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To study response different herbicides and herbicide mixtures on performance of wheat and their residual effect of succeeding crops

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Abstract
The field experiment conducted at research farm, RARI, Durgapura for two consecutive years during *rabi* seasons 2013-14 and 2014-15. Results revealed that hand weeding recorded the lowest weed dry matter of 173.04 kg/ha at harvest stage than rest of the treatments. Sulfosulfuran @ 25 gm a.i./ha, clodinafop-propargyl 15 % + metsulfuran methyl 1 % @ 64 g a.i. /ha, sulfosulfuran 75 % + metsulfuran methyl 5 WG @ 32 g a.i. /ha, carfentrazone ethyl 40 % DF @ 20 g a.i./ha, metsulfuran methyl @ 4 g a.i. / ha, 2,4-D ester @ 0.5 kg/ha as post emergence was found effective herbicidal treatment in reducing weed dry matter production. Yield attributes of wheat were also significantly improved due to different weed control measures. The maximum number of effective tillers per square meter (279), spike length (12.6) and grains/spike (43.6) were achieved under hand weeding and weed free treatment. Clodinafop-propargyl 15 % + metsulfuran methyl 1 % @ 64 g a.i. /ha also enhanced these characters by 27.7, 24.2, 74.7, 31.6 and 7.1 per cent, respectively over weedy check and stood as the next best herbicidal treatment. Further, none of the applied herbicides/mixtures in *rabi* season (wheat) had residual toxicity on plant height of succeeding crops (pearlmillet, mungbean and clusterbean) grown in *kharif* season.

Keywords: Herbicide mixture, weed dry matter, wheat, succeeding crops

Introduction
Wheat crop is invaded by a large number of fast growing weeds species. It is infested with both grassy and broadleaf weeds. The losses caused by weeds have been estimated to be much higher than those caused by insects, pests and diseases together. Weeds germinate even before its germination and flourish more and more taking the advantage of its slow initial growth. Competition from weeds throughout the crop season reduces yield by 10 to 38 % depending upon time and intensity of weed infestation. So, there is an urgent need to evolve appropriate weed management strategy for both grassy and broadleaf weeds for exploiting the yield potential of this crop. Conventional method of physical weed control in wheat is time consuming and labour intensive. However, the additional benefits of providing greater aeration, improving root growth enabling greater absorption of moisture and nutrients from deeper soil layers and moisture conservation cannot be ignored. On the other hand chemical control of weeds in general has been realized to be more cost effective and easy compared to manual weeding. To combat this situation, refinement in existing technology is a researchable issue.

Materials and Methods
The field experiment conducted at research farm, RARI, Durgapura for two consecutive years during *rabi* seasons 2013-14 and 2014-15 on loamy sand soil. The experiment comprised of eleven weed control treatments i.e. Weedy check (T_1), Hand weeding at 30-35 DAS (T_2), 2,4-D ester @ 0.5 kg/ha at 30-35 DAS (T_3), Sulfosulfuron @ 25 g a. i. at 30-35 DAS (T_4), Metsulfuron methyl @ 4 g/ha at 30-35 DAS (T_5), Sulfosulfuron 75% + Metsulfuron methyl 5% WG @ 32g at 30-35 DAS (T_6), Piroxofop- propargyl 15% WP @60g a. i./ha 30-35 DAS (T_7), Clodinafop-propargyl15% + Metsulfuron methyl 1% @ 64g a.i./ha at 30-35 DAS (T_8), Carfentrazone ethyl @15 g/ha at 30-35 DAS (T_9), Pendimethalin pre emergence (T_{10}) and Weed free (T_{11}) were laid out in Randomized block design and replicated four times. Dry weight of weeds were weeds samples from two randomly selected spots in each plot were taken at harvest stage with the help of 0.25 m2 quadrate and the average was worked out. The samples so collected were subjected to oven dry, weighed and average was computed.

Number of effective tillers having fully developed spikes were counted from the plants used for total tillers count in each plot at maturity of the crop. These were averaged and expressed in per plant. At harvest, the length of five randomly selected spikes was measured in cm and average length of spike was calculated**.** Number of grains per spike randomly selected productive spikes was threshed separately, numbers of grains were counted and average numbers of grains per spike were then recorded. Five plants were selected randomly from each plot and tagged permanently. The height of each plant was measured from base of the plant to the tip of main shoot at harvest. The mean plant height (cm) at each growth stage was worked out and recorded as plant height (cm) at respective stages. The harvest index was calculated by using following formula and expressed as percentage (Singh and Stoskopf, 1971) [11].

$$\text{Harvest Index (\%)} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

Results and Discussion

Effect of different weed control practices on yield attributes of Wheat

Data table 1 pertaining to the effect of various weed control treatments on effective tillers revealed that all the treatments significantly enhanced the number of effective tillers/plant of wheat than weedy check during both the years as well as in pooled analysis. Pooled results showed that weed free situation produced the highest number of effective tillers per square meter (282.7) that was significantly higher over treatment weedy check, 2, 4-D ester @ 0.5 kg/ha, sulfosulfuran @ 25 gm a.i./ha, piroxofop-propargyl 15 % WP 60 g a.i./ha &pendimethalin pre emergence and was statistically at par with other treatments under study. It increased the number of effective tillers by of 1.1, 1.8, 2.9, 5.2, 5.6, 11.9, 12.8, 13.7, 19.5 and 26.5 per cent over hand weeding , clodinafoppropargyl 15 % +metsulfuran methyl 1 % @ 64 g a.i./ha , sulfosulfuran 75 % +metsulfuran methyl 5% WG @ 32 g a.i./ha , carfentrazone ethyl 40 % DF @ 20 g a.i./ha , metsulfuran methyl @ 4 g a.i./ ha , 2,4-D ester @ 0.5 kg/ha , sulfosulfuran @ 25 gm a.i./ha , pendimethalin pre emergence, piroxofop-propargyl 15 % WP 60 g a.i./ha and weedy check respectively. Hand weeding was found the second most effective treatment that also witnessed a significant increase of 10.7, 11.6, 18.2, 12.5 and 25.1 per cent in effective tillers over 2, 4-D ester @ 0.5 kg/ha , sulfosulfuran @ 25 gma.i./ha , piroxofop-propargyl 15 % WP 60 g a.i./ha , pendimethalin pre emergence and weedy check treatments, respectively. However, it was found at par with, metsulfuran methyl @ 4 g a.i./ ha , sulfosulfuran 75 % +metsulfuran methyl 5% WG @ 32 g a.i./ha , clodinafoppropargyl 15 % +metsulfuran methyl 1 % @ 64 g a.i./ha and carfentrazone ethyl 40 % DF @ 20 g a.i./ha wherein 19.7, 22.9, 24.2 and 20.2 per cent more number of effective tillers in wheat were recorded than weedy check. 2,4-D ester @ 0.5 kg/ha , sulfosulfuran @ 25 gm a.i./ha , piroxofop-propargyl 15 % WP 60 g a.i./ha and Pendimethalin pre emergence also attained 13.0, 12.1, 5.8 and 11.2 per cent higher number of effective tillers than weedy check but were observed less effective than above described treatments. Similar findings were also reported by Nadeem *et al.* (2007) [5] and Surin *et al.* (2013) [12] in wheat and Kumar *et al.* (2010) [4] in wheat

A perusal of data (Table 1) reflected that ear length under weed free treatment remained at par with hand weeding, sulfosulfuran 75 % + metsulfuran methyl 5% WG @ 32 g a.i./ha, clodinafoppropargyl 15 % + metsulfuran methyl 1 % @ 64 g a.i./ha and clodinafoppropargyl 15 % + metsulfuran methyl 1 % @ 64 g a.i./ha and significantly higher over all other treatments. These treatments recorded pooled spike length of 12.8, 12.6, 12.4 and 12.4 cm that were 24.5, 22.8, 21.0 and 20.7 per cent more over carfentrazone ethyl 40 % DF @ 20 g a.i./ha, 32.16, 30.41, 28.55 and 28.14 per cent over metsulfuran methyl @ 4 g a.i./ ha, 36.38, 34.57, 32.65 and 32.23 per cent over 2,4-D ester @ 0.5 kg/ha, 42.44, 40.55, 38.55 and 38.11 per cent over sulfosulfuran @ 25 gm a.i./ha, 47.18, 45.23, 43.16 and 42.70 per cent over pendimethalin pre emergence, 62.27, 60.12, 57.84 and 57.34 per cent over piroxofop-propargyl 15 % WP 60 g a.i./ha and 80.05, 77.66, 75.14 and 74.57 per cent over weedy check treatments, respectively. Similar findings were also reported by Nadeem *et al.* (2007) [5], Surin *et al.* (2013) [12] and Kumar *et al.*, (2010) [4].

Table 1: Effect of weed control treatments on effective tillers and length of spike of wheat

Treatments	Effective tillers (No m^{-2})			Length of spike (cm)		
	2014	2015	Pooled	2014	2015	Pooled
Weedy check	221.0	226.4	223.7	7.0	7.2	7.1
Hand weeding at 30 – 35 DAS	281.8	277.2	279.5	12.6	12.7	12.6
2,4-D ester @ 0.5 kg/ha at 30 – 35 DAS	251.8	253.0	252.4	9.4	9.4	9.4
Sulfosulfuran @ 25 gm a.i./ha at 30 – 35 DAS	249.1	251.2	250.1	9.0	9.0	9.0
Metsulfuran Methyl @ 4 g a.i. / ha at 30 – 35 DAS	265.9	269.5	267.8	9.6	9.8	9.7
Sulfosulfuran 75 % +metsulfuran methyl 5% WG @ 32 g a.i. /ha at 30 – 35 DAS	275.6	273.4	274.6	12.4	12.5	12.4
Piroxofop-Propargyl 15 % WP 60 g a.i. /ha at 30 – 35 DAS	238.8	233.4	236.3	7.8	8.0	7.9
Clodinafoppropargyl 15 % +metsulfuran methyl 1 % @ 64 g a.i. /ha at 30 – 35 DAS	279.3	275.9	277.6	12.4	12.5	12.5
Carfentrazone Ethyl 40 % DF @ 20 g a.i./ha at 30 – 35 DAS	267.0	270.4	268.7	10.2	10.4	10.3
Pendimethalin pre emergence	246.5	249.5	248.0	8.8	8.6	8.7
Weed free	285.2	280.1	282.6	12.8	12.8	12.8
SEm±	7.6	7.8	5.5	0.37	0.38	0.27
CD (P=0.05)	22.0	22.6	15.5	1.07	1.11	0.76

Effect of different weed control practices on weed dry matter production

All the weed control treatments that were evaluated for their efficacy were noted to reduce the weed dry matter during both the years of investigation as well as in pooled analysis (Table 2). Pooled results indicated that hand weeding, sulfosulfuran @ 25 g a.i./ha, clodinafoppropargyl 15 % + metsulfuran methyl 1 % @ 64 g a.i./ha, sulfosulfuran 75 % + metsulfuran methyl 5% WG @ 32 g a.i./ha, carfentrazone Ethyl 40 % DF @ 20 g a.i./ha, metsulfuran methyl @ 4 g a.i./ ha, 2,4-D ester

@ 0.5 kg a. i./ha applied all at 30-35 DAS were the most superior and equally effective treatments that reduced considerably lowest weight 173.04, 173.67, 178.46, 179.23, 181.22, 202.10 and 206.21 kg/ha, respectively than rest of the treatments. The highest weed dry matter of 1634.70 kg/ha at harvest were recorded in weedy check plots. In this way, these treatments controlled the weeds to the extent of 89.4, 89.3, 89.1, 89.0, 87.6, and 87.6 per cent at harvest, respectively in comparison to weedy check. The increase in dry weight of weeds under weedy check might be attributed to uninterrupted growth of weeds throughout the crop season. Heavy infestation of weeds and their dry matter accumulation under weedy check has also been reported by Agarwal and Jain (1998), Sardana *et al*. (2001) [6] and Singh and Singh (2005) [10]. It was obvious from the data presented in table 2 that different weed control treatments could not influence the harvest index of wheat up to the level of significance during both years of investigation as well as in pooled mean.

Table 2: Effect of weed control treatments on Harvest index and weed dry matter production

Treatments	Harvest index (HI %)			Weed dry matter production (kg/ha)		
	2014	2015	Pooled	2014	2015	Pooled
Weedy check	45.63	45.46	45.54	1638.4	1631.0	1634.7
Hand weeding at 30 – 35 DAS	44.97	45.48	45.22	173.7	172.4	173.0
2,4-D ester @ 0.5 kg/ha at 30 – 35 DAS	45.49	45.87	45.68	205.6	206.8	206.2
Sulfosulfuran @ 25 gm a.i./ha at 30 – 35 DAS	44.87	45.47	45.17	174.8	172.5	173.7
Metsulfuran Methyl @ 4 g a.i. / ha at 30 – 35 DAS	45.25	46.00	45.63	203.0	201.1	202.1
Sulfosulfuran 75 % +metsulfuran methyl 5% WG @ 32 g a.i. /ha at 30 – 35 DAS	45.07	45.19	45.13	178.3	180.1	179.2
Piroxofop-Propargyl 15 % WP 60 g a.i. /ha at 30 – 35 DAS	45.77	44.90	45.34	212.5	213.7	213.1
Clodinafoppropargyl 15 % +metsulfuran methyl 1 % @ 64 g a.i. /ha at 30 – 35 DAS	44.96	45.23	45.09	176.7	180.2	178.5
Carfentrazone Ethyl 40 % DF @ 20 g a.i./ha at 30 – 35 DAS	45.46	46.04	45.75	180.9	181.4	181.2
Pendimethalin pre emergence	45.05	44.78	44.92	210.3	208.4	209.4
Weed free	45.42	45.47	45.45	0.00	0.00	0.00
SEm+	1.74	1.84	1.27	14.87	19.59	12.30
CD (P=0.05)	NS	NS	NS	42.94	56.58	34.78

Residual effect of different weed control practices on succeeding crops

Pearl millet: It is obvious from the pooled data of two years (Table 3) that highest plant height (180 cm) was noted in plots of weedy check followed by hand weeding (177 cm), metsulfuran methyl @ 4 g a.i./ ha (173 cm) and sulfosulfuran @ 25 gm a.i./ha (171 cm). However, the lowest plant height was manifested by weed free plot i.e. 141 cm.

Moongbean: It is obvious from the pooled data of two years (Table 3) revealed that highest plant height (47 cm) was reported for weedy free followed by hand weeding, sulfosulfuran @ 25 gm a.i./ha, metsulfuran methyl @ 4 g a.i./ ha, sulfosulfuran 75 % +metsulfuran methyl 5% WG @ 32 g a.i./ha and clodinafoppropargyl 15 % +metsulfuran methyl 1 % @ 64 g a.i./ha. These treatments attained 46 cm plant height However, the lowest plant height was manifested by carfentrazone Ethyl 40 % DF @ 20 g a.i./ha, pendimethalin pre emergence and weedy check i.e. 45 cm.

Cluster bean: it is obvious from the pooled data of two years (Table 3) revealed that highest plant height (154 cm) was reported for weed free followed by hand weeding (151 cm), sulfosulfuran 75 % +metsulfuran methyl 5% WG @ 32 g *a.i.*/ha (150 cm) and metsulfuran methyl @ 4 g *a.i.*/ha(148 cm). However, the lowest plant height was manifested by weedy check*i.e.*141 cm.These results are in line with those of Yadav *et al.* (2003) [13], Singh and Ali (2004) [8], Chopra and Chopra (2005), Vala (2005) [14] and Singh *et.al*, (2012) [10].

Table 3: Residual effect of weed control treatments on plant height of pearl millet, moongbean and clusterbean

Treatments	Plant height (cm)								
	Pearl millet			Moongbean			Clusterbean		
	2014	2015	Mean	2014	2015	Mean	2014	2015	Mean
Weedy check	178	182	180	45	44	45	141	142	141
Hand weeding at 30 – 35 DAS	174	180	177	46	47	46	150	151	151
2,4-D ester @ 0.5 kg/ha at 30 – 35 DAS	150	152	151	46	45	45	143	149	146
Sulfosulfuran @ 25 gm a.i./ha at 30 – 35 DAS	170	172	171	46	45	46	142	146	144
Metsulfuran Methyl @ 4 g a.i. / ha at 30 – 35 DAS	172	174	173	46	46	46	147	149	148
Sulfosulfuran 75 % +metsulfuran methyl 5% WG @ 32 g a.i. /ha at 30 – 35 DAS	166	170	168	46	45	46	150	150	150
Piroxofop-Propargyl 15 % WP 60 g a.i. /ha at 30 – 35 DAS	156	158	157	45	45	45	143	143	143
Clodinafoppropargyl 15 % +metsulfuran methyl 1 % @ 64 g a.i. /ha at 30 – 35 DAS	160	162	161	46	46	46	149	143	146
Carfentrazone Ethyl 40 % DF @ 20 g a.i./ha at 30 – 35 DAS	164	166	165	46	45	45	148	148	148
Pendimethalin pre emergence	159	161	160	45	45	45	143	145	144
Weed free	140	142	141	47	47	47	153	155	154

Conclusion

Based on the results of two years experimentation, it is concluded that conventional method of hand weeding is the most effective and remunerative weed control measure in wheat. Amongst herbicides, clodinafop propargyl 15 % + metsulfuran methyl 1 % @ 64 g a.i /ha or sulfosulfuran 75 % + metsulfuran methyl 5 WG @ 32 g a.i./ha found best option for weed control in wheat under especially in labour scarce regions. Further, none of the applied herbicides/mixtures applied in *rabi* season (wheat) had residual toxicity on predominant crops (Pearlmillet, mungbean and clusterbean) grown in *kharif* season.

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