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Halosulfuron Methyl: For effective control of *Cyperus* spp. in sugarcane (*Saccharum officinarum* L.) and its residual effect on succeeding green-gram (*Vigna radiata* L.)

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ABSTRACT

Sugarcane (Saccharum officinarum L.) growers in India are fronting glitches of an increase infestation of purple nutsedge (C. rotundus L.) in addition to normal weed pest problems. Cyperus rotundus is stern menace in all upland crops at inceptisols. The newly developed Halosulfuron Methyl 75% WG showed encouraging results in managing the world's worst weed purple nut sedge. An experiment was conducted at 'C' Block Farm, BCKV, West Bengal, India during 2013-14 to 2014-15 to study the effect of Halosulfuron Methyl 75% WG on inhibiting important weed species of sugarcane including Cyperus spp., yield of sugarcane, effect on soil microflora and succeeding crop Vigna radiata. POE Halosulfuron methyl 75 WG was used at 30 DAP in four different doses (60.0, 67.5, 90.0 and 135 g ha^{-1}) along with PE Atrazine 50 WP @ 2.0 kg ha^{-1} at 3 DAP, POE 2,4-D amine salt 58 SL @ 3.5 kg ha^{-1} at 30 DAP, twice hand weeding at 30 and 60 DAP and weedy check. Significantly higher inhibition on Cyperus spp., enhanced weed control efficiency and weed control index (WCE 87.8-90.0 % and WCI 84.7-89.2 %) and superior cane yield (66.8-67.9 t ha^{-1}) were recorded at Halosulfuron methyl @ 67.5, 90.0 and 135.0 g. ha^{-1} excepting its lowest dose (60 g ha^{-1}). The brix value (20.98-21.47 %), sucrose content (18.21-18.68 %) and commercial cane sugar (14.25-14.76 %) did not have any perceptible variation under different weed management treatments. All the herbicidal treatments recorded detrimental effect on soil microflora (total bacteria, actinomycetes and fungi) immediately after application but at their post persistence period, populations were recovered. All organic herbicides including different doses of Halosulfuron methyl 75 WG applied on sugarcane crop did not affect the germination and yield of succeeding green gram crop (0.78-0.82 t ha^{-1}) during both the years. Considering the weed inhibition, cane productivity, cost of treatments and effect on environment POE Halosulfuron methyl 75 WG @ 67.5 g ha^{-1}may advocate for effective control of Cyperus spp. in sugarcane-green gram crop sequence.

Keywords: *Cyperus* spp., green gram, halosulfuron methyl, sugarcane, weed control efficiency

Sugarcane (*Saccharum officinarum* L.) is one of the most important agro-industrial cash crops in Indian economy. Being a long duration (above 180 days) widely spaced crop with slow initial growth, sugarcane provides a congenial ambiance to all weeds for their growth and development that causes 73.5per cent reduction in cane yield (Singh *et al.*, 2011). Among the different weeds, purple nut sedge (*Cyperus rotundus*) is probably the most difficult perennial weed for its faster germination and rapid ground coverage in alluvial soil along with its associated weed *Saccharum spontaneum* (Ghosh *et al.*, 2013). Sugarcane growers in India have experienced an increase infestation of purple nut (*C. rotundus* L.) and yellow nut sedge (*Cyperus esculentus* L.) over the past few years and often 60–80 per cent population of total weed flora in cane fields is occupied by *C. rotundus* (Roshan *et al.*, 2006). Nut sedge possesses a predominant basal bulb normally around 15 cm below ground surface which produces a chain of horizontal tubers. Under favourable conditions, a single tuber can produce 99 tubers in 90 days. Several herbicides like Atrazine 50 WP, Quizalofop ethyl 5 EC, Pendimethalin 30 EC, Pretilachlor 50 EC *etc*. however, had been tried to manage purple nut sedge but successful control of *Cyperus spp.* could not be achieved. Different registered herbicides in field crops are found to be relatively tolerant against purple nutsedge (Webster and Coble, 1997). Halosulfuron methyl (3-chloro-5-4,6-dimethoxypirimidin2-ylcarbamoylsulfamoyll-l-metbyl-pyrasole-4-carboxylate) is a selective, post-emergence new organic sulfonyl urea herbicide used for the control of mainly nutsedge and other grassy weeds in sugarcane, maize, cotton *etc*. Hence, an experiment was conducted to generate information regarding the effect of Halosulfuron methyl 75 WG on management of weed flora including *Cyperus* spp., cane productivity, sugar quality as well as the crop tolerance, impact on soil micro flora and residual effect on following crop green gram.

MATERIALS AND METHODS

The field experiment was conducted during 2013-14 and 2014-15 at university 'C' Block farm (latitude: 22°57'E, longitude: 88°20'N and altitude: 9.75 m) on sugarcane cv. Co-1148 in plot size of 5 x 4m. The experimental soil was well drained, alluvial in nature and sandy loam in texture, having pH 6.91 and organic carbon 0.589 per cent, available nitrogen, phosphorus

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and potassium 241.57, 18.85 and 261.18 kg ha^{-1}, respectively. Eight treatments comprised of four different doses (T_1-T_4) of POE Halosulfuron methyl 75 WG (60.0, 67.5, 90.0 and 135 g ha^{-1}) applied at 30 DAP, PE Atrazine 50 WP @ 2.0 kg ha^{-1} (T_5) at 3 DAP, POE 2,4-D amine salt 58 SL @ 3.5 kg ha^{-1} (T_6) at 30 DAP, hand weeding twice (T_7) at 30 and 60 DAP and control (T_8) were used in a randomized block design with 3 replications.

The treated sugarcane setts by using *Trichoderma viride* @ 4 g kg^{-1} were planted at 50 x 90 cm spacing in the beginning of June in two consecutive years with 5 t ha^{-1} neem cake (NC), 100 kg ha^{-1} phosphorus (SSP) and 25 per cent of 100 kg ha^{-1} potash (MOP) as basal during final land preparation. Recommended dose of nitrogen @ 150 kg ha^{-1} through urea was applied in 4 splits, 25 per cent at 10 DAP and along with 25 per cent potash each at the beginning and mid of tillering stage and at grand growth stage. The cane crop was harvested during February on 267 and 263 DAP during 2013-14 and 2014-15, respectively. The treated seed of follow up crop green gram cv. Sonali (B-1) was sown at 15 x 30 cm spacing on March without breaking the layout and harvested in May. The recommended NC: N: P: K:: 2000:20:40:40 kg ha^{-1} was used at basal and a common HW at 25 DAS was done in green gram crop. The irrigation was applied mainly during *rabi* and *summer* season as and when required. For insect and disease control, the recommended ecosafe chemical method was used by applying insecticide and fungicide mixtures.

The weed density and biomass, WCE, WCI, WMI, AMI, HEI and IPMI (Ghosh *et al*., 2013); cane yield, brix value and sucrose content of sugarcane and germination and green gram yield were recorded. For microbial study the requisite composite sample of each treatment from the experimental plots were collected at a depth 0-15 cm at initial, 10 and 30 DAA and at harvest of sugarcane crop. Data were analyzed using analysis of variance (ANOVA) to evaluate the differences among treatments.

RESULTS AND DISCUSSION

The dominant weed flora in the experimental plot was *Brachiaria mutica*, *Dactyloctenium aegyptium*, *Digitaria sanguinalis*, *Echinochloa colona*, *Eleusine indica*, *Leptochloa chinensis*, *Saccharum spontaneum* and *Setaria glauca* (grass), *Cyperus rotundus* and *Cyperus difformis* (sedge) and *Alternanthera philoxeroides/sessilis*, *Blumea lacera*, *Chenopodium album*, *Commelina diffusa*/*benghalensis*, *Digera arevensis*, *Eclipta alba*, *Euphorbia hirta*, *Fumaria parviflora*, *Melilotus alba*, *Phyllanthus niruri*, *Physalis minima*, *Portuleca oleracea*, *Scoparia dulcis*, *Stellaria media* among broadleaves. Average weed population of narrow leaved species (grass and sedge) was more than broadleaf weeds at all dates of observation.

Weed density and biomass

Significant differences were recorded among the herbicidal treatments for weed density and biomass of various categories of grass, sedge and broadleaf species and also the total weed at 30, 45 and 60 DAA (Table 1 and 2). As normally expected, maximum pooled total weed density and biomass during 2013-14 and 2014-15 were recorded from the control plot at 30, 45 and 60 DAA (81.01, 98.67 and 112.67 no. m^{-2} and 63.49, 92.21 and 122.27 g m^{-2}, respectively). The corresponding figures for lowest pooled total weed density and biomass that was recorded in twice HW (8.66, 11.22, 13.45 no. m^{-2} and 6.46, 10.86 and 18.89 g m^{-2}, respectively) followed by Atrazine 50 WP @ 2 kg ha^{-1} (28.90, 36.89, 43.89 no. m^{-2} and 18.33, 27.26 and 39.38 g m^{-2}, respectively). Similar trends of variation were recorded in grass and broadleaf weeds. But considering the sedge weed control Halosulfuron Methyl 75 WG at four different doses (60.0, 67.5, 90.0 and 135 g ha^{-1}) showed better results at 30, 45 and 60 DAA on both density (2.56-3.11, 3.22-3.89 and 3.89-4.56 no. m^{-2}, respectively) and biomass (1.63-1.78, 2.56-2.83 and 3.82-4.10 g m^{-2}, respectively) than all other herbicidal treatments.

Among the various four doses of Halosulfuron methyl the highest dose @ 135 g ha^{-1} recorded 87.66 and 84.38 per cent better sedge weed control in regards to density and biomass, respectively than PE application of Atrazine 50 WP @ 2.0 kg ha^{-1}. The corresponding figures for Halosulfuron methyl applied @ 135 g ha^{-1} over the POE application of 2,4-D amine salt 58 SL @ 3.5 kg ha^{-1} were 88.01and 84.71per cent. The findings were in accordance with the findings of Webster and Coble (1997) while worked on Halosulfuron at 72.0 g ha^{-1} in corn. Being a sulfonylurea herbicide it is rapidly absorbed by the foliage as well as by the roots of plants and translocated throughout the plant. Halosulfuron usually stops the reserve food supply and blocks the normal function of enzyme ALS or AHAS which is essential for amino acid (protein) synthesis (Vencill *et al.,* 1995). Decomposition of the sulfonylureas in the soil takes place by both hydrolytic and microbial processes. According to the Gannon *et al.* (2012), soil plus foliar applications of Halosulfuron provided the highest level of growth suppression against *Cyperus spp.*

Efficiency parameters

The weed control efficiency (WCE) of different treatments was higher during initial stages of growth (30 DAA) and it was declined with days of crop growth

(Table 3). Among the herbicidal treatments highest WCE was achieved with PE application of Atrazine 50 WP @ 2.0 kg ha^{-1} (30, 45 and 60 DAA- 64.3, 62.6 and 61.0 %, respectively) followed by Halosulfuron Methyl 75 WG @ 135 g ha^{-1} (30, 45 and 60 DAA- 44.2, 40.1 and 37.4 %, respectively) and its lower doses at different days of observation. Similar trends have been observed in weed control index (WCI). But for inhibition of sedge weeds the highest WCE and WCI was observed against application of Halosulfuron Methyl 75 WG @ 135 g ha^{-1} followed by its lower doses. At 30 DAA Halosulfuron Methyl 75 WG @ 135 g ha^{-1} recorded 77.88 and 84.41per cent greater WCE on sedges than PE application of Atrazine 50 WP @ 2 kg ha-1 and 2,4-D amine salt 58 SL @ 3.5 kg ha^{-1}, respectively. This is in conformity with the earlier findings of Rathika *et al.* (2013). The WCI was higher at initial observation and then gradually decreased as the crop growth advances towards maturity. The probable reason is WCI is basically determined on weed dry weight basis which normally increases over time as the herbicide efficacy is decreased gradually after its half-life period. Highest herbicide efficiency index (HEI) was recorded with the application of Atrazine 50 WP @ 2.0 kg ha^{-1} (0.96%) followed by 2,4-D amine salt 58 SL @ 3.5 kg ha^{-1} (0.33%), Halosulfuron Methyl 75 WG applied @ 135 g ha^{-1} (0.23 %) and its lower three doses. This is because of the reason that Halosulfuron Methyl 75 WG mainly controls the grassy weeds while 2,4-D amine salt 58 SL is capable to control only the broadleaf weeds but Atrazine 50 WP can able to manage all categories of annual weeds in sugarcane (Table 4). Similar trend has been reflected in case of agronomic management index (AMI), weed management index (WMI) and integrated weed management index (IWMI).

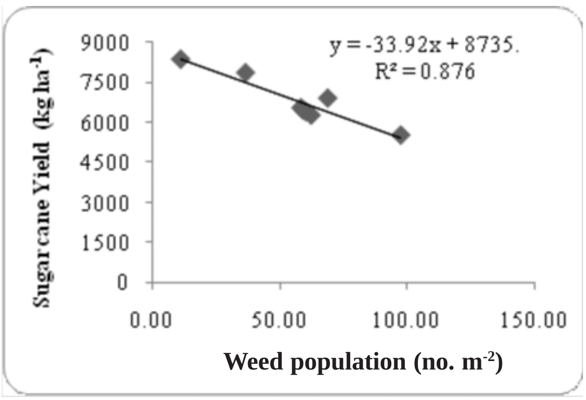
Effect on crop growth and cane yield and quality

The effective suppression of weeds resulting in lesser weed competition during critical crop weed competition period, more soil aeration, enhancing uptake of nutrients, light and moisture by crop as result of which the cane length, weight of a cane and no. of millable cane per hectare were significantly higher with all herbicidal treatments than control. Highest cane length (2.14 m), weight of a cane (1.14 kg) and no. of millable cane per hectare (88, 220) was recorded from the hand weeded treatment followed by Atrazine 50 WP @ 2 kg ha^{-1} (T_5), 2,4-D amine salt 58 SL @ 3.5 kg ha^{-1} (T_6) and highest dose of Halosulfuron methyl (T_4). Singh and Kaur (2004) also observed similar findings. All the weed management treatments recorded significantly superior cane yield of sugarcane (10.9 to 46.8 %) over control (59.11 t ha^{-1}). The maximum cane yield was recorded in the hand weeded plots (86.78 t ha^{-1}) followed by Atrazine 50 WP @ 2.0 kg ha^{-1} (80.11 t ha^{-1}), 2,4-D Amine 58 SL @ 3.5 kg ha^{-1} (72.29 t ha^{-1}) and Halosulfuron methyl 75WG @ 135 g ha^{-1} (67.93 t ha^{-1}). There was not much variation observed in sugarcane productivity between the four different doses of Halosulfuron methyl 75 WP (60.0, 67.5 and 90.0 g ha^{-1}). The per cent brix, sucrose and commercial cane sugar also did not show any perceptible variations among the different weed management treatments (Table 5) and the findings is corroborated with the results obtained by Dashora and Singh, (2008).

Relationship between weed density and weed biomass with sugarcane yield

A negative linear correlation was found between weed density and weed biomass with cane yield (Fig.1). Weed biomass had a stronger relationship with cane yield ($R^2 = 0.982$) than weed density ($R^2 = 0.876$). Regression analysis showed that a weed density of 100 m^{-2} reduced cane yield by 33.92 kg ha^{-1}.

Effect on soil microorganism



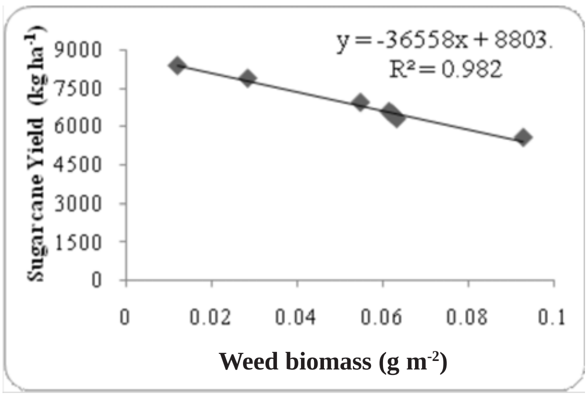


Fig. 1: Relationship between weed density and biomass with sugarcane yield

Table 1: Effect of treatments on grass, sedge, broadleaf and total weed density at 30, 45 and 60 DAA in sugarcane (Pooled over two years)

Treatments	Weed density (no. m^{-2})											
	30 DAA				45 DAA				60 DAA			
	Grass	Sedge	Broad leaf	Total	Grass	Sedge	Broad leaf	Total	Grass	Sedge	Broad leaf	Total
T_1	26.33	3.11	19.11	48.55	48.55	3.89	26.00	63.55	39.78	4.56	30.45	74.79
	(5.23)	(2.03)	(4.48)	(7.04)	(7.04)	(2.21)	(5.19)	(8.03)	(6.38)	(2.36)	(5.61)	(8.70)
T_2	25.56	2.89	18.56	47.01	47.01	3.56	25.33	61.33	39.00	4.22	29.44	72.66
	(5.15)	(1.97)	(4.42)	(6.93)	(6.93)	(2.14)	(5.13)	(7.89)	(6.32)	(2.28)	(5.52)	(8.58)
T_3	25.00	2.67	18.22	45.89	45.89	3.33	24.89	59.89	38.56	4.11	29.22	71.89
	(5.10)	(1.92)	(4.38)	(6.85)	(6.85)	(2.08)	(5.09)	(7.80)	(6.29)	(2.26)	(5.50)	(8.54)
T_4	24.66	2.56	18.00	45.22	45.22	3.22	24.67	59.12	37.89	3.89	28.78	70.56
	(5.07)	(1.89)	(4.36)	(6.80)	(6.80)	(2.05)	(5.07)	(7.75)	(6.24)	(2.21)	(5.46)	(8.46)
T_5	4.45	20.56	3.89	28.90	28.90	26.78	4.33	36.89	6.89	31.00	6.00	43.89
	(2.33)	(4.64)	(2.21)	(5.47)	(5.47)	(5.27)	(2.31)	(6.15)	(2.81)	(5.66)	(2.65)	(6.70)
T_6	29.55	22.00	4.45	56.00	56.00	27.22	4.78	69.89	42.67	31.44	6.34	80.45
	(5.53)	(4.80)	(2.33)	(7.55)	(7.55)	(5.31)	(2.40)	(8.42)	(6.61)	(5.70)	(2.71)	(9.02)
T_7	3.66	2.33	2.67	8.66	8.66	3.00	3.55	11.22	5.78	3.56	4.11	13.45
	(2.16)	(1.83)	(1.92)	(3.11)	(3.11)	(2.00)	(2.13)	(3.50)	(2.60)	(2.14)	(2.26)	(3.80)
T_8	32.78	25.67	22.56	81.01	81.01	29.11	28.56	98.67	45.89	34.78	32.00	112.67
	(5.81)	(5.16)	(4.85)	(9.05)	(9.05)	(5.49)	(5.44)	(9.98)	(6.85)	(5.98)	(5.74)	(10.66)
SEm (±)	**0.02**	**0.02**	**0.03**	**0.04**	**0.04**	**0.03**	**0.03**	**0.04**	**0.04**	**0.03**	**0.03**	**0.05**
LSD (0.05)	**0.07**	**0.07**	**0.08**	**0.12**	**0.12**	**0.08**	**0.10**	**0.13**	**0.11**	**0.09**	**0.10**	**0.14**

Note: Data in parentheses are $\sqrt{x+1}$ *transformed values and used for statistical analysis*

[T_1- Halosulfuron Methyl 75% WG @ 60 g ha^{-1}, T_2- Halosulfuron Methyl 75% WG @ 67.5 g ha^{-1}, T_3- Halosulfuron Methyl 75% WG @ 90 g ha^{-1}, T_4- Halosulfuron Methyl 75% WG @ 135 g ha^{-1}, T_5- Atrazine 50% WP @ 2.0 kg ha^{-1}, T_6- 2,4-D amine salt 58% SL @ 3.5 kg ha^{-1}, T_7- Hand weeding at 30 & 60 DAP, T_8- Control]

Table 2: Effect of treatments on grass, sedge, broadleaf and total weed biomass at 30, 45 and 60 DAA in sugarcane (Pooled over two years)

Treatments	Weed biomass (g m^{-2})											
	30 DAA				45 DAA				60 DAA			
	Grass	Sedge	Broad leaf	Total	Grass	Sedge	Broad leaf	Total	Grass	Sedge	Broad leaf	Total
T_1	20.05	1.78	18.67	40.50	29.85	2.83	29.61	62.29	39.66	4.10	42.71	86.47
	(4.59)	(1.67)	(4.43)	(6.43)	(5.55)	(1.96)	(5.53)	(7.95)	(6.37)	(2.26)	(6.61)	(9.35)
T_2	19.77	1.73	18.44	39.94	29.41	2.71	29.35	61.47	39.42	3.95	42.36	85.73
	(4.56)	(1.65)	(4.41)	(6.39)	(5.51)	(1.93)	(5.50)	(7.90)	(6.36)	(2.23)	(6.58)	(9.31)
T_3	19.50	1.70	18.37	39.57	29.15	2.64	29.24	61.03	39.22	3.89	42.13	85.24
	(4.53)	(1.64)	(4.40)	(6.37)	(5.49)	(1.91)	(5.50)	(7.87)	(6.34)	(2.21)	(6.57)	(9.29)
T_4	19.05	1.63	18.14	38.82	28.79	2.56	29.15	60.50	38.81	3.82	41.97	84.60
	(4.48)	(1.62)	(4.37)	(6.30)	(5.45)	(1.89)	(5.49)	(7.84)	(6.31)	(2.19)	(6.55)	(9.25)
T_5	3.06	12.25	3.02	18.33	5.17	16.96	5.13	27.26	8.84	22.08	8.46	39.38
	(2.02)	(3.64)	(2.00)	(4.39)	(2.48)	(4.24)	(2.47)	(5.31)	(3.14)	(4.80)	(3.08)	(6.35)
T_6	21.07	12.62	3.13	36.82	31.28	17.25	5.43	53.96	41.89	22.52	8.76	73.17
	(4.70)	(3.69)	(2.03)	(6.14)	(5.68)	(4.27)	(2.53)	(7.41)	(6.55)	(4.85)	(3.12)	(8.61)
T_7	2.70	1.44	2.32	6.46	4.53	2.24	4.09	10.86	7.52	3.75	7.12	18.39
	(1.92)	(1.56)	(1.82)	(2.73)	(2.35)	(1.80)	(2.26)	(3.44)	(2.92)	(2.18)	(2.85)	(4.40)
T_8	25.75	15.15	22.59	63.49	37.31	20.09	34.81	92.21	47.83	25.74	48.70	122.27
	(5.17)	(4.02)	(4.85)	(8.02)	(6.18)	(4.59)	(5.98)	(9.65)	(6.99)	(5.17)	(7.05)	(11.10)
SEm (±)	**0.017**	**0.041**	**0.051**	**0.060**	**0.057**	**0.046**	**0.062**	**0.072**	**0.036**	**0.023**	**0.040**	**0.050**
LSD (0.05)	**0.052**	**0.125**	**0.154**	**0.182**	**0.173**	**0.139**	**0.187**	**0.218**	**0.109**	**0.069**	**0.121**	**0.151**

Note: Data in parentheses are $\sqrt{x+1}$ *transformed values and used for statistical analysis*

Table 3: Effect of treatments on weed control efficiency (WCE) and weed control index (WCI) at 30, 45 and 60 days after herbicide application (DAHA) (mean of two years)

Treatments	30 DAA				45 DAA				60 DAA			
	WCE		WCI		WCE		WCI		WCE		WCI	
	Sedges	Total	Sedges	Total	Sedges	Total	Sedges	Total	Sedges	Total	Sedges	Total
T_1	87.9	40.1	88.2	36.2	86.6	35.6	85.9	32.4	86.9	33.6	84.1	29.3
T_2	88.7	42.0	88.5	37.1	87.8	37.8	86.5	33.3	87.9	35.5	84.7	29.9
T_3	89.6	43.4	88.7	37.7	88.6	39.3	86.9	33.8	88.2	36.2	84.9	30.3
T_4	90.0	44.2	89.2	38.9	88.9	40.1	87.3	34.4	88.8	37.4	85.2	30.8
T_5	19.9	64.3	19.1	71.1	8.0	62.6	15.6	70.4	10.9	61.0	14.2	67.8
T_6	14.3	30.9	16.7	42.0	6.5	29.2	14.1	41.5	9.6	28.6	12.5	40.2
T_7	90.9	89.3	90.5	89.8	89.7	88.6	88.9	88.2	89.8	88.1	85.4	85.0
T_8	-	-	-	-	-	-	-	-	-	-	-	-

Table 4: Effect of treatments on herbicide efficiency index (HEI), weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) at harvest of sugarcane (mean data of two years)

	Treatments	HEI	WMI	AMI	IWMI
T_1	Halosulfuron Methyl 75%WG @ 60 g ha^{-1}	0.17	1.13	0.13	0.63
T_2	Halosulfuron Methyl 75%WG @ 67.5 g ha^{-1}	0.20	1.16	0.16	0.66
T_3	Halosulfuron Methyl 75%WG @ 90 g ha^{-1}	0.21	1.17	0.17	0.67
T_4	Halosulfuron Methyl 75%WG @ 135 g ha^{-1}	0.23	1.18	0.18	0.68
T_5	Atrazine 50% WP @ 2 kg ha^{-1}	0.96	1.42	0.42	0.92
T_6	2,4-D amine salt 58% SL @ 3.5 kg ha^{-1}	0.33	1.25	0.25	0.75
T_7	Hand weeding	2.61	1.51	0.51	1.01
T_8	Control -	-	-	-	-

Table 5: Effect of treatments on cane length and weight, millable cane, yield, brix, sucrose and CCS of sugarcane (pooled over two years)

	Treatments	Plant height (m)	Weight of one cane (kg) (‘000 ha^{-1})	No. of millable cane	Yield (t ha^{-1})	Brix (%)	Sucrose (%)	CCS (%)
T_1	Halosulfuron Methyl 75%WG @ 60 g ha^{-1}	1.86	0.94	69.33	65.57	21.18	18.66	14.57
T_2	Halosulfuron Methyl 75%WG @ 67.5 g ha^{-1}	1.98	1.02	74.67	66.76	21.04	18.61	14.72
T_3	Halosulfuron Methyl 75%WG @ 90 g ha^{-1}	2.04	1.05	76.67	67.72	21.31	18.58	14.76
T_4	Halosulfuron Methyl 75%WG @ 135 g ha^{-1}	2.07	1.06	77.33	67.93	20.98	18.61	14.58
T_5	Atrazine 50% WP @ 2 kg ha^{-1}	2.10	1.11	83.00	80.11	21.31	18.43	14.70
T_6	2,4-D Amine 58% SL @ 3.5 kg ha^{-1}	2.09	1.09	81.33	72.29	21.25	18.68	14.25
T_7	Hand weeding	2.14	1.14	88.22	86.78	21.47	18.54	14.76
T_8	Control	1.61	0.82	60.00	59.11	21.22	18.21	14.55
	SEm (±)	**0.028**	**0.008**	**0.010**	**1.282**	**0.174**	**0.153**	**0.120**
	LSD (0.05)	**0.084**	**0.025**	**0.029**	**3.89**	**NS**	**NS**	**NS**

Table 6: Effect of treatments on plant population and germination at 20 DAS and yield of succeeding green gram crop (pooled over two years)

	Treatments	Plant population (m^{-2})	Germination (%)	Seed Yield ($t\ ha^{-1}$)
T_1	Halosulfuron Methyl 75%WG @ 60 g ha^{-1}	39.11	93.12	0.93
T_2	Halosulfuron Methyl 75%WG @ 67.5 g ha^{-1}	39.00	92.64	0.96
T_3	Halosulfuron Methyl 75%WG @ 90 g ha^{-1}	38.67	92.70	1.02
T_4	Halosulfuron Methyl 75%WG @ 135 g ha^{-1}	38.67	92.22	0.99
T_5	Atrazine 50% WP @ 2 kg ha^{-1}	38.00	93.27	1.02
T_6	2,4-D Amine 58% SL @ 3.5 kg ha^{-1}	37.67	92.55	0.99
T_7	Hand weeding	39.33	92.85	1.05
T_8	Control	39.33	93.51	0.90
	SEm (±)	**0.305**	**0.704**	**0.053**
	LSD (0.05)	**NS**	**NS**	**NS**

Significant variations on soil micro-flora population (Total bacteria, fungi and actinomycetes in rhizosphere of soil were found among the herbicides tested in this experiment at 10 and 30 DAA while as normally observed did not show any significant influence on these population (bacteria 97.56-98.67 CFU x 10^6 g^{-1}, fungi 29.33-30.67 CFU x 104 g^{-1} and actinomycetes 139.56-140.67 CFU x 10^5 g^{-1} of soil) at initial stage (Table 7). In HW and control plots a gradual increase in microflora population is observed from initial to crop harvest. Microorganisms are competent to degrade herbicides and utilize them as a source of biogenic elements for their own physiological processes. However, before degradation, all chemical herbicides have toxic effects on microorganisms, reducing their abundance, activity and consequently, the diversity of their communities. Due to inhibition of soil microflora population by the toxic chemical sup to the persistence period of the herbicides the decrease in the microbial population was observed and that varied in different herbicides and in time of observations.

The toxic effects of herbicides are normally most severe immediately after application (at 10 DAA bacteria 50.00-51.67 CFU x 10^6 g^{-1}, fungi 9.56-10.67 CFU x 10^4 g^{-1} and actinomycetes 65.56-67.33 CFU x 10^5 g^{-1} of soil), when their concentrations in soil are the highest. Later on, microorganisms take part in a degradation process and herbicide concentration and its toxic effect gradually decline up to half-life. Then the degraded organic herbicide provides the substrate with carbon, which leads to an increase of the soil microflora. Thus, at harvesting the recorded soil micro-flora population (bacteria 107.33- 108.67 CFU x 10^6 g^{-1}, fungi 37.33-38.90 CFU x 10^4 g^{-1} and actinomycetes 152.33-153.90 CFU x 10^5 g^{-1} of soil) again did not differ significantly because of the reason that half life of none of the herbicides used in this experiment is more than a month. Bera *et al.* (2012) and Poddar *et al.* (2014) working with related other herbicides in alluvial region found similar results.

Effect on succeeding crop

The population density (37.67-39.33 m^{-2}) and germination percentage (92.22-93.51%) of green gram crop was recorded at 20 DAS that did not show any significant variation among the treatments used in the previous sugarcane crop. This proved that the residual effect of the tested all herbicides did not have any detrimental effect on the follow up crop. The seed yield (minimum in control 0.90 t ha^{-1}-maximum in HW 1.05 t ha^{-1}) of green gram (Table 6) also did not vary significantly among all the treatments used in the previous sugarcane crop. No phytotoxic symptoms such as epinasty, hyponasty, leaf yellowing, necrosis, stunting growth or wilting were found in both sugarcane and succeeding green gram crop. The findings were in line with the findings of Chand *et al.* (2014).

From the study it could be concluded that among all the herbicidal treatments, though PE application of Atrazine 50% WP @ 2.0 kg ha^{-1} gave highest cane yield (80.11 t ha^{-1}) because of effective control on both grasses and broad leaf weeds but it is not much effective on controlling purple nut sedge *Cyperus rotundus*. POE application of Halosulfuron methyl 75% WG showed excellent control on *Cyperus rotundus* (86.6-90.0 %) in addition to no phytotoxic effect on both sugarcane as well as its succeeding green gram crop. Considering the weed inhibition, cane quality and productivity, cost of treatments and effect on environment POE Halosulfuron methyl 75 WG @ 67.5 g ha^{-1} may advocate for effective control of purple nut sedge *Cyperus rotundus* in sugarcane-green gram crop sequence.

Table 7: Effect of treatments on soil microflora population at initial, 10 and 30 DAA and at harvest (pooled over two years)

Treatments	Total bacteria (CFU × 10^6 g^{-1} of soil)				Fungi (CFU x 10^4 g^{-1} of soil)				Actinomycetes (CFU x 10^5 g^{-1})			
	Initial	10 DAA	30 DAA	Harvest	Initial	10	30 DAA	Harvest DAA	Initial	10 DAA	30 DAA	Harvest
T_1	98.00	51.67	80.89	108.67	30.11	10.67	17.11	38.90	140.22	67.33	94.22	153.78
T_2	97.89	50.78	80.33	108.56	30.00	10.44	17.00	38.56	140.00	66.78	94.00	153.67
T_3	97.56	50.56	80.22	108.33	30.00	10.33	17.00	38.78	139.89	66.56	93.89	153.33
T_4	98.33	50.56	80.00	107.33	30.11	10.11	16.89	38.89	139.78	66.33	93.67	153.56
T_5	98.00	50.00	79.56	108.00	30.67	9.67	16.56	38.00	140.00	65.67	93.00	152.56
T_6	97.89	50.00	79.33	107.56	29.33	9.56	16.33	37.78	140.67	65.56	92.78	152.33
T_7	98.33	99.67	101.78	108.11	30.44	30.44	31.56	37.33	140.00	141.67	143.11	153.22
T_8	98.67	99.33	101.89	107.56	30.11	30.56	31.44	38.56	139.56	141.22	142.67	153.90
SEm (±)	**0.773**	**0.438**	**0.557**	**0.859**	**0.238**	**0.458**	**0.260**	**0.302**	**1.108**	**0.860**	**0.603**	**1.208**
LSD (0.05)	**NS**	**1.33**	**1.69**	**NS**	**NS**	**1.39**	**0.79**	**NS**	**NS**	**2.61**	**1.83**	**NS**

DAA = Days after herbicide application

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