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Efficacy and Selectivity of Pendimethalin, Diuron and their Mixtures for Weed Control in Sesame (*Sesamum indicum* L.), Gezira State, Sudan

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Abstract: *Sesame is the one of the most important oil crop in Sudan as a raw material for industry and a leading export crop. Weed infestation is one of the major factors limiting the yield of sesame. The objective of this study was to evaluate the efficacy and selectivity of pendimethalin (Agrimethalin 50% EC) diuron (Easy 80%WDG), and their combinations on weed control in sesame. An experiment was carried out at Gezira Research Station Farm (GRSF), Wad Medani, Sudan. The herbicides pendimethalin at two rates (1.92 and 2.4 kg a.i./ha), diuron at two rates (0.36 and 0.48 kg a.i./ha) and their mixtures at (1.93+0.36 and 2.40+0.36 kg a.i./ha), were applied as pre-emergence. Weeded and unweeded treatments were added for comparison. The treatments were arranged in a Randomized Complete Block Design (RCBD) with four replicates. Pendimethalin at the rate of 1.93 kg a.i./ha gave good control of grassy weeds (71-75%) 4 and 8weeks after sowing (WAS), while the rate of 2.4 kg a.i./ha gave (87%-93%) grass weed control throughout the growing season. Diuron at the two rates tested gave 75%- 86% broadleaved weed control four weeks after sowing. The tank mixture of diuron with pendimethalin at the rate 1.93+0.36kg a.i./ha gave 81% -93% grassy weeds control and 67%-82% broadleaved weed control. Pendimethalin at 2.4 kg a.i./ha and its mixture with diuron at 2.4+0.36 kg a.i./ha reduced sesame plant population by 43% and 28%, respectively. Diuron at 0.48 kg a.i./ha and its mixture with pendimethalin at 1.93+0.36 kg a.i./ha produced significantly high seed yields, and minimized losses due to weeds by 25%-29% as compared to un weeded control (81%). Depending on the results of this study, a weed management program which includes a pre-emergence application of diuron alone or in tank mixture with pendimethalin could be recommended to obtain an early weed free period and high yield of sesame.*

Keywords: Sesame, weed control, herbicides, diuron

(1) INTRODUCTION

Sesame (*Sesamum indicum* L.) is an annual plant that belongs to the family Pedaliaceae. It is one of the world's oldest oil seed crop grown mainly for its high oil contents [1,2]. In Sudan, sesame is the one of the most important oil crop beside groundnut and sunflower and coming third in cultivated area after sorghum and millet particularly at rain fed sector. Sesame plant is very sensitive to environmental conditions and a biotic stress factor, which cause quantitative and qualitative reduction in [3].

Reference [4] stated that the critical period of weed/crop competition in sesame is between 30 and 10 days after seedling emergence. Some studies reported yield reduction in the oil yield by 70% under weedy conditions as compared to grain yield under two hand weeding at 20 and 40 days after sowing [5].

Presence of weeds throw the growing season can cause significant reduction in plant height, number of branches, number of capsules, seeds per capsules, weight and seed yield [6].

The conventional method for weed control like manual weeding and hand hoeing is the common practice to control weeds in sesame. But, it is expensive and labor intensive especially at the critical period of weed competition. Most of the herbicides applied for weed control in sesame in Sudan are post emergence herbicides and with the few pre-emergent herbicides registered for use in sesame in Sudan; there is an urgent need to search for a selective pre-emergent herbicides for weed control in sesame. Therefore, this study aimed to evaluate the efficacy and selectivity of pendimethalin, diuron and their combination on weed control in sesame.

(2) MATERIALS AND METHODS

2.1 Experimental site

A field experiment was conducted at the Gezira Research Station Farm, Wad Medani (latitude. 14° 24` N, longitude. 33° 29´ E) during (2017/18) summer season. The soil of the farm is a heavy cracking vertisol with clay contents of 55-58%. It has an alkaline reaction (pH = 8.1), low in nitrogen (300-400 ppm) and organic carbon (0.5%) [7].

2.2 Field methods

The experimental plots were disc ploughed, harrowed, leveled and ridged at 80cm width. Sesame; variety Bromo was sown on the top of the 80 cm ridge by drilling. The sowing date was the 3rd week of July 2017. The crop was irrigated at 15 days interval or when it was needed. Plants were thinned to a single plant/hole (5cm between plants) four weeks after sowing. Nitrogen, as urea, was applied 30 days after plant emergence and before thinning at 95.2 Kg N/ha (40kg N/fed) immediately before the third irrigation. The experiment was laid out in a randomized complete block design (RCBD) with 12 treatments and 4 replicates. Two

herbicides; pendimethalin at (1.93 and 2.40 kg a.i/ha), diuron at (0.36 and 0.48 kg a.i/ha) and their mixtures at (1.93+0.36 and 2.40+0.36 kg a.i/ha) were tested as pre-emergence treatments as aqueous solution by Knapsack sprayer which calibrated to deliver 230 l/ha. The plot size was 4.5 x 10m. Each plot comprised 10 m long 5 ridges. The unweeded and hand-weeded treatments were also included for comparison. The hand weeding was done manually whereby emerging weeds removed by hand biweekly during the whole season, while the unweeded treatment was kept weedy the whole season.

2.3 Data collection

2.3.1 Weed count

The effects of herbicide treatments on weeds were assessed by counting total and individual weed species in 5 fixed quadrates (25 x 40 cm) and percent ground covered by weeds at 4 and 8 weeks after sowing (WAS) henceforth referred to as early and late season weeds, respectively.

The percentage weed ground cover was estimated visually at both the 4 and 8 WAS. The percentage control of grassy and broadleaf weeds, as compared with the weedy check for each treatment was calculated according to the formula:

$$\frac{Wx - Wy}{Wx} \times 100$$

Where: *Wx*= number of weeds in un-weeded control.

Wy= number of weeds in herbicide treatment.

The scale of weed control was: 0-49 = poor control, 50-59 = moderate, 60-69 = satisfactory, 70-79 = good and 80 ≥ excellent weed control. At harvest weeds from 1m² in each plot, were cut, air dried and weighed (weed biomass).

2.3.2 Yield and yield components

2.3.2.1 Plant height (cm)

Five plants were selected randomly and the height of each plant was measured from the ground level to the tip of the plant. The average height of the five plants was then calculated.

2.3.2.2 Plant population

Plant population in each plot (the harvested area $1m^2$) were counted and converted into Plant /ha.

2.3.2.3 Number of branches per plant

Five plants were selected randomly and the number of primary branches in each plant was counted. The average number of the total primary branches/plant was calculated.

2.3.2.4 Number of capsules per plant

Five plants were selected randomly and the number of capsules in each plant was counted.

2.3.2.5 Yield

At physiological maturity, when the plant started to turn yellow and dry, crop in each plot was harvested separately. After discarding 1m from each side, the central ridge from each plot was harvested. The harvested areas from each plot were 1.25 ×0.8 (1 m^2). The yield in each plot was then weighed and converted to kg/ha by calculation.

2.3.2.6 Grain yield

The harvested area was threshed and the grain yield was weighed. The grain yield converted into Kg/ha by calculation.

2.3.2.7 Thousand seeds weight (g)

From the seed yield of each net plot, 1000 seeds were randomly counted and weight was recorded. This weight was taken as 1000 seed weight and expressed in gram.

2.4 Data analysis

The standard analysis of variance procedure (ANOVA) for the randomized complete block design was used to analyze the collected data using STATCIC. Means were statically separated using LSD. For mean separation at $p < 0.05$ coefficient of variation (CV) was computed.

(3) RESULTS

3.1 Weed flora of the experimental site

High infestation of broadleaved weeds dominated the experimental plots throughout the growing season with *Ipomoea cordofana, Ocimum basilicum, Corchorus* spp., and *Digera muricata,* being the main species. Whereas, grassy weeds showed moderate infestation at 4 and 8 WAS, the most prevalent grass weeds in the 4 and 8 WAS include, *Setaria pallide-fusca, Ischaemum afrum.* However, other grasses emerged late in the growing season showing moderate infestation include, *Panicum hygrocharis, Dinebra retroflexa* and *Eragrostis diphicantia*. Low infestation was observed in broad leaf weeds (*Sonchus corntus, Tephrosi suniflora, Aristolochia bracteolate, Boerhavia repens, Phyllanthus mederaspatensis, Euphorbia aegyptiaca* and *Heliotropium sudanicum*) and grassy weeds (*Sorghum arundinaceum, Echinochlo acolona,* and *Commelina kotschyi*) which were minimized in response to herbicide treatments.

3.2 Effect of herbicides treatments on total weeds control

As listed in table 1pendimethalin at 1.93-2.4 kg a.i./ha, gave 46-55% total weed control and 18-45% at the rate of 1.93-2.4 kg a.i./ha 4 and 8 WAS. Diuron at 0.36 kg a.i./ha gave 21-52%and 77-76% total weed control early and late in the season, while the tank mixture of pendimethalin and diuron at the rates tested gave satisfactory weed control throughout the growing season (58-70%)(63-68%) respectively.

3.3 Effect of herbicides treatments on individual dominant weed species

Data presented in table 2 showed that Pendimethalin perform poor activity against I. *cordofana*(15%) at the two rates, satisfactory control (63%) for *Ocimum basilicum* at the rate of 1.93 kg a.i./ha and good control (75%) at the rate of 2.40 kg.a.i/ha. On the other hand pendimethalin at the two tested rates did not minimize infestation of *D. muricata* and gave poor control of *S. pallide-fusca* (20-40%) at the two rates.

Diuron showed poor control (25%) for I. *cordofana*at the two rates but, excellent control (88%) at the rate of 0.48 kg.ai/ha. Effect of diuron on the control of *Digera* was poor (7%) at the rate of 0.36 kg a.i./ha and excellent control (100%) at the rate of 0.48 kg a.i./ha and gave 40-70% weed control for *S.pallide-fusca*. While the tank mixture of

pendimethalin and diuron at the high rate performs excellent control (100%) for dominant weed species except of I. *cordofana*.

3.4 Effect of the herbicides treatments on broadleaved and grassy weeds control

Diuron at the rate of 0.36 kg a.i./ha gave 75% control of broadleaf weeds early in the season and 51% late in the season. While the rate of 0.48 kg a.i./ha gave excellent control 86% of broadleaf weeds early in the season and 51% late in the season.

Diuron in the tank mixture with pendimethalin at the rate of 1.93+0.36 kg a.i./ha gave excellent control of broadleaf weeds (82%) early in the season and good control (72%) late in the season. While the rate of 2.40+0.36 kg a.i./ha gave good control (79%) early season and moderate control (57%) late in the season.

Pendimethalin at the rate of 1.93 kg a.i./ha gave good control (71-75%) 4 and 8 WAS as shown in (table 7). While the rate of 2.40 kg a.i./ha gave 71%at 4 WAS and 87% at 8 WAS. The tank mixture of pendimethalin and diuron at the rate of 1.93+0.36 kg a.i./ha gave excellent control for grassy weeds at 4 and 8 WAS (81%-93%), while the rate of 2.40+0.36 kg a.i./ha gave excellent control (81%) early and good control (71%) late in the season (Table 3).

3.5 Effect of the herbicides treatments on weed ground cover percentage and dry weight

All herbicides treatments reduced weed ground cover percentage, respectively. Pendimethalin at 1.93 kg a.i/ha resulted in low weed ground cover 18-46% and 27.5-48% at the rate of 2.4 kg a.i./ha 4 and 8 WAS. Diuron at 0.48 kg a.i./ha gave the lowest weed ground cover percentage (5.2%) compared to the un-weeded control (33%) 4WAS and 28% compare to 70% (un-weeded control) 8WAS. Whereas, the tank mixture of pendimethalin and diuron at 1.93+0.36 kg a.i./ha gave18-32% early and late in the season and 12-42% weed ground cover at 2.4+0.36kg a.i./ha kg a.i./ha.

The total dry weight of weeds significantly varied due to different herbicides treatments throughout the growing season (Table 4). There were significant differences in weeds dry weight between herbicides treatments. Pendimethalin at the two rates gave highest weed dry weight (470 and 635 g/m^2). Diuron at the two rates gave 186.7-522.5 g/m^2.Diuronin tank mixture with pendimethalin at the two rates tested, significantly reduced total dry weight of weeds by 60%-77% and 37%-53%, respectively.

3.6 Effect of the herbicides treatments on sesame

3.6.1 Effect of the herbicides treatments on phyto-toxcicity and plant population

Pendimethalin at 2.4 kg a.i./ha and pendimethalin mixture with diuron at 2.4+0.36 kg a.i./ha reduced sesame plant population by 43% and 28%, respectively. Diuron caused slight yellowing on the leaves which disappeared after few days but it did not reduce sesame population significantly (Table 5).

3.6.2 Effect of the herbicides treatments on plant height

All herbicides treatments showed no significant adverse effect on plant height compare to the control.

3.6.3 Effect of the herbicides treatments on number of branches per plant

The results showed that unrestricted weed growth for the whole season reduced the number of branches per plant of sesame by 33.3% as compared to hand-weeded control. Diuron at the rate of 0.48 kg a.i./ha and their tank mixture with pendimethalin gave highest number of branches/ plant (Table 5).

3.6.4 Effect of the herbicides treatments on number of capsules per plant

Unrestricted weeds growth significantly reduced the number of capsules/plant by 30% (table 9). The herbicide diuron in tank mixture with pendimethalin gave highest number of capsules per plant (52) comparable to the number of capsules per plant to that of hand weeded control (25) (Table 5).

3.6.5 Effect of herbicide treatments on sesame seed weight and yield

The results presented in table 6 revealed that uncontrolled weeds reduced sesame yield by 81% compare to the hand-weeded control. There is no significant difference between all herbicides treatments and the control in 1000 seed weight. The highest seed yield (670 kg/ha) was obtained by hand weeding control and the lowest seed yield (127 kg/ha) recorded in the weedy check. Herbicide treatments significantly increased sesame seed yield compared to un-weeded control. The highest yield (505 kg/ha) was obtained by application of diuron at 0.48 kg a.i./ha, followed by (475 kg/ha) was obtained by the application of tank mixture of diuron and pendimethalin at the rate of (1.93+0.36) kg ai/ha.

(4) Discussion

The predominant weeds in the experimental site were mainly broadleaved weeds. The study showed that, herbicide treatment diuron displayed good control 65% at the low rate and excellent control 86% against broadleaved weeds at the high rate early in the season.

Since broadleaved weeds are the majority of the total weeds, their performance against total weeds were excellent. Pendimethalin at the low rate gave good control 75% for grasses and the high rate gave excellent control 93% early in the season.

Diuron, when used in tank mixture with pendimethalin, showed excellent performance 81%-93% against grasses and good to excellent control of broadleaved weeds 79%-82%. This was reflected on growth and yield of sesame. On the other hand the herbicide treatments of pendimethalin displayed excellent control 81%against grasses, but, its performance against total weeds was poor 18%-46% and hence the growth and yield of sesame was greatly affected comparable with the weeded control. Unrestricted weed growth reduced growth and yield of sesame by 81%. These results are in agreement with the finding of Elkhawad who reported that unrestricted weed growth decreased sesame grain yield by 85% [8].

It is important to realize that there are many pre-emergence herbicides such as pendimethalin and diuron used in sesame growing regions worldwide reduce sesame populations [9,10]. These herbicides act differently under certain environmental conditions. The results obtained in this study revealed that pendimethalin at 2.4 kg a.i./ha and pendimethalin mixture with diuron at 2.4+0.36 kg a.i./ha reduced sesame plant population by 43% and 28%, respectively. These results are in agreement with the results that obtained by Viera who found that diuron mixtures (0.8, 1.0, and 1.3 kg/ha) with pendimethalin and alachlor caused greater phytotoxicity with the greatest dose [11].

Other treatments were slightly phytotoxic on sesame plant. In most of the herbicides treatments tested worldwide there are few herbicides that do not affect sesame plant population and yield; however, it is clear that growth and yield of sesame could be reduced by 81% in weedy conditions. Therefore, some damage should be acceptable and with this minimal damage to the sesame, some of the tested herbicides produced significantly high economic yields as compared to un-weeded control.

(5) Conclusion

The results of the study showed that the herbicide treatments Diuron gave excellent control for broadleaved weeds in sesame and its tank mixture with pendimethalin gave good to excellent control of both grasses and broadleaved weeds and hence increased sesame yield.

Table 1. Effect of herbicides treatments on total weeds control

Treatments	Herbicides rate (Kg a.i./ha)	Weed control (%) Total weeds	
		4WAS	8WAS
Pendimethalin	1.93	46	55
	2.40	18	45
Diuron	0.36	21	52
	0.48	77	76
Pendimethalin+Diuron	1.93+0.36	58	70
	2.40+0.36	68	63
Hand weeded control	-	100	100
Un-weeded control	-	-	-

Table 2. Effect of herbicides treatments on individual weed species

Treatments	**Herbicides rate (Kg a.i./ha)**	**% Weed control**			
		Ipomea cordofana **(تبر)**	***Ocimumbacilicum*** **(ريحان)**	***Digera muricata*** **(لبلاب احمر)**	***Steria pallide-fusca*** **(لصيق)**
Pendimethalin	1.93	15	75	0	20
	2.40	0	63	0	40
Diuron	0.36	0	25	7	40
	0.48	35	88	100	100
Pendimethalin+ Diuron	1.93+0.36	46	100	73	40
	2.40+0.36	0	100	100	100

Table 3. Effect of the herbicide treatments on annual grasses and broad leaved control

Treatments	Herbicides rate (Kg.ai/ha)	Control%			
		Grasses		Broadleaved	
		4WAS	8WAS	4WAS	8WAS
Pendimethalin	1.93	75	71	50	39
	2.40	93	87	46	34
Diuron	0.36	54	37	75	51
	0.48	78	53	86	61
Pendimethalin+ Diuron	1.93+0.36	93	81	82	67
	2.40+0.36	81	73	79	57
Hand weeded control	-	-	-	-	-
Un-weeded control	-	-	-	-	-

Table 4. Effect of herbicide treatments on weed ground cover and weed dry weight

Treatments	Herbicides rate (Kg.ai/ha)	Weed ground cover (%) 4WAS	8WAS	weed dry weight (g/m^2)
Pendimethalin	1.93	18	46	470bc
	2.40	27.5	48	635a
Diuron	0.36	31	50	233.5de
	0.48	5.2	28	186.75e
Pendimethalin+Diuron	1.93+0.36	18	32	370cd
	2.40+0.36	12	42	272de
Un-weeded control	-	33	70	585ab
SE±	-	-	-	**49.655**
CV %	-	-	-	**24.65 %**

*WAS weeks after sowing
* Means in the same column followed by the same letter(s) are not significantly different at P 0.05DMRT.

Table 5. Effects of pre–emergence herbicides for weed control in sesame characteristics

Treatments	Herbicides rate (Kg a.i./ha)	plant population (plant/ha)	Plant height	No of branches/ plant	No of capsules/ plant
Pendimethalin	1.93	240.000 ab	85.25 ab	4.25 ab	22.50 cd
	2.40	150.000 cd	88.75 ab	3.75 ab	25.25 cd
Diuron	0.36	245.000 ab	76.00 b	4.00 ab	25.50 cd
	0.48	195.000 abc	103.50 ab	4.75 a	29.50 bcd
	1.93+0.36	217.500 abc	112.00 a	4.75 a	36.50 bc

Pendimethalin+Diuron	2.40+0.36	190.000 bcd	102.25 ab	4.50 ab	52.50 a
Hand weeded control		265.000 a	85.25 ab	4.50 ab	25.25 cd
Un-weeded control		222.500 abc	77.25 b	3.00 b	17.75 d
SE±		**21896**	**10.324**	**0.5563**	**5.4083**
CV%		**26.08%**	**23.07%**	**26.31%**	**37.11%**

* Means in the same column followed by the same letter(s) are not significantly different according to least significant difference test (LSD) at $P \leq 0.05$.

Table 6. Effect of pre-emergence herbicides treatment on 1000 seed weight and sesame yield

Treatments	Herbicides rate (Kg a.i./ha)	1000 seed weight(g)	seed yield(Kg/ha)
Pendimethalin	1.93	3.3	327.50 bc
	2.40	3.0	220.00 cd
Diuron	0.36	3.1	227.50 cd
	0.48	3.3	505.00 ab
Pendimethalin+Diuron	1.93+0.36	3.3	475.00 b
	2.40+0.36	3.3	355.00 bc
Hand weeded control		3.2	670.00 a
Un-weeded control		3.1	127.50 d
SE±		**0.0775**	**61.764**
CV%		**4.82%**	**35.96%**

* Means in the same column followed by the same letter(s) are not significantly different according to least significant difference test (LSD) at $P \leq 0.05$.

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