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Bio-efficacy of herbicides against complex weed flora in wheat and their residual effects on succeeding crops

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ABSTRACT

Isoproturon, clodinafop and sulfosulfuron alone at 750 g ha^{-1}, 60 g ha^{-1} and 30 g ha^{-1} respectively and tank mixture of isoproturon at 500 g ha^{-1} + 2, 4-D at 500 g ha^{-1}, isoproturon at 500 g ha^{-1} + clodinafop at 30 g ha^{-1} and isoproturon at 500 g ha^{-1} + sulfosulfuron at 15 g ha^{-1} were evaluated against mixed weed flora in wheat. Tank mix application of isoproturon at 500 g ha^{-1} + sulfosulfuron 15 g ha^{-1} was highly effective against both grassy and broadleaf weeds - Phalaris minor, Chenopodium album, C. murale, Melilotus indica , Fumeria perviflora and Coronopus didymus. While clodinafop alone and as a tank mixture with isoproturon effectively controlled grassy weeds only, the tank mix application of isoproturon at 500 g ha^{-1} + 2, 4-D at 500 g ha^{-1} was effective against broadleaf weeds only. The broadleaf weeds being dominant in the experimental field, the overall weed density and dry matter production recorded at different stages of crop growth was minimum in isoproturon at 500 g ha^{-1} + sulfosulfuron at 15 g ha^{-1} followed by isoproturon at 500 g ha^{-1} + 2, 4-D at 500 g ha^{-1}. The tank mix application of isoproturon at 500 g ha^{-1} + sulfosulfuron at 15 g ha^{-1} recorded grain yield (58.0 q ha^{-1}) similar to tank mixture of isoproturon at 500 g ha^{-1} + 2, 4-D at 500 g ha^{-1} (55.34 q ha^{-1}) but significantly higher over other herbicidal treatments with an increase of 70 % over weedy check (34.10 q ha^{-1}). None of the herbicides alone or in mixture showed residual effect on germination, plant height and dry matter of succeeding crops of green gram and cucumber. The maize crop in succession was adversely affected due to application of sulfosulfuron at 30 g ha^{-1}. Nutrient management with vermicompost at 1.5 t ha^{-1} and 3.0 t ha^{-1} along with 75% and 50% recommended dose of fertilizer (RDF) respectively and 100% RDF alone had no significant effect on grassy, broadleaf as well as total weed density. However, weed biomass and grain yield increased significantly with the application of vermicompost over 100 % RDF alone.

Key words: Bio-efficacy, herbicide, nutrient management, residual effect, tank mixture and weed density

Wheat crop grown under irrigated conditions is heavily infested with grasses and broadleaf weeds due to dwarf genotypes coupled with high fertility and moisture content. The weeds cause alarming decline in wheat productivity to the tune of 15-40 % or even higher besides lowering down the quality of produce (Chopra *et al.*, 2001). Isoproturon, an herbicide against grassy weeds is recommended across the country. But continuous use of isoproturon, a single site or mode of action herbicide, over the years has lead to the problem of herbicide resistance in *Phalaris minor* in the northwestern plain zone of the country (Chhokar and Malik, 2002). Besides isoproturon, several other herbicides are used in wheat. But the herbicide found effective against one weed species is generally ineffective against the other. Thus, in order to broaden the weed control spectrum and to prevent the development of resistant biotypes, herbicide mixtures must be employed for effective and economically viable wed control. Clodinafop is a post emergent systemic herbicide for grasses, belonging to the aryloxyphenoxypropionic family. Sulfosulfuron, a sulfonylurea herbicide is used for effective control of broadleaf weeds and grasses in wheat crop. As the information on residual activity of clodinafop, sulfosulfuron and herbicide mixtures of isoproturon + clodinafop and isoproturon + sulfosulfuron is meager, the present investigation was carried out to find out the suitable herbicide (clodinafop or sulfosulfuron) to be used as tank mixture with isoproturon to widen the weed control spectrum and their phytotoxicity, if any to the crop and their residual effect on the succeeding crops of maize, green gram and cucumber.

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MATERIALS AND METHODS

The field experiment was conducted at Agronomy Farm, Rajasthan College of Agriculture, Udaipur during two consecutive *rabi* seasons of 2004-05 and 2005-06. The soil of the experimental site was clay loam in texture, medium in available N (26.9 kg ha^{-1}), low in P (19.1 kg ha^{-1}), high in K (322.2 kg ha^{-1}), medium in organic carbon content (0.72 %) and slightly alkaline in reaction with pH 8.1. The experiment comprised of seven weed control treatments [weedy check, post emergent isoproturon (IPU) at 750 g ha^{-1}, clodinafop (CLF) at 60 g ha^{-1}, sulfosulfuron (SSF) at 30 g ha^{-1}, isoproturon at 500 g ha^{-1}+ 2,4-D at 500 g ha^{-1}, isoproturon at 500 g ha^{-1}+ clodinafop at 30 g ha^{-1}and isoproturon at 500 g ha^{-1}+ sulfosulfuron at 15 g ha^{-1}] and three nutrient management treatments [Recommended dose of fertilizer (RDF, 120:40:30 kg NPK ha^{-1}), 75% RDF + vermicompost at 1.5 t ha^{-1} and 50% RDF + vermicompost at 3.0 t ha^{-1}] making thus twenty one treatment combinations. These treatments were evaluated under randomized block design with three replications. Wheat variety GW 322 was sown in rows 23 cm apart using 100 kg seed ha^{-1} on 8th and 11th November in the respective years. Herbicide treatments were applied 32 DAS with the help of knapsack sprayer fitted with flat fan nozzle using a spray volume of 650 l ha^{-1}. Weed density was recorded by placing a quadrate of 0.25 m^2 at two randomly selected spots in each plot and the samples

were then kept in hot air oven at 70 ^{0}C till constant weight to determine dry matter accumulation. The data on weed density was subjected to square root transformation $\sqrt{X + 0.5}$ to normalize their distribution. As per treatment, vermicompost was applied uniformly one week before sowing and incorporated into the soil while among fertilizers, half N and full dose of P_2O_5 and K_2O were applied at sowing and remaining N was top dressed in two splits at first and second irrigations through urea, DAP and MOP respectively. In order to assess the residual carryover effects of herbicides applied in wheat crop on succeeding crops in rotation, bioassay technique was used (Sankaran, 1993). After the harvest of wheat crop, soil samples were drawn randomly at 0-15 cm depth from three places in each plot, mixed thoroughly and filled in earthen pots of 20 cm diameter. Counted seeds of the entire three test crops *viz.*, maize, green gram and cucumber were sown in pots separately on March 28, 2005 and April 2, 2006. These pots were watered immediately after sowing and subsequent irrigations were given on alternate days. After recording germination count 10 DAS, only five plants were retained in each pot. During both the years, the trials were terminated 30 DAS after recording final observations for plant height and dry matter accumulation pot^{-1}.

RESULTS AND DISCUSSION

Effect on weeds and crop yield

The major weeds of the experimental field were *Phalaris minor* (28.15%), *Chenopodium murale* (22.33%), *Melilotus indica* (15.40%), *Fumaria parviflora* (9.45%) *Chenopodium album* (8.52%) and *Coronopus didymus* (7.20%). Other weeds with low density (9.0%) were *Anagallis arvensis, Avena fatua, Convolvulus arvensis,* and *Spergula arvensis.* Among the herbicides tested, tank mix application of isoproturon at 500 g ha^{-1} + sulfosulfuron 15 g ha^{-1} was most effective against *P. minor* and *A. fatua.* While against broad leaf weeds – *C. murale, M. indica, F. parviflora, C. album and C. didymus* tank mixture of isoproturon at 500 g ha^{-1} + 2, 4-D at 500 g ha^{-1} and isoproturon at 500 g ha^{-1} + sulfosulfuron 15 g ha^{-1} proved equally effective. Thus, total weed density recorded was minimum with the application of isoproturon at 500 g ha^{-1} + sulfosulfuron 15 g ha^{-1}. The efficacy of clodinafop at 60 g ha^{-1} against broad leaf weeds was higher in combination with isoproturon than its application alone. When applied alone clodinafop proved effective against grassy weeds but was ineffective against broad leaf weeds. Sulfosulfuron at 30 g ha^{-1} was equally effective against grassy and broad leaf weeds. Similar findings pertaining to isoproturon and sulfosulfuron as tank mixture than individual application were also reported by Kewat *et al.* (2003). Nutrient management with vermicompost at 1.5 t ha^{-1} and 3.0 t ha^{-1} along with 75% and 50% RDF respectively and 100% RDF alone had no significant effect on grassy, broadleaf as well as total weed density. However, weed biomass increased significantly with the application of vermicompost over 100 % RDF alone. In the present study, vermicompost increased the weed biomass significantly without an increase in weed population, probably due to the fact that, vermicompost did not contribute to viable seeds, but it does act as a plant nutrient for weeds, as also for the crop, resulting in greater dry matter production. Singh *et al.* (2004) have also reported increase in weed dry weight with the application of organic manures. The grain yield of wheat increased significantly by all the herbicide treatments as compared to weedy check. The tank mix application of isoproturon at 500 g ha^{-1} + sulfosulfuron at 15 g ha^{-1} and isoproturon at 500 g ha^{-1} + 2, 4-D at 500 g ha^{-1} , being statistically similar, recorded significantly higher grain yield (58.0 and 55.34 q ha^{-1}, respectively) over other herbicidal treatments with an increase of 70.09 and 62.29 % respectively over weedy check (34.10 q ha^{-1}). The increase in yield with tank mixtures is due to reduced crop-weed competition as they effectively suppressed both grassy and broad leaf weeds throughout crop growth period. Sulfosulfuron at 30 g/ha and isoproturon at 750 g ha^{-1} remained statistically similar but gave significantly higher yield over weedy check, clodinafop at 60 g ha^{-1} and isoproturon at 500 g ha^{-1} + clodinafop at 30 g ha^{-1} . These results are similar to those reported by Saini and Angiras (2005). The grain yield of wheat improved significantly with the application of 75% RDF + vermicompost at 1.5 t ha^{-1} and 50% RDF + vermicompost at 3.0 t ha^{-1} over 100%RDF alone. There was an increase of 13.01% in grain yield with 75% RDF+ vermicompost at 15 t ha^{-1} over 100% RDF alone. These findings are in line with the studies conducted by Rajkhowa *et al.* (2001) and Singh *et al.* (2005). Hence, it can be concluded that tank mixture of post emergent isoproturon at 500 g ha^{-1} + 2,4-D at 500 g ha^{-1} or isoproturon at 500 g ha^{-1} + sulfosulfuron at 15 g ha^{-1} along with nutrient dose of 75% RDF (90:30:22.5 kg NPK ha^{-1}) through chemical source and vermicompost at 1.5 t ha^{-1} as organic source can be a good choice for wide spectrum weed control and nutrient management in timely sown irrigated wheat.

Residual effects of herbicides on succeeding crops

Herbicidal treatments applied in wheat had no significant effect on the germination of the three test crops *viz.*, maize, green gram and cucumber. The lowest germination of maize (81.3 %) and cucumber (62.6 %) seeds was recorded in sulfosulfuron treated plots while that of green gram (82.98 %) in soil from the isoproturon and clodinofop treated plots.

Table 1: Effect of weed control and nutrient management on weed growth and wheat yield (Pooled data of 2 years)

Treatment	Weed density m^{-2}						Total weed		Grain yield (q ha^{-1})
	C. murale	*M. indica*	*F. perviflora*	*C. album*	*C. didymus*	*P. minor*	Density m^{-2}	Dry matter (kg ha^{-1})	
Weed control									
Weedy check	6.22 (38.3)	5.18 (26.4)	4.07 (16.2)	3.88 (14.6)	3.58 (12.3)	7.0 (48.3)	13.1 (171.5)	1277.7	34.10
Isoproturon @ 750 g ha^{-1}	2.21 (4.42)	1.86 (2.99)	1.53 (1.87)	1.47 (1.68)	1.38 (1.42)	2.06 (3.8)	4.25 (17.65)	202.5	49.15
Clodinafop @ 60 g ha^{-1}	5.20 (26.7)	4.33 (18.3)	3.45 (11.5)	3.27 (10.3)	3.04 (8.75)	1.52 (1.8)	9.15 (83.59)	738.3	39.91
Sulfosulfuron @ 30 g ha^{-1}	2.16 (4.22)	1.82 (2.82)	1.51 (1.81)	1.44 (1.57)	1.36 (1.35)	1.48 (1.7)	3.92 (15.04)	168.4	50.72
IPU @ 500 g ha^{-1}+ 2,4 D @ 500 g ha^{-1}	1.43 (1.55)	1.24 (1.05)	1.06 (0.65)	1.04 (0.59)	0.99 (0.50)	2.17 (4.2)	3.12 (9.37)	114.9	55.34
IPU @ 500 g ha^{-1}+ CLF @ 30 g ha^{-1}	3.64 (12.8)	3.06 (8.88)	2.45 (5.59)	2.33 (4.93)	2.18 (4.27)	1.56 (2.0)	6.53 (42.44)	495.0	44.96
IPU @ 500 g ha^{-1}+ SSF @ 15 g ha^{-1}	1.59 (2.07)	1.37 (1.39)	1.17 (0.89)	1.12 (0.76)	1.07 (0.66)	1.44 (1.6)	2.89 (7.94)	87.9	58.00
SEm(±)	**0.59**	**0.43**	**0.28**	**0.23**	**0.20**	**0.42**	**0.125**	**12.6**	**0.96**
LSD(0.05)	**1.68**	**1.21**	**0.80**	**0.66**	**0.57**	**1.20**	**0.351**	**35.5**	**2.71**
Nutrient management									
RDF (120:40:30 kg NPK ha^{-1})	3.14 (12.5)	2.65 (8.63)	2.14 (5.38)	2.05 (4.83)	1.92 (4.10)	2.41 (8.7)	6.01 (48.06)	407.1	43.28
75 % RDF + Vermicompost @ 1.5 t ha^{-1}	3.21 (12.9)	2.69 (8.77)	2.17 (5.44)	2.08 (4.89)	1.93 (4.12)	2.47 (9.1)	6.15 (49.70)	450.9	48.91
50 % RDF + Vermicompost @ 3.0 t ha^{-1}	3.27 (13.3)	2.74 (9.09)	2.22 (5.70)	2.11 (5.03)	1.98 (4.32)	2.51 (9.4)	6.25 (51.16)	464.0	50.17
SEm(±)	**0.39**	**0.28**	**0.18**	**0.15**	**0.13**	**0.28**	**0.082**	**8.26**	**0.63**
LSD(0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**23.24**	**1.78**

Note: The values are transformed ($\sqrt{X+0.5}$). Figures in parentheses are original values.

Height of maize plants at 30 DAS showed significant reduction when grown in soil collected from plots treated with sulfosulfuron at 30 g ha^{-1} as compared with other treatments. On an average, the height of maize plants was reduced by 34.3 % due to residual effect of sulfosulfuron as compared to untreated check. Alike plant height the dry weight of maize plants also reduced significantly due to residual effect of sulfosulfuron applied in wheat at 30 g ha^{-1} as compared to weedy check and other herbicidal treatments. Maize biomass reduced, on an average, by 19 % due to persistence of sulfosulfuron in soil as compared to weedy check. However, tank mix application of isoproturon at 500 g ha^{-1} + sulfosulfuron at 15 g ha^{-1} did not cause an adverse effect on maize crop and recorded plant height and dry matter accumulation almost similar to other herbicides. Plant height and dry weight of green gram and cucumber were not influenced by the residual effect of herbicides applied either alone or tank mixed in wheat. The phytotoxic effect of sulfosulfuron on maize crop may be attributed to its slow degeneration in soil, which increased its persistence in soil for longer period. Sulfosulfuron which is having field half life of 14 to 75 days is degraded by soil microorganisms and by acid hydrolysis in low pH soils (Hatzios, 1998). Herbicide persistence is greater in soil with high pH and clay content.

Table 2: Residual effect of herbicides applied in wheat on germination, plant height and biomass of maize, green gram and cucumber (Mean of 2 years)

Treatment	Germination (%)			Plant height (cm)			Biomass (g plant^{-5})		
	Maize	Green gram	Cucumber	Maize	Green gram	Cucumber	Maize	Green gram	Cucumber
Weed control									
Weedy check	85.56	86.42	65.84	21.34	10.00	7.31	2.71	0.39	1.60
Isoproturon @750 g ha^{-1}	83.19	82.98	66.52	20.73	10.41	7.36	2.65	0.38	1.52
Clodinafop @60 g ha^{-1}	82.68	83.37	63.25	20.76	10.05	7.31	2.64	0.38	1.53
Sulfosulfuron @30 g ha^{-1}	81.27	83.69	62.61	13.95	10.27	7.36	2.18	0.37	1.50
IPU @500 g ha^{-1}+2,4 D@ 500 g ha^{-1}	82.86	85.50	64.13	21.45	10.43	7.47	2.61	0.36	1.54
IPU @500 g ha^{-1}+CLF @ 30 g ha^{-1}	82.27	84.81	63.60	21.45	10.20	7.43	2.65	0.39	1.53
IPU @500 g ha^{-1}+SSF @15 g ha^{-1}	82.95	84.47	62.83	20.87	10.30	7.58	2.60	0.37	1.49
SEm(±)	**1.47**	**1.52**	**1.21**	**0.37**	**0.19**	**0.14**	**0.04**	**0.009**	**0.03**
LSD (0.05)	**NS**	**NS**	**NS**	**1.05**	**NS**	**NS**	**0.13**	**NS**	**NS**
Nutrient management									
RDF (NPK =120:40:30 kgha^{-1})	82.08	85.18	63.54	19.86	10.14	7.30	2.55	0.37	1.51
75 % RDF + Vermicompost @1.5 t ha^{-1}	83.35	84.58	63.81	20.12	10.25	7.44	2.58	0.38	1.52
50 % RDF + Vermicompost @3.0 t ha^{-1}	83.04	83.85	64.22	20.26	10.34	7.47	2.60	0.38	1.54
SEm(±)	**0.96**	**1.00**	**0.78**	**0.24**	**0.13**	**0.09**	**0.03**	**0.006**	**0.02**
LSD(0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Therefore, higher soil pH (8.0 and 8.2) coupled with higher clay content (34.5 and 33.70%) of experimental soil might have prolonged sulfosulfuron persistence in soil. The results of the present study are in accordance with the findings of Yadav *et al.* (2003), Yadav *et al.* (2004), Kour *et al.* (2007) and Chopra *et al.* (2008). Based on our study, it is suggested to use sulfosulfuron at recommended dose of 30 g ha^{-1} only in specified crop rotations, which do not include sensitive crops like maize. However, sulfosulfuron at 15 g ha^{-1} can be used safely as tank mixture with isoproturon at 500 g ha^{-1} without any detrimental effect on succeeding rotational crops.

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