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Research Paper

Efficacy of various herbicides for weed control in wheat (*Triticum aestivum*) intercropped with autumn sugarcane (*Saccharum officinarum*) under sub-mountaineous conditions of Punjab

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2011–12 and 2012–13 at Gurdaspur, Punjab, to assess the efficacy of various herbicides for weed control in wheat (*Triticum aestivum* L.) intercropped in autumn planted sugarcane. The experiment comprising 8 treatments was laid out in a randomized block design with 3 replications. Among herbicidal treatments, sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha was found to be significantly superior to the application of clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, isoproturon 75 WP @ 0.94 kg/ha and metribuzin 70 WP @ 0.26 kg/ha in reducing the biomass of weeds, but at par with sulfosulfuron 75 WG @ 0.02 kg/ha. Sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha resulted in 20.5, 17.5, 42.4 and 23.7% increase in wheat grain yield; 5.3, 4.7, 6.6 and 4.9% increase in cane yield; and 8.5, 7.0, 12.8 and 8.7% increase in cane-equivalent yield over clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, isoproturon 75 WP @ 0.94 kg/ha and metribuzin 70 WP @ 0.26 kg/ha respectively. Significantly higher effective tillers/m^2 and number of grains/ear were recorded with sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha over the application of clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, isoproturon 75 WP @ 0.94 kg/ha and metribuzin 70 WP @ 0.26 kg/ha. The highest weed-control efficiency (87.8%) and benefit: cost ratio (1.59) were found under sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha-treated plots, closely followed by sulfosulfuron 75 WG @ 0.02 kg/ha and mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g/ha.

Key words **:** Herbicides, Intercropped sugarcane, Weed-control methods, Wheat

Autumn sugarcane planted in wide rows and being a long-duration crop poses ample chance for profuse weed growth which causes heavy reduction in cane yield ranging from 40 to 67% (Singh *et al.,* 2011). Besides suppressing weeds in the inter-row spaces, additional production could be achieved by growing suitable intercrops between the cane rows. Hence autumn sugarcane offers a unique potential for intercropping because of its slow growth rate during the winter and early spring owing to prevalence of low temperature. This period can safely be utilized for raising suitable winter (*rabi*) intercrops maturing up to the end of April without doing much damage to the sole cane crop. Intercropping if properly managed and looked after can go a long way to solve the problems of low productivity per unit area and sustainability of the production system (Aggarwal *et al.*, 1992). It ensures economic utilization of land, labour and capital resources (Moris and Garrity, 1993).

Wheat, being the staple crop of Punjab, fits well as an intercrop in autumn-planted sugarcane (Sharma *et al*., 1997). This system of intercropping produces 35–40 quintals of wheat per hectare and is more remunerative than wheat and sugarcane sown separately in rotation. Famers face a greater complexity of weed management in an intercropping system. The losses caused by weeds in sole and intercropped sugarcane range from 26–75% (Srivastava *et al.,* 2005). Infestation by wide range of grassy and non-grassy weeds, in general and *Phalaris minor* in particular in wheat is the one of the major problems faced by the farmers. The control of weeds is the basic requirement and major component of management in the production system (Young *et al.,* 1996). Weed management plays a vital role in realizing potential yield of crops. Among the weed-control methods, the chemical method of weed control can provide us abrupt and promising results. Various herbicides have been recommended for the control of weeds in

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sole wheat, but their feasibility in controlling weeds when intercropped in sugarcane is yet to be established. Keeping in the view these facts, the current study was explored to evaluate various herbicides for the weed control in wheat intercropped with autumn planted sugarcane crop.

MATERIALS AND METHODS

The field experiment was conducted during the winter (*rabi*) season of 2011–12 and 2012–13 in sub-mountaineous region of Punjab (31° 56.4' 43.4" N, 75° 13.2' 39.5" E and 265.17 m from mean sea-level) of district Gurdaspur. The experimental site was clay loam in texture, medium in organic carbon (0.75%), high in available phosphorus (32.5 kg P_2O_5/ha) and low in potassium (75 kg K_2O/ha) at 0–15 cm soil depth. The soil was neutral in reaction (7.3 *p*H) with normal electrical conductivity (0.62 dS/m). The experiment was laid out in randomized block design with 3 replications. Eight treatments comprised sulfosulfuron 75 WG @ 0.02 kg/ha, sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha, mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g/ha, clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, isoproturon 75 WP @ 0.94 kg/ha, metribuzin 70 WP @ 0.26 kg/ha and weedy check (control) were evaluated.

The planting of autumn sugarcane variety 'CoJ 85' was done on 17 and 19 October during 2011–12 and 2012–13 respectively. The sowing of wheat variety 'HD 2967' was done by using seed rate of 75 kg/ha on November 3 and 2 during 2011–12 and 2012–13 respectively. Two rows of wheat in between two rows of sugarcane 67.5 cm apart were sown. The sugarcane was fertilized with recommended doses of fertilizers, viz. 225 kg N/ha and 60 kg K_2O/ha through urea and muriate of potash respectively. The whole quantity of potassium and one-third dose of nitrogen were applied at the time of planting, one-third N at the end of March and remaining one-third of N was given by end of April. In addition, 62.5 kg/ha was given to wheat intercrop. Overall 21 irrigations were applied to sugarcane–wheat intercropping system.

Herbicidal treatments (sulfosulfuron 75 WG @ 0.02 kg/ha, sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha, mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g/ha, clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, isoproturon 75 WP @ 0.94 kg/ha and metribuzin 70 WP @ 0.26 kg/ha) were applied as post-emergence 35 days after wheat sowing at their respective doses as per treatments. Herbicides were applied with manually operated knapsack sprayer fitted with flat-fan nozzle using 500 litres water/ha. The data on weed density (plants/m^2) and dry matter of weeds (g/m^2) were recorded using a quadrate measuring 1 m × 1 m in wheat at harvesting. From each plot 500 g representative fresh sample was taken to estimate the dry matter of weeds. The weed-control efficiency (WCE) was calculated by using the following formula (Singh *et al*., 2000).

The data regarding yield attributes of wheat were recorded randomly from 10 plants of each plot before harvesting and finally averaged into a single value. The wheat crop was manually harvested on 25 and 23 April during 2011–12 and 2012–13, respectively, when the straw became dry and brittle and grains turned hard. The sugarcane was harvested on 14 and 8 November during 2011–12 and 2012–13 respectively.

Cane-equivalent yield was calculated as per Singh *et al*. (2009) and production efficiency (₹/ha/day) was calculated as per Chopra *et al*. (2013)

Economics was computed using the prevailing market price of inputs and outputs such as wheat grains @ ₹11,700/t in 2011–12 and ₹13,350/t in 2012–13, while sugarcane @ ₹2,500/t in 2011–12 and ₹2,900/t in 2012–13 respectively. All data were analyzed statistically. Statistical analysis and interpretation of results were done by calculating values of critical difference (CD) at 5% level of probability through analysis of variance techniques as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Weed flora and weed-control efficiency

The prominent weed species observed in the experimental field included *Phalaris minor* Retz. and broad-leaf weed species comprised *Chenopodium album* L., *Anagalis arvensis* L., *Medicago denticulata* Willd, *Trigonella polycerata* L., *Melilotus albusa* Medik. during both the years. The pooled data of 2 years indicated that weed infestation as referred in terms of total weed density and biomass was maximum under weedy check plots, where weeds were allowed to grow with wheat crop and it was significantly reduced due to all weed-control treatments (Table 1). The post-emergence application of sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha being at par with sulfosulfuron 75 WG @ 0.02 kg/ha curtailed the density and dry weight of weeds effectively which was significantly superior to the application of clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, isoproturon 75 WP @ 0.94 kg/ha and metribuzin 70 WP @ 0.26 kg/ha. The better performance of this treatment could be attributed to the reduced weed competition. Similar results were also reported by Yadav and Dixit (2014). Moreover, clodinafop 15 WP @ 0.06 kg/ha and fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha were slightly inferior to sulfosulfuron+metsulfuron 75 WG @ 0.03 kg/ha, sulfosulfuron 75 WG @ 0.02 kg/ha and mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 kg/ha but clearly had an

edge over metribuzin 70 WP @ 0.26 kg/ha and isoproturon 75 WP @ 0.94 kg/ha. Metribuzin 70 WP @ 0.26 kg/ha when applied, showed phytotoxicity to wheat crop but with the passage of time, plants recovered. The weed control efficiency of different weed-control measures ranged from 51.6 to 87.8%. Higher weed-control efficiency was achieved with sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha (87.8%), closely followed by sulfosulfuron 75 WG @ 0.02 kg/ha (86.4%). However, the lowest weed-control efficiency (51.6%) was recorded for the treatment involving isoproturon 75 WP @ 0.94 kg/ha. Kaur *et al.* (2015) also reported better weed-control efficiency with the application of herbicides in sugarcane + vegetable intercropping system.

Crop growth and yield

The yield-attributing traits, viz. effective tillers/m^2, spike length, grains/spike and 1,000-grain weight, and grain yield were affected significantly due to weed-control treatments (Table 2). These attributes attained the poorest values under weedy check plots. Maximum yield attributes and grain yield of wheat were recorded with the application of sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha and it was statistically at par with the application of either sulfosulfuron 75 WG @ 0.02 kg/ha or mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g/ha. Fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha and clodinafop 15 WP @ 0.06 kg/ha were the next best treatments, as these registered the higher values for above parameters than metribuzin 70 WP @ 0.26 kg/ha and isoproturon 75 WP @ 0.94 kg/ha. This might be owing to effective control of weeds which in turn significantly increased the number of tillers/m^2, ear length, grains/spike and 1,000-grain weight and consequently improved the grain yield (Khan *et al.*, 2006). Sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha showed 20.5, 17.5, 42.4 and 23.7% increase in wheat grain yield (pooled mean) over clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, isoproturon 75 WP @ 0.94 kg/ha and metribuzin 70 WP @ 0.26 kg/ha respectively.

Table 1. Effect of weedicidal treatments on weed density, dry weight and weed-control efficiency in wheat intercropped with sugarcane (pooled data of 2 years)

Treatment	Weed density (plants/m^2)	Dry weight of weeds(g/m^2)	Weed-control efficiency (%)
Sulfosulfuron 75 WG @ 0.02 kg/ha	1.96 (2.9)*	4.66 (20.8)	86.4
Sulfosulfuron+metsulfuron 75 WG @ 0.03 kg/ha	1.77 (2.1)	4.46 (18.9)	87.8
Mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g/ha	2.04 (3.1)	4.71 (21.2)	85.5
Clodinafop 15 WP @ 0.06 kg/ha	2.54 (5.5)	5.49 (29.1)	81.3
Fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha	2.47 (5.1)	5.24 (26.5)	82.9
Isoproturon 75 WP @ 0.94 kg/ha	5.42 (28.4)	8.73 (75.2)	51.6
Metribuzin 70 WP @ 0.26 kg/ha	3.10 (8.6)	5.98 (34.8)	77.7
Weedy check	7.67 (57.8)	12.51 (155.5)	–
SEm±	0.08	0.09	–
CD (P=0.05)	0.23	0.27	–

*Figures in parentheses indicate original values

Table 2. Effect of weedicidal treatments on different parameters of wheat and sugarcane intercropping system (pooled data of 2 years)

Treatment	Plant height (cm)	Effective tillers/m^2	Ear length (cm)	Grains/ spike	1,000-grain weight (g)	Grain yield (t/ha)	Number of millable canes (×10^3 /ha)	Cane yield (t/ha)	Cane-equivalent yield (t/ha)
Sulfosulfuron 75 WG @ 0.02 kg/ha	102.5	328.4	10.61	49.1	42.8	4.6	88.4	82.2	103.5
Sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha	102.5	330.6	10.75	50.8	43.4	4.7	88.9	82.8	104.8
Mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g/ha	102.7	328.1	10.64	48.2	42.1	4.5	88.2	81.9	102.9
Clodinafop 15 WP @ 0.06 kg/ha	103.6	313.3	10.26	43.9	42.0	3.9	85.1	78.6	96.6
Fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha	103.0	317.2	10.30	45.2	42.1	4.0	85.0	79.1	97.9
Isoproturon 75 WP @ 0.94 kg/ha	103.2	302.3	10.21	41.4	41.3	3.3	82.2	77.7	92.9
Metribuzin 70 WP @ 0.26 kg/ha	103.3	312.5	10.22	43.3	41.7	3.8	85.0	78.9	96.4
Weedy check	101.8	261.6	9.84	38.5	37.6	2.4	60.3	57.7	68.7
SEm±	0.52	3.06	0.59	0.87	0.74	0.09	1.66	0.6	0.9
CD (P= 0.05)	NS	9.4	NS	2.7	2.3	0.3	5.09	1.8	2.6

Table 3. Economics and production efficiency of various treatments in autumn sugarcane–wheat intercropping system (pooled data of 2 years)

Treatment	Gross returns (× 10^3₹/ha)	Cost of cultivation (× 10^3₹/ha)	Net returns (× 10^3₹/ha)	Benefit: cost ratio	Production efficiency (₹/ha/day)
Sulfosulfuron 75 WG @ 0.02 kg/ha	291.0	114.0	177.0	1.55	464.9
Sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha	294.9	114.1	180.9	1.59	475.1
Mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g/ha	289.3	114.2	175.1	1.53	459.8
Clodinafop 15 WP @ 0.06 kg/ha	270.7	114.0	156.7	1.37	411.4
Fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha	274.4	114.1	160.3	1.41	421.0
Isoproturon 75 WP @ 0.94 kg/ha	258.9	113.8	145.1	1.27	381.0
Metribuzin 70 WP @ 0.26 kg/ha	269.6	113.6	156.0	1.37	409.7
Weedy check	191.5	113.1	78.4	0.69	206.0

Cane yield and cane-equivalent yield

Application of all the herbicides resulted in significantly higher number of millable canes than weedy check plots (Table 2). These findings are in agreement with those of Rana *et al*. (2004). The highest number of millable canes was recorded in plots receiving sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha followed by sulfosulfuron 75 WG @ 0.02 kg/ha, mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 g/ha, clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha and metribuzin 70 WP @ 0.26 kg/ha, which were at par with each other. On the contrary, isoproturon 75 WP @ 0.94 kg/ha produced the lowest number of millable canes among the herbicidal treatments. The treatments, viz. clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, metribuzin 70 WP @ 0.26 kg/ha and isoproturon 75 WP @ 0.94 kg/ha recorded at par with each other for the production of millable canes. These observations are in confirmation to the findings of Singh *et al*. (2011).

Among the weed-control treatments, the maximum cane yield was obtained with application of sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha, which was closely followed by sulfosulfuron 75 WG @ 0.02 kg/ha (82.2 t/ha) and mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 kg/ha (81.9 t/ha). These above treatments resulted in significantly higher cane yield than clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, metribuzin 70 WP @ 0.26 kg/ha and isoproturon 75 WP @ 0.94 kg/ha. The results corroborate the findings of Khan *et al.* (2006). Sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha gave 5.3, 4.7, 6.6 and 4.9% higher cane yield and 8.5, 7.0, 12.8 and 8.7% higher cane-equivalent yield than clodinafop 15 WP @ 0.06 kg/ha, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha, isoproturon 75 WP @ 0.94 kg/ha and metribuzin 70 WP @ 0.26 kg/ha respectively.

Economics

Owing to higher crop yield and timely management of weeds with sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha resulted in attaining the maximum net returns and benefit: cost ratio followed by sulfosulfuron 75 WG @ 0.02 kg/ha and mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 kg/ha. The minimum net return and benefit: cost ratio were associated with weedy check. The lower crop yields in weedy check are the reasons for lower net return in this treatment. The maximum production efficiency was obtained with sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha, followed by sulfosulfuron 75 WG @ 0.02 kg/ha and mesosulfuron + iodosulfuron 3.6 WDG @ 0.01 kg/ha. The minimum production efficiency of 206.04₹/ha/day was found in weedy check.

Based on 2 years data, it may be concluded that post-emergence application of sulfosulfuron + metsulfuron 75 WG @ 0.03 kg/ha appeared to be the most effective method of chemical weed control and profitable in wheat intercropped with autumn-planted sugarcane.

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