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Full Length Research Paper

Efficacy of various herbicides against weeds in wheat (*Triticum aestivum* L.)

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Weeds are one of the most important factors that impose a great threat to the crop yield. In order to alleviate the weeds infestation in wheat (*Triticum aestivum* L.), the efficacy of various pre and post-emergence herbicides were tested during Rabi 2009 to 2010 at the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. Results promised that clodinafop propargyl at 0.045 kg a.i. ha^{-1} with maximum weed kill efficiency severely reduced the *Avena fatua*, *Coronopus didymus* and *Melilotus indica* population and dry weights compared with the control. Poor weed control was achieved using isoproturon at 1.5 kg a.i. ha^{-1}, isoproturon + diflufenicon at 0.98 kg a.i. ha^{-1}, fenoxaprop-p-ethyl at 1.00 kg a.i. ha^{-1}, tralkoxydim at 0.5 kg a.i. ha^{-1} and chlorsulfuron at 0.074 kg a.i. ha^{-1}. Considering total grain and straw yields (4900 kg ha^{-1}); (6600 kg ha^{-1}), post-emergence clodinafop propargyl at 0.045 kg a.i. ha^{-1} causes an excellent increase in wheat yield (51.02%) over control. The highest spikebearing tillers (380.67), number of grains spike^{-1} (47.28) and 1000-grain weight (49.38 g) were maximum in clodinafop propargyl at 0.045 kg a.i. ha^{-1} as post-emergence treated plots. Based on the total wheat yield (grain and straw) obtained, isoproturon at 1.5 kg a.i. ha^{-1}, metribuzin + fenoxaprop-p-ethyl at 1.00 + 1.00 kg a.i. ha^{-1}, chlorsulfuron at 0.074 kg a.i. ha^{-1} seemed someway phytotoxic to crop plants and depressed wheat yield. Hence, maximum net income of Rs. 136997 ha^{-1} and maximum MRR (%) of 231316.6 was recorded with the use of clodinafop propargyl at 0.045 kg a.i. ha^{-1} as post applied followed by carfentrazone ethyl (0.015 kg a.i ha^{-1}) with the MRR (%) of 89700.

Key words: *Triticum aestivum* L., *Avena fatua*, *Coronopus didymus*, *Melilotus indica*, clodinafop propargyl, weed control, herbicides.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important cereal crop and occupies a significant position in the economy of Pakistan. It constitutes 60% of average diet to a common man and provides food for poultry and also a cheap source of feed for livestock in the country. About one third of the world population is based on wheat crop for protein and caloric requirements (Khan, 2003; Montazeri et al., 2005).

Although, the soil and climatic conditions of Pakistan are favorable for wheat production but it's per hectare yield is very low. Among various factors, weeds infes-ation is one of the main causes of low wheat yield in Pakistan. Crop suffers stress created by weeds through competition for moisture, nutrition, space, light and many other growth factors through competition and allelopathy. These tend to persist while man's efforts for eradication, resulting in direct loss to quantity and quality of the produce (Qasim and Foy, 2001; Gupta, 2004). Weeds are hidden enemies of wheat and cause huge losses to crop yields which amount to Rs. 115 to 200 billion per annum. Wheat productivity losses in Pakistan due to weeds competition (45%) are greater than those resulting from the combined effect of insects and diseases (Rao,

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2000). Weed infestation is one of the main causes of low wheat yield not only in Pakistan but all over the world, as it reduces wheat yield by 37 to 50% (Waheed et al., 2009). Weeds problem is getting from bad to worse in wheat sown under irrigated areas, crop-ping intensity is rapidly increasing as a result the weed control with traditional method as Dab (suicidal germination) and hand weeding has become impossible. Weeds can be controlled by manual hoeing which is laborious, time consuming, energy intensive and only possible on small scale. Mechanical means are economical but it controls only inter row weeds, not intra row weeds. In such situations, herbicides offer most ideal, practical, effective and economical means of reducing early weed competition and crop production losses. So, chemical method for controlling weeds is most effective, efficient, up-to-date and time saving (Ashiq et al., 2007).

At present, a number of pre and post-emergence herbicides are used in wheat fields for controlling weeds and to enhance maximum wheat grain yield. Pendimethalin + fluometuron as pre-emergence controlled sickle pod 82, goosegrass 89, palmer amaranth 92 and the other species at least 95% (Bostrom and Fogelfors, 2002). The application of metribuzin and atrazine alone or in combination significantly reduced the weeds density and biomass (Wallia et al., 2001). Some researchers reported that isoproturon, affinity and sencor provided good control against weeds and resulted in maximum grain yield (Alvi et al., 2004; Hassan et al., 2005). Naseer-ud-din et al., (2011) promised that chemical weed control has been ascertained to be more efficient in suppressing weeds density.

The information about the efficacy of various herbicides against weeds in wheat crop is still lacking in Pakistan. So, keeping in view the present study, was therefore, planned

(i) To find out the appropriate weed management options for obtaining higher grain yield of wheat crop.
(ii) To trace out most effective and economical herbicide for controlling weeds.
(iii) To assess the effects of different herbicides on wheat crop and its response to different herbicides under agro climatic conditions at Faisalabad.

MATERIALS AND METHODS

The proposed study was conducted at the Research Area, Department of Agronomy, University of Agriculture, Faisalabad, during Rabi season 2009 to 2010. The crop was sown during 2nd week of November, 2009 on a sandy clay loam soil. Inqalab-91 variety was used as a test crop in 25 cm apart rows with a single row hand drill using a seed rate of 100 kg ha^{-1}. The soil was ploughed at desirable field condition and followed by single planking. Nitrogen (N) and phosphorus (P) were applied at 120 and 85 kg ha^{-1} in the form of urea and diammonium phosphate (DAP) respectively. Whole P and half of the N were side dressed at the sowing time, while remaining N was top dressed with first irrigation. The field was irrigated five times as the first irrigation was done 30 days after crop emergence and subsequent irrigations were applied as per crop water stages especially at tillering, booting, anthesis and grain development stage. All other agronomic practices except those under study were kept normal and uniform for all treatment combinations. The crop was harvested manually at physical maturity on last week of April. Threshing of each plot was done separately. Most commonly surveyed weed flora at the experimental site throughout the growing season as shown in (Table 1).

Experiment was laid out in a randomized complete block design (RCBD) with three replications having a net plot size of 2 × 5 m^2. The experiment comprised eleven treatments (Table 2). The pre-emergence herbicides just after sowing and post-emergence herbicides were sprayed at 4-6 leaf stage of wheat crop in moist field by “knapsack sprayer” using flat fan nozzle. Volume of spray was determined by calibration and water was used at 250 L ha^{-1}.

Data for weed density (m^{-2}) was recorded at 30 to 60 days after sowing (DAS) using standard procedures during the course of study. A quadrate measuring (50 × 50 cm) was randomly placed at two sites in respective plots and density of individual weeds was recorded and their average was calculated. The counted weeds were cut near ground surface, stored in polythene bags and then recorded their biomass. The dry weight of each weed species was determined after oven-drying at 70°C till constant weight was achieved. A unit area of 1 m^2 was selected at random from two different sites of each plot for recording plant height (cm), number of fertile tillers (m^{-2}), number of grains per spike, 1000 grain weight (g), straw yield (kg ha^{-1}) and grain yield (kg ha^{-1}).

Data was analyzed statistically according to Fisher’s analysis of variance technique (Steel et al., 1997) and least significant difference (LSD) test at 5% probability level was applied to compare the treatments’ means.

RESULTS

Effect of herbicides on weeds

The effect of pre and post-emergence herbicides on weeds growth is shown in (Figure 1). The highest weed numbers were found in the control. All herbicides reduced the (A) *A. fatua* (B) *C. didymus* and (C) *M. indica* growth compared with the control. Results concerning the suppression of (A) *A. fatua* density (Figure 1) at 30 DAS showed that minimum density (3.00 plants m^{-2}) was found with post application of clodinafop propargyl at 0.045 kg a.i. ha^{-1} compared to the control (32.0 plants m^{-2}). Isoproturon at 1.5 kg a.i. ha^{-1} and Chlorsulfuron at 0.074 kg a.i. ha^{-1} also gave a better control against *A. fatua.* Isoproturon + diflufenicon at 0.98 kg a.i. ha^{-1}, bromoxynil + MCPA + fenoxaprop-p-ethyl at 0.445 + 1.00 kg a.i. ha^{-1}, metribuzin + fenoxaprop-p-ethyl at 1.00 + 1.00 kg a.i. ha^{-1} and fenoxaprop-p-ethyl at 1.00 kg a.i. ha^{-1} provide a satisfactory control. At 60 DAS lesser *A. fatua* density (3.33 plants m^{-2}) was attained in post applied clodinafop propargyl at 0.045 kg a.i. ha^{-1} treated plots. Isoproturon at 1.5 kg a.i. ha^{-1} and metribuzin plus fenoxaprop-p-ethyl at 1.00 + 1.00 kg a.i. ha^{-1} statistically gave a similar *A. fatua* control. Extreme *A. fatua* count (33.33 plants m^{-2}) was recorded in the control. Poor control was with carfentrazone ethyl at 0.015 kg a.i. ha^{-1} at both 30 and 60 DAS. However, exellent *A. fatua* control (3.00 plants m^{-2}) and (3.33 plants m^{-2}) was gained with clodinafop

Table 1. Weed flora of the experimental site.

Weed species	Density (m^{-2})
Avena fatua L.	51
Coronopus didymus L.	49
Melilotus indica L.	47
Anagallis arvensis L.	5
Chenopodium album L.	5
Asphodelus tenuifolius L.	4
Carthamus oxyacantha M.	4
Medicago polymorpha L.	4
Phalaris minor R.	3
Emex spinosa L.	3
Polygonum plebejum L.	3
Convolvulus arvensis L.	2
Cynodon dactylon	2
Euphorbia helioscopia L.	2
Lolium temulentum L.	2
Sinapis arvense L.	1
Amaranthus viridis L.	1
Bromus spp.	1
Fumaria indica L.	1
Rumex spp.	1

Table 2. Various herbicides used in wheat crop during Rabi 2009 to 2010.

Herbicide	Application time	Trade name	Rate (kg a.i. ha^{-1})
Control	--	--	--
Isoproturon	Post	Isoproturon 50WP	1.5
Isoproturon + diflufenicon	Post	Panther 52SC	0.98
Isoproturon + carfentrazone ethyl	Post	Affinity 50WP	2.0
Bromoxynil + MCPA + fenoxaprop-p-ethyl	Pre	Buctril Super 60EC + Puma super 75EW	0.445+1.00
Metribuzin + fenoxaprop-p-ethyl	Pre	Sencor 70WP + Pujing 10EC	1.00+1.00
Fenoxaprop-p-ethyl	Pre	Pujing 10EC	1.00
Clodinafop propargyl	Post	Topik 50WP	0.045
Carfentrazone ethyl	Post	Aim 40DF	0.015
Tralkoxydim	Post	Grasp 10EC	0.5
Chlorsulfuron	Post	Lasher 70WP	0.074

propargyl at 0.045 kg a.i. ha^{-1} as post-emergence application at both 30 and 60 DAS respectively. The lowest (B) *C. didymus* density (4.33 plants m^{-2}) and (3.66 plants m^{-2}) at 30 and 60 DAS respectively was obtained with post-emergence application clodinafop propargyl at 0.045 kg a.i. ha^{-1}. Results indicate that metribuzin + fenoxaprop-p-ethyl at 1.00 + 1.00 kg a.i. ha^{-1} and carfentrazone ethyl at 0.015 kg a.i. ha^{-1} statistically could not recover the *C. didymus* control efficacy except clodinafop propargyl at 0.045 kg a.i. ha^{-1}. The maximum *C. didymus* density (45.00 plants m^{-2}) and (48.00 plants m^{-2}) at both 30 and 60 DAS respectively was found in non treated control (Figure 1). Analysis of the data exhibited that there were significant effects of various herbicide treatments on weed control while comparison of treatment's means disclosed that minimum (C) *M. indica* numbers (3.66 plants m^{-2}) and (4.00 plants m^{-2}) at 30 and 60 DAS respectively was noted, where post-emergence clodinafop propargyl at 0.045 kg a.i. ha^{-1} was sprayed. Isoproturon + carfentrazone ethyl at 2.0 kg a.i. ha^{-1} also gave a better control against *M. indica* afetr clodinafop propargyl at 0.045 kg a.i. ha^{-1}. *M. indica* number was also affected giving the lowest (3-4 plants m^{-2}) with clodinafop propargyl at 0.045 kg a.i. ha^{-1} and (9 to 10 plants m^{-2}) with carfentrazone ethyl at 30 and 60 DAS as post-emergence spray. The highest *M. indica* number (16

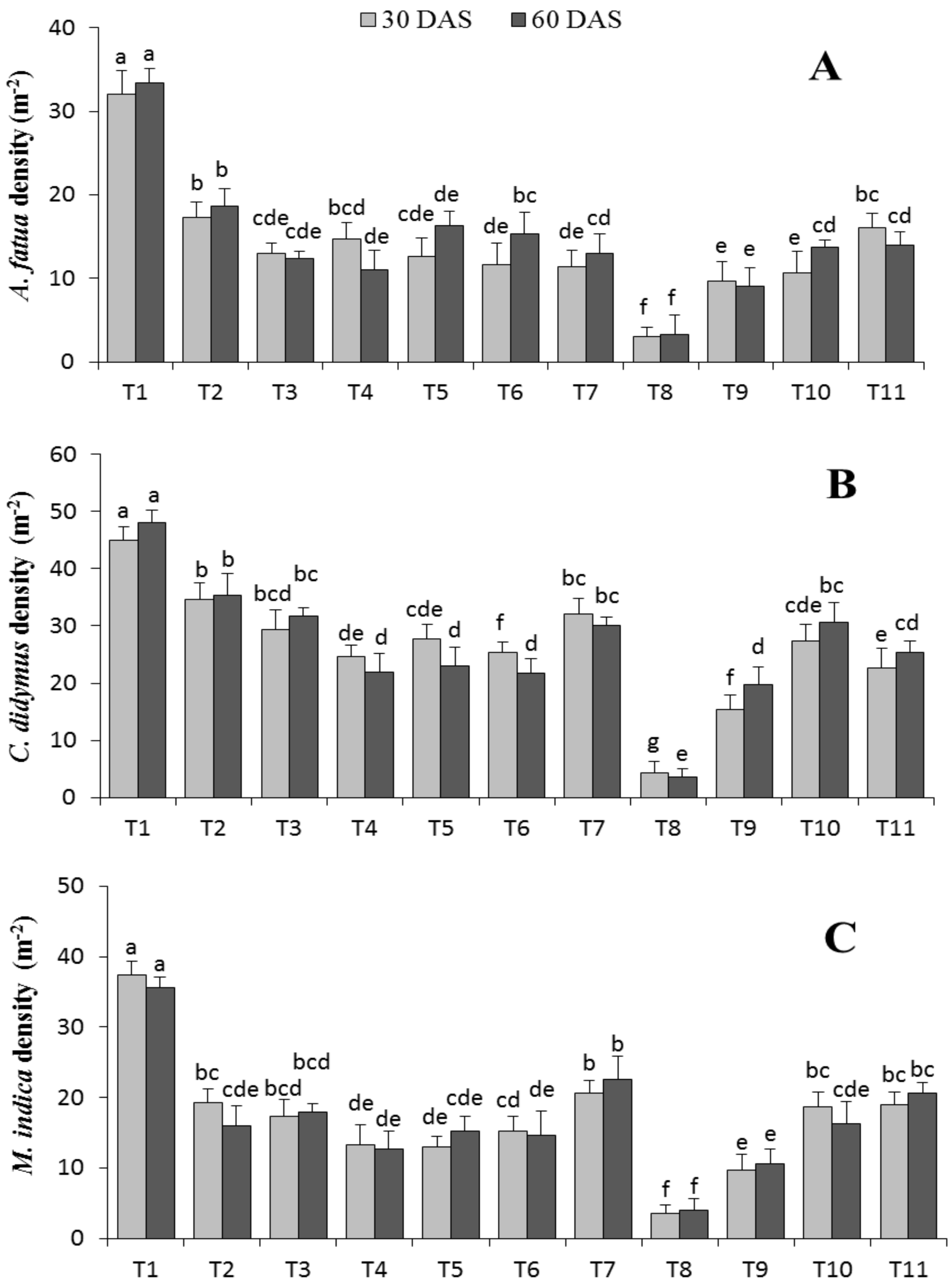

Figure 1. Individual weed density **(A)** *A. fatua* **(B)** *C. didymus* and **(C)** *M. indica* as affected by various pre and post-emergence herbicides. Vertical bars denote standard errors of the means of 3 replicates. T1, Control; T2, isoproturon; T3, isoproturon+diflufenicon; T4, isoproturon+carfentrazone ethyl; T5, bromoxynil+MCPA+fenoxaprop-p-ethyl; T6, metribuzin+fenoxaprop-p-ethyl ; T7, fenoxaprop-p-ethyl; T8, clodinafop propargyl; T9, carfentrazone ethyl; T10, tralkoxydim; T11, chlorsulfuron.

plants m^{-2}) was with fenoxaprop-p-ethyl at 1.00 kg a.i. ha^{-1}, tralkoxydim at 0.5 kg a.i. ha^{-1} and chlorsulfuron at 0.074 kg a.i. ha^{-1} at 30 and 60 DAS which were statistically similar with the control (Figure 1).

The highest dry weights of **(A)** *A. fatua* (9.43; 8.70 and 8.16 g m^{-2}) was with Isoproturon at 1.5 kg a.i. ha^{-1}, Isoproturon + diflufenicon at 0.98 kg a.i. ha^{-1}, Isoproturon + carfentrazone ethyl at 2.0 kg a.i. ha^{-1} respectively

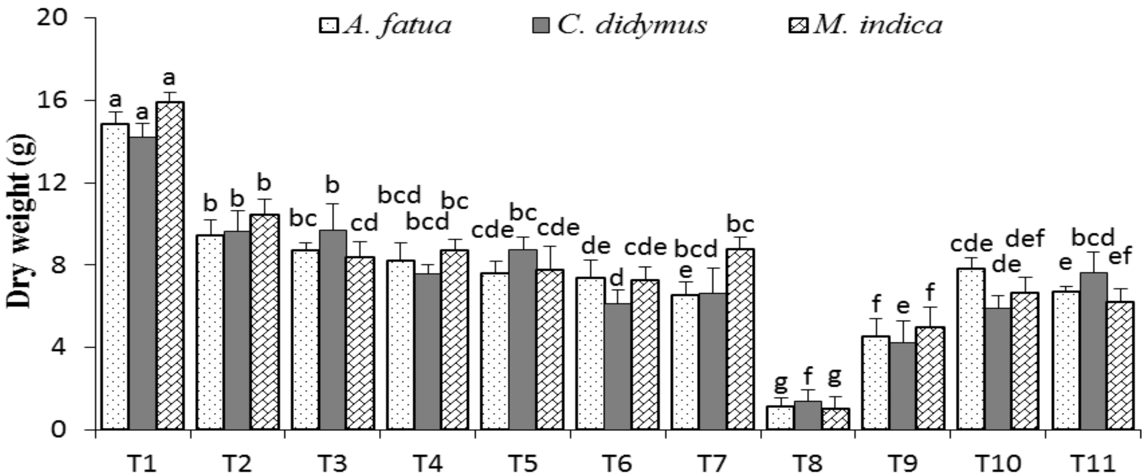

Figure 2. Effect of various pre and post-emergence herbicides on weeds dry weight (g m^{-2}) at 60 DAS. Vertical bars denote standard errors of the means of 3 replicates; T1, Control; T2, isoproturon; T3, isoproturon+diflufenicon; T4, isoproturon+carfentrazone ethyl; T5, bromoxynil+MCPA+fenoxaprop-p-ethyl; T6, metribuzin+fenoxaprop-p-ethyl ; T7, fenoxaprop-p-ethyl; T8, clodinafop propargyl; T9, carfentrazone ethyl; T10, tralkoxydim; T11, chlorsulfuron.

followed by the control (14.83 g m^{-2}). Carfentrazone ethyl at 0.015 kg a.i. ha^{-1} as post application also gave a better control of (A) *A. fatua* with minimum *A. fatua* dry weight (4.53 g m^{-2}) after clodinafop propargyl at 0.045 kg a.i. ha^{-1}. The significant reduction in dry weight of *A. fatua* (1.13 g m^{-2}) was attained by clodinafop propargyl at 0.045 kg a.i. ha^{-1}. The maximum dry weight of (B) *C. didymus* and (C) *M. indica* (14.20 g m^{-2}) and (15.86 g m^{-2}) respectively was obtained from control plots while lowest dry weight (1.36 g m^{-2}) and (0.98 g m^{-2}) respectively was recorded in clodinafop propargyl at 0.045 kg a.i. ha^{-1} plots followed by post-emergence carfentrazone ethyl at 0.015 kg a.i. ha^{-1} other herbicides including isoproturon at 1.5 kg a.i. ha^{-1}, isoproturon + diflufenicon at 0.98 kg a.i. ha^{-1} and fenoxaprop-p-ethyl at 1.00 kg a.i. ha^{-1} produced maximum (B) *C. didymus* and (C) *M. indica* dry weight similar to that of the control (Figure 2).

Effect of herbicides on wheat yield

The effect of pre and post-emergence herbicides on growth and yield of wheat is shown in Table 3. Herbicides during the entire growing season increased the yield attributes compared to the control. Spraying wheat with herbicide treatments significantly affected the plant height. Maximum plant height (83.16 cm) was achieved from the control while the minimum plant height (72.78 cm) was achieved with Isoproturon + diflufenicon at 0.98 kg a.i. ha^{-1}. Highest plant height (79.78 cm), (77.61 cm) and (77.50 cm) was obtained from plots treated with isoproturon + carfentrazone ethyl at 2.0 kg a.i. ha^{-1}, carfentrazone ethyl at 0.015 kg a.i. ha^{-1} and tralkoxydim at 0.5 kg a.i. ha^{-1} respectively which was statistically similar with the control. Maximum number of fertile tillers (m^{-2}) (380.67) was observed in those plots where post-emergence clodinafop propargyl at 0.045 kg a.i. ha^{-1} was applied as compared to the control (217.67). Fenoxaprop-p-ethyl (1.00 kg a.i. ha^{-1}) provided minimum fertile tillers (280.0) likewise a control treatment. All herbicide treatments significantly increased the number of grains $spike^{-1}$ over control. So, differences in number of grains $spike^{-1}$ among isoproturon + diflufenicon, isoproturon + carfentrazone ethyl and fenoxaprop-p-ethyl at 0.98, 2.0 and 1.00 kg a.i. ha^{-1} respectively were not significant. The number of grains $spike^{-1}$ (47.28) and 1000-grain weight (49.38 g) were maximum in clodinafop propargyl at 0.045 kg a.i. ha^{-1} treated plots followed by carfentrazone ethyl at 0.015 kg a.i. ha^{-1} (79.78) and (47.20 g), respectively compared to the control. Straw yield was the highest (6600 kg ha^{-1}) with the clodinafop propargyl at 0.045 kg a.i. ha^{-1} followed by carfentrazone ethyl at 0.015 kg a.i. ha^{-1} (5630 kg ha^{-1}) contrast to the control. In case of straw yield obtained, isoproturon + diflufenicon at 0.98 kg a.i. ha^{-1}, isoproturon + carfentrazone ethyl at 2.0 kg a.i. ha^{-1}, bromoxynil + MCPA + fenoxaprop-p-ethyl at 0.445 + 1.00 kg a.i. ha^{-1}, metribuzin + fenoxaprop-p-ethyl at 1.00 + 1.00 kg a.i. ha^{-1} and chlorsulfuron at 0.074 kg a.i. ha^{-1} behaves statistically alike. Of all the herbicides evaluated, lesser grain yield (3230 kg ha^{-1}) was realized in metribuzin + fenoxaprop-p-ethyl at 1.00 + 1.00 kg a.i. ha^{-1} treated plots afterward control which was followed by chlorsulfuron at 0.074 kg a.i. ha^{-1} (3400 kg ha^{-1}). Carfentrazone ethyl at 0.015 kg a.i. ha^{-1} also gave a satisfactory grain yield (4300 kg ha^{-1}) against the control.

However, differences in grain yield between isoproturon + diflufenicon, isoproturon + carfentrazone ethyl, bromoxynil + MCPA + fenoxaprop-p-ethyl, tralkoxydim

Table 3. Effect of various herbicide treatments on wheat yield during 2009 to 2010.

Treatment	Rate (kg a.i. ha^{-1})	Parameter					
		Plant height (cm)	Number of fertile tillers	Number of grains $spike^{-1}$	1000 grain weight (g)	Straw yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Control	--	83.16^{a}	217.67^{e}	29.08^{i}	34.17^{i}	3500^{f}	2400^{g}
Isoproturon	1.5	75.18^{bc}	293.67^{cd}	34.07^{g}	42.20^{fg}	4560^{e}	3500^{de} (31.43%)
Isoproturon + diflufenicon	0.98	72.78^{c}	307.67^{bcd}	34.98^{f}	42.51^{ef}	5300^{c}	3800^{c} (36.84%)
Isoproturon + carfentrazone ethyl	2.0	77.61^{abc}	322.67^{bcd}	35.67^{f}	43.47^{de}	5330^{c}	3730^{c} (35.65%)
Bromoxynil + MCPA + fenoxaprop-p-ethyl	0.445+1.00	74.37^{bc}	309.00^{bcd}	38.86^{e}	43.85^{d}	5260^{c}	3860^{c} (37.82%)
Metribuzin + fenoxaprop-p-ethyl	1.00+1.00	73.76^{c}	305.67^{bcd}	32.16^{h}	37.02h	5230^{c}	3230^{f} (25.69%)
Fenoxaprop-p-ethyl	1.00	74.80^{bc}	280.00^{d}	35.35^{f}	41.11^{g}	4800^{d}	3700^{cd} (35.13%)
Clodinafop propargyl	0.045	74.39^{bc}	380.67^{a}	47.28^{a}	49.38^{a}	6600^{a}	4900^{a} (51.02%)
Carfentrazone ethyl	0.015	79.78^{ab}	352.33^{ab}	43.61^{b}	47.20^{b}	5630^{b}	4300^{b} (44.18%)
Tralkoxydim	0.5	77.50^{abc}	345.00^{abc}	42.35^{c}	47.06^{b}	4360^{e}	3800^{c} (36.84%)
Chlorsulfuron	0.074	75.68^{bc}	328.00^{abcd}	40.87^{d}	45.18^{c}	5130^{c}	3400^{ef} (29.41%)
LSD ($P = 0.05$)		5.87	54.10	0.90	1.15	0.21	0.20

at 0.98, 2.0, 0.445 + 1.00 and 0.5 kg a.i. ha^{-1} treatments were not significant. The maximum grain yield (4900 kg ha^{-1}) was produced by the clodinafop propargyl at 0.045 kg a.i. ha^{-1} over the control. Most of the herbicides including carfentrazone ethyl, isoproturon + diflufenicon, isoproturon + carfentrazone ethyl, bromoxynil + MCPA + fenoxaprop-p-ethyl, fenoxaprop-p-ethyl, tralkoxydim increased grain yield over the control but maximum was obtained by clodinafop propargyl at 0.045 kg a.i. ha^{-1} which was up to 51.02%.

Prevailing market prices of herbicides

Isoproturon at Rs. 375; Isoproturon + diflufenicon at Rs. 370; Isoproturon + carfentrazone ethyl at Rs. 750; Bromoxynil + MCPA+fenoxaprop-p-ethyl at Rs. 690 + 510 = 1200; Metribuzin + fenoxaprop-p-ethyl at Rs. 760 + 320 = 1080; Fenoxaprop-p-ethyl at Rs. 320; Clodinafop propargyl at Rs. 450; Carfentrazone ethyl at Rs. 400; Tralkoxydim at Rs. 435; Chlorsulfuron at Rs. 350.

DISCUSSION

The herbicides that could weaken the physical and biochemical defences of the plant used for weed control has already been considered. Results of this experiment clearly showed that there were significant effects of different pre and post-emergence herbicides on (A) *A. fatua* (B) *C. didymus* and (C) *M. indica* density at different days after sowing (DAS). All the weed control treatments reduced significantly weed numbers after 30 and 60 DAS compared to the control (Figure 1). Post-emergence application of carfentrazone ethyl at 0.015 kg a.i. ha^{-1} recorded a better significant reduction for *A. fatua* density compared to other weed control treatments while clodinafop propargyl at 0.045 kg a.i. ha^{-1} gave highest 90.6 and 90.0% reduction in *A. fatua* population after 30 and 60 DAS. Reduction in *A. fatua* density was accredited to the reason that clodinafop propargyl at 0.045 kg a.i. ha^{-1} is a strong inhibitor of acetyl CoA carboxylase (ACCase). This chemical actually blocks an enzyme called ACCase which helps the formation of lipids in the roots of grass plants. Without lipids, susceptible weeds die (Bharat and kachroo, 2007). Clodinafop propargyl proved to be very effective and hence recommended for controlling weeds in wheat crop and for maximizing of wheat yield (Jarwar et al., 2005) and (Stagnari et al., 2006). Isoproturon at 1.5 kg a.i. ha^{-1} and isoproturon + diflufenicon at 0.98 kg a.i. ha^{-1} when applied as post-emergence acted poorer against *C. didymus* as compared to other herbicide treatments. As observed, clodinafop propargyl at 0.045 kg a.i. ha^{-1} provided highest *C. didymus* reduction (90.37 and 92.37%) at both 30 and 60 DAS respectively whereas bromoxynil + MCPA +

fenoxaprop-p-ethyl, fenoxaprop-p-ethyl and tralkoxydim treatments performed less effectively in these respects. The herbicides used in the present study have target sites in plants. These sites in the plant body as acetolactate synthase the key plant enzyme, inhibiting branched chain amino acids leucine, isoleucine and valine and the plant enzyme protopor-phyrinogen oxidase, sulfamoylurea inhibition of acetohydroxyacid synthase which is the key plant enzyme amino acids biosynthesis, are targeted by means of these herbicides. Authorizing results in this respect were cited by Saini and Singh (2001), Khan et al. (2004) and El-Metwally et al. (2010) who depicted that appli-cation of post-emergence clodinafop propargyl can reduced narrow and broad leaved weeds to a varying degree sometimes impending to 100% control. Isoproturon + carfentrazone ethyl at 2.0 kg a.i. ha^{-1}, bromoxynil + MCPA + fenoxaprop-p-ethyl at 0.445 + 1.00 kg a.i. ha^{-1} and carfentrazone ethyl at 0.015 kg a.i. ha^{-1} gave better results in alleviation of *M. indica* density after 30 and 60 DAS. As perceived from the results (Figure 1), it is mentioned that clodinafop propargyl at 0.045 kg a.i. ha^{-1} proved as an effective hebicide against *M. indica* which gave maximum reduction (90.19) and (88.78%) in *M. indica* density after 30 and 60 DAS compared to weedy check plots. These herbicides have definite target sites resulting in the inhibition of acetyl CoA carboxylase (ACCase), the synthesis of fatty acids, the enzyme catalyzing the first committed step in fatty acids synthesis. Inhibition of fatty acid synthesis seemingly blocks the production of phospholipids used in building new membranes required for cell growth. Similar results were obtained by Bailey and Wilson (2003), Singh (2004), Barros et al. (2005) and El-Metwally et al. (2010).

The shift in effectiveness of various pre and post-emergence herbicides is clearly verified through the effect of clodinafop propargyl that alleviated the popu-lation, growth and dry weed biomass by almost 90-95%. Clodinafop propargyl at 0.045 kg a.i. ha^{-1} used in the present study actually targeted the photosynthetic process that inhibits the carotenoid synthesis in plants (El-Metwally and Soudy, 2009). So, clodinafop propargyl at 0.045 kg a.i. ha^{-1} was highly effective in controlling narrow and broadleaved weeds and resulted in highest reduction in dry weight compared with other treatments. Maximum reduction in weeds dry weight may be caused by the inhibition effect and high weed kill efficiency of post-emergence clodinafop propargyl at 0.045 kg a.i. ha^{-1} on growth and development of weeds. These results are agree with the previous findings of other workers (Tucker et al., 2006; Nassar, 2008; Chhokar et al., 2008; El-Metwally et al., 2010) who reported that post-emergence application of clodinafop propargyl at 0.045 kg a.i. ha^{-1} significantly increased the weed control efficacy, reduced the weeds dry weight and ultimately improved the wheat grain yield.

Weeds competition instigated a great reduction in wheat grain yield. Most of the weeds emerged with wheat, resembles crop plants in morphology, physiology and has a great demand for light, space, water and nutrients (Grishin et al., 2001; Gonzalez-Ponce and Santin, 2001; Khalil et al., 2008). Highest plant height was recorded in control plots because of competition among weeds and wheat plants enforced to grow up the plant height higher than the actual height (Marwat et al., 2005). Clodinafop propargyl at 0.045 kg a.i. ha^{-1} signifi-cantly encouraged the growrh of fertile tillers through better crop growth as a result of less weeds competition. Significant increase in number of grains $spike^{-1}$ and 1000 grain weight by the post application of clodinafop propargyl at 0.045 kg a.i. ha^{-1} may be attributable to availability of more nutrients because of weeds competition reduction.

The lowest grain production per spike and 1000-grain weight in control plots (29.08 kg ha^{-1}); (34.17 g) res-pectively, was due to severe competition between the crop plants and weeds. This competition prominently reduced the nutrients mobility towards the grains which ultimately affected the grain development potential of the plant. These results on weeds competition reduction are agree with the previous finding of Qureshi et al. (2002) and Ijaz et al. (2008).

The highest straw yield (6600 kg ha^{-1}) was attained with clodinafop propargyl at 0.045 kg a.i. ha^{-1} followed by carfentrazone ethyl (5630 kg ha^{-1}) over the control. Nevertheless, clodinafop propargyl at 0.045 kg a.i. ha^{-1} gave maximum straw and grain yield (6600 kg ha^{-1}); (4900 kg ha^{-1}) which exhibited that outstanding control can be achieved by means of this herbicide. Due to lessening the competition between the weeds and crop plants results in increased flow of nutrients towards grains which eventually enhance wheat grain yield. Increase in grain yield might be that weeds control by clodinafop propargyl at 0.045 kg a.i. ha^{-1} herbicide in this study diverted the nutrients availability to the crop, which in turn ensured in maximum grain yield was due to more number of grains per spike and 1000-grain weight compared to the control.

However, results show that clodinafop propargyl (0.045 kg a.i. ha^{-1}) can increased the wheat yield by 51.02% over the control. Tunio et al. (2004), Baghestani et al. (2007) and Chhokar et al. (2008) found that application of herbicides proved to be effective in controlling weeds and maximizing wheat grain yield.

Economic and marginal analysis

Economic analysis assessed on the basis of average grain yield depicted that all the herbicides gave consi-derably higher net benefit than the control (Table 4). Economic analysis revealed that maximum net benefits of Rs. 136997 ha^{-1} was obtained from clodinafop propargyl 50WP at its label dose which was followed by carfentrazone ethyl at 0.015 kg a.i. ha^{-1} providing a net benefit of Rs. 119372 ha^{-1}. Marginal and dominance analysis (Table 5) showed that clodinafop propargyl at

Table 4. Economic analysis of various weed control treatments.

Treatment	Grain yield (kg ha^{-1})	Adjusted yield (kg ha^{-1})	Grain yield value (Rs.)	Straw yield (kg ha^{-1})	Straw yield value (Rs.)	Gross income (Rs.)	Variable weed control cost				Total cost that varied (a+b+c+d)	Net benefit (Rs. ha^{-1})
							a. Labour charges for 2 hand weeding	b. Cost of herbicides	c. Sprayer rent	d. Labour charges for herbicides application		
T_1	2400	2160	51300	3500	17500	68800	---	---	---	---	---	68800
T_2	3500	3150	74812	4560	22800	97612	---	375	90	200	665	96947
T_3	3800	3420	81225	5300	26500	107725	---	370	90	200	660	107065
T_4	3730	3357	79728	5330	26650	106378	---	750	90	200	1040	105338
T_5	3860	3474	82507	5260	26300	108807	---	1200	90	200	1490	107317
T_6	3230	2907	69041	5230	26150	95191	---	1080	90	200	1370	93821
T_7	3700	3330	79087	4800	24000	103087	---	320	90	200	610	102477
T_8	4900	4410	104737	6600	33000	137737	---	450	90	200	740	136997
T_9	4300	3870	91912	5630	28150	120062	---	400	90	200	690	119372
T_{10}	3800	3420	81225	4360	21800	103025	---	435	90	200	725	102300
T_{11}	3400	3060	72675	5130	25650	988325	---	350	90	200	640	97685

Prevailing market prices of herbicides: Isoproturon at Rs. 375; Isoproturon + diflufenicon at Rs. 370; Isoproturon + carfentrazone ethyl at Rs. 750; Bromoxynil + MCPA+fenoxaprop-p-ethyl at Rs. 690 + 510=1200; Metribuzin + fenoxaprop-p-ethyl at Rs. 760 + 320=1080; Fenoxaprop-p-ethyl at Rs. 320; Clodinafop propargyl at Rs. 450; Carfentrazone ethyl at Rs. 400; Tralkoxydim at Rs. 435; Chlorsulfuron at Rs. 350.

Table 5. Marginal analysis of various weed control treatments.

Treatment	Cost that varied (Rs. ha^{-1})	Net benefit (Rs. ha^{-1})	*MRR (%)
$T_{1=}$ Control	---	68800	-
$T_{7=}$ Fenoxaprop-p-ethyl at 1.00 kg a.i. ha^{-1}	320	102477	10524.2
$T_{11=}$ Chlorsulfuron at 0.074 kg a.i. ha^{-1}	350	97685	D**
$T_{3=}$ Isoproturon + diflufenicon at 0.98 kg a.i. ha^{-1}	370	107065	46900
$T_{2=}$ Isoproturon at 1.5 kg a.i. ha^{-1}	375	96947	D
$T_{9=}$ Carfentrazone ethyl at 0.015 kg a.i. ha^{-1}	400	119372	89,700
$T_{10=}$ Tralkoxydim at 0.5 kg a.i. ha^{-1}	435	102300	D
$T_{8=}$ Clodinafop propargyl at 0.045 kg a.i. ha^{-1}	450	136997	231316.6
$T_{4=}$ Isoproturon + carfentrazone ethyl at 2.0 kg a.i. ha^{-1}	750	105338	D
$T_{6=}$ Metribuzin+ fenoxaprop-p-ethyl at 1.00+1.00 kg a.i. ha^{-1}	1080	93821	D
$T_{5=}$ Bromoxynil+MCPA+fenoxaprop-p-ethyl at 0.445+1.00 kg a.i. ha^{-1}	1200	107317	11246.8

Cost that vary is the cost that is incurred on variable inputs in the production of a particular commodity; *Marginal rate of return (MRR%)= change in net benefit/change in variable cost × 100; **D= dominated, any treatment that had net benefits that were less than or equal to those of a treatment with lower variable cost was taken to be dominated.

0.045 kg a.i. ha^{-1} treatment producing maximum marginal rate of return (MRR) which was 231316.6% and was followed by MRR of 89700%. These results are more or less in accordance with the findings of Mishra, (2006) who stated that clodinafop propargyl at 0.045 kg a.i. ha^{-1} significantly increased grain yield of wheat and recorded the maximum net return (Rs. 11940 ha^{-1}).

Conclusion

From the overhead discussion, it can be concluded that clodinafop propargyl at 0.045 kg a.i. ha^{-1} was most effective to control *A. fatua*, *C. didymus* and *M. indica* densities in wheat fields. Therefore, this herbicide would be the best suggestion than other herbicides as mediated by reductions in weeds density, biomass and increase in wheat yield.

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