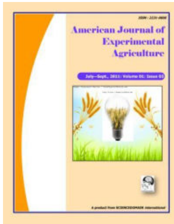

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Sesame Tolerance to Herbicides Applied Postemergence-Directed

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Authors' contributions

This work was carried out in collaboration between all authors. Authors PAD, DRL and WJG designed the study and wrote the protocol. Authors PAD and WJG performed the statistical analysis. Author WJG wrote the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Studies were conducted to determine sesame tolerance to herbicides applied postemergence-directed (PDIR) to the lower 5 and 15 cm of the stem.
Study Design: Randomized complete block design with a 14 (herbicide) x 2 (spray height) factorial arrangement with 3 replicates.
Place and Duration of Study: In south Texas near Uvalde and in the Texas High Plains near Lorenzo between May 2006 and November 2007.
Methodology: Herbicides included carfentrazone-ethyl at 0.02 kg/ha, glufosinate-ammonium at 0.58 kg/ha, glyphosate at 0.84 kg/ha, lactofen at 0.22 kg/ha, linuron at 1.12 kg /ha, paraquat at 0.28 kg/ha, propazine at 1.12 kg/ha, pyraflufen-ethyl at 0.002 kg/ha, pyrithiobac at 0.07 kg/ha, trifloxysulfuron-sodium at 0.008 kg/ha, trifloxysulfuron-sodium at 0.008 kg/ha plus prometryn at 1.12 kg/ha, linuron at 0.56 kg/ha plus diuron at 0.56 kg/ha, glyphosate at 0.84 kg/ha plus prometryn at 1.12 kg/ha, and glyphosate at 0.84 kg/ha plus diuron at 1.12 kg/ha. Herbicides were applied when sesame was $\leq$ 76 cm tall with one spray tip on each side of the row adjusted to spray a PDIR band to the lower 5 to 15 cm of the stem.
Results: Glyphosate at 0.84 kg/ha and pyrithiobac at 0.07 kg/ha resulted in 28 to 90%

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stunting when applied to lower 15 cm of the stem. Glyphosate applied to lower 15 cm and pyrithiobac applied to the lower 5 and 15 cm consistently reduced sesame yield (51 to 89%) when compared with the control. Glufosinate-ammonium and the premix of linuron plus diuron applied to the lower 5 cm caused the least sesame stunting ($\leq$ 8%) and only linuron plus diuron resulted in a reduction in yield at one location when compared with the non-treated.
Conclusion: Sesame injury was greatest when herbicides were applied to the lower 15 cm of the stem compared to 5 cm applications.

Keywords: Injury; Sesamum indicum; weed-free; yield.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the oldest crops known to humans. There are archeological remnants of sesame dating to 5500 BC in the Harappa Valley in the Indian-Pakistan subcontinent [1]. Assyrian tablets from 4300 BC describe how before the gods battled to restore order to the universe, they ate bread and drank sesame wine [2]. Sesame was a major oilseed in the ancient world because of its ease of extraction, great stability, and drought resistance. In India today, almost as in old days, farmers can take their crop to an expeller which consists of grinding mortar and pestle stones driven by a bullock. They can place the oil in a vessel, take it back to their home and have cooking oil for a year without the oil going rancid (S.S. Rajan, personal communication).

The presence of weeds can negatively influence sesame yield. Kropff and Spitters [3] reported that the major factor influencing sesame yield loss in a competitive situation between the crop and weed is the ratio between the relative leaf area of the weed and the crop at the time of canopy closure. The effects of weeds on sesame establishment and growth have been well-documented. Balyan [4], Gurnah [5], Singh et al. [6], and Upadhyay [7] reported weed-induced reductions of sesame yield up to 100% and a need for a critical weed-free period up to 50 day after planting. Under weedy conditions, Eagleton et al. [8] recorded a weed biomass six times that of sesame 48 days after planting and Bennett [9] reported a weed biomass 1.3 fold that of sesame 42 days after planting.

Mechanically harvested non-dehiscent varieties present another problem that is not present in manual harvest which comprises 99% of all sesame harvested in the world [10]. If there are weeds in manual harvest, only the sesame plants are cut and placed in shocks. However, in mechanical harvest, sesame and weeds are cut together. In Venezuela, a binder cuts the sesame and weeds together while they are still green. This is not a big problem because the weeds dry down at the same time as the sesame. However, dense population of weeds may delay combining because the leaves of the weeds may envelop plants and trap moisture or thicker stem weeds such as pigweed (*Amaranthus* spp.) and will take longer to dry down.

In direct combining, weeds can be a big problem because they are normally green and add moisture to the combine bin. There are many instances where the sesame seeds are dry and weed seeds are not. Thick stems can add moisture, but the major problem is with weed seeds. Since it is logistically difficult to scalp off the weed seeds at harvest, moisture from the weed seed will transfer to sesame seeds. Sesame is 50% oil and needs to be harvested at 6% moisture or below in order to be handled in lots of 25 tons in trucks and in 2,000 ton silos. High moisture under these conditions may lead to heating and ruining of the seed. A second concern is that mechanically harvested sesame moves through a series of augers from the combine screen, to the combine bin, to the truck, to the silo, to the cleaning equipment, and within the cleaning process. Moist sesame seeds may be damaged by this movement forming free fatty acids which leads to spoiling [10].

The size of sesame seed is similar to the size of many weed seeds [11,12]. In the production of oil from sesame, weed seeds within the sesame samples are not as critical unless they are toxic. However, a large percentage of sesame is used in edible markets that require 99.99% purity. There are weed seeds such as johnsongrass [*Sorghum halepense* (L.) Pers] that would seemingly be easy to remove because of their size and shape, and yet the johnsongrass seed go through the round holes end first and are difficult to separate in gravity tables because they have a similar specific gravity to sesame [11]. In decortication of the seed for bakery products and tahini, the seed from lanceleaf sage (*Salvia reflexa* Hornem.) causes a unique problem. When the lanceleaf sage seed is hydrated, the seed surface forms a gelatinous substance that will cause adjacent sesame seeds to stick; therefore, forming balls. Kochia [*Kochia scoparia* (L.) Schrad] and grass weeds produce seeds that are difficult to remove from sesame. Any weed seed that is in a sesame sample in a large percentage is difficult to clean out, no matter the size and specific gravity, without having to slow down the processing or reprocessing. In Japan, purity needs to be 100% since processors have to pay claims to customers that find anything other than pure sesame seeds [10].

Sesame is mainly grown in countries where abundant and inexpensive labor is available [13]. However, the trend in agriculture around the world is towards mechanization. Sesame has disappeared in Japan and parts of Mexico as the sesame growing areas mechanized. In Korea, sesame hectares have continually decreased since 1987 as the labor migrates to the cities (C. Kang, personal communication). With weak seedling vigor, limited competitive ability, and a lack of cheap labor, the use of preemergence (PRE) or postemergence (POST) herbicides is essential for commercial mechanized sesame production.

All POST herbicides which control broadleaf weeds in sesame have caused some sesame injury or yield reduction [14,15,16]. For broadleaf weed problems in sesame, the use of soil-applied herbicides still appears to be the only option [14,17]. However, since sesame hectares are increasing in portions of the southern United States and since no POST broadleaf herbicides are presently cleared for use on sesame or have shown sesame tolerance [14,16], the objective of these studies was to identify herbicides that could be used postemergence-directed (PDIR) to control broadleaf weeds and not injure sesame.

2. MATERIALS AND METHODS

2.1 Research Sites

Field studies were conducted during the 2006 and 2007 growing seasons near Uvalde in south Texas and near Lorenzo in the Texas High Plains to evaluate sesame response to herbicides applied PDIR. Fields were selected that had low weed populations since weed efficacy of each herbicide is known; however, nothing is known about sesame response to herbicides applied PDIR. Soil type at Uvalde was a Winterhaven silty clay loam (fine-silty, carbonatic, hyperthermic Fluventic Ustochrepts) with less than 1.0% organic matter and pH 7.8. Soil type at Lorenzo was a Amarillo sandy clay loam (fine-loamy, mixed, thermic Aridic Paleustalf) with 0.8% organic matter and pH 7.8.

2.2 Plot Design

A randomized complete block experimental design was used and treatments were replicated three times. Treatments consisted of a factorial arrangement of fifteen herbicides applied at two different PDIR spray heights. A non-treated control was included for comparison. Plot size was five rows (0.97 m apart, total width was 4.85 m) by 9.1 m. long in south Texas and four rows (1.01 m apart, total width was 4.04 m) by 7.3 m. long in the Texas High Plains. Only the two middle rows were sprayed and the other rows were untreated and served as buffers.

2.3 Herbicides and spraying information

Herbicides and doses included in this study are shown in Table 1. Spray heights were applied up to 5 cm and 15 cm the sesame main stem. Spray nozzles were adjusted to spray a PDIR spray band on sesame stem and 15 to 25 cm band on the soil to simulate spray of a PDIR spray applicator. All PDIR applications, with the exception of glufosinate-ammonium, included a crop oil concentrate (Agri-Dex®, a blend of 83% paraffin-based petroleum oil and 17% surfactant, Helena Chemical Company, Suite 500, 6075 Poplar Avenue, Memphis, TN38137) at 1.0% v/v or a nonionic surfactant (X-77®, 90% nonionic surfactant, Loveland Industries, P.O. Box 1289, Greeley, CO 80632) at 0.25% v/v.

Table 1. Herbicides, trade names, manufacturer, and dose used in sesame study

Common name	Trade name	Manufacturer	Dose
Carfentrazone-ethyl	Aim	FMC	0.02 kg/ha
Glufosinate-ammonium	Ignite 280	Bayer Crop Science	0.58 kg/ha
Glyphosate	Roundup Weathermax Durango	Monsanto Company Dow AgroSciences	0.84 kg/ha
Lactofen	Cobra	Valent USA	0.22 kg/ha
Linuron	Lorox	DuPont Crop Protection	1.12 kg/ha
Paraquat	Gramoxone Max	Syngenta Crop Protection	0.28 kg/ha
Propazine	Milo-Pro	Albaugh, Inc	1.12 kg/ha
Pyraflufen-ethyl	ET	Nichino America, Inc	0.002 kg/ha
Pyrithiobac	Staple	DuPont Crop Protection	0.07 kg/ha
Trifloxysulfuron-sodium	Envoke	Syngenta Crop Protection	0.008 kg/ha
Glyphosate + prometryn	Roundup Weathermax + Caparol	Monsanto Company Syngenta Crop Protection	0.84 kg/ha +1.12 kg/ha
Glyphosate + diuron	Roundup Weathermax + Direx	Monsanto Company DuPont Crop Protection	0.84 kg/ha +1.12 kg/ha
Linuron + diuron	Lay-by Pro	Tessenderlo Kerley, Inc	0.56 kg/ha +0.56 kg/ha
Trifloxysulfuron-sodium + prometryn	Suprend	Syngenta Crop Protection	0.008 kg/ha +1.12 kg/ha

At Uvalde, herbicides were applied in water using a CO_2-pressurized backpack sprayer calibrated to deliver 190 L/ha at 180 kPa. Spray tips were two Teejet 8004E (Teejet Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60188) nozzles per row (one on each side of the row). At the Lorenzo location, a tractor-mounted compressed-air Red Ball sprayer with Teejet 8001 flat fan spray tips (Teejet Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60188) calibrated to deliver 93 L/ha at 207 kPa was used in the same configuration as Uvalde. Herbicides were applied when sesame was 38 to 76 cm in height.

2.4 Sesame Varieties, Planting, and Harvesting

Sesame variety in 2006 was S29 while in 2007 S32 was planted at both locations. Planting dates at the Uvalde location was late May in 2006 and early June in 2007 while at the Lorenzo location, sesame was planted mid-June in both years. Each sesame cultivar was seeded approximately 1.0 cm deep at 3.4 kg/ha at both locations. At maturity, sesame in the plots was hand-harvested, dried for 7 d under dry field conditions, and threshed with a harvester.

2.5 Data Analysis

The treatment design was a factorial arrangement using a randomized complete block design with herbicides and PDIR spray height as factors. An analysis of variance was performed using the ANOVA procedure for SAS (SAS Institute. 1998. SAS user's guide. SAS Inst., Cary, NC.) to evaluate the significance of herbicides and spray height on sesame response and yield. The Fishers Protected LSD at the 0.05 level of probability was used for separation of mean differences.

3. RESULTS AND DISCUSSION

Since there was a treatment by location or year interaction for sesame stunting and yield, data by location and year is presented separately. Data was not collected in Uvalde in 2006 due to uneven distribution of irrigation water which resulted in inconsistent plant growth and sesame development.

3.1 High Plains (Lorenzo)

3.1.1 Sesame stunt

In 2006, glyphosate and pyrithiobac applied to the 15 cm stem height resulted in 28 and 42% sesame stunting, respectively. When applied up to the 5 cm sesame stem height, stunting was no greater than 15% with either herbicide (Table 2). Glyphosate is cleared in the US for use in sesame as a burndown, with wiper applicators, and using hooded sprayers in row middles [18]. For burndown use, glyphosate should be applied before, during, or just after planting but before the sesame seedlings emerge. Glyphosate applied POST to sesame will result in plant death or yellowing and a lack of capsule formation for one to three weeks [18]. When capsule formation does somewhat recover, the capsules will be smaller and contain less seeds and have a reduced seed weight. Glyphosate plus diuron stunted sesame 10% when applied up to 15 cm; however, no other herbicides stunted sesame more than 4% when applied to sesame at either height (Table 2). In Venezuela, diuron at 0.6 and 1.2 kg/ha applied preemergence reduced sesame yield, but yield would have been much lower without weed control [19]. In the U.S., in one year, diuron at 0.8 and 1.7 kg/ha applied pre-emergence resulted in adequate weed control without apparent crop injury whereas in another year, there was stand reduction and chorosis [20]. Grichar et al. [15] reported that diuron at 1.12 kg/ha reduced sesame stands and caused chlorosis injury in one year in the

Texas High Plains area; however, in south Texas no adverse effects with diuron were seen in the two years.

In 2007, sesame stunting was more severe with glyphosate, glufosinate, pyrithiobac, and trifloxysulfuron applied up to 15 cm in sesame height compared with applications made up to the 5 cm height (Table 2). Only glufosinate-ammonium, pyraflufen-ethyl, linuron alone, and linuron + diuron applied up to 5 cm caused less than 10% sesame stunting. Pyrithiobac caused the greatest sesame stunting whether applied up to 5 or 15 cm sesame.

Table 2. Sesame stunt and yield as influenced by height of postemergence-directed herbicides sprays.[a,b]

			Lorenzo					
			Stunt (%)		Yield (kg/ha)		Uvalde	
Treatment	**Dose (kg/ha)**	**Height (cm)**	**2006**	**2007**	**2006**	**2007**	**Stunt (%)**	**Yield**
Non-treated	-	-	0	0	612	810	0	1223
Glyphosate	0.84	5	12	18	526	830	20	984
		15	28	50	268	399	90	426
Glufosinate-ammonium	0.58	5	2	8	556	1047	7	1173
		15	4	27	538	754	45	786
Carfentrazone-ethyl	0.02	5	0	22	608	1080	24	996
		15	3	19	540	777	37	654
Pyraflufen-ethyl	0.002	5	2	9	588	1068	0	1446
		15	3	15	582	1015	2	-
Paraquat	0.28	5	0	13	630	1014	5	1062
		15	0	15	516	963	30	705
Lactofen	0.22	5	0	20	494	882	13	1191
		15	2	19	452	812	38	1194
Pyrithiobac	0.07	5	15	52	412	298	65	345
		15	42	67	392	117	85	129
Trifloxysulfuron	0.008	5	0	27	588	477	20	687
		15	5	47	528	468	57	273
Trifloxysulfuron + prometryn	0.008 + 1.12	5	0	22	520	690	10	1194
		15	2	33	574	942	17	933
Linuron	1.12	5	-	8	-	1046	0	1272
		15	-	18	-	1014	7	1068
Linuron + diuron	0.56 + .56	5	2	7	552	567	8	1386
		15	0	11	540	1005	0	1215
Propazine	1.12	5	-	19	-	750	0	1317
		15	-	18	-	822	0	1272
Glyphosate + prometryn	0.84 + 1.12	5	0	13	462	964	2	1440
		15	3	17	398	843	1	1425
Glyphosate + diuron	0.84 + 1.12	5	2	17	382	760	12	917
		15	10	28	280	611	35	773
LSD (0.05)			5	15	90	210	17	264

[a] All POST herbicides, except glufosinate, included a non-ionic surfactant at 0.25 % v/v or a crop oil concentrate at 1.0 % v/v; [b] Stunt ratings taken approximately 30 d after herbicide application; [c] Uvalde data for 2007 only; [d] Height that herbicides sprays reached up the main stem of sesame.

3.1.2 Sesame yield

In 2006, glyphosate or paraquat applied up to the 15 cm height resulted in a yield reduction when compared with applications made to lower stem height (Table 2). Trifloxysulfuron plus prometryn reduced yield compared to the non-treatedcontrol when applied up to 5 cm height but not up to the 15 cm height while lactofen, pyrithiobac, and glyphosate plus either prometryn or diuron reduced sesame yield regardless of application height. Although sesame stunting appeared greater in 2007, not as many herbicides caused a reduction in yield from the non-treated control as 2006. Pyrithiobac and trifloxysulfuron applied to sesame at either height and glyphosate applied up to 15 cm sesame reduced yield when compared to the non-treated control. Glyphosate applied up to 15 cm sesame reduced yield; however, the application made up to 5 cm on sesame stem did not.

3.2 South Texas

3.2.1 Sesame stunt

In 2007, glyphosate, glufosinate-ammonium, paraquat, lactofen, pyrithiobac, trifloxysulfuron, and glyphosate plus diuron caused greater sesame stunting when applied to the sesame stem up to the 15 cm height than the 5 cm height (Table 2). Pyraflufen-ethyl, trifloxysulfuron + prometryn, linuron + diuron, linuron alone, propazine, and glyphosate + prometryn applied either up to 5 or 15 cm resulted in sesame stunting that was not different from the non-treated control.

Preemergence applications of prometryn at 0.5 kg/ha caused no sesame injury, but prometryn applied preplant incorporated almost completely wiped out the sesame (D. Howell, unpublished data). Prometryn at 0.6 and 1.1 kg/ha resulted in lower sesame populations, lowered plant height, and also reduced yields compared with metolachlor at 1.1 or 2.2 kg/ha [21]. However, in a later study in south Texas and the Texas High Plains, prometryn injured sesame but yields were not reduced from that of *S*-metolachlor [15].

3.2.2 Sesame yield

Glyphosate, glufosinate-ammonium, carfentrazone-ethyl, paraquat, and trifloxysulfuron + prometryn applied up to 5 cm height did not reduce sesame yield when compared with the non-treated control although these herbicides applied up to the 15 cm height did reduce yield 36 to 65% (Table 2). Pyrithiobac, trifloxysulfuron, and glyphosate + diuron reduced sesame yield when applied at either height. The premix of linuron + diuron, linuron alone, pyraflufen-ethyl, or propazine resulted in little or no sesame stunting ($\leq$8%) and did not affect sesame yield when applied at either height.

4. CONCLUSION

As height of herbicide spray up the main stem of sesame increased, the chances of sesame stunting and a reduction in yield also increased. The combination of linuron + diuron produced the least sesame injury whether applied 5 or 15 cm up the sesame main stem. Work by Grichar et al., [15] reported that diuron at 1.12 kg/ha reduced sesame stands and caused sesame injury in one year in the Texas High Plains area; however, in south Texas no adverse effects with diuron were seen in the two years of research. Limited information is available on linuron use in sesame. Santelmann et al. [22] found slight phytotoxicity and a reduction in sesame yield with linuron at 2.24 kg/ha. Although glyphosate stunted sesame when applied up to the 5 cm height, it did not result in a reduction in yield. Under close examination, the sesame population was high and the glyphosate appeared to kill the less vigorous (minor) plants under the canopy and thus thinned the population. In a high population situation, the minor plants are actually a weed because they use moisture and fertility without giving commensurate yield. Glyphosate is cleared in the U.S. for use in sesame as a burndown, with wiper applicators, and /or hooded sprayers in row middles [18]. For burndown use, glyphosate should be applied before, during, or just after planting but before the sesame seedlings emerge. Glyphosate applied POST to sesame will result in plant death or yellowing of the sesame and a lack of capsule formation for one to three weeks [18]. When capsule formation does somewhat recover, the capsules will be smaller and will have less seeds and seed weight.

Glufosinate is also a nonselective POST herbicide that may have potential for use in sesame in many of the same ways that glyphosate can be used. It controls a wide range of weed species and is especially effective on some species such as morningglory (*Ipomoea* spp.) that can be difficult to control with glyphosate [23,24,25].

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bedigian D, Harlan JR. Evidence for cultivation of sesame in the ancient world. Econ. Bot. 1986;40:137–154.
2. Weiss EA. Castor, sesame, and safflower. Leonard Hill Books, London, p.311–525, 1971.
3. Kropff MJ, Spitters CJT. A simple model of crop loss by weed competition from early observations on relative leaf area of weeds. Weed Res.1991;31:97-105.
4. Balyan RS. Integrated weed management in oilseed crops in India. Indian Soc. Weed Sci. 1993;1:317-323.
5. Gurnah AM. Critical weed competition periods in annual crops. Proc. Fifth East African Weed Control Conf. Nairobi, Kenya. 1974;5:89-98.
6. Singh D, Dagar JC, Gangwar B. Infestation by weeds and their management in oilseed crops – a review. Agric. Rev. 1992;13:163-175.
7. Upadhyay UC. Weed management in oilseed crops. In: Srivastava HC, Bhaskaran S, Vatsya B, Menon KKG, editors Oilseed Production Constraints and Opportunities. New Delhi: Oxford & IBH Publishing Company.1985;491-499.
8. Eagleton G, Sandover S, Dickson M. Research report:sesame seed 1982-1986, Kununrra Regional Office, Dept. of Agriculture, Western Australia, 1987.

9. Bennett M. Sesame Research Report 1991-92. Wet season, Katherine. NorthernTerritory, Australian Dept. of Primary Industries and Fisheries, Technical Bulletin No. 215, 1993.
10. Langham DR, Wiemers T. Progress in mechanizing sesame in the U.S. through breeding. In: Janick J, Whipkey, editors. Trends in New Crops and New Uses. Alexandria, VA: ASHS Press. 2002:157-173.
11. Langham DR. Growth and Development of Sesame. Sesaco Corp. 42 p., 2008.
12. Langham DR, Riney J, Smith G, Wiemers T. Sesame Grower Guide. Sesaco Corp. 30 p., 2008.
13. Schrodter GN, Rawson JE. Herbicide evaluation studies in sesame. Aust. Weeds 1984; 3:47-49.
14. Grichar WJ, Sestak DC, Brewer KD, Besler BA, Stichler CR, Smith DT. Sesame (*Sesamum indicum* L.) tolerance with various postemergence herbicides. Crop Protect. 2001;20:685-689.
15. Grichar WJ, Dotray PA, Langham DR. Sesame (*Sesamum indicum* L.) response to preemergence herbicides. Crop Protect. 2009;28:928-933.
16. 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, ISBN: 978-953-307-975-2, InTech. Accessed 29 May 2013. Available from: http://www.intechopen.com/articles/show/title/weed-control-and-the-use-of-herbicides-in-sesame-production, 2011.
17. 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.
18. Langham D, Riney J, Smith G, Wiemers T, Peeper D, Speed T. Sesame Producers Guide. Sesaco Corp. 2010, 33 p.
19. Mazzani B. Mejoramiento del ajonjoli en Venezuela," Ministerio de Agricultura y Cria, Maracay, Venezuela. 1957, p. 127. Spanish.
20. Culp TW, McWhorter GG. Annual report of cooperative industrial crops and weed investigations–1959. Crops Research Division. ARS, USDA. Stoneville, MS. 1959.
21. Grichar WJ, Sestak DC, Brewer KD, Besler BA, Stichler CR, and Smith DT. Sesame (*Sesamum indicum* L.) tolerance and weed control with soil-applied herbicides. Crop Protect. 2001;20:389-394.
22. Santelmann P, Elder W, Murlock R. The effect of several pre-emergence herbicides on guar, cowpeas, mungbeans, and sesame. Proc. South. Weed Sci. Soc. 1963;16:83.
23. Askew S, Shaw D, Arnold J. Weed control in Liberty-Link soybean. Proc. South. Weed Sci. Soc. 1997;50:59.
24. Corbett J, Askew S, Thomas W, Wilcut J. Weed efficacy evaluations for bromoxynil, glufosinate, glyphosate, pyrithiobac, and sulfosate. Weed Technol. 2004;18:443-453.
25. Hydrick D, Shaw D. Non-selective and selective herbicide combinations in stale seedbed soybean (*Glycine max*). Weed Technol. 1995;9:158-165.

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