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Herbicide Management for Sustainable Sugar Cane (*Saccharum officinarum* l.) Production in Sudan

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field investigations were carried out during 2018/19 at Sugarcane Research Center Farm El Guneid, Sudan, in two sites, to evaluate the effect of the combination of chemical herbicides, Ametryne (3.8 L/ha) + Atrazine (3.8 L/ha), Atrazine (3.0 L/ha) + Pendimethalin (2.9 L/ha) and Metribuzin (5.21 L/ha) + Pendimethalin (3.57 L/ha), on common weed control, sugar cane growth, yield and quality. Experimental design was a randomized complete block (RCBD) with three replications. Results revealed that the combination of Metribuzin (5.21 L/ha) + Pendimethalin (3.57 L/ha) recorded the best results in weed control efficiency percent (WCE%) for both grass and broadleaved weeds in sugarcane crop compared to the other treatmentsand the control in the two sites. On the other hand, significant difference of means between treatments was observed in growth parameters and yield of sugar cane at 3, 6 and 9-month ages. Among all treatments the

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combination of Metribuzin (5.21 L/ha)+Pendimethalin (3.57 L/ha) showed the best results, irrespective to parameters compared to the other treatments and the control in the two sites. The mixture of Metribuzin+pendimethalin sustained the highest WCE% for both, grass and broadleaved weeds in addition to increased cane yield and yield component compared to other treatments and the corresponding control. Based on this study, it can be concluded that the herbicide combination provided effective weed control and promoted sugarcane quality and yield. Therefore, the use of herbicides not only increases the net income of farmers, but also demise weeds seed bank.

Keywords: Sugarcane; herbicides; weed management; yield.

1. INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is considered as one of the major strategic crops in Sudan. It is mainly processed into sugar in Kenana Sugar Company owned largely by the private sector, in addition to four other publicly owned factories under the control of the Sudanese Sugar Company. All Sudan sugarcane schemes at Guneid, New Halfa, Sennar, Assalaya, Kenana and White Nile, lie in the central clay plain where abundant flat land and sufficient irrigation water are available [1,2]. The nature of weed problem in sugarcane cultivation is quite different from other crops because it is planted with a relatively wider row spacing and the growth habit of the sugarcane. In the initial stages of sugarcane development, it takes about 30 to 45 days for complete germination, and another 60-75 days for developing full canopy cover. This provides ample opportunity for weed to occupy the vacant spaces between rows and offer serious crop weed competition [3]. Weeds have been estimated to cause 12 to 72% reduction in cane yield, depending upon the severity of infestation [4]. Weed management methods are time consuming and expensive due to increased labor costs [5]. However, with the scarcity of manual labor and intensive crop production, introduction of chemical weed control was necessary to be introduced that replaced traditional weed control measures and more effective in controlling weeds without any adverse effect on cane quality and is time saving [3,6,7].

The main objective of the present study is to evaluate the effects of various chemical herbicides on weed control and plant cane crop growth, yield and quality.

2. MATERIALS AND METHODS

2.1 Experimental Site

A field experiment was conducted for one seasons 2018/19 in two sites,at Sugarcane Research Center at EL Guneid area, about 120 km south east of the capital Khartoum (33^{o} 19″E, 14^{o} 47″N). The climate is tropical arid, the soil of the experimental site was classified as Suleimi soil series which is clayey semioticalluvium, clayey vertisol with moderate soil fertility. The variety tested was Co 6806. Recommended package of practices were followed to raise the crop.

2.2 Chemical Herbicides

Three combination of chemical herbicides; **W_2**; Ametryne (3.8 L/ha)+Atrazine (3.8 L/ha), **W_3**; Atrazine (3.0 L/ha)+Pendimethalin (2.9 L/ha) and **W_4**;Metribuzin (5.21 L/ha)+Pendimethalin (3.57 L/ha) were used.

2.3 Method of Spraying

A knapsack sprayer (CP_3) with a capacity of 16 liter was used for applying herbicides.

2.4 Experimental Design

A Randomized Complete Block Design (RCBD) replicated three times and four treatments.

2.5 Parameters

2.5.1 Weed parameters

Common weed species in the sugarcane field wereidentified and classified into categories by using a quadrat (0.5 m x 0.5 m) to determine the weed density (no m^{-2}), Dry matter percent (DM%) and weed control efficiency percent (WCE%) by using the standard practices applied to determine the average of these weed control parameters.

2.5.2 Sugarcane Growth and Yield Parameters

Cane yield and yield components viz; cane yield (tc ha^{-1}), plant population/ha, cane length, cane diameter and numberof nodes were recorded. The juice quality parameters including total soluble solids cane (brix%), sucrose percent

(pol%), purity% cane and Estimated recoverable sugar (ERS%) weredetermined from juice analyzed according to ICUMSA method methods of analysis [8].

The data collected for the different characters were subjected toanalysis of variance (ANOVA) using the standard procedure of the complete randomize plot design and means separation was done by Duncan Multiple Range Test (DMRT) for the main and interaction effects.

3. RESULTS AND DISCUSSION

3.1 Weed Flora

Results displayed that 15 common weed flora were identified and classified into two categories; grasses and broad-leaved weeds. (Table 1). The most common grass weeds were *Brachiariaercuiformis* (89.3 m^{-2}) and *Echinochloacolonum* (46.9 m^{-2}) while broad leaved weeds include *Ipomoea cordofana* (16.9 m^{-2}), *Corchorusfascicularis* (10.9 m^{-2}), *and Euphorbia convolvuloides* (4.5 m^{-2}) *Rhyncosiamemnonia* (3.5 m^{-2}). The least broad leaved weeds density were *Hibiscus esculentus*, *Tribulusterrestris*, *Ecliptaprostrata*, *Amaranthusgraecizans*, *Sorghum sudanese*, *Digeraalternifolia* and *Phyllanthusniruri*.

3.2 Weed Density m^{-2}

Results showed that among different treatments, the minimum grass weeds density (0.3-0.8 m^{-2}) recorded with application of newly recommended herbicide mixture **W_4** treatment followed by **W_3, W_2** and **W_1** which were3.9-2.5, 39.6-83.0 and 83.7–136.2 m^{-2}, respectively in the two season (Table 2). Also, the minimum broadleaved weeds density (6.3–6.8 m^{-2}) recorded with application of the herbicide mixture of **W_4** treatment followed by **W_3, W_2** and **W_1** which recorded (13.0–13.7, 11.8–13.3 and 47.7–41.5 m^{-2}) respectively in the twoseasons. The weed density results achieved in different treatments may be due to the performance of different combination chemical herbicides applied in the study. the results are line with those of Pratap et al. [9] who concluded that application of Metribuzin herbicide was found most effective in minimizing weeds density (no/m^2) as compared to the corresponding control. The results agreed with Mishra et al. [10] who reported that application of Metribuzin significantly reduced weed density in sugarcane ratoon. Also, similar findings were also reported by Singh et al. [11].

3.3 Dry Matter of Weeds (DMW%)

Experiment results data (Table 2) showed that among different treatments, the minimum DMW% (34.2–36.2 %) recorded with application of newly recommended herbicide mixture of **W_4:** Treatment followed by the other treatments **W_3, W_2** and **W_1** which recorded (52.5–54.1, 53.9–62.6 and 71.2–72.9%), respectively in the two season. The results of DMW% according to the difference in weed density and the performance of the chemical herbicides applied in the study. These results were in agreement with Rana, [12] who reported that application of chemical herbicides for weed control reduced DMW %. Efficacy of metribuzin in controlling weed biomass has also been reported by Mishra et al. [13].

Table 1. Major weed species in experimental field

Scientific Name	Local Name	Weed type	Weed density (m^{-2})
Brachiariaer cuiformis	Um koreaat	Grass	89.3
Echinochloacolonum	Difra	Grass	46.9
Corchorusfascicularis	Khodra	Broadleaved	10.9
Ipomoea cordofana	Tabar	Broadleaved	16.9
Euphorbia convolvuloides	Labana	Broadleaved	4.5
Rhyncosiamemnonia	Adana	Broadleaved	3.5
Phyllanthusniruri	Soreeb	Broadleaved	2.0
Tribulusterrestris	Derassa	Broadleaved	0.9
Digeraalternifolia	Lublab	Broadleaved	0.9
Hibiscus esculentus	Pamea	Broadleaved	0.7
Eclipta prostrate	Tamer Elgnam	Broadleaved	0.3
Trianthemapentandra	Rabaa	Broadleaved	0.1
Amaranthusgraecizans	LisanElteer	Broadleaved	0.1
Sorghum Sudanese	Adar	Broadleaved	0.1

3.4 Weed Control Efficiency (WCE%)

Regarding to weed control efficiency percent (WCE%), results showed that among different treatments, the highest WCE% for grass weeds was 99.6–99.4 % recorded with application of **W_4** treatment followed by the **W_3**, **W_2** and **W_1** which recorded 95.3–98.1, 52.7–39.1 and 0.0–0.0%, respectively in the two site (Table 2). Experiment results achieved for grass weeds control showed that the application of newly recommended herbicide mixture of **W_4** and **W_3** combinations gave excellent results in controlling grass weeds compared to combination herbicides **W_2** and the control. The highest WCE% for broadleaved weeds was 86.7–83.6% recorded with application of **W_4** treatment followed by the other **W_2**, **W_3** and **W_1** which recorded 75.3–67.9, 72.8–66.9 and 0.0– 0.0%, respectively in the two sites. Our results achieved for broadleaved weeds control showed that the application of **W_4** and **W_2** combinations gave excellent results in controlling broadleaved weeds compared to **W_3** combination herbicides and the control. These results might be due to control of initial weed growth due to the application of chemical herbicides. Results revealed that all the weed control methods significantly reduced weed flora and weed biomass as compared to weedy check (Singh et al., [14]. Similar to those of Mishra, et al. [10] who reported that high weed control efficiency (WCE%) as a result of the application of metribuzin herbicide in sugarcane. In general, application of the newly recommended herbicide combination of **W_4** treatment in plant cane crop gave an excellent result in weed control efficiency percent (WCE%) for grass and broadleaved weeds compared to the old recommended herbicide combinations **W_2**, **W_3** and the control in the study. Integration of pre-emergence application of metribuzin or atrazine and post emergence spray of 2,4-D during the most intensive growth period of sugarcane (75 DAP) might have effectively controlled the weeds [15].

3.5 Effects of Chemical Herbicides on Growth, Yield and Quality of Sugarcane

Results showed that all herbicide treatments significantly differ in plant height (cm), number of millable stalks (x1000 ha^{-1}) and cane yield (tc ha^{-1}) compared to the control (Table 4). Among different treatments, the highest cane length was recorded at **W_4**(214.8–209.0cm) compared to the other treatments in two sites. The number of millable canes is one of the most important parameters in cane cultivation deciding the final cane yield. Among different treatments, the highest cane length values (132.9–122.0 x1000) recorded significantly at **W_4** treatment compared to the other treatments and the control. Our results are in line with the work of Tan et al. (1999) who concluded that in weedy check plots, presence of weeds restricted the growth of sugarcane plants.

In regard to cane yield (ton ha^{-1}), the application of **W_4** treatment recorded the highest cane yield values (119.9–122.0 ton ha^{-1}) followed by the other treatments **W_3** and **W_2,** respectively in the two sites.

Table 2. Effects of various chemical herbicides on weed density, weed DM% and WCE%

Experiment Site	Treatments	Weed density (no m^{-2})		Dry Matter percent (DM %)	Weed Control Efficiency Percent (WCE %)	
		Grasses	Broad leaved		Grasses	Broad Leaved
Site 1	W_1	83.7	47.7	71.2	0	0
	W_2	39.6	11.8	53.9	52.7	75.3
	W_3	3.9	13.0	52.5	95.3	72.8
	W_4	0.3	6.3	34.2	99.6	86.7
Site 2	W_1	136.2	41.5	72.9	0	0
	W_2	83.0	13.3	62.6	39.1	67.9
	W_3	2.5	13.7	54.1	98.1	66.9
	W_4	0.8	6.8	36.2	99.4	83.6

W_1: un-weeded (control) W_2 :(Ametryne3.8 L/ha + Atrazine 3.8 L/ha), W_3 :(Atrazine3.0 L/ha + pendimethalin 2.9 L/ha) and W_2 :(Metribuzin 5.21 L/ha + pendimethalin 3.57 L/ha)

Table 3. Effects of various chemical herbicides on plant cane growth parameters

Site	Treatments	Plant height (cm)			No of tillers/m^2			No of internodes		
		Monthly								
		3	6	9	3	6	9	3	6	9
Site 1	W_1	28.4b	57.0c	164.2c	9.8b	12.0b	14.6b	0.0a	2.0b	11.0b
	W_2	31.4b	60.6bc	169.4bc	10.8ab	12.8ab	15.8a	0.0a	3.4a	12.4ab
	W_3	47.8a	72.6a	174.8b	11.8a	13.2a	15.8ab	0.0a	3.0ab	12.2a
	W_4	48.0a	75.8a	185.8a	12.2a	14.0a	16.0a	0.0a	4.0a	13.2a
	Mean	38.9	66.5	173.6	11.2	13.0	15.4	0.0	3.1	12.2
	CV%	17.0	13.4	2.8	12.1	10.2	4.9	0.0	2.3	10.6
	LSD(0.05)	9.1	12.2	6.8	1.9	1.8	1.0	0.0	1.3	1.8
Site 2	W_1	31.4b	62.6c	171.6c	8.6b	12.0 b	14.0 b	0.0a	3.2a	9.2b
	W_2	36.4b	66.0bc	178.4b	9.6ab	12.8ab	15.6ab	0.0a	3.4a	11.0a
	W_3	51.0a	78.0ab	184.0b	9.8ab	12.9ab	15.4ab	0.0a	3.6a	10.6ab
	W_4	52.0a	81.2a	193.8a	10.2a	14.6a	16.0 a	0.0a	4.2a	11.8a
	Mean	42.7	72.0	182.0	9.6	12.5	15.3	0.0	3.6	10.7
	CV%	12.3	12.7	2.6	11.4	7.5	5.3	0.0	2.8	11.3
	LSD(0.05)	7.3	12.6	6.4	1.5	1.3	1.1	0.0	1.1	1.7

***W_1:**Un weeded (control), **W_2:**Ametryne3.8 L/ha + Atrazine 3.8 L/ha,**W_3:** Atrazine 3.0 L/ha + Pendimethalin2.9 L/ha and **W_4:**Metribuzin5.21 L/ha + Pendimethalin3.6 L/ha.*

Table 4. Effects of various chemical herbicides on yield and quality of plantcane crop

Parameters	Site one				LSD	Site two				LSD
	W_1	W_2	W_3	W_4	(0.05)	W_1	W_2	W_3	W_4	(0.05)
Cane length (cm)	154.3^d	170.6^c	198.0^b	214.8^a	11.9	159.6^b	161.3^b	196.4^a	209.0^a	18.9
Cane diameter (cm)	2.0^a	2.0^a	2.1^a	2.1^a	0.1	2.1^a	2.1^a	2.0^a	2.0^a	0.2
Millable stalks (x1000 ha^{-1})	64.3^b	86.3^b	94.5^{ab}	132.9^a	45.9	63.1^c	63.7^c	93.9^b	111.3^a	14.3
Cane yield (tc ha^{-1})	89.9^c	72.0^c	96.1^b	119.9^a	18.3	70.1^c	76.3b^c	101.9^{ab}	122.0^a	26.0
Pol % cane	12.5^b	12.7^{ab}	12.7^{ab}	12.9^a	0.3	12.6^a	12.6^a	12.6^a	12.9^a	0.4
Purity% cane	88.6^{ab}	8.4^{ab}	88.2^b	89.6^a	1.1	89.0^a	89.1^a	87.2^a	89.1^a	3.5
Fiber% cane	18.6^a	18.4^a	18.8^a	18.2^a	0.8	18.7^a	18.4^a	18.7^a	18.2^a	1.5
Sugar yield (ts ha^{-1})	7.7^b	8.0^b	11.2^a	10.9^a	1.8	6.7^c	7.3^c	9.7^b	12.0^a	2.0

With respect to cane quality parameters, there was no significant difference between herbicide treatments on all cane quality parameters except for sugar yield (ton ha^{-1}). For sugar yield (ton ha^{-1}), **W_4** treatment recorded the highest cane yield (11.2–12.0 tc ha^{-1}) followed by the other treatments **W_3**, **W_2** respectively, irrespective to the site. The achieved results are attributed to the importance of chemical herbicides applications for weed control in sugarcane fields resulting in an increase in cane and sugar yields. The results are in line with those of Devi et al. [16] who reported that application of Metribuzin was effective in controlling weeds and had favorable influence on growth, yield and quality of sugarcane. Also, these results are similar to those of Pratap et al. [9] concluded that application of Metribuzin herbicide was found to be most effective in controlling weeds of sugarcane ratoon crop which resulted in increasing cane yield. Regarding the phytotoxicity, the tested herbicides showed visible phytotoxic effects on sugarcane plants. After the application of the W $_2$ herbicide combination, phytotoxic effect on sugarcane development was obvious throughout the first 4 weeks of sugarcane growth. These effects were reduced within 8 and 12 weeks after the application.

Weed species and habitat are the major criteria required for weed management in the field. The experimental results from Table (3) showed that there was a significant difference in average values between treatments in all growth parameters; (plant height, no of tillers/m^2 and no

of internodes) at 3 , 6 and 9 month ages. The new combination of chemical herbicides, Treatment **W_4** recorded the highest values in plant height, No. of tillers/m^2 and No. of internodes at 3, 6 and 9 months age, compared to the old recommended chemical herbicide treatment and the untreated control in both experimental sites. Aekrathok et al. [17] reported that Paraquat proved more effective in weed control than Ametryn for tillering and Agronomy 2021, 11, 429 6 of 19 stalk elongation stage on sugarcane at every assessment period. Richardson [18] reported that the growth stages of sugarcane at the time of herbicide application and the method of application, both play an essential role in determining the degree of phytotoxicity within of the cane.

These results are in agreement with the findings of Srivastava and Chauhan [19] Un treated control plot sustained the lowest number of millable canes and cane yield on account of higher competition by the weeds for the resources to be utilized by the sugarcane crop in the weed free environment. Similar findings has also been reported by Chitkala Devi et. al. [15].

4. CONCLUSIONS

It could be concluded that, the newly recommended herbicide mixture of (Metribuzin+pendimethalin) provided the best results in weed control efficiency percent (WCE%) for both, grass and broadleaved weeds and gave the highest cane and sugar yield compared to the old recommended herbicide mixture of (Ametryne+Atrazine) and (Atrazine+Pendimethalin) and the untreated control. Based on this study, it can be concluded that the herbicide combination provided effective weed control and promoted sugarcane quality and yield. Therefore, the use of herbicides not only increases the net income of farmers, but also demise weeds seed bank.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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