lower total weed count and total weed dry weight over unweeded check (Table 2). Weed free resulted in significantly lower total weed count and total weed dry weight at 90 DAS during 2011 and at harvest during 2012. However other treatments except sulfosulfuron 25 g/ha and clodinafop 60 g/ha were comparable to weed free in influencing the total weed count and total weed dry weight at other stages.

Effect on crop

Clodinafop 60 g + metribuzin 122.5 g/ha resulted in significantly higher grain yield of wheat. However, clodinafop + metribuzin (60 + 105 g/ha), pinoxaden 50 g/ha, and weed free were as good as clodinafop + metribuzin (60 + 122.5 g/ha). Higher grain yield of wheat was owing to effective control of weeds and higher growth and yield attributes of wheat. However, plant height during 2012, spike length during 2011 and 1000-seed weight during both the years were not affected significantly due to treatments under study. Weeds in unweeded check reduced the grain yield of wheat by 59.3% over clodinafop + metribuzin (60 + 122.5 g/ha) (Table 3).

The grain yield was negatively associated with total weed count (r= -0.856**, significant at 1% level of significance) and total weed dry weight (r= -0.935**) and positively associated with plant height (r= 0.729**), spike length (r= 0.877**), spikelets/spike (r= 0.867**) and ef-

Table 2. Effect of different treatments on total weed count and dry weight in wheat

Treatment	Total weed count (no./m^2)				Total weed dry weight (g/m^2)			
	90 DAS		At harvest		90 DAS		At harvest	
	2011	2012	2011	2012	2011	2012	2011	2012
T_1	8.1 (65.3)	4.6 (22.7)	7.8 (60.0)	7.3 (53.3)	4.1 (16.0)	4.3 (19.9)	5.7 (31.7)	3.7 (12.8)
T_2	7.3 (52.7)	7.1 (50.7)	6.9 (46.7)	6.6 (44.7)	4.3 (17.7)	6.0 (35.2)	4.5 (19.7)	6.0 (37.2)
T_3	5.6 (30.7)	4.9 (24.0)	4.8 (22.7)	5.6 (30.7)	3.5 (11.7)	4.9 (24.8)	3.8 (13.3)	4.9 (24.4)
T_4	7.0 (48.0)	5.9 (34.7)	6.1 (38.7)	5.5 (29.3)	3.9 (14.7)	3.5 (11.6)	4.8 (22.3)	2.6 (5.9)
T_5	5.2 (26.7)	5.3 (30.7)	6.0 (36.0)	5.3 (28.0)	3.0 (8.0)	3.2 (9.7)	3.9 (14.3)	3.0 (7.7)
T_6	5.9 (33.7)	4.5 (20.0)	5.2 (26.7)	5.2 (26.7)	3.7 (13.0)	3.8 (13.7)	3.5 (11.7)	2.5 (5.2)
T_7	5.8 (33.3)	4.9 (24.0)	6.1 (37.3)	6.0 (36.0)	3.5 (11.7)	3.2 (9.6)	4.0 (14.7)	4.2(17.1)
T_8	6.0 (34.7)	5.7 (32.0)	6.8 (45.3)	5.7 (32.0)	3.6 (12.3)	4.5 (20.3)	4.9 (22.7)	2.7 (6.5)
T_9	3.3 (10.7)	4.7 (21.3)	5.1 (25.3)	1.0 (0.0)	2.0 (5.0)	3.1 (8.7)	4.4 (18.7)	1.0 (0.0)
T_{10}	11.7(136.7)	7.1 (49.3)	9.8 (96.0)	7.4 (54.7)	7.3 (52.7)	6.8 (45.7)	9.3 (84.7)	5.7 (31.8)
LSD (P=0.05)	1.9	1.4	1.9	1.4	1.0	1.7	1.1	1.4

Treatment details are given in Table 1; Values given in the parentheses are the original means.

Table 3. Effect of treatments on plant height, yield attributes and yield of wheat

Treatment	Plant height (cm)		Spike length (cm)		Spikelets/ spike		Effective tillers (no./m²)		1000-grain weight (g)		Grain yield (t/ha)		
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	Mean
T_1	100	108	9.7	11.2	20.1	29.6	200	129	47.8	46.7	3.18	3.17	3.18
T_2	99	108	9.8	11.2	20.3	24.9	196	109	46.8	47.3	3.17	2.12	2.64
T_3	100	106	9.7	10.5	20.2	28.1	199	114	46.5	46.0	3.26	2.78	3.02
T_4	100	109	9.9	11.6	19.8	28.9	196	120	46.4	46.3	3.12	3.84	3.48
T_5	102	109	10.1	11.8	20.9	30.1	207	101	46.8	45.7	3.48	3.39	3.44
T_6	101	106	10.2	12.1	20.8	28.0	202	132	47.1	45.3	3.48	4.05	3.76
T_7	99	110	9.9	10.1	19.9	28.9	200	92	46.8	46.7	3.37	1.98	2.67
T_8	100	103	9.8	11.2	20.1	29.4	200	107	47.2	47.0	3.32	3.07	3.19
T_9	100	107	10.6	12.1	20.3	31.6	201	135	46.8	45.7	3.46	3.84	3.65
T_{10}	88	108	8.8	10.5	17.9	24.5	153	100	45.8	46.0	1.22	1.85	1.53
LSD (P=0.05)	7	NS	NS	0.9	1.7	4.2	28	27	NS	NS	0.38	0.80	0.51

Treatment details are given in Table 1; Values given in the parentheses are the original means.

Table 4. Impact assessment indices, economics and economic thresholds

Treatment	WCE	WPI	CRI	EI	WI	CWC	NRwc (x10³ ₹/ha)	MBCR	Gt	Et	
										SP	UM
T_1	61.8	0.81	5.42	2.80	13.0	1605	26.37	16.43	128	4.9	5.0
T_2	51.2	0.88	3.53	1.48	27.6	1036	17.86	17.25	83	3.2	3.4
T_3	67.6	1.10	6.08	2.99	17.3	830	24.50	29.53	66	2.6	2.2
T_4	75.8	0.54	9.37	5.24	4.7	2280	30.89	13.55	182	7.0	6.3
T_5	81.1	0.61	11.86	6.56	5.9	1815	30.59	16.86	145	5.6	4.7
T_6	85.5	0.50	16.91	10.02	-3.1	1849	36.17	19.56	148	5.7	4.6
T_7	72.7	0.89	6.38	2.72	26.8	1246	18.16	14.58	100	3.8	3.4
T_8	74.9	0.70	8.31	4.32	12.5	2476	25.82	10.43	198	7.6	6.9
T_9	83.9	0.93	14.82	8.59	0.0	14760	21.31	1.44	1181	45.4	38.5
T_{10}	-	1.00	1.00	0.00	58.0	-	-				
LSD (P=0.05)											

Treatment details are given in Table 1. WCE, weed control efficiency (%); WPI, weed persistence index; CRI, crop resistance index; EI, efficiency index; WI, weed index. CWC, cost of weed control (₹/ha); NR_{WC}, net returns due to weed control (/ha); MBCR, Marginal benefit: cost ratio; Gt, gain threshold; Et, economic threshold; SP, after Stone and Pedigo (1972); UM, after Uygur & Mennan (1995).

fective tillers (r= 0.922**). The linear relationship between weed count/weed dry weight (x) and grain yield (Y) of wheat is given hereas under,

Weed count

Y= 4074 – 26.02 x (R^2= 0.734).......(i)

Weed weight

Y= 3893 – 41.55 x (R^2= 0.875).......(ii)

The equation (i) explains that 73.4% variation in yield due to weed count could be explained by the regression equation. The further analysis indicated that decrease in yield per unit increase in weed count (1 weed/m²) is estimated to be 26.02 kg/ha. Similarly from the equation (ii) it may be inferred that 87.5% of variation in grain yield of wheat due to weed dry weight could be explained by the regression equation. With every 1 g/m² increase in weed dry weight, the grain yield of wheat was expected to fall by 41.55 kg/ha.

The economic threshold levels of weeds at the current prices of treatment application and the crop production on the basis of weed infestation (population) in wheat are given in Table 4. The economic threshold levels (number of weeds/unit area) with the weed management practices studied varied between 2.6 - 45.4/m² when determined after Pedigo and Stone (1972) and 2.2 - 38.5/m² after Uygur and Mennan (1995). The trend was almost similar under the methods of determination. It was clearly indicated that any increase in the cost of treatment would lead to higher values of economic threshold, whereas an increase in price of crop produce would result in lowering the economic threshold.

Clodinafop 60 g/ha+ metribuzin 122.5 g/ha resulted in highest weed control efficiency, crop resistance index and efficiency index. This was followed by weed free and clodinafop *fb* metribuzin 105 g/ha. Weed persistence index and weed index were lowest under clodinafop + metribuzin 122.5 g/ha which was followed by pinoxaden 50 g/ha and clodinafop + metribuzin 105 g/ha.

Herbicidal treatments had only 0.06-0.17 times of application cost than that under weed free (hand weeding thrice). Due to higher grain and straw yield owing to effective weed control, clodinafop 60 g/ha + metribuzin 122.5 g/ha resulted in highest net return. This was followed by pinoxaden 50 g/ha, clodinafop 60 g/ha + metribuzin 105 g/ha. Due to lower cost, herbicidal treatments resulted in 7.2 - 20.4 times higher marginal benefit cost ratio than weed free. Metribuzin 175 g/ha resulted in highest marginal benefit cost ratio followed by clodinafop + metribuzin 122.5 g/ha and sulfosulfuron 25 g/ha.

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