Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 2250-2253
Received: 25-07-2020
Accepted: 27-08-2020

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Efficacy of different weed management practices on growth and yield of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted was conducted during *rabi*, season of 2019-20 at the Research farm, Bihar Agricultural College, Sabour, Bhagalpur. The experiment consisting of fourteen treatments was laid out in randomized block design with three replications. The crop was infested with the divergent type of weed flora e.g. *Phalaris minor*, *Fumaria parviflora* and *Cynodon dactylon* of grassy, *Chenopodium album*, *Anagallis arvensis*, *Melilotus alba*, *Argemona Mexicana* and *Solanum nigrum* of broad-leaved and *Cyperus rotundus*, *Cyprus iria* and *Cyprus difformis* of sedges group. The wheat variety HD-2967 was grown on 23th November 2019, and harvesting was done on 5th April, 2020. The results revealed that ready-mix application of (clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g a.i. ha^{-1} PoE) and (mesosulfuron @ 12 g a.i. ha^{-1} + iodosulfuron-methyl-sodium @ 2.4 g a.i. ha^{-1} PoE) gave higher weed control efficiency (82.02%, 79.31%), lower weed index (4.56%, 6.81%0) respectively. Both of these treatments recorded 69.04 and 65.47 per cent grain yield enhancement along with 62.61% and 61.06% higher net returns over the weedy check with the highest benefit-cost ratio (1.65 and 1.57). No any phytotoxic symptoms has been recorded under these two treatments. Based on all the observation recorded, clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g a.i. ha^{-1} PoE has performed better in all respects amongst all the herbicide applied treatment followed by mesosulfuron @ 12 g a.i. ha^{-1} + iodosulfuron-methyl-sodium @ 2.4 g a.i. ha^{-1} PoE.

Keywords: Post-emergence herbicides (PoE), benefit-cost ratio, weed free and weedy check

Introduction
Wheat (*Triticum aestivum* L.) is India's second most important cereal crop after rice, and accounts for 31.5% of the country's total food grain basket. Wheat is generally infested by both grassy weeds viz., *Phalaris minor* and *Avena spp.* and broad leaf weeds i.e. *Chenopodium album, Fumaria parviflora, Melilotus indica, Anagalles arvensis, Cirsium arvense, Lathyrus aphaca and Vicia sativa*. Hence, weed control is essential for increasing wheat production. It has been reported that with production of each kilogram of weed, one-kilogram wheat grains are reduced (Chaudhary *et al*., 2008) [4]. Weed infestation is one of the main causes of low wheat yield not only in India but all over the world, as it reduces wheat yield by 37-50% (Waheed *et al*. 2009) [12]. Rice-wheat is one of the most important cropping systems in northern part of the country. The *Phalaris minor* is one of the very serious problems in wheat in this cropping system and sometimes almost 65% crop losses have been reported (Chhokar *et al*. 2008) [6]. Broad-leaved weeds (BLWs) are also causing a threat, but their management is comparatively easier and effective, whereas, control of *Phalaris minor* has become a serious challenge. Chemical weed control is a preferred practice due to scare and costly labour as well as lesser feasibility of mechanical or manual. This crop has competition with several grassy and broad-leaf weeds during its growth period depending upon the adopted agronomic practices, soil types, underground water quality, weed control techniques and cropping system followed. However, due to the continuous use of these herbicides, *P. minor* also evolved resistance against them (Dhawan *et al*. 2009) [7]. Presently, its control has become even more weeding in wheat. Difficult after it evolved multiple herbicide resistance to recommended herbicides: diclofop-methyl, fenoxaprop-p-ethyl, clodinafop propargyl, pinoxaden (ACCase); sulfosulfuron and pre-mix of mesosulfuron + iodosulfuron (ALS inhibitors); mediated by enhanced metabolism and target site mutations (Dhawan *et al*. 2012) [8]. During surveys and meeting with farmers, it was reported that the herbicide resistance in weeds evolved due to non-following of herbicide rotation, wrong time and method of herbicide application. If one herbicide stops working, farmers only change the brand, not the group of the herbicides. This indicated the need for intervention of herbicides with different mode of action in the rotation or sequential application for control of complex weed flora in wheat. Tank-mix or pre-mix use of different herbicide chemistries or sequential application of pre and post emergence herbicides at different times showed effective weed control (Baghestani *et al*. 2008) [2].

Keeping all the above facts in view, an attempt was made to find out the efficacy of different herbicides against complex weed flora to improve the productivity of wheat.

Materials and Methods

The experiment was conducted during *rabi* season of 2019-20 at Research farm of Bihar Agricultural University, Sabour, Bhagalpur (Bihar). Geographically, Bhagalpur is situated at latitude of 25°15' 40" N and longitude 87°2' 42" E with altitude of 45.75 meters above the mean sea level under Gangetic plains of India.The average annual rainfall of this locality is 1167.0 mm, about 75 to 80% of which precipitates during middle of June to middle of October (about 120 days) and there is very scanty rainfall during the remaining period (245 days). Pre-monsoon showers are usually received in the month of May which is the hottest month when average monthly temperature reaches around 36 °C while winter monthly average temperature drops below 10 °C in the month of January. During crop season Nov.2019-April 2020, minimum and maximum temperature ranged between 5.5 ºC to 22.6 °C and 17.3 °C to 36.4 °C, respectively. While the mean relative humidity was in the ranges of 84.9% to 97.8% at 7:00 AM and 55% to 82.4 % at 2:00 PM respectively.

Total rainfall received during the crop growing season was 118.5 mm. The range of average sun shine hour and evaporation were 1.1 hr. to 8.9 hr. and 0.4 mm to 8.5 mm, respectively. Fertility status of the experiment as envisaged through organic C (0.50), available nitrogen (192.45) was low and phosphorus (22.64) and potash (191.88) was in medium range. Fourteen weed management practices viz, T_1: Pendimethalin 30% EC @ 1000g a.i. ha^{-1} + Metribuzin 70% WP @ 210 g a.i. ha^{-1} as PE, T_2: Metribuzin 70% WP @ 210 g a.i. ha^{-1} as PE, T_3: Metribuzin (70% WP) @ 210 g a.i. ha^{-1} as PoE, T_4: Carfentrazone-ethyl 40% DF @20 g a.i. ha^{-1} as PoE, T_5: Metsulfuron-methyl 20% WP @ 4 g a.i. ha^{-1} as PoE, T_6: 2,4-D ethyl ester 38% EC @ 500 ml a.i. ha^{-1} as PoE, T_7: Sulfosulfuron 75% WG @ 25 g a.i. ha^{-1} as PoE, T_8: Clodinafop-propargyl 15% + Metsulfuron-methyl 1% WP @ 60+4 g a.i. ha^{-1} as PoE, T_9: Sulfosulfuron 75% + Metsulfuron-methyl 5% WG @ 30+2 g a.i. ha^{-1} as PoE, T_{10}: Carfentrazone-ethyl 20% + Sulfosulfuron 25% WG @ 20+25 g a.i. ha^{-1} as PoE, T_{11}: Clodinafop-propargyl 15% WP + Metribuzin 70% WP @ 60+175 g a.i. ha^{-1} as PoE, T_{12}: Mesosulfuron-methyl 3% + Iodosulfuron-methyl-sodium 0.6% WG @ 12+2.4 g a.i. ha^{-1} as PoE, T1$_3$: Weed free and T_{14}: Weedy check respectively in a randomized block design (RBD) with three replications. The size of the experimental plot was 16.24 m^{-2}. The wheat variety 'HD-2967' were sown in row to row 20 cm, on November 23, 2019, using seed-rate @ 125 kg ha^{-1}. Urea, DAP, muriate of potash and sulphur were used to supply 150 kg N, 60 kg P_2O_5 and 40 kg K_2O respectively. Half dose of nitrogen and full dose of phosphorus potassium were applied as basal dressing in the field at the time of sowing. Remaining half dose of nitrogen through urea was top-dressed after first irrigation. The recommended cultural practices and plant protection measures were followed to raise the healthy crop. The number of weeds was recorded from three places selected at random in each plot by using quadrant of 50 cm x 50 cm size after that the samples were dried in a hot air oven at 70±2 °C for 48 hours or till a constant weight attained and then weed dry weight was recorded in gm^{-2}. The five number of plants was selected at random in each plot to take crop growth parameters and yield attributes. The herbicides were sprayed with the help of a hand-operated Knapsack sprayer fitted with flat fan nozzle using 500 liters of water ha^{-1}.

Results and Discussion

Effect on growth, weed and yield attributes

There was no any significant difference in plant height between treatments at harvest stage. However, Maximum plant height was recprded under clodinafop-propargyl @ 60 g *a.i.* ha^{-1} + metsulfuron-methyl @ 4 g *a.i.* ha^{-1} PoE and minimum plant height was recorded in weedy check (Ahmed and Tarique 2010) (Table 1). LAI has increased from initial stages to 90 DAS. However significantly maximum LAI was observed at 90 DAS in the weed free treatment T_{13} (4.93) which was at par with treatments *viz*, T_8 (4.76), T_9 (4.54), T_{10} (4.5) and T_{12} (4.59) except weedy check. Irrespective of all treatments, weedy check treatment (T_{14}) showed significantly minimum LAI at all the stages of crop growth (Chahal *et al*. 2003) [3]. Among all the herbicides applied treatments, maximum LAI was observed under T_8 (clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g *a.i.* ha^{-1} PoE) which was at par with T_{12} (mesosulfuron-methyl @ 12 g a.i. ha^{-1} + iodosulfuron-methyl-sodium @ 2.4 g a.i. ha^{-1} PoE), T_9 (sulfosulfuron @ 30 g *a.i.* ha^{-1} + metsulfuron-methyl @ 2 g a.i. ha^{-1} PoE) and T_{10} (carfentrazone-ethyl @ 20 g *a.i.* ha^{-1} + sulfosulfuron @ 25 g *a.i.* ha^{-1} PoE) at 90 DAS.Weed free plot (T_{13}) has obtained significantly highest yield attributes *viz.*, number of grains per spike (62.12), number of spikes per m^2 (333.87 m^{-2}) and test weight (44.76 g) . Among herbicide applied treatments, T_8 (clodinafop-propargyl @ 60 g *a.i.* ha^{-1} + metsulfuron-methyl @ 4 g *a.i.* ha^{-1} PoE) has recorded significantly higher yield attributes *viz.* number of spikes per m^2 (311.93), number of grains per spike (58.64 m^{-2}) and test weight (44.40) which were at par with the treatment T_{12} (mesosulfuron @ 12 g a.i. ha^{-1} + iodosulfuron-methyl-sodium @ 2.4 g a.i. ha^{-1} PoE) and T_9 (sulfosulfuron @ 30 g a.i. ha^{-1}+ metsulfuron-methyl @ 2 g a.i. ha^{-1} PoE). The increased yield attributing characters is because of positive impact of hand weeding at 20, 40 and 60 DAS and low weed density leads to better uptake of nutrients.It may be also due to low weed density, weed dry weight and higher WCE as it controlled the weeds effectively starting from initial stages to the critical weed competition stage leading to better growth of crop (Pal *et al*. 2016) [10]. The minimum yield attributes in weedy check is because of weed competition by uncontrolled weed growth. The highest value of WCE and WI was obtained with weed free (100%) with respect to weedy check. Amongst herbicides, the maximum value of WCE at 60 DAS was achieved by clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g *a.i.* ha^{-1} PoE (82.02%) closely followed by mesosulfuron @ 12 g a.i. ha^{-1} + iodosulfuron-methyl-sodium @ 2.4 g a.i. ha^{-1} PoE (79.31%). Both these treatments were comparable to weed free treatment. So far as the effect of weed control treatments on weed index (%) was concerned, the reverse trend of WCE (%) was observed (Choudhary *et al*. 2016) [5]. The treatment in which WCE was achieved higher, reduction in grain yield was lower and its vice-versa. Significantly lower value of weed index (4.56%) was obserbed in clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g *a.i.* ha^{-1} PoE and was at par with T_{12} (6.81) and T_9 (11.00).

Effect on economics and yield of wheat

Weed free treatment has recorded significantly higher grain (4.49 t ha^{-1}) and straw yield (5.53 t ha^{-1}) (Table 2). The grain yield enhancement of 5.1% (T_8), 7.12% (T_{12}), 24.4 % (T_{12})

and 43.87% (weedy check) were observed in weed free treatment. However Both grain and straw yield were at par with T_8 (4.26 t ha^{-1},, 5.25 t ha^{-1}), T_{12} (4.17 t ha^{-1}, 5.14 t ha^{-1}) and T_9 (3.93, 4.86 t ha^{-1}).The increased grain yield in these treatments is because of weed density & better WCE along with betterment in yield attributes like number of spikes per m^2, number of grains per spike and test grain weight. This corroborates with the findings of (Tiwari *et al*. 2015) [11]. The highest gross returns (Rs. 103551 ha^{-1}) was recorded under weed free (T13), which was statistically at par with T_8 (Rs. 98342 ha^{-1}), T_{12} (Rs. 96245 ha^{-1}) and T_9 (Rs. 90738 ha^{-1}) and lowest gross returns (Rs. 22879 ha^{-1}) was obtained under weedy check (T14). Among all the herbicidal treatments, highest gross return (Rs. 98342 ha^{-1}) was obtained from treatment $T_{8.}$ weed free treatment was found significantly superior over the rest of the treatments except $T_{8,}$ T_9 and $T_{12.}$ The highest net return (Rs. 61719 ha^{-1}) was recorded under weed free and the lowest net return of (Rs. 22879 ha^{-1}) was recorded under T_{14} (weedy check). weed free was statistically at par with T_8 (Rs. 61206 ha^{-1}), T_{12} (Rs. 58759 ha^{-1}), T_9 (Rs. 53702 ha^{-1}) and T_{10} (Rs. 49284 ha^{-1}). Weed free treatment is significantly superior over the rest of the treatments (Meena *et al*. 2019) [9]. The significantly highest benefit: cost ratio was observed in T_8 (2.67) and the lowest B:C ratio (0.65) was observed in T_{14} (weedy check). However T_8 treatment was found statistically at par with T_{12} (1.57), T_9 (1.45), T_{10}(1.32) and weed free treatment (1.48).

Table 1: Effect of different weed management practices on growth, weed and yield attributes of wheat

Treatment		Dose (g/ml a.i. ha^{-1})	Plant height (cm)	LAI at 90 DAS	Spikes/ m^2	Grains/ spike	Test weight (gm)	WI (%) (at harvest)	WCE (%) at 60 DAS
T_1	Pendimethalin + Metribuzin (TM) -PE	1000 + 210	99.35	4.33	276.39	48.52	41.24	22.87	52.86
T_2	Metribuzin – PE	210	96.75	4.28	266.73	47.88	41.06	32.75	44.23
T_3	Metribuzin	210	96.37	4.25	263.92	47.04	40.82	35.45	52.98
T_4	Carfentrazone-ethyl	20	99.10	4.36	281.44	52.46	41.80	24.29	58.82
T_5	Metsulfuron-methyl	4	99.54	4.39	287.33	52.56	42.32	22.66	61.87
T_6	2,4-D Ethyl Ester	500	98.66	4.34	279.72	51.94	41.52	25.14	56.83
T_7	Sulfosulfuron	25	100.36	4.46	287.33	53.18	42.76	19.93	66.97
T_8	Clodinafop-propargyl+Metsulfuron-methyl (RM)	60 + 4	101.83	4.76	311.93	58.64	44.40	4.56	82.02
T_9	Sulfosulfuron + Metsulfuron-methyl (RM)	30 + 2	100.70	4.54	294.89	54.20	43.66	11.00	74.08
T_{10}	Carfentrazone-ethyl + Sulfosulfuron (RM)	20 + 25	100.64	4.53	292.46	54.02	43.40	16.27	71.01
T_{11}	Clodinafop-propargyl + Metribuzin (TM)	60 + 175	100.31	4.51	289.48	53.60	43.22	19.60	68.56
T_{12}	Mesosulfuron+Iodosulfuron-methyl-sodium (RM)	12 + 2.4	101.08	4.59	301.26	56.93	43.84	6.81	79.31
T_{13}	Weed free	-	102.08	4.93	333.87	62.12	44.76	0.00	100.00
T_{14}	Weedy check	-	96.08	3.85	206.62	42.41	40.24	43.09	0.00
S.Em. ±			3.25	0.14	13.93	2.76	2.33	4.64	1.29
CD (P=0.05)			NS	0.41	40.51	8.02	NS	13.49	3.74

In T_3 to $T_{12,}$ herbicides were applied as post emergence i.e. 32 DAS; PE: Pre emergence.

Table 2: Effect of different weed management practices on economics and yield of wheat

Treatment		Dose (g/ml a.i. ha^{-1})	Grain yield (t/ha)	Straw yield (t/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
T_1	Pendimethalin + Metribuzin (TM) -PE	1000 + 210	3.19	3.94	73591	35775	0.95
T_2	Metribuzin – PE	210	2.95	3.66	68278	31562	0.86
T_3	Metribuzin	210	2.87	3.55	66286	29570	0.81
T_4	Carfentrazone-ethyl	20	3.38	4.15	77894	41358	1.13
T_5	Metsulfuron-methyl	4	3.43	4.25	79246	43030	1.19
T_6	2,4-D Ethyl Ester	500	3.32	4.10	76635	40339	1.11
T_7	Sulfosulfuron	25	3.58	4.45	82849	45663	1.23
T_8	Clodinafop-propargyl+Metsulfuron-methyl (RM)	60 + 4	4.26	5.25	98342	61206	1.65
T_9	Sulfosulfuron + Metsulfuron-methyl (RM)	30 + 2	3.93	4.86	90738	53702	1.45
T_{10}	Carfentrazone-ethyl + Sulfosulfuron (RM)	20 + 25	3.75	4.67	86750	49284	1.32
T_{11}	Clodinafop-propargyl + Metribuzin (TM)	60 + 175	3.61	4.46	83340	45839	1.22
T_{12}	Mesosulfuron+Iodosulfuron-methyl-sodium (RM)	12 + 2.4	4.17	5.14	96245	58759	1.57
T_{13}	Weed free	-	4.49	5.53	103551	61719	1.48
T_{14}	Weedy check	-	2.52	3.15	58279	22879	0.65
S.Em. ±			2.76	0.27	5107	5107	0.13
CD (P=0.05)			8.02	0.78	14846	14846	0.39

In T_3 to $T_{12,}$ herbicides were applied as post emergence i.e. 32 days after sowing; PE: Pre emergence

Conclusion

Application of clodinafop-propargyl @ 60 g a.i. ha^{-1} + metsulfuron-methyl @ 4 g a.i. ha^{-1} PoE can be recommended for wheat in enhancing grain yield in terms of better growth, yield attributes and then ultimately higher grain and straw yield was observed under this treatment was found better among all the herbicide applied treatments.

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