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Research Article

Growth and Tolerance of Sesame (*Sesamum indicum* L.) Varieties to Pre and Postemergence Graminicides

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The use of herbicides for weed control in arable crop production is known to be fast and effective. However, there is paucity of information on the safety of commonly used grass herbicides on emergence, growth, and productivity of sesame (*Sesamum indicum* L.) genotypes currently being grown in Zimbabwe. A study was carried out in Zimbabwe during the 2017/18 cropping season in Gokwe South to evaluate the effect of alachlor, metolachlor, propaquizafop, and fluazifop-p-butyl on seed germination, growth, and yield of three sesame genotypes, namely, IETC, Lind 02, and Ziada 94. A laboratory experiment was laid in a completely randomised design with genotype and herbicide type as the factors. Seed germination, radicle, and plumule length were recorded at the end of the experiment. In the pot studies, two separate experiments were carried out to evaluate the effect of pre and postemergence herbicides on 50% emergence, plant height, number of branches, 50% flowering, number of pods, and yield of three sesame genotypes. The laboratory experiment results revealed significant ($p < 0.05$) interactions among varieties and preemergence graminicides for germination percentage, radicle length, plumule length, and germination vigor index. Alachlor and metolachlor differentially reduced all germination parameters in the sesame genotypes used in the study. In the preemergence pot studies, there were significant ($p < 0.05$) interactions on 50% emergence, plant height, and number of branches but not on number of pods and yield. Metolachlor significantly reduced all the measured parameters in IETC and Ziada 94. In the postemergence pot study, propaquizafop significantly ($p < 0.05$) reduced plant height, number of pods, and yield of sesame more than fluazifop-p-butyl and hand pulling. It can be concluded that metolachlor and propaquizafop are not safe for use in these sesame genotypes at dosage rates that were used in this study. There is need for further screening of more sesame genotypes for tolerance to these and other commonly used genotypes to avoid unintentional phytotoxic damage on sesame.

1. Introduction

Sesame (*Sesamum indicum* L.) belongs to the family Pedaliaceae that is also known to have 60 species of different genotypes. It is drought tolerant but is susceptible to water logging and excessive rainfall [1]. The crop is adapted to a wide range of soils, but does well in deep, well drained, fertile sandy loams [2]. Sesame suffers from severe stress due to weed interference during its early growth stages reducing yield by 65% [3]. This is because sesame is a slow starter that does not tolerate weed interference during the early vegetative phase of its growth. This makes it a very poor competitor when grown in weedy environments, which concomitantly results in reduced growth and low yields [4, 5]. Hence, a critical weed free period of up to 50 days after crop emergence should be observed [6].

Smallholder sesame farmers rely predominantly on hand hoeing and ox-drawn cultivators to control weeds at the early stages of plant growth [7]. These methods are time consuming, labour intensive, and less effective under wet conditions because the weeds may reestablish a few days after weeding. Delayed weeding in production systems that rely solely on mechanical and manual weed control methods results in low crop productivity because farmers prefer to plant in new areas and crops that would have been sown early are usually neglected [8].

Bhadauria et al. [9] and Kujur et al. [10] advocated for the use of herbicides in sesame production to curb these challenges. Application of herbicides proved to be more effective and efficient on checking early weed competition between crops and weeds leading to higher yields compared to manual weed control methods. Moreover, Anil and Thakur [11] reported that selective herbicides applied as an alternative to hand weeding are cost effective, easy to apply, and less persistent in soils. However, in Zimbabwe, chemical weed control has been mainly used in commercial farming to control weeds in maize (*Zea mays* L.) with only 5% of the smallholder farmers reported to be using herbicides [12, 13]. The use of graminicides can be an effective strategy to curb the negative effects of weeds during the early vegetative stage of sesame. It has been noted that smallholder farmers in Zimbabwe lack adequate basic information on herbicide technology predisposing them to fears and lack of confidence on herbicide use [14]. In addition, there are no herbicides registered for weed control in sesame production in Zimbabwe [15] making it difficult for farmers to make informed decisions on herbicide use in this crop.

Owing to the mentioned reasons, it is posited that herbicides that are commercially labeled for controlling weeds in other oil seed crops such as cotton (*Gossypium hirsutum* L.), soyabeans (*Glycine max* L.), and groundnuts (*Arachis hypogaea* L.) can be safely used in sesame' they all belong to the same morphological class. Therefore, the pre and postemergence graminicides (grass killing herbicides), at larger extent meant for broad leaved crops, were used in this study. There is scarcity of information on the response of sesame varieties to locally available pre and postemergence graminicides registered in Zimbabwe, hence the need to evaluate their response to these herbicides. This study was carried out to evaluate the effects of lasso (alachlor), dual (metolachlor), propaquizafop (propaquizafop), and fusilade (fluazifop-p-butyl) on sesame germination, growth, and productivity of three sesame genotypes.

2. Materials and Methods

2.1. Study Site Description. The experiment was carried in Musauki village in ward 16 of Gokwe South District in the Midlands Province of Zimbabwe. This site is situated at an altitude of 1225 meters above sea level, longitude of 18°.32′147″, and latitudes of 29°.10′889″. The site has sandy loam soils. The area is in agroecological region IV that receives an average annual rainfall of 450–650 mm per annum. The mean temperature is 25°C with significant frost occurring in June up to early August. The region has got a semiextensive farming system with low and periodic droughts and severe dry spells during the rainy season [16].

2.1.1. Laboratory Experiment. The effects of metolachlor and alachlor on germination parameters of three sesame seed varieties are given in this section.

The experiment was arranged in a 3×3 factorial structure in a completely randomized design (CRD) with four replications. The first factor was variety with three varieties which were Ziada 94, Lindi 02, and IETC. The second factor was herbicides type with three levels that were metolachlor, alachlor, and distilled water (control). Alachlor and metolachlor were applied at a rate of 1.4 and 0.5 L active ingredient (a.i.) ha^{-1}, respectively.

2.2. Petri Dish Medium Preparations and Management. The study was carried out in 90 mm diameter Petri dishes lined with two Whatman number 1 filter papers. Twenty-five seeds were placed in each Petri dish and wetted with 10 ml of the respective treatments. Thereafter, the Petri dishes were sealed with parafilm and placed in an incubator with night and day temperature set at 20 and 30°C, respectively, for five days. Seed germination data were recorded on day seven by counting seeds that had a protruded radicle. The germination data were used to calculate germination percentage (G%).

2.2.1. Pot Studies. Effect of pre and postemergence herbicides on germination, growth, and productivity of sesame varieties.

2.3. Experimental Design and Treatments. The pot experiments were arranged in a 3°×°3 factorial structure in CRD with treatments replicated four times. The first factor was genotype with three levels, Ziada 94, Lind 02, and IETC. The second factor was three herbicides types. The pre and postemergence pot experiments were carried out separately. In the preemergence, the herbicides used included metolachlor (0.5 litres a.i ha^{-1}) and alachlor (1.4 litres a.i ha^{-1}), whereas fluazifop-p-butyl (225 g a.i. ha^{-1}) and propaquizafop (100 g a.i. ha^{-1}) were used in the postemergence pot experiment. In both cases, hand pulling was used as the control.

2.4. Polythene Bags (Pots) Soil Preparation. Sandy soil used in the pot experiments was collected from a field where herbicides had never been used before. Sixty perforated polythene bags measuring 400×250 mm were three quarter filled with soil. Thereafter, 2.25 g of basal compound D (7% N; 14% P_2O_5; and 7% K_2O) was mixed with soil in each polythene bag to attain the blanket application rate of 200 kg·ha^{-1}. Twenty-five seeds were planted in each polythene bag at a depth of 20 mm. Subsequently, all the pots were watered to field capacity using a watering can fitted with a fine rose. Afterwards, the preemergence herbicides were applied in 24 polythene bags for the preemergence experiment. Sesame seedlings were thinned to two seedlings per polythene bag at three weeks after crop emergence (WACE) in all polythene bags used in both experiments. In the postemergence experiments, the remaining 24 polythene bags were sprayed with postemergence herbicides 3 WACE in polythene bags that had not been sprayed before. Second thinning was done at 4 WACE to remain with one plant per polythene bag. All the sesame plants were top dressed using 0.78 g of ammonium nitrate (34.5% N) to achieve an application rate of 69 kg·N·ha^{-1}. The pots were irrigated regularly with the same amount of water using a watering can.

2.5. Data Collection

2.5.1. Sesame Emergence. Seedling emergence was recorded until there was no further emergence of seedlings, and the data were used to calculate emergence percentage (E%). Plant height was measured from the base of the plant to the tip of the plant weekly from week one up to week 18 using a tape measure. Number of branches was recorded by counting the number of branches on each plant from week 4 to week 12. Number of pods per plant was counted from each plant at 12 WACE. The grain yield per plant per treatment was collected by measuring the harvested seeds in grams using a balancing scale and converting grams per plant to kilograms per hectare. The information on seed yield was used to calculate yield ha^{-1}.

2.6. Data Analysis. Data were tested for normality and homogeneity of variance before being subjected to analysis of variance using GenStat 18th edition. Number of pods, plant height, and number of branches per plant data were subjected to repeated measures analysis of data. Mean separation was done using least significance difference (LSD) at $p < 0.05$.

Table 1: The effect of preemergence herbicides on germination and early seedling growth of sesame varieties.

Herbicide	Genotype		
	IETC	Lind 02	Ziada 94
Germination (%)			
Distilled water	100.00^{f}	100.00^{f}	98.00^{f}
Alachlor	75.00^{cd}	93.00^{ef}	83.00^{de}
Metolachlor	11.00^{a}	63.00^{c}	26.00^{b}
P value		<0.001	
LSD		13.120	
CV		12.5	
Radicle growth (mm)			
Distilled water	20.25^{d}	20.5^{d}	26.00^{e}
Alachlor	9.25^{c}	7.75^{bc}	5.50^{ab}
Metolachlor	5.50^{ab}	4.75^{a}	4.00^{a}
P value		<0.001	
LSD		2.764	
CV		16.5	
Plumule growth (mm)			
Distilled water	20.25^{d}	22.00^{d}	26.50^{e}
Alachlor	6.25^{b}	5.25^{ab}	10.25^{c}
Metolachlor	3.25^{a}	5.25^{ab}	3.50^{a}
P value		0.004	
LSD		2.675	
CV		16.1	
Seedling vigor index (SVI)			
Distilled water	8.30^{e}	8.35^{e}	8.54^{e}
Alachlor	7.04^{d}	7.10^{d}	7.16^{d}
Metolachlor	4.52^{a}	6.39^{d}	5.17^{b}
P value			
LSD		0.426	
CV		4.2	

Means for the same parameter followed by different letters are significantly different at $p < 0.05$.

3. Results

The interaction between herbicide type and genotype was significant ($p < 0.05$) on germination %, radicle growth, plumule growth, and seedling vigor index (SVI). Metolachlor reduced all germination parameters significantly better than alachlor (Table 1). On the other hand, alachlor significantly reduced all germination parameters compared to distilled water.

3.1. Response of Sesame Genotypes to Different Postemergence Herbicides. The herbicide × genotype interaction was not significant ($p > 0.05$) on plant height, number of branches, 50% flowering, number of pods, yield plant^{-1}, and yield ha^{-1} (Table 2). Propaquizafop significantly reduced plant height, number of pods, and yield of sesame more than fluazifop-p-butyl and hand pulling. However, flowering was not affected by herbicide treatment.

Linda 02 had significantly ($p < 0.05$) shorter plants than Ziada 94, although its plant height was statistically the same as that of IETC (Table 3). Both Lind 02 and Ziada 94 had significantly fewer branches than IETC. Days to 50% flowering did not significantly differ among the sesame genotypes. Consequently, Ziada 94 had a significantly lower yield than the other genotypes.

There was no significant ($p > 0.05$) interaction between herbicide and genotype on number of pods, yield plant^{-1}, and yield ha^{-1} (Table 4). However, the different treatments significantly ($p < 0.05$) reduced number of pods, yield plant^{-1}, and yield ha^{-1} in the order metolachlor > alachlor > hand pulling.

Number of pods plant^{-1} did not significantly ($p > 0.05$) vary among sesame genotypes. On the other hand, yield was significantly ($p < 0.05$) lower in Ziada 94 than in IETC and Lind 02 (Table 5).

There was a significant ($p < 0.05$) interaction between genotype and herbicide on 50% emergence of sesame seedlings (Figure 1). Metolachlor completely inhibited emergence of IETC and Ziada 94, but had the same effect as hand pulling and alachlor on Lind 02. There were no significant differences between hand pulling and alachlor across all the genotypes.

There was a significant ($p < 0.05$) time *x* herbicide × genotype interaction on plant height of sesame (Figure 2). Sesame plants were significantly taller where metolachlor was applied compared to the other treatments. In contrast, there were no significant differences in plant height between plants that were grown in soil sprayed with alachlor and where hand pulling was used.

Table 2: Response of different sesame varieties to commonly used selective postemergence graminicides.

Herbicide	Parameter					
	Plant height	No. of branches	50% flowering	No. of pods	Yield (g) plant^{-1}	Yield (kg) ha^{-1}
Control (hand pulling)	54.19^{b}	10.583^{b}	54.42	92.1^{b}	37.77^{b}	3357^{b}
Propaquizafop	49.79^{a}	9.258^{a}	54.67	73.6^{a}	26.79^{a}	2381^{a}
Fluazifop-p-butyl	52.17^{ab}	8.542^{a}	54.00	84.6^{ab}	35.34^{b}	3141^{b}
P value	0.015	0.025	0.856	0.021	0.004	0.004
LSD	2.876	1.454	ns	12.71	6.36	565.4
CV	6.7	14.5	5.4	18.1	22.7	22.7

Means followed by the same letter in the same column are not significantly different at $p < 0.05$.

Table 3: The effect of different sesame varieties on vegetative and reproductive parameters.

Genotype	Parameter					
	Plant height	No. of branches	50% flowering	No. of pods	Yield (g) plant^{-1}	Yield (kg) ha^{-1}
IETC	52.40^{ab}	14.267^{b}	54.08	94.8^{b}	37.13^{b}	3300^{b}
Lind 02	50.04^{a}	6.600^{a}	53.33	77.4^{a}	37.11^{b}	3299^{b}
Ziada 94	53.71^{b}	7.517^{a}	55.67	78.1^{a}	25.65^{a}	2280^{a}
P value	0.044	<0.001	0.163	0.014	0.001	0.001
LSD	2.876	1.454	ns	12.71	6.36	565.4
CV	6.7	14.5	5.4	18.1	22.7	22.7

Means followed by the same letter in the same column are not significantly different at $p < 0.05$.

Table 4: Response of different sesame varieties to commonly used selective preemergence herbicides.

Herbicide	Parameter		
	No. of pods	Yield (g) plant^{-1}	Yield (kg) ha^{-1}
Control (hand pulling)	92.1^{c}	39.72^{c}	3531^{c}
Alachlor	77.8^{b}	32.76^{b}	2912^{b}
Metolachlor	35.6^{a}	12.55^{a}	1115^{a}
P value	<0.001	<0.001	<0.001
LSD	13.04	5.86	520.6
CV	24.7	24.5	24.5

Means followed by the same letter in the same column are not significantly different at $p < 0.05$.

Table 5: The effect of different sesame varieties to vegetative and reproductive parameters.

Genotype	Parameter		
	No. of pods	Yield (g) plant^{-1}	Yield (kg) ha^{-1}
IETC	76.3	31.19^{b}	2773^{b}
Lind 02	65.9	30.02^{b}	2668^{b}
Ziada 94	63.2	23.83^{a}	2118^{b}
P value	0.112	0.035	0.035
LSD	ns	5.86	520.6
CV	24.7	24.5	24.5

Means followed by the same letter in the same column are not significantly different at $p < 0.05$.

The time x herbicide × genotype interaction was significant ($p < 0.05$) on number of branches of sesame (Figure 3). Metolachlor caused significantly fewer branches than hand pulling and alachlor which did not differ from each other on IETC and Ziada 94. On the other hand, there was no significant difference on the number of branches among the treatments on Lind 02.

4. Discussion

Alachlor and metolachlor showed a suppressive effect on all sesame seed germination parameters and seedling emergence across all genotypes under study. Lind 02 had the highest percent seed germination and seedling emergence where alachlor was applied. This was attributed to high tolerance to alachlor phytotoxicity and variances on genetic makeup's response to herbicide toxicity levels. Most varieties planted in soils treated with alachlor recorded highest percentage germination and emergence compared to metolachlor. These results concur with findings of Grichar et al. [6] who reported that application of alachlor promoted growth of sesame better than metolachlor. These results are also comparable to the findings by Grichar et al. [17] who stated that application of metolachlor resulted in unacceptable crop injury or reduced plant population compared to untreated checks. According to Bernards et al. [18], metolachlor has been found to inflict crop injury even at recommended rates but under certain conditions such as high soil moisture content and soil with low organic matter. Selectivity of metolachlor and alachlor is positional; hence, given the research was a pot experiment on sandy loam soil with low organic matter content and poor water holding capacity, this might have led to the confinement of sesame roots to the leached herbicide zone following heavy irrigation. Nunes and Vidal [19] reported that 90% of applied metolachlor was concentrated in the first 10 cm of crop root zone. Sesame seeds that were planted at 5 cm depth also received the metolachlor leachates, thereby, predisposing them to herbicide injury and suppressing the emergence process due to herbicide absorption. The fact that these two also suppressed seedling emergence percentage in the pot experiment suggests that they induce crop injury by affecting the cell division process.

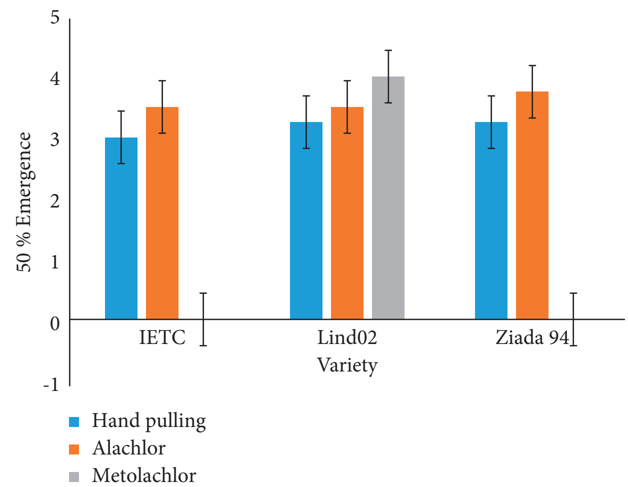

Figure 1: Effect of preemergence herbicides on 50% emergence of different sesame varieties. Errors bars represent error bars at $p < 0.05$.

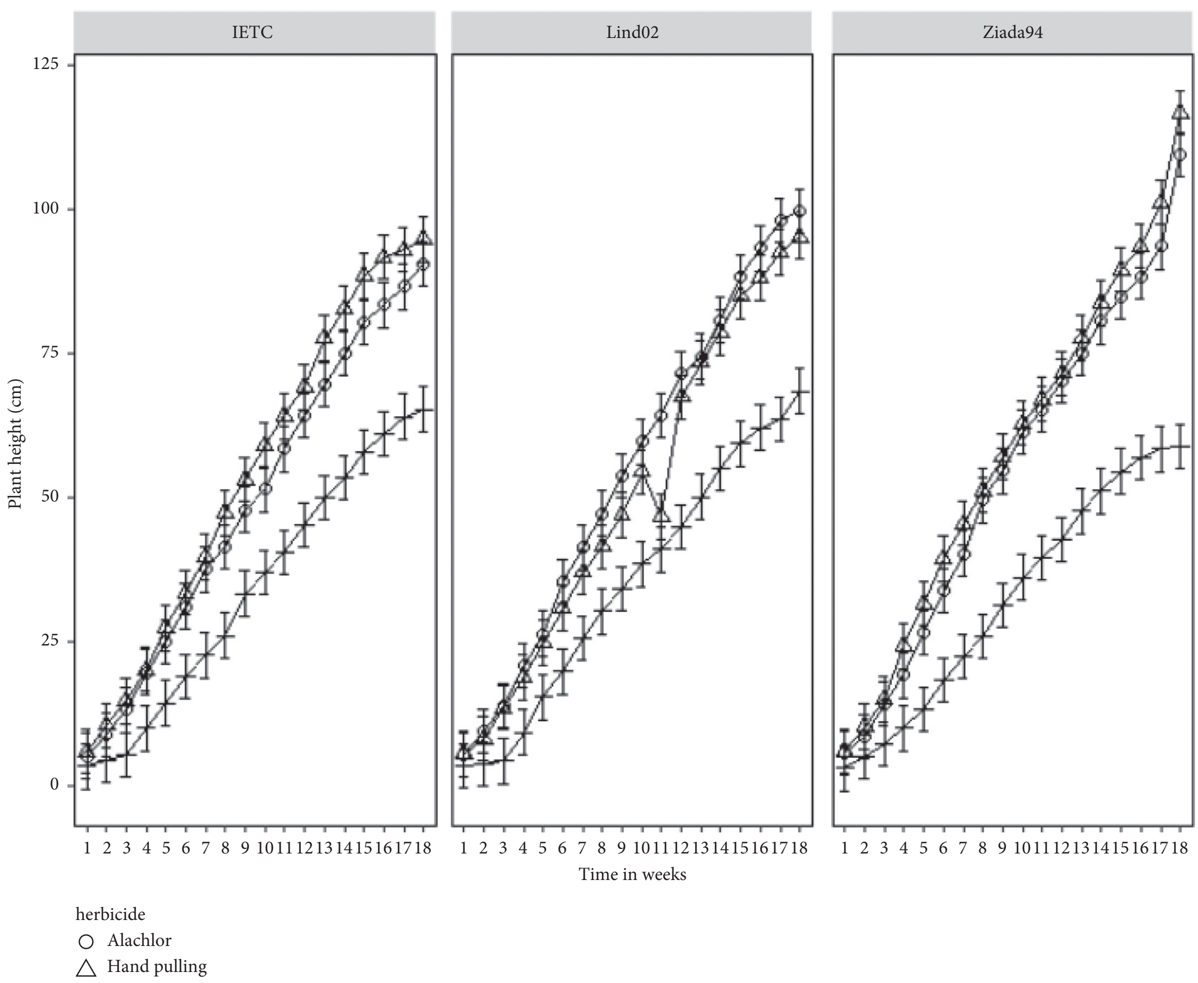

Figure 2: Effect of different preemergence herbicides on plant height of three sesame varieties. Error bars represent LSD at $p < 0.05$.

The results revealed a significant interaction between weeding and sesame varieties at 42 and 126 days after application of weeding treatments. The trend observed showed that hand uprooting recorded the tallest plants in Ziada 94, while IETC and Lind 02 were shorter and not statistically different. Ziada 94 also recorded the highest plant height under alachlor application at day 126 postherbicide application. Lind 02 plants in soil treated with alachlor and

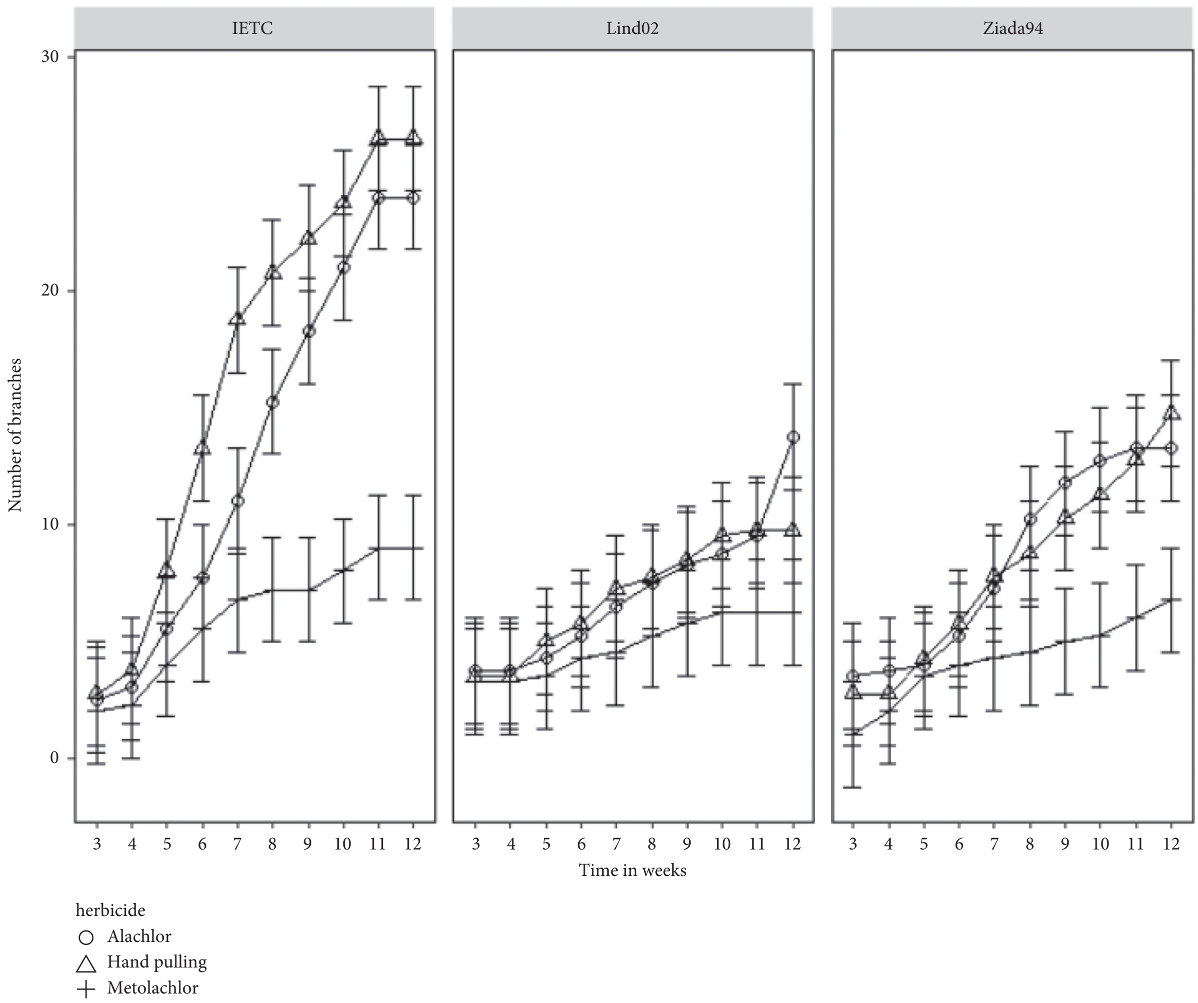

Figure 3: Effect of different preemergence herbicides on number of branches of three sesame varieties. Error bars represent LSD at $p < 0.05$.

metolachlor were tallest at day 42. The sesame height differences might be attributed to variety in genetic constitution variations, since plant height is controlled by three to ten pairs of genes with heritability value of 40–50% in sesame [20]. The author also indicated that environmental situations and management practices might also influence plant height. Furthermore, the number of nodes and internode length on the stem also have an impact on sesame plant height. The experiment showed that Ziada 94 produced taller plants that tolerated both alachlor and hand uprooting. However, metolachlor suppressed plant height across all the genotypes with Ziada 94 recording the least height at day 42 and 126 under metolachlor treatments when compared to IETC and Lind 02, respectively. The results are in line with the study by Sperry et al. [21] which revealed that metolachlor resulted in 25–51% sesame plants stunting and reduced yields by 33%. This is mainly related to the mode of action of the herbicide which involves inhibition of cell development, cell division, and cell enlargement concomitantly resulting in reduced shoot and root development. Leaf elongation, lipid synthesis, and leaf cuticle formation are inhibited by these herbicides resulting in tissue desiccation or permanent stunted growth. O'sullivan et al. [22] revealed that the reduction in plant height observed due to metolachlor and alachlor may probably mean reduced biomass translating to low yields. Hence, basing on weeding treatments application (metolachlor), all genotypes were susceptible to herbicide injury and Ziada 94 was most affected. This indicated that Ziada 94 is less tolerant to metolachlor when compared to other genotypes. The differences in plant height explains the consistent differences among the tested genotypes in all growth parameters that were measured in this research.

There was a significant interaction between weeding treatments on varieties on number of branches per plant. On both alachlor and hand uprooting treatments, IETC variety produced the highest number of branches, while Lind 02 and Ziada 94 had the lowest and were not statistically different from each other. Metolachlor treated plants had the least number of branches when compared to other treatments with no significant difference on branches observed. This may be attributed to genotype differences. Significant differences were observed from weeding treatments with more pods recorded in hand uprooting followed by alachlor and metolachlor, respectively. This might be because of the effect of chloroacetamide herbicides on seedlings which contributed to reduced number of pods which may also contribute to low yields. IETC was observed to have more pods as compared to Lind 02 and Ziada 94. The sesame varieties differ genotypically on the number of pods produced per axil, plant, pod length, shape, locules per pod, and pod dehiscence, which help in the classification into different groups [23].

5. Conclusions

The research showed that alachlor and metolachlor reduce germination, seedling development, plant height, number of branches, and pod number on sesame varieties. The three sesame varieties under study were found to significantly suffer preemergence graminicides (metolachlor and alachlor) phytotoxicity at recommended dosages. However, metolachlor was more phytotoxic than alachlor. These findings suggest the need for dose response experiments in order to establish the safe dosages of alachlor and metolachlor for use in sesame. Propaquizafop exhibited phytotoxic effects on sesame more than fluazifop-p-butyl, which performed the same as hand pulling. This demonstrates that propaquizafop is safer in sesame than fluazifop-p-butyl.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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