Sesame (*Sesamum indicum* L.) Response toDiuron Applied at the 3- and 4-Leaf Pair Stageof Development

ABSTRACT

Aims: Studies were conducted to evaluate sesame response to diuron at 1X (1.12 kg ha^{-1}), 2X (2.24 kg ha^{-1}), and 4X (4.48 kg ha^{-1}) the labeled US rate applied at 3- or 4 leaf pair growth stage.
Study design: Treatments consisted of a factorial arrangement of three diuron rates (1.12, 2.24, and 4.48 kg ha^{-1}) and two application timings (3-leaf pair or 4-leaf pair). An untreated check was included in each study with 3-4 replications depending on location.
Place and Duration of Study: In south-central Texas near Yoakum (29.2765^o N; -97.1237^o W)and the High Plains of Texas near New Deal(33.7354^o N; -101.7369^o W) during the 2022 growing season.
Methodology: Sesame variety 'S-4302' was seeded 1.0 to 2.0 cm deep under conventionally tilled conditions. Weeds were controlled either by hand-hoeing or with the use of postemegence herbicides. Plot size was two rows (76 cm apart) by 8.9 m at Yoakum and four rows (101 cm apart) by 9.5 m at New Deal. At New Deal, only the two middle rows were sprayed and the other rows were untreated and served as buffers. Sesame was harvested with a small plot combine. An analysis of variance was performed using the ANOVA procedure for SAS to evaluate the significance of herbicides and application timing on sesame response and yield. Fisher's Protected LSD (0.05) was used for separation of mean differences.
Results: Sesame stunting was evident at both locations and increased as diuron rate increased. Stand reductions were noted at Yoakum as diuron at 4.48 kg ha^{-1} resulted in a 9% stand reduction compared with $\leq$1% with diuron at 1.12 or 2.24 kg ha^{-1}. Also, application timing had an effect on sesame growth.
Conclusion: Sesame yields decreased as the diuron rate increased at the High Plains location but not the south-central Texas location while application timing had no effect at either location.

Comment [AS1]: Add two sentences of introduction.

Keywords: Application timing; sesame injury; postemergence; yield.

1. INTRODUCTION

Weeds are a major obstacle in sesame production (Bhadauria et al. 2012; Grichar et al., 2009; 2011; 2012; 2015; 2018; Rose et al., 2023) and can negatively influence yield. Babiker et al. (2014) reported that unrestricted weed growth reduced sesame yield by 30% and keeping the sesame crop weed-free for 2, 4, 6, and 8 weeks after planting increased yield by 8, 37, 40, and 43%, respectively. They concluded that the critical period of weed control in sesame appeared to be between 2 to 6 weeks after planting. Bhadauria et al. (2012) reported hand-weeding 15 and 30 days after sowing improved sesame yield 162%

Comment [AS2]: Mention weeds that effect on the yield of sesame.

over that of the untreated check. Zuhair et al. (2011) found that insufficient weed control during the early growth period of sesame caused 35 to 70% yield reductions and they also concluded that the critical period of weed control in sesame was 2 to 3 weeks after crop emergence.

Sesame has several unique features that contribute to challenges in weed management (Debnath et al., 2022; Langham 2008; Langham et al. 2008; 2010). In the early stages of sesame development, weeds grow faster than the sesame. Sesame grows very slow especially during the first 4 weeks after planting and the slow growth allows weeds to compete for nutrients, soil moisture, and sunlight and become established during the early part of the growing season (Langham 2007; 2008; Langham et al. 2008). In the first 30 days, sesame plants reach approximately 28 cm in height; however, sesame will double to 60 cm in the next 11 days, triple to 90 cm in the following 8 days, and quadruple to 120 cm in the following 9 days (Langham 2007). In many cases, weeds such as *Amaranthus* spp. can suppress a sesame stand as they grow over the sesame and crowd it out. This feature can affect both manual and mechanical agronomic practices (Langham 2007; 2008; Langham et al. 2008).

Comment [AS3]: Write importance of sesame crop.

All postemergence (POST) herbicides that control broadleaf weeds in sesame have caused some sesame injury or yield reduction (Grichar et al., 2011). For broadleaf weed problems in sesame, the use of soil-applied herbicides still appears to be the only option (Grichar et al., 2009; 2011; 2012). However, since sesame hectares are increasing in areas of the US, there is a critical need to find more herbicides that can be used in sesame to extend weed control especially during the early portion of the growing season (Babiker et al., 2014; Zuhair et al., 2011). Diuron is a systemic urea herbicide (Weed Science Society of America group 5) that inhibits photosynthesis and is used in broadleaf weed crops such as cotton (*Gossypium hirsutum* L.) to control many broadleaf weeds (Sosnoskie and Culpepper, 2014). It has proved to be successful at controlling broadleaf weeds in sesame when applied preemergence (PRE) or POST; however, sesame tolerance has been an issue in several studies (Grichar et al., 2009; 2011; 2018). Therefore, to better understand sesame tolerance to various rates of diuron at different growth stages, studies were undertaken with diuron at 1X, 2X, and 4X of the proposed rate (Roger Batts, personal communication) applied POST (3 leaf pair or 4 leaf pair).

2. MATERIAL AND METHODS

2.1 Research Sites.

Field studies were conducted during the 2022 growing season near Yoakum (29.2765^{o} N; -97.1237^{o} W) at the Texas A&M Research site in south-central Texas and in the Texas High Plains near New Deal (33.7354^{o} N; -101.7369^{o} W) at the Texas Tech Research Farm to evaluate sesame response to diuron applied POST at the 3 or 4-leaf pair stage of development under weed-free conditions. Soil type near Yoakum was a Elmendorf-Denhawken complex (fine, smectitic, hyperthermicVerticArgiustolls) with less than 1.0% organic matter and pH 7.4 while the soil near New Deal was a Amarillo sandy clay loam (fine-loamy, mixed, thermic AridicPaleustalf) with 0.8% organic matter and pH 7.8. Sprinkler irrigation was applied on a 1- to 2-wk schedule throughout the growing season as needed to supplement natural rainfall at Yoakum while sub-surface irrigation was used (0.25 mm/day as needed) to supplement natural rainfall at the New Deal location

2.2 Herbicides, plots, and application.

Treatments consisted of a factorial arrangement of three rates of diuron (1.12, 2.24, and 4.48 kg ha^{-1}) and two application timings (3-leaf pair or 4-leaf pair). An untreated check was included in each study and each study was replicated three times at Yoakum and four times at New Deal. Other specifics of each study can be seen in Table 1.

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Table 1. Variables associated with the study.

	Location	
Variable	**New Deal**	**Yoakum**
Coordinates	33.7354^{o} N -101.7369^{o} W	29.2765^{o} N -97.1237^{o} W
Planting date	June 21	May 16
Variety	S-4302	S-4302
Application		
Sprayer type	CO_2 backpack	CO_2 backpack
Spray pressure (kPa)	168	180
Nozzle type	Flat fan Turbo Tee	Flat fan Drift Guard
Nozzles tips	11002	11002
Spray volume (L ha^{-1})	140	187
3 Leaf pair (LP)	July 13	June 2
Air temp	25	24
Relative humidity (%)	52	97
Soil temp	25	24
Soil moisture	Good	Excellent
4 LP	July 20	June 12
Air temp	31	27
Relative humidity (%)	36	81
Soil temp	27	27
Soil moisture	Good	Good
Harvest date	December 9	December 15

Plot size was two rows (76 cm apart) by 8.9 m at Yoakum and four rows (101 cm apart) by 9.5 m at New Deal. At New Deal, only the two middle rows were sprayed and the other rows were untreated and served as buffers.

2.3 Sesame plantings, observations, and harvest.

The sesame cultivar, 'S-4302', was seeded approximately 1.0 to 2.0 cm deep at a planting density of approximately 40,500 seed ha^{-1} at both locations under conventionally tilled conditions. Broadleaf weeds were controlled by hand-hoeing at both locations while annual grasses were controlled with a POST application of either clethodim or sethoxydim at the Yoakum location or hand-hoeing at New Deal. When sesame was mature, sesame was harvested with a small plot combine on December 9 at New Deal and December 15 at Yoakum.

At New Deal, sesame injury was evaluated as a combination of leaf necrosis/chlorosis and stunting at 7, 14, 21, 28, and 77 days after herbicide application (DAA). At Yoakum, sesame injury consisted of stand reduction, leaf necrosis/chlorosis, and stunting and each variable was evaluated separately at either 7, 14, 28, or 59 DAA. Stand reduction was evaluated 7 and 28 DAA while leaf necrosis/chlorosis was evaluated 7 and 14 DAA. All these evaluations were based on a scale of 0 (no type of injury) to 100 (complete plant death).

2.4 Data analysis.

An analysis of variance was performed using the ANOVA procedure for SAS (SAS Institute, 2019) to evaluate the significance of herbicides and application timing on sesame 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 stunting, stand and yield comparison but was only included in yield data analysis.

3. RESULTS AND DISCUSSION

3.1 New Deal location.

3.1.1 Sesame injury.

Injury consisted ofleaf necrosis/chlorosis and stunting. There was not a diuron rate by application timing interaction; however, there was a diuron rate and application timing response and those values are presented separately. Sesame injury increased as the diuron rate increased at all evaluations (Table 2). At the 7 day after application (DAA) evaluation, there were no differences in injury with the 2.24 and 4.48 kg ha^{-1} rate of diuron; however, injury was greater than that observed with diuron at 1.12 kg ha^{-1}. At the other evaluations, differences were seen between diuron rates with the greatest injury seen with the high rate of diuron. Sesame injury did decrease over time with all rates of diuron.

Table 2. Sesame response to diuron rate and application timing in the Texas High Plains (New Deal).

		Injury[1]					
		Days after application					
Treatment	**Rate**	**7**	**14**	**21**	**28**	**77**	**Yield**

	Kg ha^{-1}			%			Kg ha^{-1}
Untreated	-	0	0	0	0	0	1203
Diuron	1.12	48	44	41	33	15	1018
	2.24	58	54	48	38	19	957
	4.48	59	60	54	43	24	919
LSD (0.05)		**5**	**5**	**3**	**3**	**3**	**80**
Appl timing	**Leaf pair**						
	3	63	63	53	48	22	975
	4	45	42	42	28	17	955
LSD (0.05)		**4**	**4**	**3**	**3**	**2**	**NS**

[1]Injury consisted of leaf necrosis/chlorosis and stunting.

Sesame injury differences were noted between application timings with greater injury noted with the 3-leaf pair application compared with the 4-leaf pair at all evaluations (Table 2). Injury did decrease over time with both application timings.

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3.1.2. Sesame yield.

There was not a diuron rate by application timing interaction; therefore, each variable is presented separately (Table 2). When comparing diuron rate, the untreated check produced a greater yield than any rate of diuron. As the diuron rate increased sesame yield decreased. The diuron-induced injury, which lasted throughout the growing season, was still noticeable at harvest (data not shown) and the lack of sesame maturity (plants were still blooming at harvest) was quite evident and likely a major factor in the reduced yield. Sesame treated with diuron at 1.12 kg ha^{-1} yieldedgreater than sesame treated with diuron at 4.48 kg ha $^{-1}$. Although greater injury was seen with the 3-leaf application over the 4-leaf application, application timing had no effect on sesame yield (Table 2).

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3.2 Yoakum location.

There was not a diuron rate by application timing for any variable tested; therefore, each variable (diuron rate and application timing) is presented separately.

3.2.1 Sesame stunt.

No differences in stunting between diuron rate was noted at any evaluation (Table 3). At the 7 DAA evaluation, stunting ranged from 18 to 28% while at the 59 DAA evaluation stunting was < 5% with all diuron rates. Stunting numerically increased as diuron rate increased at all evaluation dates. Application timing did result in differences(Table 3). At 7, 28, and 59 DAA, the 3-leaf application exhibited greater stunting than the 4-leaf application; however, no differences were noted at the 14 DAA treatment although numerically, the 3-leaf application showed greater stunting. Previous research has also reported more stunting with an early diuron application than a later application (Grichar et al., 2011).

3.2.2 Sesame stand reduction.

The high rate of diuron resulted in a stand reduction at both evaluations (Table 3) and this was evident throughout the growing season (data not shown). Also, the early 3-leaf pair application resulted in a stand reduction at the 7 DAA evaluation; however, no differences between application timings were noted at the 28 DAA evaluation.

Comment [AS7]: Add reference

3.2.3 Sesame leaf burn.

Sesame leaf necrosis and chlorosis was evident with the three diuron rates with the high rate of diuron resulting in the greatest necrosis and chlorosis at the 7 and 14 DAA evaluation (Table 3). Typically, diuron injury with POST applications to sesame is transient and by late-season only slight leaf chlorosis may be found on the lower leaves (Grichar et al., 2009; 2011; 2015). Grichar et al. (2009) reported that diuron applied PRE at 1.12 kg ha^{-1} reduced sesame stands and caused injury in one year in the Texas High Plains; however, in south Texas no adverse effects with diuron were seen in the two-year study.

3.2.4 Sesame yield.

No differences in sesame yield were noted with diuron rate or application timing even though diuron at the high rate caused a reduction in stand from the lower rates and the untreated check (Table 3). With some herbicides that caused severe sesame injury, sesame yields were comparable to the untreated check because the sesame plant can compensate for open space and poor growth by adding branches with capsules (Langham 2007, 2008; Langham et al., 2008; 2010). Typically, branching can only compensate for gaps of less than 30 cm. Wider gaps not only lead to lower yields, but also let light through the canopy to promote late-season weed emergence and growth (Langham 2007, 2008: Langham et al., 2008; 2010).

Table 3. Sesame response to diuron rate and application timing in south Texas (Yoakum).

		Stunt				Stand Reduction		Leaf burn		
		Days after application								
	Rate	**7**	**14**	**28**	**59**	**7**	**28**	**7**	**14**	**Yield**
Treatment	**Kg ha^{-1}**					**%**				**Kg ha^{-1}**
Untreated	-	0	0	0	0	0	0	0	0	938
Diuron	1.12	18	23	4	2	0	0	19	3	994
	2.24	23	19	12	3	0	1	18	6	1051
	4.48	28	33	15	2	8	9	28	10	1012
LSD (0.05)		**NS**	**NS**	**NS**	**NS**	**6**	**6**	**6**	**2**	**NS**
Appl timing	**Leaf pair**									
	3	32	29	19	5	5	5	23	4	1065
	4	14	20	1	0	0	2	20	8	974
LSD (0.05)		**10**	**NS**	**10**	**2**	**4**	**NS**	**NS**	**3**	**NS**

Differences in sesame stunting between the High Plains and the south-central Texas locations were noted. Greater stunting throughout the growing season was noted at the High Plains location. Relative humidity differences were noted between the two locations and moisture

conditions were different at the 3-leaf pair application (Table 1). Also, ambient temperatures at the time of herbicide application were higher at the High Plains location (Table 1). Herbicide activity is often related to the environment. Typically, greater herbicidal activity is seen at higher temperatures and higher humidities. Phytotoxicity of POST herbicides can depend on rate, temperature, relative humidity, light intensity, and rainfall (Ritter and Coble 1981a, b). Herbicide absorption is also influenced physically and physiologically by the relative humidity of the microclimate around the plant (Hammerton, 1967) and increasing herbicide penetration and absorption may increase herbicide activity (Wichert et al., 1992). Bentazon applied at higher temperature and higher relative humiditycontrolled redroot pigweed (*Amaranthus retroflexus* L.) better than at lower temperature and lower relative humidity (Nalewaja et al., 1975). Less than 10% of the applied ^{14}C-glyphosate penetrated the treated leaf surface of bermudagrass (*Cynodon dactylon* L. Pers) at 22^{o} C and 40% relative humidity but 5 to 6 times as much penetrated and was translocated at 32^{o} C and 100% relative humidity (Jordan, 1977).

4. CONCLUSION

Diuron controls many problem broadleaf weeds in sesame and would be of great benefit to sesame growers (Baraki et a., 2023; Grichar et al., 2009, 2011, 2014, Jain and Badkul, 2013); however, it does not come without any risks. Sesame stunting and leaf necrosis and chlorosis are a common occurrence with diuron when applied early in the growing season (Grichar et al., 2011). Typically, it is suggested that grower's delay the diuron application until 3-4 weeks after sesame emergence to avoid these issues (Gerald De La Fuente, personal communication). In these studies, the diuron applications were timed to coincide with these recommendations and injury with the 1X rate was still unacceptable, especially at the Texas High Plains location. Sesame quickly grew out of the diuron induced injury in south Texas; however, this was not true in the High Plains as the injury lingered throughout the growing season and this transcended into a reduction in yield when compared with the untreated check. This may affect future labelling for the use of diuron in sesame in the US and may require restrictions for its use in certain areas.

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