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Evaluation of Phytotoxicity of Sulfantrazone 48% F to Sugarcane *Saccharum officinarum* L.

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Abstract: A field experiment was conducted at the Indian Institute of Sugarcane Research, Luchnow, under subtropical Indian conditions during the season 2012-2013 to study the evaluation of phytotoxicity of sulfantrazone 48% f to sugarcane variety CoSe 92423. The experimental design was Randomized Complete Block Design (RCBD) with four replications. The treatments used in the experiment are sulfentrazone PPI 720 g a.i.ha^{-1}, sulfentrazone PPI 1440 g a.i.ha^{-1}, sulfentrazone Pre-em: 3 DAP 720 g a.i.ha^{-1}, sulfentrazone Pre-em: 3 DAP 1440 g a.i.ha^{-1} and untreated control(weedy). The results showed that sulfentrazone PPI 1440 g ai.ha^{-1} registered the highest increase of germination (56.9 %) that didn't differ significantly from other treatments**.** The dry matter accumulation in weeds was the lowest (7.2, 10.6 and 22.8 g.m^{-2}) in sulfentrazone PPI 1440 a.i.ha^{-1} treatment achieved highest inhibition proportion of dry matter (90.2, 88.9 and 83.5 %) at the 60, 90 and 120 DAP respectively. Phytotoxicity was not significantly affected by use of sulfentrazone herbicide. a significant increase in average number of canes by using sulfentrazone PPI 1440 g a.i.ha^{-1} led to even the highest increase in this attribute at the 90,120,150, 210 and 300 DAP. The use of sulfentrazone PPI 1440 g a.i.ha^{-1} registered the highest cane yield (84.1 t.ha^{-1}) that was significantly higher to the tune of 44.94 % over control. Addition of sulfentrazone treatments significantly affected sugar yield. Sulfentrazone PPI 1440 g a.i.ha^{-1} and sulfentrazone Pre-eme 1440 g a.i.ha^{-1}caused highest increase in this character which reached to 13.850 and 13.500 t.ha^{-1}respectively.

Keywords: Phytotoxicity, Sulfentrazone, Sugarcane**.**

Introduction

Early experiment with sugarcane confirmed need to control weeds and efficiency of herbicide treatments for their control (Gosnell, 1965). Some herbicides have little effect on plant growth in companion with the effects of competition from weeds (Gosnell & Thompson, 1964). Results have shown a little effects on cane yield by use herbicides (Almubarak *et al.*, 2012) without necessarily reaching level of statistical significance in experiments. However, average reduction on yield from all post-emergence applications was 3%, while no reduction in yield was apparent with pre-emergence applications (Turner *et al*., 1990).

The stage of growth of cane at the time of spraying is likely to be an important factor in determining the extent of reduction in cane yield, but this factor needs to be studied further to eliminate the possible effect of the age of the crop at the time of harvest and the weather condition at the time of spraying (Turner *et al*., 1990). Sugarcane varieties present different responses to the herbicides and have as results phytotoxicity problem that could cause reduction in sugarcane yield (Monquero *et al*., 2011).

Sulfentrazone is a phenyl triazolinone herbicide use for control of certain broad-leaf and grassy weeds. Sulfentrazone persists in soil and has residual activity beyond the season of application. A laboratory bioassay was developed for detection of sulfentrazone in soil using shoot and root response of several crops. Concentrations corresponding to 50% inhibition(I50 values) were obtained from dose–response curves constructed for the soils. Sulfentrazone phytotoxicity was strongly correlated to percentage organic carbon and also to percentage clay content, whereas correlation with soil pH was non-significant, because sulfentrazone phytotoxicity was found to be soil dependent, the efficacy of sulfentrazone for weed control and sulfentrazone potential carryover injury will vary with soil type in the Canadian prairies (Szmigieiski *et al*., 2009).

Sulfentrazone movement was limited in the Sequatchie loam, but was greater in the other soils examined. No clear relationship was evident between the sulfentrazone mobility and adsorption in these soils (Ohmes & Mueller, 2007).

In view of soil dependant behavior of sulfentrazone its effect including phyto-toxicity on sugarcane crop was studied at higher concentration with objectives of assessing phyto-toxicity symptoms, trend of mortality and loss in yield, if any.

Materials & Methods

Study was conducted during 2012-13 to evaluate phytotoxicity of sulfentrazone to sugarcane plants at normal or higher than recommended rate of applications. Package of practices for raising sugarcane crop was similar as in first experiment. In this field experiment two levels of sulfentrazone with three times of application was evaluated against control for phyto-toxic effects on sugarcane (cv CoSe 92423). The experiment was laid in Randomized Completly Block Design (RCBD) with four replications. The following table indicates about the treatments used (Table 1). The soil of the experimental site was sandy loam with pH 7.83, organic carbon 0.40%, and available N, P, K were 222.65, 16.86 and 186.12 Kg ha^{-1}, respectively. The gross plot size was 51 m^2 and the distance between the experimental unit and others was 0.5 m while distance between replicate was 1.5 m. Each experimental unit contains six row-length of 8 m and the distance between lines was 0.75 m. 150 kg N. ha^{-1} was added to experimental land by application of urea (46% N), in three parts. First part before planting , second part at 60 days after planting and third part at 90 DAP . Dap fertilizer (18-46-0) at the rate of 60 Kg ha^{-1} (Almubarak, 2013) was applied once after planting. So, KCL at the rate of 60 Kg ha^{-1} was applied once after planting. Bavistin (systemic fungicide) at the rate of 200 Kg. ha^{-1} and Hilban (chloribyriphos)

(Insecticide) at the rate of 5 $L.ha^{-1}$ were used and 37000 – 40000 sets. ha^{-1}.

Germination percentage:

Calculated number of plants that appeared above soil surface 45 DAP.

Weed Species:

Been diagnosed type of weeds in land of the experiment.

Weed density (number.m^{-2}):

A quadrant sized 1.0 m × 1.0 m was thrown randomly in each experimental unit three times at 60, 90 and 120 days after planting and green weed plants those were not affected by herbicides were counted and averaged .

Percentage of weed control(%) :

Was calculated from the following equation:

$$\text{Percentage of weed control} \quad \frac{\text{Control treatment} - \text{Weed control treatment}}{\text{Control treatment}} \times 100$$

Table (1): Different treatments used in the experiment.

Treatment	application	Dose (g $a.i.ha^{-1}$)	Dose /$ml.ha^{-1}$	Dose /ml/acre
Sulfentrazone	PPI	720	1500	600
Sulfentrazone	PPI	1440	3000	1200
Sulfentrazone	Pre-em: 3 DAP	720	1500	600
Sulfentrazone	Pre-em: 3 DAP	1440	3000	1200
Untreated control (weedy)	-	-	-	Untreated control (weedy)

Dry weight of weeds (g)

Green weed plants were cut at the soil surface from the same site in the experimental unit in three times, the quadrant (1.0 m²) was used for counting of weeds for calculating weed density. The weeds samples were air dried under laboratory conditions (Almubarak, 2013) .

Inhibition proportion of dry matter (%)

Was calculated from the following equation:

$$\text{Inhibition proportion of dry matter} = \frac{\text{Control treatment} - \text{Dry matter treatment}}{\text{Control treatment}} \times 100$$

Phytotoxicity:

Calculated of numbers of plants affected by herbicide at 70 DAP.

Number of Tillers

Millable cane, Non-millable cane and Total counted at 60,90,120,150,180, 210 and 300 DAP.

Number of Internode

Number of internode calculated at 180 and 300 DAP.

Number of green Leaves

Number of green leaves calculated at 90 DAP.

Cane yield ($t.ha^{-1}$)

The canes were collected from middle lines of each experimental unit and after topping cane were weighed to obtain cane yield.

Five samples were selected from each experimental unit to measure juice quality parameters. Following tests were conducted on selected samples:

Percentage of total soluble solids:

It was recorded with the help of Hand-refractometer by putting a drop of fresh sugarcane juice on the reading glass. This indicates presence of total soluble solids in the juice assumed to indicate sucrose concentration.

Percentage of sucrose in juice

It was indirectly measured with the help of polarimeter/ suchrometer based on dextro rotatory properties of sugar. The sucrose concentration is expressed as sucrose (%) in juice.

Purity

Relative concentration of sucrose, compared with other solids, dissolved in juice was calculated using following equation:

$$\text{Purity} = \frac{\text{Sucrose (\%)}}{\text{Brix (\%)}} \times 100$$

Sugar yield:

Was calculated using following equation:

Sugar Yield ($t.\ ha^{-1}$) = Cane Yield ($t\ ha^{-1}$.) x Percentage of Sucrose

Analysis of data was made using statistical tools of Randomized Complete Block Design. LSD was used to compare treatments at significant level of 0.05 (Steel & Torrie, 1980).

Results & Discussion

Germination percentage

Data below (Fig. 1) indicated significant effect of sulfentrazone on average germination in sugarcane. Sulfentrazone PPI 1440 g $ai.ha^{-1}$ registered the highest increase of germination (56.9 %) that didn’t differ significantly from other treatments. However, all the sulfentrazone treatments helped to produce significantly higher germination percentage of sugarcane compared to the control (38.6 %).

Weed density ($g.m^{-2}$) and weed control proportion (%)

The weed species present in the second field of sugarcane were: *Amaranthus* sp., *Chenopodium album, Portulaca oleracea, Digera arvensis, Trianthema monogyna, Cyperus rotundus, Sorghum halepense, Cynodon dactylon, Convolvulus arvensis* (Table 2).

At 60 DAP among these the prominent weed species were the sedges occupying 72.1 per cent share in total weed population . Whereas, the broad leaved weeds viz *Amaranthus hybridus* and grasses like *Cynodon dactylon* were in a very few numbers that constitutes 12.1 and 15.8 per cent of the total weed population respectively (Table 3).

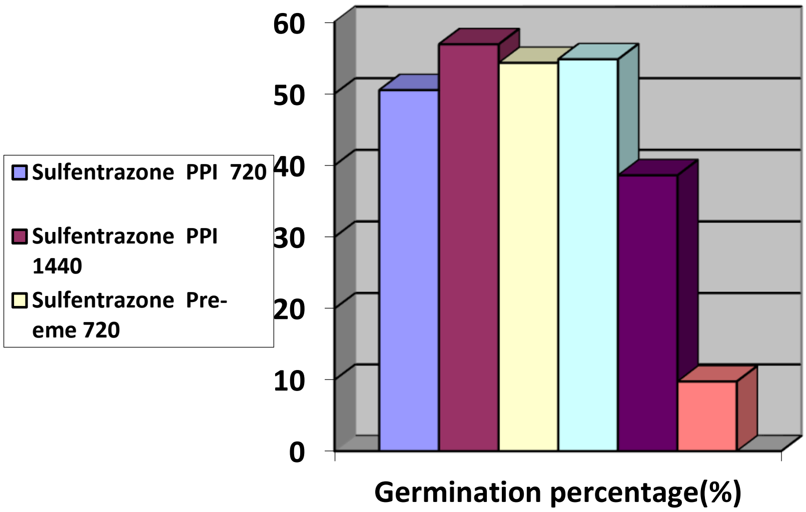

Fig.(1): Effect of sulfentrazone on germination (%) of sugarcane.

Table (2): Weed species spreading in second experimental field.

Scientific name	Common name	Family	Life cycle	Weed type
Amaranthus hybridus	Pigweed, mooth	Amaranthaceae	Annual	Broadleaf
Chenopodium album	Lambsquarters	Chenopodiaceae	Annual	Broadleaf
Portulaca oleracea	common purslane	Portulacaceae	Annual	Broadleaf
Digera arvensis	False Amaranth	Amaranthaceae	Annual	Broadleaf
Trianthema monogyna	Carpetweed	Gland pigweed	Annual	Broadleaf
Cyperus rotundus	Nutsedge, purple	Cyperaceae	Perennial	Sedge
Sorghum halepense	Johnsongrass	Poaceae (Graminae)	Perennial	Grass
Cynodon dactylon	Bermudagrass	Poaceae	Perennial	Grass
Convolvulus arvensis	Bindweed	Convolvulaceae	Perennial	Broadleaf

At 90 DAP, prominent weed species were the sedges that occupied 55.8 per cent share in total weed population .Whereas, the broad leaved weeds viz *Amaranthus hybridus* and

At 120 DAP sedges, broad leaved weeds and grasses occupied 44.4, 22.4 and 33.2 per cent share in total weed population respectively (Table 5). Use of weed control methods controlled the weeds. The weed density was the least under its treatments at

grasses like *Cynodon dactylon* were in a very few numbers that constituted 19.8 and 24.4 per cent of the total weed population respectively (Table 4).

all the growth stages of the crop till harvest compared with the control treatment. Weed growth in the plots treated with sulfentrazone (PPI; 1440 g ai.ha^{-1}) led to a high decrease in weed density (12.8, 19.8 and 30.5 plant/m²), achieved highest increase in proportion of

Table (3): Effect of sulfentrazone herbicide on density of weed (No.m^{-2}) of sugarcane (60 DAP).

Treatments	Grasses	Broadleaf	Sedge	Total
Sulfentrazone 720 PPI	10	1	72	83
Sulfentrazone 1440 PPI	2	0	49	51
Sulfentrazone 720 Pre-em: 3 DAP	6	1	85	92
Sulfentrazone 1440 Pre-em: 3 DAP	1	1	63	65
Untreated control (weedy)	61	58	96	215
Total	80	61	365	506

Table (4): Effect of sulfentrazone herbicide on density of weed (No.m^{-2}) of sugarcane (90 DAP).

Treatments	Grasses	Broadleaf	Sedges	Total
Sulfentrazone 720 PPI	27	14	88	129
Sulfentrazone 1440 PPI	13	9	57	79
Sulfentrazone 720 Pre-em: 3 DAP	26	19	93	138
Sulfentrazone 1440 Pre-em: 3 DAP	12	10	58	80
Untreated control (weedy)	88	83	84	255
Total	166	135	380	681

Table (5): Effect of sulfentrazone herbicide on density of weed (No./m^2) of sugarcane (120 DAP).

Treatment	Grasses	Broadleaf	Sedges	Total
Sulfentrazone 720 PPI	59	29	115	203
Sulfentrazone 1440 PPI	29	21	72	122
Sulfentrazone 720 Pre-em: 3 DAP	62	34	100	196
Sulfentrazone 1440 Pre-em: 3 DAP	34	25	84	143
Untreated control (weedy)	194	145	133	472
Total	378	254	504	1136

Table (6): Effect of sulfentrazone herbicide on weed density (No.m^{-2}) atdifferent growth stages of sugarcane.

Treatment	Time of application	Dose (g a.i.ha^{-1})	60DAP	90DAP	120DAP
Sulfentrazone	PPI	720	20.8	32.3	50.8
Sulfentrazone	PPI	1440	12.8	19.8	30.5
Sulfentrazone	Pre-eme	720	23.0	34.5	49.0
Sulfentrazone	Pre-eme	1440	16.3	20	35.8
Untreated control(weedy)	-	-	53.8	63.8	118.0
L.S.D. 0.05					

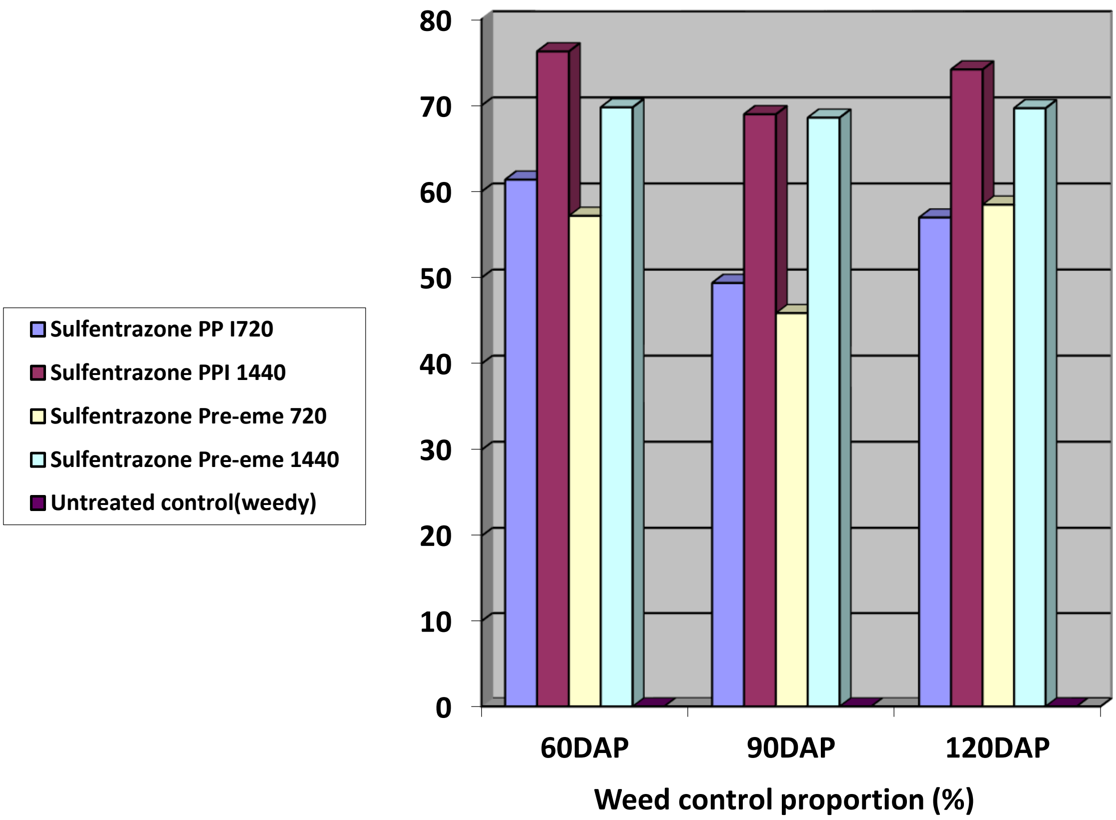

Fig. (2): Effect of sulfentrazone herbicide on Proportion of weed control (%) density during the different growth stages of sugarcane.

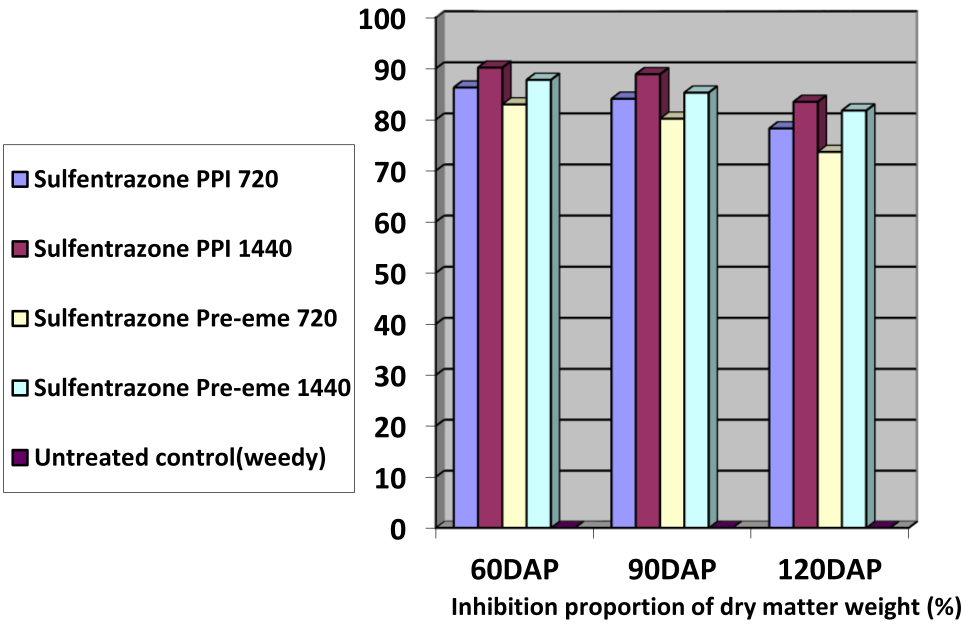

Fig. (3): Effect of sulfentrazone on inhibition of dry matter (%) of weeds during the different growth stages of sugarcane.

Table (7): Effect of sulfentrazone on dry matter weight (g.m^{-2}) of weeds at different growth stages of sugarcane.

Treatments	Time of application	Dose (g a.i.ha^{-1})	60DAP	90DAP	120DAP
Sulfentrazone	PPI	720	9.9	15.2	29.9
Sulfentrazone	PPI	1440	7.2	10.6	22.8
Sulfentrazone	Pre-eme	720	12.4	18.9	36.3
Sulfentrazone	Pre-eme	1440	8.8	14.1	25.1
Untreated control(weedy)	-	-	72.6	95.5	138.0
L.S.D. 0.05			7.59	6.70	21.68

Table (8): Phytotoxicity of sulfentrazone herbicide in sugarcane (shoots.ha^{-1}) 70 DAP.

Treatments	Time of application	Dose (g a.i.ha^{-1})	Phytotoxicity (shoots.ha^{-1})
Sulfentrazone	PPI	720	4062.435
Sulfentrazone	PPI	1440	7291.550
Sulfentrazone	Pre-eme	720	2187.465
Sulfentrazone	Pre-eme	1440	3749.940
Untreated control (weedy)	-	-	0000.000
L.S.D. 0.05			NS

weed control (76.3, 69.0 and 74.2 %) (Fig. 2) as compared to the control treatment (53.8, 63.8 and 118.0.m^{-2}) at the 60, 90 and 120 DAP respectively).

Dry matter of weeds (g.m^{-2}) and inhibition proportion of dry weight (%)

The research finding presented in table (7) indicates that weed control methods significantly affected dry weight of weeds. All the treatments were found effective in significantly reducing the dry weight of weeds compared to the control treatment. The dry matter accumulation in weeds was the lowest (7.2, 10.6 and 22.8 g.m^{-2}) in sulfentrazone PPI 1440 a.i./ha treatment achieved highest inhibition proportion of dry matter (90.2, 88.9 and 83.5 %) (Fig. 3) compared with the control treatment (72.6, 95.9 and 138.0 g.m^{-2}) at the 60, 90 and 120 DAP respectively.

Phytotoxicity

Phytotoxicity was not significantly affected by use of sulfentrazone herbicide(table 8).

Number of tillers

The table (9) indicates a significant increase in average number of canes by using sulfentrazone PPI 1440 g a.i.ha^{-1}led to even the highest increase in this attribute amounted to 262000, 181700, 186500, 188500 and 169900 cane.ha^{-1}.Sulfentrazone Pre-eme 1440 g a.i.ha^{-1} application also significantly enhanced average number of canes (258300 ,199800, 199200, 188900 and 171100 cane.ha^{-1}) over control (73400, 153100, 94300, 1148000 and 138300 cane .ha^{-1} at the 90,120,150,210 and 300 DAP respectively. Also, The figure 4 indicates a significant increase in average number of millable canes and decrease in average number of non-millable cane by using sulfentrazone PPI 1440 g a.i.ha^{-1}and sulfentrazone Pre-eme 1440 g a.i.ha^{-1} led to even the highest increase in millable canes amounted to 169.2 and

169.2 cane.ha^{-1} and the highest decrease in non-millable canes amounted to 19.2 and 19.6 cane.ha^{-1} at the 210 DAP (fig. 4) . In the same direction, the highest increase in millable canes amounted to 131.9 and 132.8 cane.ha^{-1} and the highest decrease in non-millable canes amounted to 38.0 and 38.3 cane.ha^{-1} at the 300DAP (fig. 5).

Table (9): Effect of sulfentrazone herbicide on number of tillers (000.ha^{-1}) during the different growth stages of sugarcane .

Treat. No.	Time of application	Dose (g a.i.ha^{-1})	90 DAP	120 DAP	150 DAP	210 DAP	300 DAP
Sulfentrazone	PPI	720	202.7	176.0	148.9	150.7	153.0
Sulfentrazone	PPI	1440	262.0	181.7	186.5	188.5	169.9
Sulfentrazone	Pre-eme	720	232.6	158.1	160.4	174.8	164.6
Sulfentrazone	Pre-eme	1440	258.3	199.8	199.2	188.9	171.1
Untreated control(weedy)	-	-	073.4	153.1	094.3	114.8	138.3
L.S.D 0.05			60.94	NS		32.83	20.35

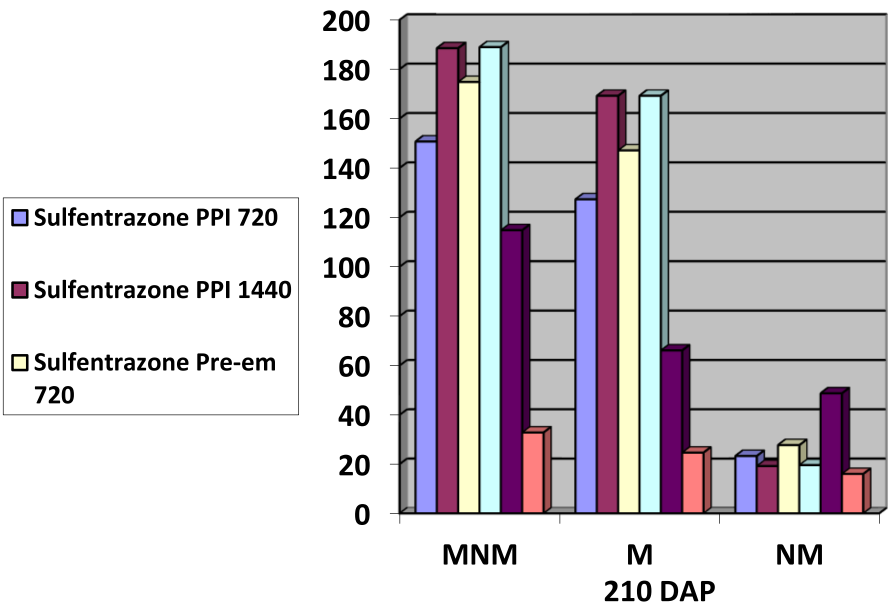

Fig. (4): Effect of sulfentrazone herbicide on number of Millable canes (M), Non –millable canes (NM) and total (MNM) (000.ha^{-1}) of sugarcane at 210 DAP.

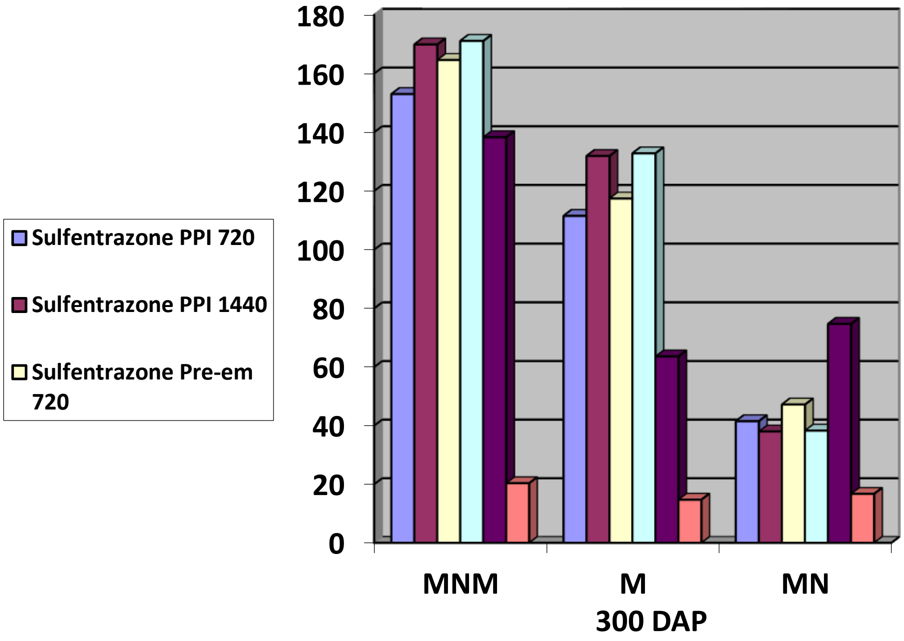

Fig. (5): Effect of sulfentrazone herbicide on number of millable canes (M), Non -millable cans (NM) and total (MNM) (000.ha^{-1}) of sugarcane at 300 DAP.

Cane length (cm)

Sulfentrazone treatments in sugarcane to control weeds registered significant effect on cane length (Fig. 6). Application of sulfentrazone PPI 1440 g a.i.ha^{-1} led to increase in cane length to the highest level to 257 cm.

Cane girth (cm)

Also, Sulfentrazone treatments in sugarcane to control weeds registered significant effect on cane girth (Fig. 7). Application of sulfentrazone PPI 1440 g a.i.ha^{-1} led to increase in cane girth to the highest level to 2.85 cm.

The increase in cane length , cane girth , number of tillers and number of millable canes and decrease in non-millable canes as a result of use of sulfentrazone PPI 1440 g a.i. .ha^{-1} may be due to the role of this treatment in decrease weed density (Table 6) and increase weed control proportion (Fig. 2) and inhibition proportion of dry matter weight (Fig. 3). Causing weakness or absence of competition between the crop and the weeds on the necessary growth requirements such as water, food, light and space. Low of competition on the place may cause an increase in the number of tillers during the different growth stages of sugarcane (Table 9) and that the low of competition on the water and food may cause an increase in number of millable cane (Figs. 4 & 5) while low of competition on the light may cause increased cane girth (Fig. 7).

This means that low or absence of competition between the crop and the weeds because of use of sulfentrazone PPI 1440 g a.i.ha^{-1} has led to the events of these morphological changes of the crop.

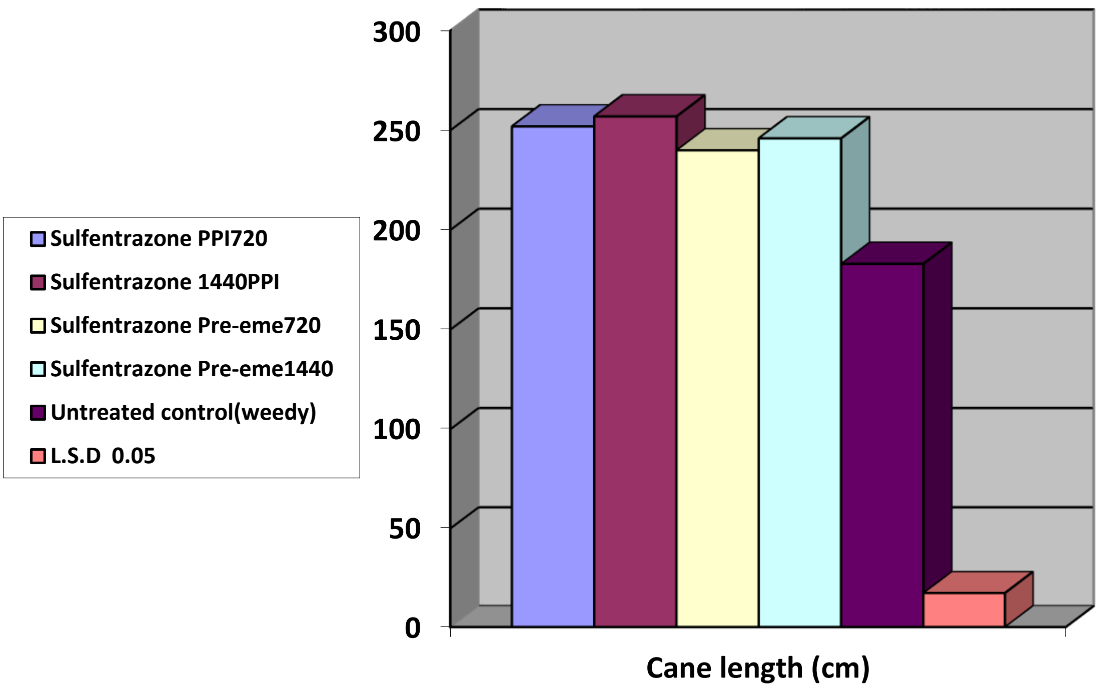

Fig. (6): Effect of sulfentrazone herbicide on cane length (cm) of sugarcane at 330 DAP.

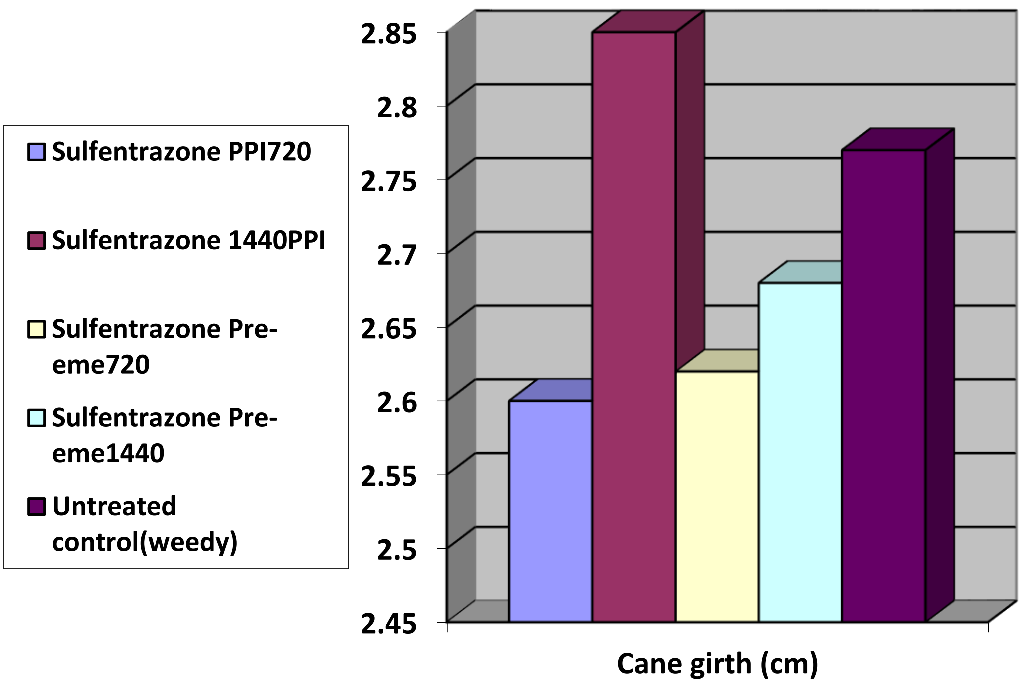

Fig. (7): Effect of sulfentrazone herbicide on cane girth (cm) of Sugarcane at 330 DAP.

Cane yield (t.ha^{-1})

The data presented in table (10) reveals that use of sulfentrazone treatments to control weeds in sugarcane significantly enhanced the cane yield. The use of sulfentrazone PPI 1440 g a.i.ha^{-1} registered the highest cane yield (84.1 t.ha^{-1}) that was significantly higher to the tune of 44.94 % over control.

Table (10): Effect of sulfentrazone herbicide on cane yield and quality characters of sugarcane at 330 days after planting.

Treatments	Time of application	Dose (g a.i.ha^{-1})	Cane yield (t.ha^{-1})	Sucrose (%)	Purity (%)	Sugar yield (t.ha^{-1})
Sulfentrazone	PPI	720	74.3	16.56	87.96	12.325
Sulfentrazone	PPI	1440	84.1	16.48	88.39	13.850
Sulfentrazone	Pre-eme	720	69.1	16.26	88.08	11.225
Sulfentrazone	Pre-eme	1440	80.8	16.73	88.59	13.500
Untreated control(weedy)	-	-	39.2	16.10	88.74	6.300
L.S.D 0.05			5.00	NS	NS	1.03

That the reason increase cane yield by using sulfentrazone PPI 1440 g a.i. .ha^{-1} and sulfentrazone Pre-eme 1440 g a.i.ha^{-1} may be due to role of the herbicide in increasing the number of millable cane since the early stages of crop growth until harvest.

Brix (%)

Use of various weed control methods in sugarcane to control weeds registered no significant effect on Percentage of total soluble solids (Table 10).

Sucrose (%)

Sucrose was not significantly affected by use of various weed control methods (Table 10) .

Purity (%)

Also, the table (10) indicated no significant effect of weed control methods on average of purity of sugarcane .

Sugar yield (t.ha^{-1})

Addition of sulfentrazone treatments significantly affected sugar yield (table 10). Sulfentrazone PPI 1440 g a.i.ha^{-1} and sulfentrazone Pre-eme 1440 g a.i.ha^{-1} caused highest increase in this character to 13.850 and 13.500 t.ha^{-1} respectively.

The reason of increase sugar cane by using sulfentrazone PPI 1440 g a.i. .ha^{-1} may be due to its role in increasing proportion of attendant weed control of sugarcane crop and increase percentage of inhibition of dry matter weight of as well as the role of this herbicide in increasing number of millable canes with no significant differences in percentage of sucrose. All these factors were reflected positively in increasing sugar yield.

Conclusions

The using sulfentrazone PPI 1440 g a.i.ha^{-1} led to even the highest increase in number of tillers, number of millable canes, cane length, cane girth, cane yield and Sugar yield.

Conflict of interest: The authors declare that they have no conflict of interest.

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Conflict of interest: The authors declare that they have no conflict of interest.

References

Almubarak, N.F. (2013). Evaluation of sulfentrazone 48% F for weed control in sugarcane *Succharum officinarum* L. Dissertation of post doctorate research programme. Indian Institute of Sugarcane Research: 1720pp.

Almubarak, N.F.; Al-Chalabi, F.T.; Ala Aljanabi and Singh, I. (2012). Effect of chemical herbicides on growth, yield characters and weeds of sugarcane grown in central region of Iraq. Indian J. Weed Sci., 44(4): 259-26.

Szmigieiski, A.M.; Schoenau, J.J.; Johnson, E.N.; Holm, F.A.; Sapsford, K.L. & Liu, J. (2009). Development of a laboratory bioassay and effect of soil properties on sulfentrazone phytotoxicity in soil. Weed Technol., 23(2): 486-491.

Gosnell, J.M. (1965). Herbicide trials in Natal sugarcane, 1964-65. Proc. S. Afr. Sug. Technol. Ass., 39: 171-181 .

Gosnell, J.M. & Thompson, G.O. (1964). The results of herbicide Trials 1963-64. Proc. S. Afr. Sug. Technol. Ass., 38: 166-174.

Monquero, P.A.; Binha, D.P.; Inácio, E.M.; da Silva, P.V. & do Amaral, L.R. (2011). Selectivity of herbicides in varieties of sugarcane. Bragantia., 70(2): 286-293. (In Portuguese, English abstract).

Ohmes, G.A. & Mueller, T.C. (2007). Sulfentrazone adsorption and mobility in surface soil of the southern United States. Weed Technol., 21: 796-800.

Turner, P.E.T.; Leibbrandt, N.B. & Wiehe, L.H.G. (1990). The phytotoxic effects of herbicides on sugarcane in south Africa. Proceedings of The South African Sugar Technologists' Association. June, 1990: 49-55.

Steel, R.G. & Torrie, J.H. (1980). Principles and procedures of statistics. McGraw Hill Book company. Inc. USA: 485pp.