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Effect of different doses of halosulfuron methyl 6% + metribuzin 50% on weed management in sugarcane (*Saccharum officinarum* L.)

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Abstract
Sugarcane is the most adaptable plant under varied ecological conditions and the critical period of crop-weed competition has been recorded to be 60-120 days after planting in spring cane and 150 days in autumn cane (Singh *et al*., 2011). The primary objective of this research was to evaluate the Effect of different doses of Halosulfuron methyl 6% + Metribuzin 50% on weed management in sugarcane an experiment was conducted at Agricultural Research farm of Banaras Hindu University, Varanasi, Uttar Pradesh during spring seasons of 2018-19. The maximum suppression of total weed density, total weed biomass and the highest weed control efficiency were obtained with post-emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} better than pre-emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1}.

Keywords: sugarcane**,** total weed management, yield

Introduction
Sugarcane (*Saccharum officinarum*) is an important agro-industrial cash crop grown primarily for sugar production in India, and plays a pivotal role in agricultural and industrial economy of the country. Sugarcane is the most adaptable plant under varied ecological conditions. India is the second largest producer country after Brazil contributing approximately 411.00 million tonnes production of milleable cane from an area 5.04 million hectares with annual average productivity of 8.15 tonnes ha^{-1} (FAOSTAT, 2018) [1]. Singh *et al.* (2009) [17] reported 20.3% yield gap in sugarcane because of the heavy infestation of weeds. Due to weed infestation, the yield loss in sugarcane was reported to be 40 to 60 percent (Khan *et al*., 2004) [9]. However, due to labour scarcity use at herbicide for weed management is gaining momentum. The critical period of crop-weed competition has been recorded to be 60-120 days after planting in spring cane and 150 days in autumn cane (Singh *et al*., 2011) [19]. Due to continuous use of metribuzin and 2,4-D in sugarcane fields, the population of grassy and broad-leaved weeds has been decreased, whereas the population of *Cyperus* species has increased tremendously. *C. rotundus* population has been reported to be 60–80 % of total weed flora in sugarcane fields in India (Raskar 2004; Roshan *et al*. 2006) [13, 15]. Halosulfuron methyl l75%WG (Sempra), a new sulfonylurea herbicide was evaluated for selective control of *C. rotundus* in sugarcane and to observe the phyto toxicity symptoms on the sugar-cane and succeeding crops (Mehar Chand *et al*., 2013) [10]. Sugarcane yield, quality and recovery losses occurred due to weed infestation depend upon the nature and density of weeds and stage of crop growth (Srivastava, 2001) [21]. Keeping these views in mind, a field experiment was taken up to evaluate the new early post emergence herbicides halosulfuron methyl, metribuzin and their combination along with 2,4-D herbicide for weed management in sugarcane. Soil micro-organisms are an important link in soil-plant-herbicide-fauna-man relationships. Soil microbes are directly or indirectly affected by the impact of toxic substances of herbicides used to control in intensive agriculture. At normal recommended rates, herbicides of field are considered to have no major or long-term effect on microbial populations. It has been reported that some microorganisms were able to degrade the herbicide, while some others are adversely affected depending on the application rates and the type of herbicide used (Sebiomo *et al.* 2011) [16].

Materials and methods

A field experiment was conducted at Agricultural Research Farm of Institute of Agricultural sciences, Banaras Hindu University, Varanasi to effect of different levels of herbicidal combinations on total sedges, narrow and broad leaves weeds management in sugarcane crop during the year 2017-2018 and 2018-2019. The soil of the experimental field was clay loam in texture with pH 7.55, EC 0.40 dSm^{-1} with low availability of nitrogen, medium in available phosphorus and potash. It is located on $25^0$18' N latitude, $83^0$3' E longitude and at an altitude of 75.70 meters above mean sea level in the Northern Gangetic alluvial plains. The temperature during winter dips down to 3.9ºC and it goes up to 44.0 ºCin 2017-18 and 4.7ºC and it goes up to 41.0 ºC during 2018-19. The average rainfall of the region is around 698.7 mm and 85 % of the total rainfall is received during July-September by South-West monsoon (2017-18) and average rainfall of the region is around 834.3 mm and 80 % of the total rainfall is received during July-September by South-West monsoon (2018-19). The tillering period for sugarcane is very limited and sugarcane experiences very hot and dry weather during April to June. Grand growth period is also limited due to start of cold weather from October onward. Field was dominated with sedges, grasses and broad leave weeds. The treatments comprises *viz*. Halosulfuron methyl 6% + Metribuzin 50% WG PE @ 1.0 kg a.i. ha^{-1}, Halosulfuron methyl 6% + Metribuzin 50% WG PE@ 1.125 kg a.i. ha^{-1}, Halosulfuron methyl 6% + Metribuzin 50% WG PE@ 1.25 kg a.i. ha^{-1}, Halosulfuron methyl 75% WG -PE@ 0.09 kg a.i. ha^{-1}, Metribuzin 70% WP-PE@ 2.0 kg a.i. ha-1, Halosulfuron methyl 6% + Metribuzin 50% WG-POE@ 1.0 kg a.i. ha-1, Halosulfuron methyl 6% + Metribuzin 50% WG-POE@ 1.125 kg a.i. ha^{-1}, Halosulfuron methyl 6% + Metribuzin 50% WG-POE@ 1.25 kg a.i. ha-1, Halosulfuron methyl 75% WG –POE@ 0.09 kg a.i. ha-1, Metribuzin 70% WP-POE@ 2.0 kg a.i. ha^{-1}, 2,4-D Dimethyl amine salt 58 % SL-POE@ 6.0L. ha^{-1}, Hand weeding (30,60 and 90 DAP) and untreated control was laid out in randomized block design with replicate thrice. Sugarcane early maturing variety Co 0239 (Karan-6) was planted during spring season on March in both of the year at 75 cm row to row distance using 75.0 q seed cane/ha. Fertilizers doses of 120 kg N/ha, 60 kg P2O5/ha and 40 kg K_2O/ha was applied to the experimental crop. Emisan (0.25%) @ 500 g ha^{-1} was used for treatment of setts.

Observations on weed flora of sedges, grasses and broad leave weeds. Were recorded before pre and post emergence application of herbicide in both year. The observations on population of weed flora and dry weight recorded at 30, 60, 90 DAP and at harvest stage. The observation related to germination of sugarcane was recorded at 30 days after planting during both year.

Results and discussion

Total weed density

The data pertaining to total weed density of BLWs, Grasses and Sedges are presented in (Table 1). During both the seasons, major weed flora of the experimental field at 60 DAA consisted of grassy weeds, *viz. cynodon dactylon* and *Echinochloa crusgalli*, broad-leaved weeds, (BLWs), *viz*. *Parthenium hysterophorus* and *Trianthema portulocastrum*, whereas, *Cyperus rotundus* In the herbicidal treatment post-emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} had significantly superior to over the rest treatment at all stage of observation.Whereas, three hoeing (30, 60 and 90 DAS) were effective in complete removal of BLWs in both year. Among the grassy weeds, similar observation was recorded by post-emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} in total elimination of grassy weeds during both the year. The most effective against sedges halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} applied as pre-emergence. The similar result was reported by Holm *et al*. 1997 [6] and similar observation also reported by Kalaiyarasi (2012) [8] and Singh *et al.* (2008) [20].

Table 1: Total weed Density (No. m^{-2}) as influenced by weed control treatments in sugarcane

Treatments	Dose/ha		Total weed Density (No. m^{-2})					
	a.i. (g)	Formulation	Grasses		BLWs		Sedges	
			2017	2018	2017	2018	2017	2018
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	60+500	1000	(21.29) 4.66	(30.05) 5.52	(15.13) 3.92	(18.17) 4.29	(20.76) 4.60	(22.83) 4.82
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	67.5+562.5	1125	(15.79) 4.00	(24.55) 4.99	(9.96) 3.20	(13.0) 3.65	(18.60) 4.37	(20.67) 4.60
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	75+25	1250	(13.95) 3.79	(22.71) 4.81	(8.63) 2.86	(11.67) 3.39	(17.26) 4.20	(19.33) 4.44
Halosulfuron methyl 75% WG -PE	67.5	90	(30.62) 5.57	(39.38) 6.31	(37.96) 6.19	(41.00) 6.43	(72.93) 8.57	(75.00) 8.69
Metribuzin 70% WP-PE	1400	2000	(23.95) 4.94	(32.71) 5.76	(17.63) 4.23	(20.67) 4.58	(35.26) 5.66	(37.33) 5.86
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	60+500	1000	(22.29) 4.71	(31.05) 5.58	(15.79) 3.99	(18.83) 4.36	(23.10) 4.82	(25.17) 5.03
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	67.5+562.5	1125	(18.79) 4.39	(27.55) 5.29	(12.96) 3.66	(16.00) 4.06	(19.60) 4.46	(21.67) 4.69
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	75+25	1250	(12.95) 3.67	(21.71) 4.71	(7.80) 2.88	(10.84) 3.36	(15.26) 3.97	(17.33) 4.22
Halosulfuron methyl 75% WG –POE	67.5	90	(25.23) 5.03	(33.99) 5.84	(36.09) 5.99	(39.13) 6.24	(71.93) 8.51	(74.00) 8.63
Metribuzin 70% WP-POE	1400	2000	(24.45) 4.98	(33.21) 5.79	(19.63) 4.43	(22.67) 4.77	(38.76) 5.89	(40.83) 6.08
2,4-DDimethyl amine salt 58 % SL-POE	3500	6000	(19.95) 4.50	(28.71) 5.39	(13.29) 3.70	(16.33) 4.09	(19.43) 4.45	(21.50) 4.68
Two hand weeding	-	-	(6.12) 2.55	(14.88) 3.92	(4.19) 2.13	(4.83) 2.28	(2.40) 1.69	(2.00) 1.53
untreated control	-	-	(36.95) 6.11	(45.71) 6.79	(41.29) 6.46	(44.33) 6.69	(99.26) 9.96	(101.33) 10.06
CD (P=0.05)			0.75	0.62	1.13	1.01	1.72	0.65
S.Em.±			0.26	0.21	0.39	0.35	0.59	0.22

Total weed biomass

The scrutiny of data on total weed biomass of BLWs, Grasses and Sedges are presented in (Table 2). The mean data on dry matter of grassy weed at60 DAA revealed that minimum accumulation was obtained with halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} applied as pre-emergence in case of sedges during 2017-18 and 2018-19. Being at par with halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} applied as post emergence at 30 DAP., and significantly superior to rest of the treatments. Complete control of BLWs and grasses was attained by the application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} applied as post emergence at 30DAP. Being at par with halosulfuron methyl 6% + metribuzin 50% WG 1.125 kg ha^{-1} as pre-emergence and significant to over the rest of the treatment. A similar result pointed out by Singh *et al.*, (2017) [18]. And also reported by Pandey *et al*. (2007) [11]. The same trend on grasses weeds pointed out by Gannon *et al.* (2012) [5].

Table 2: Total weed Biomass (No. m^{-2}) as influenced by weed control treatments in sugarcane

Treatments	Dose/ha		Total weed Biomass (No. m^{-2})					
	a.i. (g)	Formulation	Grasses		BLWs		Sedges	
			2017	2018	2017	2018	2017	2018
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	60+500	1000	(6.99) 2.74	(7.65) 2.85	(5.56) 2.46	(7.42) 2.81	(20.32) 4.56	(23.25) 4.87
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	67.5+562.5	1125	(4.28) 2.19	(4.94) 2.33	(5.22) 2.39	(7.08) 2.75	(18.51) 4.36	(21.44) 4.68
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	75+25	1250	(4.15) 2.15	(4.81) 2.30	(5.06) 2.36	(6.92) 2.72	(16.29) 4.09	(19.22) 4.44
Halosulfuron methyl 75% WG -PE	67.5	90	(10.19) 3.27	(10.85) 3.37	(7.58) 2.84	(9.44) 3.15	(139.07) 11.81	(142) 11.94
Metribuzin 70% WP-PE	1400	2000	(8.14) 2.94	(8.80) 3.05	(5.95) 2.54	(7.81) 2.88	(30.85) 5.60	(33.78) 5.85
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	60+500	1000	(7.54) 2.84	(8.20) 2.95	(5.60) 2.47	(7.46) 2.82	(30.56) 5.57	(33.49) 5.83
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	67.5+562.5	1125	(5.27) 2.84	(5.93) 2.53	(5.37) 2.42	(7.23) 2.78	(19.61) 4.48	(22.54) 4.79
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	75+25	1250	(3.95) 2.10	(4.61) 2.26	(4.87) 2.32	(6.73) 2.69	(15.52) 3.99	(18.45) 4.34
Halosulfuron methyl 75% WG –POE	67.5	90	(9.08) 3.10	(9.74) 3.20	(7.50) 2.82	(9.36) 3.13	(137.07) 11.73	(140) 11.85
Metribuzin 70% WP-POE	1400	2000	(8.42) 2.98	(9.08) 3.09	(6.08) 2.56	(7.94) 2.90	(118.67) 10.92	(121.6)11.05
2,4-DDimethyl amine salt 58 % SL-POE	3500	6000	(5.79) 2.51	(6.45) 2.64	(5.47) 2.44	(7.33) 2.80	(20.18) 4.54	(23.11) 4.85
Two hand weeding	-	-	(2.13) 2.51	(2.63) 1.77	(4.57) 2.25	(6.18) 2.58	(7.26) 2.76	(10.19) 3.26
untreated control	-	-	(20.25) 4.55	(20.91) 4.62	(11.69) 3.49	(13.55) 3.75	(158.07) 12.59	(161) 12.71
CD (P=0.05)			0.20	0.19	0.17	0.15	0.45	0.42
S.Em.±			0.07	0.07	0.06	0.05	0.59	0.14

Weed control efficiency (WCE)

Scanning of data on weed control efficiency as influenced by weed management practices is presented in (Table 3).

The maximum weed control efficiency was obtained with halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} applied as pre-emergence in case of BLWs, Grasses and Sedges during 2017-18 and 2018-19., followed by halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} applied as post-emergence in case of sedges during 2017-18 and 2018-19.and significantly superior to rest of the herbicidal treatments. The similar result was recorded by the (Webster and Coble 1997) [23], the same trend was also recorded by Isaacs *et al*. (2006) [7].

Table 3: Effect of different treatments on weed control efficiency (%)

Treatments	Dose ha^{-1}		Weed Control efficiency (%)					
	a.i. (g)	Formulation	Grasses		BLWs		Sedges	
			2017	2018	2017	2018	2017	2018
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	60+500	1000	65.31	63.25	52.28	45.11	87.15	85.57
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	67.5+562.5	1125	78.65	76.16	55.38	47.77	88.28	86.67
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	75+25	1250	79.56	77.04	56.69	48.90	89.68	88.05
Halosulfuron methyl 75% WG -PE	67.5	90	49.60	48.02	34.95	30.17	11.99	11.78
Metribuzin 70% WP-PE	1400	2000	59.46	57.58	49.11	42.36	80.49	79.03
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	60+500	1000	62.60	60.62	52.07	44.92	80.68	79.21
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	67.5+562.5	1125	74.05	71.70	54.14	46.69	87.61	86.01
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	75+25	1250	80.29	77.75	58.39	50.37	90.16	88.52
Halosulfuron methyl 75% WG –POE	67.5	90	54.88	53.15	36.20	31.19	13.26	13.02
Metribuzin 70% WP-POE	1400	2000	58.50	56.64	48.01	41.41	24.93	24.48
2,4-DDimethyl amine salt 58 % SL-POE	3500	6000	71.36	69.10	53.14	45.85	87.22	85.63
Two hand weeding	-	-	89.44	87.31	60.87	54.42	95.39	93.66
untreated control	-	-						
CD (P=0.05)								
S.Em.±								

Yield attributes and yield

Data with respect to Yield attributes and yield are presented in (Table 4). Yield attributes of sugarcane varied significantly with various weed control treatments. The highest number of millable cane was recorded under three hoeing (30, 60 and 90 DAP) which was significantly higher overall weed control treatments. Application of post-emergence halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} was recorded a maximum number of millable cane (000 ha^{-1}) which was statistically at par with the pre-emergence application of halosulfuron methyl 6% metribuzin 50% WG 1.25 kg ha^{-1} during both the years. A minimum number of millable cane (000 ha^{-1}) was recorded under the untreated control plot. This was the findings of Srivastava (2003) [22] who has reported that the effect of herbicides on weed control and thus increasement in a number of millable cane and also similar finding by (Srivastava, 2001) [21].

Among the herbicidal treatments post emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} was recorded tallest cane length and this was followed by pre-emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1}. This treatment significant over a weedy check and halosulfuron methyl 75% WG 0.90 kg ha^{-1} PE, halosulfuron methyl 75% WG 0.90 kg ha-1 POE and metribuzin 70% WP 2.0 kg ha^{-1} and rest of herbicidal treatments at par with halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} POE. Tallest cane length was recorded in three hoeings has also been reported by Bhullar *et al*. (2008) [2]. The decrease in the number of cane length in weedy check as reported by Bruff *et al*. (1996) [3] and Richard (1996) [3]. Data clearly indicate that different herbicidal treatments did not cause any significant effect on cane diameter. However, the maximum diameter of cane was recorded by hand weeding at 30, 60 and 90 DAP. The minimum cane diameter was recorded under the weedy check at all stages of crop growth. In herbicidal treatments, application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} POE recorded maximum cane yield which was at par with halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} PE. This treatment was followed by 2,4-D Dimethyl amine salt 58 % SL and all these three-herbicide treatments recorded significantly high cane yield over rest of the herbicidal treatment. These results were in coincidence with findings of Singh *et al*. (2011) [19] and this was also reported by Rana and Singh (2004) [12].

Table 4: Effect of different treatments on cane yield attributes of sugarcane during 2017 and 2018

Treatments	Dose ha^{-1}											
	a.i. (g)	Formulation	Cane length (cm)		Cane girth (cm)		Per cane weight (g)		Cane Yield t h^{-1}		Percent increase in yield over weedy	
			2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	60+500	1000	241.79	253.33	7.05	7.52	1027.14	1160.53	109.82	112.32	53.87	53.30
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	67.5+562.5	1125	262.62	274.16	7.19	7.66	1111.46	1244.85	124.96	127.64	75.09	74.20
Halosulfuron methyl 6% + Metribuzin 50% WG-PE	75+25	1250	265.22	276.76	7.26	7.73	1150.08	1283.47	131.30	134.07	83.97	82.98
Halosulfuron methyl 75% WG -PE	67.5	90	230.82	242.36	6.91	7.38	930.58	1063.97	90.41	92.71	26.68	26.53
Metribuzin 70% WP-PE	1400	2000	237.19	248.73	7.01	7.48	994.58	1127.97	103.43	105.86	44.92	44.48
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	60+500	1000	237.82	249.36	7.03	7.50	1006.95	1140.34	107.39	109.85	50.47	49.92
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	67.5+562.5	1125	252.49	264.03	7.14	7.61	1019.26	1152.65	114.40	116.89	60.29	59.53
Halosulfuron methyl 6% + Metribuzin 50% WG-POE	75+25	1250	265.82	277.36	7.44	7.91	1122.33	1255.72	131.75	134.46	84.60	83.51
Halosulfuron methyl 75% WG –POE	67.5	90	231.66	243.20	6.97	7.44	975.67	1109.06	99.22	101.61	39.02	38.68
Metribuzin 70% WP-POE	1400	2000	231.96	243.50	6.99	7.46	990.32	1123.71	101.50	103.93	42.22	41.85
2,4-DDimethyl amine salt 58 % SL-POE	3500	6000	249.72	261.26	7.10	7.57	1082.19	1215.58	118.36	120.98	65.84	65.12
Two hand weeding	-	-	270.42	281.96	7.50	7.97	1264.03	1397.42	160.90	163.92	125.44	123.72
untreated control	-	-	225.29	236.83	6.87	7.34	750.28	883.67	71.37	73.27		
CD (P=0.05)			38.23	40.41	1.13	1.01	3.98	7.32	4.12	6.23		
S.Em.±			12.36	13.84	0.39	0.35	1.36	2.69	1.41	2.14		

Phyto-toxicity on sugarcane crop

There was no phytotoxicity effect was observed with respect to crop discolouration, chlorosis, stunting, wilting, deformation and vein clearing in sugarcane plant by application of pre and post emergence halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} indicating safe for sugarcane crop. Etheredge *et al*. (2010) [4] was also not observed the reduction in sugarcane growth later in the growing season and any injury to the crop due to halosulfuron methyl 6% + metribuzin 50% WG 1.125 kg ha^{-1}. Etheredge *et al.* (2010) [4] also did not observe any reduction in sugarcane growth later in the growing season and any injury to the crop due to halosulfuron.

Conclusion

It is to be concluded that for effective weed management of BLWs, Grasses and Sedges. Higher yield of sugarcane was obtained with the post emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1}. Thus, pre-emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} effective control of total Sedges and post emergence application of halosulfuron methyl 6% + metribuzin 50% WG 1.25 kg ha^{-1} is the best way for effective control of total Broad leaf weeds and Grasses in sugarcane.

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