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Sesame (*Sesamum indicum* L.) Response to Combinations of Ethalfluralin Plus *S-metolachlor* Applied Prior to Planting

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Authors' contributions

This work was carried out in collaboration between both authors. Authors WJG and PAD jointly designed the studies and performed the statistical analysis. Author WJG wrote the first draft of the manuscript while author PAD reviewed the manuscript. Both authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

Aims: Determine sesame response to ethalfluralin at 0.63, 0.84, or 1.05 kg ha^{-1} in combination with *S*-metolachlor at 1.07 or 1.42 kg ha^{-1} applied and incorporated prior to planting.
Study Design: Randomized complete-block with 3 replications.
Place and Duration of Study: Studies conducted during the 2019 growing season in the Southern High Plains region of Texas near New Deal (33.5818^o N, -101.7794^o W) and in south Texas near Yoakum (29.2756^o N, -97.1226^o W).
Methodology: At New Deal, two passes (in opposite directions) using a rolling cultivator with mixing wheels was used to incorporate herbicides within one hour of application. Mixing wheels consists of four to six spider gangs approximately 10 to 13 cm long mounted on a gang tube and set to incorporate the herbicide no greater than 2.0 cm. At the Yoakum locations, listed bed tops were cut so that they were no greater than 7 cm tall. At Yoakum 1, after beds were knocked down, herbicides were applied and incorporated approximately 2.0 cm deep with a similar piece of equipment as used at New Deal. At Yoakum 2, only the mixing action of the Monosem® precision planter was used to incorporate herbicides.

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Results: At Yoakum, *Urochloa texana* (Buckl.) control with all ethalfluralin plus *S*-metolachlor treatments when evaluated 31 to 39 DAP was inconsistent and varied from 62 to 95% while *Amaranthus palmeri* S. Wats control was 98 to 100% and *Trianthema portulacastrum* L. control was 81 to 99%. At New Deal, only ethalfluralin at 0.84 kg ha^{-1} + *S*-metolachlor at 1.42 kg ha^{-1} did not reduce stand. All treatments caused sesame injury when evaluated 16 and 72 days after planting; only ethalfluralin at 1.05 kg ha^{-1} + *S*-metolachlor at 1.42 kg ha^{-1} reduced yield. At Yoakum, all herbicide treatments reduced yield regardless of incorporation method (mixing wheel vs planter action).

Keywords: Herbicide incorporation; stand reduction; yield.

1. INTRODUCTION

Well-defined cultural practices are required to produce sesame. Sesame is a small-seeded crop lacking the emergence vigor of crops such as grain sorghum [*Sorghum bicolor* (L.) Moench] or cotton (*Gossypium hirsutum* L.) and requires a well-prepared seed bed with seeds placed in soil moisture [1,2]. It is very susceptible to both drought and water-logging since it is slow in establishment [3]. Since the seed of sesame is small, shallow planting is needed for successful establishment [4,5]. With weak seedling vigor, limited competitive ability, and a lack of inexpensive and affordable labor, the use of preemergence (PRE) and/or postemergence (POST) herbicides are essential for commercial mechanized sesame production, especially in the U. S. [6].

The long growing season for sesame requires a weed management program that provides season-long weed control [2,6,7]. *S*-metolachlor is the only herbicide registered for PRE use in the U. S. and sesame injury has been observed with this treatment under certain conditions [7]. In Texas, *S*-metolachlor resulted in 9 to 29% sesame stand reduction at one location and < 8% at a different location [7]. *S*-metolachlor has provided 99% weed control and no injury at other locations [8]. Regardless of early-season injury issues, sesame yield with *S*-metolachlor applied PRE was often the greatest of all herbicides evaluated [8].

Dinitroaniline herbicides are used to reduce weed populations and aid in the establishment and production of many crops including peanut (*Arachis hypogaea* L.), soybean (*Glycine max* L.), and grain sorghum [9-12]. The dinitroaniline herbicides have extremely low water solubility and are subject to losses due to photodecomposition and volatilization [13]. Incorporation soon after application is important for effective weed control [14]. The effectiveness of soil-applied herbicides is dependent upon several factors including movement of the herbicide into the soil either through water provided by rainfall or irrigation or by mechanical incorporation [15,16]. Chenault et al. [17] reported that pendimethalin or trifluralin provided greater than 78% *Echinochloa crus-galli* control depending on incorporation method.

Tolerance to the dinitroaniline herbicides has been evaluated extensively in many crops. These herbicides injure susceptible plants by binding to β-tublin molecules, which ultimatly leads to an inhibition of cell mitosis [18]. Information on absorption and translocation within plants is less clearly defined; however, direct entry into plant tissue is considered limited, and unless the dinitroaniline herbicide enters meristematic tissues, the herbicide will have little effect on plant growth [19].

Previous research by Grichar et al. [2,20] reported sesame injury following dinitroaniline herbicides applied preplant and incorporated using various types of incorporation. Grichar et al. [21] concluded when the dinitroaniline herbicides were not placed in the seed row they provided excellent weed control and caused little to no sesame injury; however, when placed in the seed row these herbicides could damage the sesame resulting in reduced seed emergence [20,21]. There has been interest by some in the sesame industry in combining a dinitroaniline herbicide with *S*-metolachlor for improved weed control; therefore, the objective of this research was to determine sesame crop safety and weed control when applying ethalfluralin plus *S*-metolachlor at different rates prior to planting of sesame.

2. MATERIALS AND METHODS

2.1 Research Sites

Field studies were conducted during the 2019 growing season at two sites in south Texas near

Yoakum (designated as Yoakum 1 and Yoakum 2) and in the Texas Southern High Plains near New Deal. Soil characteristics and other variables for this study are shown in Table 1.

2.2 Herbicides, Plots and Application

A randomized complete-block experimental design was used and treatments were replicated three times. Treatments at all locations included ethalfluralin at 0.63, 0.84, or 1.05 kg ha^{-1} in combination with *S*-metolachlor at 1.07 or 1.42 kg ha^{-1} applied and incorporated prior to planting. At the Yoakum locations, *S*-metolachlor alone at 1.05 kg ha^{-1} was included as a standard. A non-treated control was included for comparison at all locations. At New Deal, two passes with a rolling cultivator with mixing wheels was used to incorporate the herbicides within one hour of herbicide application. These passes were made in opposite directions. The mixing wheels (may also be called "fingers") consists of four to six spider gangs approximately 10 to 13 cm long mounted on a gang tube and set to incorporate the herbicide no greater than 2.0 cm. These gangs help to lift and mix the soil. Gang angle was set to maintain the shape of the slightly raised beds. At the Yoakum locations, listed bed tops were cut so that they were no greater than 7 cm tall. At Yoakum 1, after beds were knocked down, herbicides were applied and incorporated with a similar piece of equipment as used at the New Deal location consisting of spider gangs; however, the gang angle was stationary and only the top 40 cm of the bed was incorporated to a depth of approximately 2.0 cm. At Yoakum 2, only the mixing action of the Monosem® precision planter was used to incorporate the herbicides.

Plot size was four rows (101 cm apart) by 7.6 m at New Deal and two rows (96.5 cm apart) by 9.1 m at Yoakum. Only the two middle rows were sprayed at New Deal and the other rows were untreated and served as buffers. At New Deal, sub-surface drip irrigation was used to supplement rainfall during the growing season while at Yoakum both studies were conducted under rainfed conditions.

2.3 Sesame Plantings, Observations and Harvest

The sesame cultivar S-40 was seeded approximately 1.0 to 2.0 cm deep at 9 kg/ha at both locations. Both locations were conventionally tilled. Volunteer weeds at New Deal were controlled either by hand hoeing throughout the growing season or with a POST application of diuron at 1.12 kg ai ha^{-1} approximately 8 weeks after sesame emergence. At maturity, sesame was either hand-harvested, dried, and threshed with a stationary harvester or harvested with a small-plot combine.

At New Deal, sesame stand and injury (consisted of stunting and overall biomass compared with the untreated check) were evaluated early-season, 16 days after planting (DAP), and evaluated again 72 DAP. At Yoakum 1, stands were evaluated 28 DAP and again at 153 DAP just prior to harvest while at Yoakum 2 stands were evaluated 11 and 137 DAP. Stands were determined by counting number of sesame plants in 2 m of row at New Deal and 3 m of row at both Yoakum locations and converting to % of the untreated check. The untreated check was given a 100% value.

2.4 Weed Populations and Evaluations

Weed control information was collected only at the Yoakum locations since few weeds developed at the New Deal location. At both Yoakum locations plots were infested with naturally occurring weed populations. At Yoakum 1, plots were infested with populations of Texas millet [*Urochloa texana* (Buckl.)] at 6 to 8 plants/m^2, horse purslane (*Trianthema portulacastrum* L.) at 3 to 5 plants/m^2, and Palmer amaranth (*Amaranthus palmeri* S. Wats.) at 2 to 4 plants/m^2 while at Yoakum 2 only Texas millet was present at 8 to 10 plants/m^2.

2.5 Weed Control and Weed Evaluations

Weed control was estimated visually on a scale of 0 to 100 (0 indicating no control or plant death and 100 indicating complete control or plant death) relative to the untreated check [22]. Weed control was evaluated throughout the growing season but only the 31 to 39 DAP and at sesame harvest (137 to 149 DAP) ratings are reported. Horse purslane was only evaluated 31 and 56 DAP because of poor late-season growth.

2.6 Data Analysis

An analysis of variance was performed using the PROC ANOVA procedure for SAS [23] to

Table 1. Variables associated with study

Variable	New Deal	Yoakum 1	Yoakum 2
Location	33.5818° N; -101.7794° W	29.2755° N; -97.1226° W	29.2756° N; -97.1226° W
Herbicides applied	June 11	June 10	June 27
Method of incorporation	Rolling cultivator (2X)	Mixing wheels	Planter action
Sesame planting	June 12	June 10	June 27
Variety	S-40	S-40	S-40
Rainfall after plant (mm)			
0-6 days	0	0	5.3
7-10 days	0	76.2	0
Soil characteristics			
Series	Pullman clay loam	Denhawken-Elmendorf complex	Denhawken-Elmendorf complex
Family	Fine, mixed, superactive, thermic Torrertic Paleustolls	Fine, smectitic, Hyperthermic, Vertic Ustochrepts	Fine, smectitic, Hyperthermic Vertic Ustochrepts
Organic matter (%)	0.77	<1.0	<1.0
Sand (%)	46	65	65
Silt (%)	20	23	23
Clay (%)	34	12	12
pH	8.1	7.3	7.3
CEC	27	25	25
Harvest date	Nov 14	Dec 9	Dec 12

Table 2. Sesame response to ethafluralin plus *S*-metolachlor applied and incorporated with rolling cultivator prior to planting at New Deal

		Stand	Injury		
		Days after planting			
Herbicide	Rate	16	16	72	Yield
	Kg ha^{-1}	% of check	%		Kg ha^{-1}
Untreated	-	100	0	0	1419
Ethalfluralin (E) + *S*-metolachlor (S)	0.63 + 1.07	91	37	8	1339
E + S	0.63 + 1.42	91	50	10	1339
E + S	0.84 + 1.07	65	40	8	1301
E + S	0.84 + 1.42	98	47	7	1309
E + S	1.05 + 1.07	74	42	5	1396
E + S	1.05 + 1.42	89	55	12	1208
LSD (0.05)		9	17	4	191

Table 3. Sesame response and weed control with ethafluralin plus *S*-metolachlor applied and incorporated with rolling cultivator prior to planting (Yoakum 1)

				UROTE[a]		AMAPA		TRTPO		
		Stand		Weed control						
				Days after planting						Yield
Herbicide	Rate	28	153	31	149	31	149	31	56	Kg ha^{-1}
	Kg ha^{-1}	% of check		%						
Untreated	-	100	100	0	0	0	0	0	0	699
Ethalfluralin (E) + *S*-metolachlor (S)	0.63 + 1.07	26	37	99	96	100	99	90	78	575
E + S	0.63 + 1.42	5	15	99	84	100	100	97	71	339
E + S	0.84 + 1.07	44	40	98	88	100	100	96	87	580
E + S	0.84 + 1.42	18	44	95	85	99	100	93	71	570
E + S	1.05 + 1.07	61	52	98	96	100	100	99	97	617
E + S	1.05 + 1.42	20	43	97	93	100	100	95	88	569
S	1.05	34	31	99	92	98	96	81	50	582
LSD (0.05)		41	35	3	13	2	2	34	32	90

[a] *Bayer code for weeds: UROTE, [Urochloa texana (Buckl.)] Texas millet; AMAPA, (Amaranthus palmeri S. Wats.) Palmer amaranth; TRTPO, (Trianthema portulacastrum L.) Horse purslane*

Table 4. Sesame response and weed control with ethafluralin plus *S*-metolachlor applied and incorporated with the mixing action of the Monosem® planter prior to planting (Yoakum 2)

		Stand		UROTE[a]		
		Days after planting		Control		Yield
Herbicide	Rate	39	137	39	137	Kg ha^{-1}
	Kg ha^{-1}	% of check		%		
Untreated	-	100	100	0	0	553
Ethalfluralin (E) + *S*-metolachlor (S)	0.63 + 1.07	16	14	87	55	214
E + S	0.63 + 1.42	6	9	80	60	269
E + S	0.84 + 1.07	1	6	84	52	94
E + S	0.84 + 1.42	0	1	62	35	18
E + S	1.05 + 1.07	1	1	87	55	35
E + S	1.05 + 1.42	0	2	83	71	80
S	1.05	11	14	88	45	246
LSD (0.05)		28	22	25	33	157

[a] *Bayer Code for Weeds: UROTE, Texas millet [Urochloa texana (Buckl.)].*

evaluate the significance of herbicides on sesame stand and injury response and yield. Fisher's Protected LSD at the 0.05 level of probability was used for separation of mean differences. The untreated check was used for sesame stand, injury ratings, yield comparisons, and weed control but was only included in yield data analysis.

3. RESULTS AND DISCUSSION

3.1 Sesame Stand

At New Deal when evaluated 16 DAP only ethalfluralin at 0.84 kg ha^{-1} plus *S*-metolachlor at 1.42 kg ha^{-1} did not reduce stand when compared with the untreated check (Table 2). The greatest stand reduction occurred using ethalfluralin at 0.84 kg ha^{-1} plus *S*-metolachlor at 1.07 kg ha^{-1} which resulted in a 35% stand reduction from the untreated check. At Yoakum 1, when evaluated 28 DAP, only ethalfluralin at 1.05 kg ha^{-1} plus *S*-metolachlor at 1.07 kg ha^{-1} did not reduce sesame stand when compared with the untreated check; however, at the later evaluation (153 DAP) all herbicide treatments reduced sesame stand (Table 3). At Yoakum 2, all stands were drastically reduced with ethalfluralin plus *S*-metolachlor combinations with ethalfluralin at 0.63 kg ha^{-1} plus *S*-metolachlor at 1.07 kg ha^{-1} resulting in no greater than 16% of the untreated check stand (Table 4).

3.2 Sesame Injury

At New Deal injury consisted of stand reduction, stunting, and loss of plant color when compared with the untreated check. When evaluated 16 DAP, sesame injury ranged from 37 to 55% with all ethalfluralin plus *S*-metolachlor treatments. Ethalfluralin at 1.05 kg ha^{-1} plus *S*-metolachlor at 1.42 kg ha^{-1} exhibited the greatest injury (Table 2). When evaluated 72 DAP, all treatments still produced injury that was greater than the untreated check with ethalfluralin at either 0.63 or 1.05 kg ha^{-1} plus *S*-metolachlor at 1.42kg ha^{-1} producing 10 to 12% injury. No type of injury was noticed with either study at the Yoakum location.

3.3 Weed Control

3.3.1 Yoakum 1

Early-season (31 DAP) control of Texas millet was > 95% with all ethalfluralin plus *S*-metolachlor treatments and remained > 84% until harvest (Table 3). Palmer amaranth control was 99 to 100% with ethalfluralin plus *S*-metolachlor treatments throughout the growing season. *S*-metolachlor alone provided 98% early-season Palmer amaranth control and 96% control at harvest. Horse purslane control was > 90% with all ethalfluralin plus *S*-metolachlor treatments and 81% with *S*-metolachlor alone when evaluated 31 DAT (Table 3). At the 56 days after planting (DAP) evaluation, horse purslane control was reduced considerably with only ethalfluralin at 1.05 kg ha^{-1} plus *S*-metolachlor at 1.07 kg ha^{-1} providing > 95% control.

3.3.2 Yoakum 2

When evaluated 39 DAP, Texas millet control was 80 to 87% with all ethalfluralin plus *S*-metolachlor treatments with the exception of ethalfluralin at 0.84 kg ha^{-1} plus *S*-metolachlor at 1.42 kg ha^{-1}, which controlled this weed only 62% (Table 4). At the evaluation prior to harvest Texas millet control was $\leq$ 71% with all herbicide treatments.

3.4 Sesame Yield

At New Deal only ethalfluralin at 1.05 kg ha^{-1} plus *S*-metolachlor at 1.42 kg ha^{-1} resulted in a yield reduction (15%) when compared with the untreated check (Table 2). Although ethalfluralin at either 0.84 or 1.05 kg ha^{-1} plus *S*-metolachlor at 1.07 kg ha^{-1} resulted in 26 to 35% stand reductions, no yield reductions were noted and only ethalfluralin at 1.05 kg ha^{-1} plus *S*-metolachlor at 1.42 kg ha^{-1}, which resulted in 55% early-season injury, reduced sesame yield from the untreated check. At this location sub-surface irrigation was used when needed which allowed potentially poor stands to produce good yields.

At Yoakum 1 only ethalfluralin at1.05 kg ha^{-1} plus S-metolachlor at 1.07 kg ha^{-1} did not reduce sesame yield (Table 3) while at Yoakum 2 all herbicide treatments reduced yield when compared with the untreated check (Table 4). At both Yoakum locations, stand reductions were over 45% with all herbicide treatments.

4. CONCLUSIONS

Since sesame is typically planted 2.5 cm or less in depth, incorporation limits dinitroaniline herbicide usage in sesame production. In earlier work, Grichar et al. [20] reported that rolling cultivator mixing wheels set to a depth of less than 2.5 cm when incorporating ethalfluralin, pendimethalin, or trifluralin resulted in excellent sesame stands. They suggested that a shallow incorporation of the dinitroaniline herbicides would not be harmful to sesame and would result in good stands. This research shows that any type of incorporation of a dinitroaniline herbicide will result in the potential to drastically reduced sesame stands. Just the mixing action of the Monosem® planter resulted in enough incorporation to severely reduce stand. Since the uptake of the dinitroaniline herbicides is primarily through roots and emerging shoots [18,24], the shallow planting of sesame results in roots and shoots being in the treated zone and not below the treated zone, which would not result in such injury. If sesame could be planted deeper the emerging shoots would pass through treated soil, whereas developing roots would be below the herbicide-treated soil. In related work Parker [25] found that trifluralin was more inhibitory to *S. bicolor* when absorbed through roots than emerging shoots.

Rainfall was not a factor in either study at Yoakum or at New Deal. At Yoakum 1 the sesame was planted into good moisture (approximately 27 mm of rainfall was received within a week prior to the June 10th planting date) and under these conditions sesame emerged within 3 to 5 days before the 76 mm rainfall event 7 days after planting (Table 1). At Yoakum 2 only 5.3 mm of rainfall was received 0 to 4 days after plant and this would not have been enough moisture to move either herbicide [26]. At New Deal 36.8 mm of rainfall was received 6 days before planting so moisture was adequate for planting. No rainfall was received for 10 days after planting (Table 1). Of the current chloroacetamide herbicides *S*-metolachlor appears to be the most persistent [27-29] and has the potential to leach to groundwater because of its relatively high water solubility [30]. Typically, the adsorption of herbicides increase with increased soil organic matter and clay content, and increased adsorption can slow a herbicide's movement in the soil [31].

In some instances, where ethalfluralin plus *S*-metolachlor caused significant stand reduction, sesame yields were often only slightly reduced from the untreated check because sesame can tolerate poor stand and injury and compensate for the open space and/or poor growth by adding additional branches with capsules [6,7,32]. However, wide gaps not only lead to lower yields, but also let light through the canopy to encourage late-season weed emergence and growth [32]. With these issues the use of the combination of ethalfluralin plus *S*-metolachlor applied prior to sesame planting is not a good option.

DISCLAIMER

The products used for this research are commonly and predominantly used products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any ligation but for the advancement of knowledge.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ghosh DC, Mukhopadhyay SK. Weeds and weed control is sesame. Pesticides. 1980;14:24-29.
2. Grichar WJ, Sestak DC, Brewer KD, Besler BA, Stichler CR, Smith DT. Sesame (*Sesamum indicum* L.) tolerance and weed control with soil-applied herbicides. Crop Protect. 2001;20:389-394.
3. Joshi P. Sesame production in Rajasthan-constraints and opportunities. In: Srivastava, HC, Bhaskaran S, Vatsya B, Menon KKG, editors. Oilseed Production Constraints and Opportunities. New Delhi, Oxford & IBH Publishing Co. 1985;199-204.
4. Bennett M. Sesame Research Report 1991-92. Wet season, Katherine. Northern Territory, Australian Dept. of Primary Industries and Fisheries. Technical Bulletin No. 215; 1993.
5. Eagleton G, Sandover S, Dickson M, Research report:sesame seed 1982-1986. Dept. Agric. Kununurra, West Australia; 1987.
6. Grichar WJ, Dotray PA, Langham DR. Weed control and the use of herbicides in sesame production. In Soloneski S,

Larramendy ML, editors. Herbicides, Theory and Applications; 2011
ISBN: 978-953-307-975-2, In Tech. Accessed 18 January 2022.
Available:http://www.intechopen.com/articles/show/title/weed-control-and-the-use-of-herbicides-in-sesame-production.

7. Grichar WJ, Dotray PA, Langham DR. Sesame (*Sesamum indicum* L.) growth and yield as influenced by preemergence herbicides. Internat. J. Agron;2012. DOI:10.1155/2012/809587
8. Grichar WJ, Dotray PA, Langham DR. Sesame (*Sesamum indicum* L.) response to preemergence herbicides, Crop Protect. 2009;28:928-933.
9. Dotray PA, Keeling JW, Grichar WJ, Prostko EP, Lemon RG. Peanut response to ethalfluralin, pendimethalin, and trifluralin preplant incorporated. Peanut Sci. 2004;30:34-37.
10. Grichar WJ, Colburn AE. Effect of dinitroaniline herbicides upon yield and grade of five runner cultivars. Peanut Sci. 1993;20:126-128.
11. Grichar WJ, Besler BA, Lemon RG, Brewer KD. Weed management and net returns using soil-applied and postemergence herbicide programs in peanut (*Arachis hypogaea* L.). Peanut Sci. 2005;32:25-31.
12. Grichar WJ. Using soil-applied herbicides in glyphosate-resistant soybeans along the Texas Gulf Coast. Weed Technol. 2006;20:633-639.
13. Weber JB. Behavior of dinitroaniline herbicides in soils. Weed Technol. 1990;4:394-406.
14. Smith AE, Kerr LA, Caldwell, B. 1997. Volatility of ethalfluralin, trifluralin, and triallate from a field following surface treatments with granular formulations. J. Agric. Food Chem. 1997;45:1473-1478.
15. Prostko EP, Johnson WC III, Mullinix BG Jr. Annual grass control with preplant incorporated and preemergence applications of ethalfluralin and pendimethalin in peanut (*Arachis hypogagea*). Weed Technol. 2001;15:36-41.
16. Ross MA, Lembi CA. Herbicide incorporation techniques and equipment. In: Stewart C, Stagman J, Carnis M, editors. Applied Weed Science. 2nd ed. Upper Saddle River, NJ: Prentice-Hall. 1999;371-375.
17. Chenault EW, Bean BW, Salisbury CD. Influence of incorporation methods on pigweed (*Amaranthus palmeri* S. Wats) and barnyardgrass [*Echinochloa crus-galli* (L.) Beauv] control with trifluralin and pendimethalin in sorghum (*Sorghum bicolor* L. Moench). Proc. South. Weed Sci. Soc. 1992;45:57.
18. Appleby AP, Valverde BE. Behavior of dinitroaniline herbicides in plants. Weed Technol. 1989;3:198-206.
19. Miller AJ, Bellinder RR, Bradley BX, Rauch BJ, Goffinet MC, Welser MJC.2003. Cabbage (*Brassica oleracea*) response to pendimethalin applied postemergence. Weed Technol. 2003;17:256-260.
20. Grichar WJ, Dotray PA. Weed control and sesame (*Sesamum indicum* L.) response to preplant incorporated herbicides and method of incorporation. Crop Protect. 2007;26:1826-1830
21. Grichar WJ, Rose JJ, Dotray PA, Tredaway JA, Bagavathiannan M, Shankle MW, Langham DR. Sesame (*Sesamum indicum* L.) response to delayed applications of preemergence herbicides applied 3 or 6 day after emergence. J. Experimental Agric. Internat. 2021;43:34-50.
22. Frans R, Talbert R, Marx D, Crowley H. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. In: Camper ND, editor. Research Methods in Weed Science. 3rd ed. Champaign, IL: Southern Weed Science Society. 1986;29-46.
23. SAS Institute. SAS® Enterprise Guide 8.2 User's Guide. Cary, NC; 2019.
24. Ashton FM, Crafts AS. Dinitroaniline. In: Crafts AS, editor. Mode of Action of Herbicides. Wiley. New York. 1981;201-223.
25. Parker C. The importance of shoot entry in the action of herbicides applied to the soil. Weeds. 1996;14:117-121.
26. Savage KE. Persistence of several dinitroaniline herbicides as affected by soil moisture. Weed Sci. 1978;26:465-471.
27. LeBaron HM, McFarland JE, Simoneaux BJ. Metolachlor. In: Keamey PC, Kaufman DD, editors. Herbicides: Chemistry, Degradation, and Mode of Action. New York: Marcel-Dekker. 1998;335-381.
28. Walker A, Brown PA. The relative persistence in soil of five acetanilide herbicides. Bull. Environ. Contam. Toxicol. 1985;34:14.3-149.

29. Zimdahl RL, Clark SK. Degradation of three acetanilide herbicides in soil. Weed Sci. 1982;30:545-548.
30. Westra EP, Shaner DL, Westra PH, and Chapman PL. Dissipation and leaching of pyroxasulfone and S-metolachlor. Weed Tech. 2014;28:72-81.
31. Rivard L. Environmental Fate of Metolachlor. Sacremento, CA: Environmental Monitoring Branch. Department of Pesticide Regulation; 2003.
32. Langham DR, Riney J, Smith G, Weimers T. Sesame Harvest Guide. Sesaco Corp. Austin, TX;2008. Accessed 18 January;2022.
Available:htttp://www.sesaco.com/Websites/sesaco/images/Harvest_pamphlet_080903_final_b.pdf.

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