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RESEARCH ARTICLE

Effect of different combinations of herbicides and aqua-based plants extracts on weeds in sugarcane

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ABSTRACT

A field experiment was conducted during 2016-17 and 2017-18 at Agricultural Research Farm of Institute of Agricultural Sciences, BHU, Varanasi. The experiment was laid out in split plot design with five treatments in main plots and five treatments in sub plots. In main plots, there were five herbicide combinations, *viz.* pre-emergence application (PE) of atrazine 2 kg/ha at 3 days after planting (DAP) followed by (*fb*) post-emergence application (PoE) of halosulfuron-methyl 150 g/ha at 45 DAP, metribuzin 2 kg/ha *fb* halosulfuron-methyl 150 g/ha, triazinone 1.0 kg/ha *fb* halosulfuron-methyl 150 g/ha, weed free and weedy check. In sub-plots, five aqua based plant/allelopathic extracts were tested, *viz.* cow urine (500 L/ha), parthenium extract (15%), sunflower + sorghum + maize extract (15%), eucalyptus extract (15%) and water (600 L/ha). The lowest weed density and biomass, weed index (WI), NPK uptake by weeds and the highest weed control efficiency (WCE) were recorded with atrazine 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE in combination with sorghum + sunflower + maize extract, while need based hand weeding recorded higher cane yield.

Keywords: Atrazine, Allelopathic water extracts, Herbicide combination, Halosulfuron-methyl, Sugarcane, Weed Management

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is the most imperative sugar crop in the world which plays paramount role in Indian economy by contributing about 1% of national GDP (Venkatesh and Venkateswarlu 2017). Uttar Pradesh ranks first in both area (2.17 mha) and production (133.20 mt) of sugarcane; contributing 42.89 and 39.01%, respectively of the nation.

Various factors like small and marginal holdings, non-availability of quality inputs, weed competition caused losses, occurrence of various diseases, insect-pests and inevitable stresses during the crop growth period restrict the sugarcane yield particularly in the sub-tropical region of India (Choudhary and Singh 2016). Among them inadequate management of weeds by farmers is considered as the most important yield loss causing factor. Slow initial growth of crop and wide spacing between the rows, frequent and heavy irrigations, application of heavy doses of nutrients and warm-humid climate during a large part of the growing season of crop are responsible for high weed infestation. Weeds are fast growing and multiply at alarming rate and if allowed to grow unhindered, lead to severe competition for light, space, water, nutrients *etc.* (Singh *et al.* 2001).

Yield losses caused by weeds may be minimized by keeping weed growth under control by adopting mechanical, cultural and chemical methods. Cultural methods include crop rotation and good seedbed preparation, which may reduce this problem to some extent. The mechanical methods are most effective for control of weeds but are arduous with costly, time consuming and labour shortage at proper time make it difficult to adopt by the farmers. Hence, use of herbicides for weed control is gaining ground (Kumar *et al*. 2017). However, continuous use of same herbicide over the years has given rise to resistant biotypes of weeds (Le Baron 1992, Devedee *et al*. 2022) and many others environmental problems along with health issues due to continuous and non-judicious use of herbicides compelled the search for alternative weed control strategies (Jabran *et al*. 2010; Farooq *et al.* 2011). One of the conceivable strategies for reducing or minimizing the use of herbicides may be the use of natural products and allelopathic manipulation for crop improvement and environmental protection (Hussain *et al*. 2007, Farooq *et al*. 2008). It has been reported that allelopathic water extracts of different plants (crops as well as weeds) significantly reduced germination and growth of different weeds (Jabran *et al*. 2010).

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Allelopathic water extracts and herbicides applied in combination work synergistically, helping to reduce the dose of herbicide (Cheema *et al.* 2003).

The present study was under taken to identify the best combination of herbicides with allelopathic water extracts for controlling weeds in sugarcane.

MATERIALS AND METHODS

The present study was carried out during spring season of 2016 and 2017 at the Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India. The cumulative rainfall during both the year of investigation was recorded 1229.2 mm in 2016 and 649.6 mm in 2017. Soil of the experimental field was sandy clay loam in texture and neutral in reaction with low in organic carbon, low in nitrogen and medium in available phosphorus and potassium.

The experiment was laid out in split plot design with five treatments in main plots and five treatments in sub-plots replicated three times. In main plots, there were five herbicide combinations *i.e.* pre-emergence application (PE) of atrazine 2 kg/ha followed by (*fb*) post-emergence application (PoE) of halosulfuron-methyl 150 g/ha, metribuzin 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PE, triazinone 1.0 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE, weed free (three hand weeding + hoeing) and weedy check plot. In the sub plots, five allelopathic extracts treatments *i.e.* cow urine (500 l/ha), parthenium extract (15%), sunflower + sorghum + maize extract (15%), eucalyptus extract (15%) and water (600 l/ ha) were used.

Preparation of aqua-based plant extracts

Cut plant leaves into 2-3 cm small pieces

↓

Weight the plant on balance

↓

Measure the desirable quantity of water

↓

Pieces of leaves poured into water

↓

Soaked in water from 24 to 48 hours

↓

Filter it into another pot

↓

Heat this filtrate and reduce 25% of total amount

↓

Cool it and mix with herbicide as per treatment and spray

Pre-emergence application [at 3 days after planting (DAP)] and post-emergence application (PoE) (at 45 DAP) of herbicides was done with the help of a hand- operated knapsack sprayer fitted with flat-fan nozzle. Sugarcane variety (Co-0238) was planted in lines at the row spacing of 90 cm in spring season of 2016 and 2017. Planting date of sugarcane was 03/03/2016 in the first year and 01/03/2017 in second year of experimentation. Recommended dose of fertilizers *i.e.* 150 kg N, 80 kg P and 60 kg K/ha were applied to the crop. Urea, DAP and MOP were used for fertilization. Whole of phosphorus and potassium and half dose of nitrogen were applied at the time of planting. The remaining half-dose of nitrogen was applied in two equal split doses as per requirement. Cane was harvested 8 to 13 February, 2017 for first year crop and in second year sugarcane harvested in 13 to 19 February, 2018. Weed density was recorded species wise at 30, 60 and 90 days after planting (DAP). Weed density was recorded with the help of a quadrat (50 x 50 cm = 250 cm^2) placed randomly at two spots in each plot, and counting different weeds. Weeds occurring in a quadrat of 0.25 m^2 (50 x 50 cm) were cut at ground level and were separated individual species wise at 30, 60 and 90 DAP, washed under running of tap water, sun dried, oven dried at 70^0C for 48 hours and weighed. The values were converted to per square meter basis. Weed control efficiency (WCE) was calculated at 90 DAP by using the formula suggested by Mani *et al.* (1973) and weed Index (WI), a measure of reduction in crop yield was computed as per formula given by Gill and Kumar (1969). Nutrient (N, P and K) depletion by weeds at 90 DAP was calculated by the multiplication of percent NPK content with weed dry matter. For determining the significance of differences between the treatments and to draw valid conclusions, the data obtained were subjected to statistical analysis by 'Analysis of Variance' for split plot design and the significance was tested by ''Variance ratio'' *i.e.* 'F' value (Gomez and Gomez 1984).

Weed control efficiency (WCE)

$$\text{Weed control efficiency } (\%) = \frac{WDM_C - WDM_t}{WDM_C} \times 100$$

Where,

WDM_C = Weed dry matter in control plot

WDM_t = Weed dry weight in treated plot

Weed index (WI)

$$\text{Weed index } (\%) = \frac{X - Y}{X} \times 100$$

Where,

X = Yield from weed free plots (Three hoeing)

Y = Yield from treated plot

Nutrient (N, P, K) depletion by weeds (kg/ha)

$$\text{Nutrient depletion by weeds (kg/ha)} = \text{Per cent N/P/K in weed} \times \text{weed dry matter (kg/ha)}$$

RESULTS AND DISSCUSSION

Effect on weeds

The experimental field was infested with fifteen weed species of which eight belonged to grasses, six were broad-leaved weeds and one sedge. Among grasses: *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Leptochloa chinensis*, *Eleusine indica*, *Cenchrus catharticus*, *Digitaria sanguinalis*, *Setaria glauca* and *Panicum repens*, and among broad-leaved weeds; *Parthenium hysterophorus*, *Trianthema monogyna*, *Solanum nigrum*, *Phyllanthus niruri*, *Euphorbia hirta* and *Commelina benghalensis* were noticed in the field. *Cyperus rotundus* was the only sedge. *Cyperus rotundus*, *Cynodon dactylon* and *Parthenium hysterophorus* were the dominant weed species.

Among the herbicides tested, atrazine 2 kg/ha PE at 3 DAP *fb* halosulfuron-methyl 150 g/ha PoE at 45 DAP were statistically superior than triazinone 1.0 kg/ha at 3 DAP *fb* halosulfuron-methyl 150 g/ha PoE at 45 DAP at all the weed growth stages during both the years (**Table 1**). Atrazine 2 kg/ha PE at 3 DAP *fb* halosulfuron-methyl 150 g/ha at 45 DAP and metribuzin 2 kg/ha at 3 DAP *fb* halosulfuron-methyl 150 g/ha at 45 DAP were equally effective in controlling weeds and attaining higher WCE. The sequential application of pre- and post-emergence herbicides was more effective in managing initial as well as later emerged flushes of total weeds as observed by Jayabal and Chockalingam (1990). Relative efficacy of different aqua-based plant extracts was at par with each other. The combined application of sunflower + sorghum + maize extract was significantly superior over rest of the plant extracts for the control of total weeds biomass reduction due to their effective management of all categories of weeds as observed by Cheema *et al.* (2003) and Razzaq *et al.* (2010).

Weed index of different treatments indicated that herbicide sequences and aqua-based plant extracts have significant influence on yield improvement by controlling weeds (**Table 4**). Among the herbicidal sequences, atrazine 2 kg/ha PE at 3 DAP *fb* halosulfuron-methyl 150 g/ha PoE at 45 DAP caused higher reduction of weeds resulting in minimum value of weed index. The main reason for its efficacy was the efficient control of grassy and broad-leaved weeds by atrazine and sedges by halosulfuron-methyl as also reported by Singh *et al.* (2008) and Mc Elroy and Martins (2013).

Among the different herbicide treatments tested, atrazine 2 kg/ha PE at 3 DAP *fb* halosulfuron-methyl 150 g/ha at 45 DAP has resulted in less depletion of nitrogen, phosphorus and potassium by weeds (**Table 3**) due to less infestation of weeds owing to the better efficacy of this combination. Aqua-based plant extracts and cow urine application significantly influenced the uptake of primary nutrients by weeds. Combined application of sunflower + sorghum + maize extract has resulted in lowest uptake thus saved

Table 1. Effect of herbicide sequences and aqua based plant extracts on weed density (no./m^2) in sugarcane

Treatment	Weed density (no./m^2)					
	30 DAP		60 DAP		90 DAP	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Herbicides						
Atrazine 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE	6.7(44)	7.5(55)	7.7(59)	8.3(69)	9.5(91)	10.2(105)
Metribuzin 2 kg/ha PE *fb* halosulfuron- methyl 150 g/ha PoE	7.0(49)	7.7(60)	8.0(65)	8.7(75)	9.8(96)	10.5(109)
Triazinone 1.0 kg/ha PE *fb* halosulfuron-methyl 150g/ha PoE	7.9(62)	8.5(72)	8.6(75)	9.3(86)	10.6(113)	11.1(124)
Weed free	11.5(130)	12.0(144)	5.1(27)	6.2(39)	5.0(25)	6.0(38)
Weedy check	11.5(132)	12.0(148)	15.6(243)	16.3(270)	18.1(338)	18.1(355)
LSD (p=0.05)	0.32	0.43	0.42	0.45	0.39	1.54
Aqua-based plant extracts						
Cow urine 500 l/ ha.	9.2(90)	9.9(103)	9.3(101)	10.0(114)	10.9(144)	11.7(162)
Parthenium extract 15%	9.0(83)	9.6(96)	9.1(95)	9.8(108)	10.8(135)	11.3(146)
Sunflower + sorghum + maize extract 15%	8.3(73)	9.0(85)	8.4(84)	9.2(98)	9.9(116)	10.2(121)
Eucalyptus extract 15%	8.9(82)	9.5(95)	9.0(92)	9.7(106)	10.6(132)	11.2(143)
Water 600 l/ha	9.2(88)	9.8(101)	9.2(97)	10.0(112)	10.8(136)	11.6(157)
LSD (p=0.05)	0.31	0.34	0.34	0.30	0.36	0.94

PE = pre-emergence application; PoE = post-emergence application; *fb* = followed by; DAP = days after planting
Original figures in parenthesis were subjected to square root transformation (Ö X+1) before statistical analysis

Table 2. Effect of herbicide sequences and aqua based plant extracts on weeds biomass (g/m^2) in sugarcane

Treatment	Weed biomass					
	30 DAP		60 DAP		90 DAP	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Herbicides						
Atrazine 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE	3.04(8.9)	3.43(11.4)	7.53(56.9)	8.10(65.6)	10.12(103.2)	11.03(122.0)
Metribuzin 2 kg/ha PE *fb* halosulfuron- methyl 150 g/ha PoE	3.23(10.1)	3.59(12.6)	7.80(61.1)	8.39(70.5)	10.61(112.9)	11.33(128.6)
Triazinone 1 kg/ha. *fb* halosulfuron-methyl 150g/ha PoE	3.66(13.2)	3.95(15.4)	8.54(73.5)	9.08(82.7)	11.63(135.7)	12.33(152.5)
Weed free	5.72(32.5)	6.15(37.7)	2.95(8.6)	3.73(13.7)	4.58(21.1)	4.09(16.7)
Weedy check	5.80(32.5)	6.19(38.1)	16.31(267.1)	17.18(296.0)	21.68(471.0)	22.85(523.2)
LSD (p=0.05)	0.21	0.17	0.32	0.40	0.50	0.36
Aqua-based plant extracts						
Cow urine 500 l/ ha	4.46(21.3)	4.81(24.7)	8.85(99.5)	9.54(111.7)	12.05(178.2)	12.60(199.1)
Parthenium extract 15%	4.36(20.3)	4.70(23.3)	8.65(93.5)	9.35107.9)	11.77(170.0)	12.42(190.3)
Sunflower + sorghum + maize extract 15%	3.94(16.6)	4.35(20.1)	8.22(86.1)	8.84(96.8)	11.11(154.7)	11.77 (174.7)
Eucalyptus extract 15%	4.29(19.3)	4.69(23.0)	8.62(91.9)	9.27(103.6)	11.70(167.4)	12.34(187.5)
Water 600 l/ha	4.42(20.7)	4.77(24.1)	8.79(96.2)	9.49(108.5)	11.98(173.5)	12.49(191.5)
LSD (p=0.05)	0.17	0.14	0.24	0.27	0.37	0.29

*Original figures in parenthesis were subjected to square root transformation (Ö X+1) before statistical analysis; PE = pre-emergence application; PoE = post-emergence application; *fb* = followed by; DAP = days after planting

Table 3. Effect of herbicide sequences and aqua based plant extracts on NPK depletion by weeds and sugarcane yield

Treatment	Nutrient depletion by weeds (kg/ha)							
	Nitrogen		Phosphorus		Potassium		Total sugarcane yield (t/ha)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Herbicides								
Atrazine 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE	3.80	4.42	2.73	3.05	4.77	5.47	143.45	131.96
Metribuzin 2 kg/ha PE *fb* halosulfuron- methyl 150 g/ha PoE	4.09	4.63	2.83	3.33	5.00	5.59	129.31	117.94
Triazinone 1 kg/ha PE *fb* halosulfuron-methyl 150g/ha PoE	4.50	4.99	3.70	3.82	5.44	6.17	119.18	102.05
Weed free	3.18	3.73	2.35	2.61	4.29	4.78	171.92	152.32
Weedy check	5.28	5.43	4.48	4.40	6.49	6.81	68.31	60.99
LSD (p=0.05)	0.34	0.30	0.56	0.38	0.28	0.25	11.56	14.04
Aqua-based plant extracts								
Cow urine 500 l/ ha	4.45	4.88	3.56	3.66	5.41	5.94	105.29	93.36
Parthenium extract 15%	4.08	4.60	3.29	3.51	5.25	5.82	127.35	113.17
Sunflower + sorghum + maize extract 15%	3.67	4.25	2.59	3.07	4.79	5.41	152.68	139.68
Eucalyptus extract 15%	4.15	4.66	3.16	3.39	5.17	5.72	130.61	116.57
Water 600 l/ha.	4.49	4.81	3.50	3.58	5.38	5.92	116.23	102.48
LSD (p=0.05)	0.30	0.26	0.51	0.28	0.24	0.21	6.29	6.30

*PE = pre-emergence application; PoE = post-emergence application; *fb* = followed by; DAP = days after planting

Table 4. Effect of herbicide sequence on weed control efficiency and weed index of different weeds in sugarcane

Treatment	Weed control efficiency (%) at 90 DAP		Weed index (%) at harvest	
	2016-17	2017-18	2016-17	2017-18
Herbicides				
Atrazine 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE	78.97	78.21	12.28	23.22
Metribuzin 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE	76.98	77.04	16.70	29.89
Triazinone 1.0 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE	72.30	72.80	24.91	36.98
Weed free	95.72	97.02	4.96	9.04
Weedy check	3.85	6.66	55.91	62.94
LSD (p=0.05)	3.78	3.07	7.30	7.06
Aqua-based plant extracts				
Cow urine 500 l/ha	63.63	64.50	25.71	34.97
Parthenium extract 15%	65.27	66.06	23.96	33.92
Sunflower + sorghum + maize extract 15%	68.46	68.81	18.02	26.32
Eucalyptus extract 15%	65.82	66.53	22.90	32.05
Water 600 l/ha	64.63	65.83	24.17	34.83
LSD (p=0.05)	1.97	1.42	3.31	3.75

*PE = pre-emergence application; PoE = post-emergence application; *fb* = followed by; DAP = days after planting

soil NPK content. The highest uptake of nutrients by weeds was noticed with un-weeded check due to heavy weed infestation and increased weeds biomass (Tomar *et al*. 2002; Hatcher and Melander 2003; Boquet *et al*. 2004).

Sugarcane yield

Hoeing at 30, 60 and 90 DAP (weed free) was superior over the herbicidal treatment in increasing sugarcane yield (Rana and Singh 2004). Atrazine 2 kg/ha PE at 3 DAP *fb* halosulfuron-methyl 150 g/ha PoE at 45 DAP increased cane yield due to effective management of associated (**Table 5**). The aqua based plant extracts also caused significant increase in cane yield. Maximum sugarcane yield was recorded with combine application of sorghum + maize + sunflower leaf extracts which was significantly higher than with eucalypus leaf extracts, parthenium extracts, water as well as cow urine and these four extracts remained at par with each other during both the years of experimentation. The results are in conformity with those of Ameena *et al*. (2015).

Conclusion

Atrazine 2 kg/ha PE at 3 DAP followed by halosulfuron-methyl 150 g/ha PoE at 45 DAP and metribuzin 2 kg/ha PE at 3 DAP *fb* halosulfuron methyl 150 g/ha at 45 DAP were equally effective in reducing weeds and their nutrient uptake and increasing sugarcane yield. Among the aqua-based plant extracts, highest WCE and lowest WI, lower nutrient uptake by weeds was registered with combined application of sorghum + maize + sunflower extracts.

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Table 5. Effect of herbicide sequences and aqua based plant extracts on cane yield, cane top yield and cane trash yield of sugarcane

Treatment	Cane yield (t/ha)		Cane top yield (t/ha)		Cane trash yield (t/ha)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Herbicides						
Atrazine 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE	98.65	91.96	24.55	22.38	13.34	11.84
Metribuzin 2 kg/ha PE *fb* halosulfuron-methyl 150 g/ha PoE	89.51	82.94	23.78	20.70	13.23	11.36
Triazinone 1 kg/ha PE *fb* halosulfuron-methyl 150g/ha PoE	74.38	62.05	21.90	18.67	11.25	9.39
Weed free	127.12	112.32	30.05	27.61	16.40	14.75
Weedy check	48.51	45.99	13.39	10.78	8.09	6.11
LSD (p=0.05)	11.56	14.04	1.82	1.69	1.04	1.32
Aqua-based plant extracts						
Cow urine 500 l/ ha.	65.29	59.36	21.70	18.03	11.83	9.21
Parthenium extract 15%	87.35	79.17	22.87	20.23	12.56	11.41
Sunflower + Sorghum +Maize extract 15%	118.68	105.68	24.29	23.37	13.33	13.05
Eucalyptus extract 15%	90.61	82.57	22.92	20.41	12.64	10.56
Water 600 l/ha.	76.23	68.48	21.90	18.09	11.97	9.23
LSD (p=0.05)	6.29	6.30	0.96	1.27	0.63	1.19

Table 6. Effect of herbicide sequences and aqua based plant extracts on economics of sugarcane

Treatment	Cost of cultivation (x10^3 `/ha)		Gross returns (x10^3 `/ha)		Net returns (x10^3 `/ha)		B:C	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Herbicides								
Atrazine 2 kg/ha PE *fb* halosulfuron-methyl 150g/ha PoE	80.17	96.03	251.55	234.50	171.38	138.47	2.14	1.44
Metribuzin 2 kg/ha PE *fb* halosulfuron-methyl 150g/ha PoE	88.26	104.12	228.24	211.50	139.98	107.37	1.59	1.03
Triazinone 1.0 kg/ha PE *fb* halosulfuron-methyl 150g/ha PoE	79.46	95.32	189.67	158.24	110.20	62.91	1.39	0.66
Weed free	110.55	126.40	324.16	286.42	213.61	160.01	1.93	1.27
Weedy check	78.73	94.58	123.69	117.27	44.96	22.68	0.57	0.24
Aqua-based plant extracts								
Cow urine 500 l/ ha.	87.43	103.29	166.50	151.37	79.06	48.07	0.90	0.47
Parthenium extract 15%	87.43	103.29	222.75	201.89	135.31	98.60	1.55	0.95
Sunflower + sorghum + maize extract 15%	87.43	103.29	302.63	269.48	215.20	166.19	2.46	1.61
Eucalyptus extract 15%	87.43	103.29	231.05	210.54	143.61	107.25	1.64	1.04
Water 600 l/ha	87.43	103.29	194.38	174.62	106.94	71.33	1.22	0.69

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