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Peanut (Arachis hypogaea L.) Response to Glyphosate plus Dicamba Combinations

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Abstract

Field studies were conducted in south and the High Plains of Texas as well as in southwestern Oklahoma during the 2014 and 2015 growing seasons to evaluate the effects of glyphosate plus dicamba combinations (1/16 X to 1 X of the 1.68 kg ae ha^{-1} rate) applied 30, 60, and 90 days after planting (DAP) on Spanish (Oklahoma) and runner (Texas) peanut. Rates were established to evaluate sub-labeled drift and direct application of a 1 X rate. Peanut stunting and death were more prevalent at the 30 and 60 DAP application while peanut were more tolerant of the 90 DAP application. In south Texas, peanut yields were reduced in both years when rates of ¼ X or greater were applied 30 and 90 DAP while rates of 1/8 X or greater reduced yield when applied 60 DAP. At the High Plains location, peanut yields were consistently reduced with rates of ½ X or greater applied 30 and 90 DAP and ¼ X or greater applied 60 DAP. In Oklahoma, peanut yield were consistently reduced with rates of ¼ X or greater applied 30 and 60 DAP and 1/16 X or greater when applied 90 DAP. Peanut grade was more affected by the 60 and 90 DAP application than the 30 DAP application.

Keywords: Herbicide tolerance; peanut injury; peanut yield; peanut grade.

Introduction

During the past twenty years the use of glyphosate-resistant crop production systems have been adopted and used extensively in various regions of the US [1]. By 2015, over 90% of the soybean [*Glycine max* (L.) Merr.], cotton (*Gossypium hirsutum* L), and corn (*Zea mays* L.) planted in the US contained the modified 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) gene that confers resistance to glyphosate [2]. Glyphosate-resistant weeds, specifically *Amaranthus* species, have become an issue across all the US corn and cotton producing areas [3]. Estimates are that more than 1.2 million ha of cropland in the US are now affected by glyphosate-resistant *Amaranthus* species [3]. In cotton, Palmer amaranth (*Amaranthus palmeri* S. Wats.) has been shown to reduce lint yield by 57% when growing at a density of 10 plants per 9.1 m row^{-1} [4]. Additionally, with Palmer amaranth growing at densities greater than six plants per 9.1 m row^{-1}, cotton may not be harvestable due to the potential for damage to harvest equipment [4]. A study by Smith et al. [5] found that Palmer amaranth densities of 650 to 3260 plants ha^{-1} in dryland stripper-harvested cotton increased harvesting time by 2- to 3.5-fold.

The dicamba tolerance system is important in POST weed control in cotton and soybean [6-9] to combat resistant weed issues. Dicamba (3,6-dichloro-2-methoxybenzoic acid) is a synthetic auxin herbicide that controls glyphosate-resistant Palmer amaranth and other broadleaf weeds alone or in sequential combinations with glyphosate or glufosinate [7]. An enzyme, dicamba O-demethylase, was discovered in a soil bacterium (*Pseudomonas maltophila*) that converts dicamba (3,6-dichloro-2-methylbenzoic acid) to 3,6-dichlorosalicylic acid (DCSA) [6]. The enzyme DCSA has no significant herbicidal properties. The gene responsible for this enzyme is known as DMO (dicamba monooxygenase) and was successfully inserted into mouseear cress [*Arabidopsis thaliana* (L.) Heynh.], tomato (*Solanum lycopersicum* L.), and tobacco (*Nicotiana tabacum* L.) and shown to provide plants with effective tolerance to foliar applications of dicamba [6]. Dicamba-tolerant cotton, coupled with existing glyphosate- and glufosinate-tolerant traits, was deregulated in the US in 2015, and has since become significant portion of the cotton planted in the US, comprising over 70% of the crop planted in 2019 [8,9].

In many parts of Texas and Oklahoma, peanut and cotton are grown in close proximity and even in rotation. With the development of these new herbicide systems it will likely increase the risk of unintended exposure of peanut to the herbicides through off-target movement or improper spray tank cleanout. Spray drift has been defined as the movement of pesticide dusts or droplets through the air beyond the intended area of application at the time of application or soon after [10]. The extent to which crops are damaged by herbicide spray drift depends on several factors including prevailing environmental conditions, application boom height, driving speed of the sprayer, nozzle spacing, spray droplet size, and herbicide formulation [11]. Plants at different growth stages, and even different parts of a plant can respond differently to herbicide drift [12]. Off target movement of herbicides during application, which can be as low as 1/10 and 1/100 of the applied rate [13], can cause extensive injury to susceptible crops. Grover et al. [14] reported that herbicide drift can be 1 to 8% of the spray solution, and Wolf et al. [15] indicated off-target spray drift can reach 16% when no shielding is used. When spray systems are not properly cleaned prior to applications to different crops, crop injury can occur from herbicide residue remaining in the spray system [16,17].

Glyphosate can cause severe peanut injury and a reduction in yield. When applied 75, 90, and 105 days after planting (DAP), glyphosate at 0.24, 0.32, and 0.47 kg ae ha^{-1} caused peanut yield reductions of 12 to 36% [16]. In another study, glyphosate at 0.35 kg ae ha^{-1} applied to peanut 4 wks after planting resulted in yield loss greater than 50% and peanut injury was directly correlated with yield loss [18].

The effect of dicamba on peanut has not been well documented. Dicamba at 0.002 kg ae ha^{-1} had no effect on peanut yield in one field study [19]. In another study conducted across eight locations in the US peanut belt, peanut yield loss was greater when dicamba was applied 30 and 60 DAP compared to 90 DAP at 5 of 8 locations [19]. Estimated yield losses from the dicamba at 0.04 kg ae ha^{-1} ranged from 2 to 29% while losses from dicamba at 0.56 kg ae ha^{-1} ranged between 23 to 100% [19]. In a related forage crop, rhizome peanut (*Arachis glabrata* Benth) yields were significantly reduced by a foliar application of dicamba plus 2,4-D [20]. Dicamba plus glyphosate tank mixes have been used in XtendFlex cotton starting in 2017. Since no data could be found on glyphosate plus dicamba rate effects on peanut, the objectives of this study were to determine peanut response to glyphosate plus dicamba combinations at different rates when applied at 30 (R1), 60 (R4), and 90 (R7) DAP [21].

Materials and Methods

Field studies were conducted at the Texas A&M AgriLife Research Site near Yoakum (29.276° N, 97.123° W) in south-central Texas, near Seagraves (32.953° N, 102.518° W) in the Texas High Plains, and at the Oklahoma State University Caddo Research Station near Ft. Cobb (35.091° N, 98.275° W) in southwestern Oklahoma during the 2014 and 2015 growing seasons to determine peanut response to glyphosate plus dicamba combinations applied approximately 30, 60, and 90 DAP. These studies were conducted in the same general area but different parts of the field in the second year.

Soils at Yoakum were a Tremona loamy fine sand (thermic Aquic arenic Paleustalfs) with less than 1% organic matter and pH 7.0 to 7.2 while soils at Seagraves were a Pullman clay loam (fine, mixed, thermic Torrertic Paleustoll) with less than 1% organic matter and pH 7.7 and soils at Ft. Cobb were a Cobb fine sandy loam with less than 1% organic matter and a pH of 6.0 to 7.0. The treatment design was a 6 X 3 factorial arrangement with glyphosate plus dicamba treatment rates and application timing as factors using a randomized complete block design. Each study location used three replications plus an untreated check was included with each application timing at all locations. Treatments include 0X, 1/16 X, 1/8 X, ¼ X, ½ X, and 1 X of the combination of glyphosate (Roundup WeatherMax®) plus dicamba (Clarity 4L®). These rates correspond to various scenarios where the herbicide may not have been fully cleaned out of a commercial sprayer before the sprayer was re-filled with another product and then over sprayed the peanut plants or could even be drift from an adjacent field. The assumed 1 X rate of Roundup XtendFlex® was 1.68 kg ae ha^{-1}.

Each plot at Yoakum consisted of four rows spaced 97 cm apart and 7.6 m long, plots at Seagraves were four rows wide spaced 102 cm apart and 9.5 m long, while plots at Ft. Cobb were four rows wide spaced 91 cm apart and 9.1 m long. The middle 2 rows of each plot were sprayed to prevent drift from adjacent plots affecting the results. Peanut variety (runners in Texas, Spanish in Oklahoma), planting date, and herbicide application timing are shown in Table 1.

Table 1. Peanut variety, planting date, and herbicide application dates at each location.

Variables	**Yoakum, TX**		**Seagraves, TX**		**Ft. Cobb, OK**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
Peanut variety	McCloud	Georgia 09B	Flavorrunner 458	Red River Runner	Tamnut OL06	Tamnut OL06
Planting date	June 16	June 11	April 29	May 2	May 6	June 1
Application						
30 DAP[a]	July 17	July 7	May 30	June 1	June 3	June 30
60 DAP	Aug 15	Aug 8	July 3	June 30	July 10	July 29
90 DAP	Sept 16	Sept 8	July 28	July 30	Aug 7	Aug 25

[a] DAP, days after planting.

At Yoakum, herbicides were applied with a compressed-air backpack sprayer equipped with Teejet 11002 DG flat fan spray tips (Teejet Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60188) that delivered a spray volume of 190 L/ha at 180 kPa; at Seagraves herbicides were applied using Teejet Turbo Tee 11002 flat fan nozzles that delivered 140 L/ha at 207 kPa; and at the Ft. Cobb locations, herbicides were applied using Teejet 110015XR nozzles that delivered 93 L/ha at 180kPa. None of the treatments included any type of adjuvant.

Supplemental irrigation was supplied as needed at all locations. Traditional production practices were used to maximize peanut growth, development, and yield. Plots were maintained weed-free at all locations. To help maintain plots weed-free, a combination of herbicides and hand-weeding was used. At Yoakum, plots received pendimethalin plus *S*-metolachlor applied preemergence (PRE) followed by imazapic applied postemergence (POST); at Seagraves, plots received pendimetahlin applied PRE followed by imazethapyr applied POST; and at Ft. Cobb pendimethalin plus flumioxazin was applied PRE followed by imazapic and clethodim applied POST. Any weed escapes were removed by hand-weeding throughout the growing season to maintain weed-free conditions.

Peanut injury (including stunting and leaf chlorosis or necrosis) was estimated visually on a scale of 0 to 100 (0 indicating no plant death and 100 indicating complete plant death), relative to the untreated control. Peanut injury evaluations were recorded throughout the growing season and prior to digging of peanut. For simplicity, only injury data taken prior to digging of the peanuts is presented. Peanut yields were obtained by digging each plot separately, air-drying in the field for 4 to 7 d, and harvesting peanut pods from each plot with a combine. Weights were recorded after soil and trash were removed from plot samples. For grade determination, samples were determined using screens specified in USDA grading procedures [22].

Peanut injury data were arcsine transformed prior to analysis of variance; however, because the transformation did not alter treatment means original data are presented. Visual estimates of peanut injury and yield were subjected to analysis of variance to test effects of herbicide rate and application timing. Means were compared with Fisher's Protected LSD test at the 5% probability level. The untreated controls were not included in the peanut injury analysis but was included in the yield analysis.

Results and Discussion

Since environmental conditions, peanut injury, and yield varied from year-to-year, no attempt was made to combined data over years. Peanut injury for plants sprayed 30 and 60 DAP consisted of leaf epinasty, chlorosis, stunting, and death (stand loss) while injury for plants sprayed 90 DAP consisted of leaf chlorosis and necrosis plus some plant death. Peanut grade samples were only obtained at the south Texas location.

PEANUT INJURY

Yoakum (South Texas). In 2014, peanut injury was greater than the untreated check (0 X) with glyphosate plus dicamba rates of 1/8 X or greater when applied 30 and 60 DAP or ¼ X rate or greater when applied 90 DAP (Table 2). In 2015, injury was greater than the untreated check with all glyphosate plus dicamba rates applied 30 and 60 DAP or 1/8 X rate or greater applied 90 DAP (Table 2).

Table 2. Peanut response to glyphosate plus dicamba combinations applied 30, 60, and 90 days after planting in 2014 and 2015 near Yoakum (south Texas).

	Injury[a]			Yield			Grade (SMK+SS)[b]		
2014									
Glyphosate + dicamba[c]	Day after planting spray application								
	30	60	90	30	60	90	30	60	90
	%			Kg ha^{-1}			%		
0 X	0	0	0	4410	5155	4742	72.5	72.8	72.5
1/16 X	7	4	0	3176	5014	5258	72.3	69.8	70.8
1/8 X	19	14	0	3304	4024	4641	70.3	68.3	69.3
¼ X	37	18	18	2379	3239	2931	72.3	72.0	71.3
½ X	65	38	67	1826	1890	1787	71.3	68.8	70.8
1 X	65	45	83	1208	1504	1375	69.8	68.8	68.5
LSD (0.05)	11			861			3.4		
2015									
0 X	0	0	0	2794	3617	2623	70.2	72.7	68.8
1/16 X	12	18	3	2846	2991	2417	64.8	66.7	60.8
1/8 X	37	50	17	2702	1629	2228	72.0	66.0	61.8
¼ X	65	58	48	1046	1509	1251	66.7	65.8	70.5
½ X	92	82	91	0	618	0	-	63.7	-
1 X	100	95	98	0	0	0	-	-	-
LSD (0.05)	12			625			5.6		

[a] Evaluation taken prior to digging of peanuts.

[b] Peanut grade: SMK, sound mature kernels; SS, sound splits.

[c] The 1X rate is equivalent to 1.12 kg ae ha^{-1} of glyphosate (Roundup WeatherMax®) + 0.56 kg ae ha^{-1} dicamba (Clarity 4L®).

Seagraves (High Plains of Texas). In 2014, injury was greater than the untreated check with glyphosate plus dicamba at the 1/8 X rate or greater applied 30 DAP or all glyphosate plus dicamba rates when applied 60 or 90 DAP (Table 3). In 2015, peanut injury was similar to 2014 at all application timings.

Ft. Cobb (Southwestern Oklahoma). In 2014, when the glyphosate plus dicamba combinations were applied 30 DAP, no peanut injury was observed until the ¼ X rate or greater was used (Table 4). The 60 and 90 DAP application produced injury greater than the untreated check with all rates of glyphosate plus dicamba. In 2015, peanut injury with the 30 and 90 DAP application of glyphosate plus dicamba was observed with rates of 1/8 X or greater while injury at the 60 DAP application was observed with all rates (Table 4). At the Ft. Cobb location as at all other locations, as the rate of glyphosate plus dicamba increased peanut injury increased.

Table 3. Peanut response to glyphosate plus dicamba combinations applied 30, 60, and 90 days after planting in 2014 and 2015 near Seagraves (High Plains of Texas).

	Injury[a]			Yield		
2014						
	Day after planting spray application					
Glyphosate + dicamba[b]	**30**	**60**	**90**	**30**	**60**	**90**
	%			Kg ha^{-1}		
0 x	0	0	0	7855	8546	7326
1/16 X	5	7	13	7367	7204	8181
1/8 X	12	22	12	6471	5495	7611
¼ X	38	38	15	4966	4885	7773
½ X	65	73	20	2280	2034	4803
1 X	83	73	35	1180	1221	2930
LSD (0.05)	6			1237		
2015						
0 X	0	0	0	7286	7150	6611
1/16 X	3	15	13	6400	7319	6223
1/8 X	8	18	19	6915	6628	5869
¼ X	18	68	25	6477	5591	5649
½ X	43	77	33	5364	3307	3643
1 X	72	92	42	2597	557	2833
LSD (0.05)	5			1047		

[a] Evaluation taken prior to digging of peanuts.

[b] The 1X rate is equivalent to 1.12 kg ae ha^{-1} of glyphosate (Roundup WeatherMax®) + 0.56 kg ae ha^{-1} dicamba (Clarity 4L®).

In bell pepper (*Capsicum annuum* L.), a rate effect with dicamba was noted with injury declining in a stepwise manner as the rate of dicamba decreased [23]. Also, peanut injury decreased with the later application of glyphosate plus dicamba at the Seagraves and Ft. Cobb locations but not the Yoakum location. Similar results to those seen at Seagraves and Ft. Cobb have been seen in cotton when dicamba and 2,4-D have been used [24]. Smith et al. [24] speculated that cotton sensitivity to herbicides could be enhanced at the early growth stage due to reduced plant vigor and the lack of a fully developed cuticle [25]. A more developed cuticle can slow the passive diffusion of herbicides such as dicamba and glyphosate into the leaf, delaying the rate of translocation and development of injury symptoms. Leon et al. [26] reported that peanut leaf injury symptoms following dicamba at 0.035 to 0.14 kg ae ha^{-1} included epinasty, leaf blade cupping, and chlorosis in the area where middle veins join the petiole. At the greatest dicamba rates of 0.28 to 0.56 kg ae ha^{-1}, symptoms were plant stunting, abnormal leaf and shoot growth (e.g. poor to no leaf blade development, short stems and petioles), leaf chlorosis and necrosis, and yellowing in the upper stem. They also reported that dicamba at 0.56 kg ae ha^{-1} caused 58 to 78% injury and all dicamba rates caused at least 20% injury. Glyphosate can provide inconsistent injury to peanut as illustrated in a study by Baughman et al. [27]. In one year glyphosate at 0.42 and 0.84 kg ae ha^{-1} injured peanut less than 90% while in another year peanut injury with glyphosate was at least 91%. Improved peanut kill with glyphosate under drier conditions has been seen in some years (author's personal observation). Also, York et al. [28] reported that as the glyphosate rate increased peanut injury generally increased.

Table 4. Peanut response to glyphosate plus dicamba combinations applied 30, 60, and 90 days after planting in 2014 and 2015 near Ft. Cobb, Oklahoma (southwestern Oklahoma).

	Injury[a]			**Yield**		
2014						
	Days after planting					
Glyphosate + dicamba[b]	**30**	**60**	**90**	**30**	**60**	**90**
	%			**Kg ha^{-1}**		
0 x	0	0	0	5755	5760	6098
1/16 X	0	6	8	5481	5138	5103
1/8 X	0	10	10	5342	5133	4830
¼ X	9	31	14	4162	3918	4258
½ X	25	43	26	3633	3706	3473
1 X	85	53	43	1064	1995	2427
LSD (0.05)	6			706		
2015						
0 X	0	0	0	5714	5723	5666
1/16 X	1	19	0	5551	4693	5117
1/8 X	14	26	9	4177	4137	4174
¼ X	23	33	23	3274	2855	3665
½ X	68	40	48	973	2404	2509
1 X	79	50	68	745	1753	1092
LSD (0.05)	7			532		

[a] Evaluation taken prior to digging of peanuts.

[b] The 1X rate is equivalent to 1.12 kg ae ha^{-1} of glyphosate (Roundup WeatherMax®) + 0.56 kg ae ha^{-1} dicamba (Clarity 4L®).

Peanut Yield

Yoakum. In 2014, the 30 DAP application of all rates of glyphosate plus dicamba reduced peanut yields while with the 60 DAP application, a rate of 1/8 X or greater resulted in reduced yield and at the 90 DAP application a rate of ¼ X or greater reduced peanut yield (Table 2). In 2015, glyphosate plus dicamba rates of ¼ X or greater reduced yield at the 30 and 90 DAP application while all rates of glyphosate plus dicamba reduced yield when applied 60 DAP.

Seagraves. In 2014, glyphosate plus dicamba rates of 1/8 X or greater reduced yield from the untreated check with the 30 DAP application and all rates reduced yield at the 60 DAP application (Table 3). The 90 DAP application reduced peanut yield with only rates of glyphosate plus dicamba of ½ X or greater. In 2015, peanut yields were reduced from the untreated check with ½ X or greater rates applied 30 and 90 DAP or ¼ X or greater rate applied 60 DAP.

Peanut yield reductions decreased as glyphosate plus dicamba applications were delayed at Yoakum; however, at Seagraves and Ft. Cobb peanut yield reductions were greatest with the 60 DAP application and then decreased with the later application. Prostko et al. [17] and Leon et al. [26] have both reported that peanut exposure to dicamba between 30 and 60 DAP decreased peanut yield 5 to 17% for every 0.1 kg ha-1 increase of dicamba rate. Prostko et al. [17] reported high variability in peanut yield reductions in response to increasing rates of dicamba. They felt that the effects of auxinic herbicides on peanut growth was inconsistent and strongly influenced by environmental factors and the use of injury ratings to predict yield reductions accurately were a challenge while Leon et al. [26] felt the variable results caused by auxinic herbicides could be the result of the complex effects that these types of herbicides have on the physiology of the plant.

Peanut Grade (Sound Mature Kernels + Sound Splits).

Yoakum. In 2014, the 30 DAP application of glyphosate plus dicamba resulted in no grade differences (Table 2). The 60 DAP application resulted in a lower grade than the untreated check with the 1/8 X, ½ X, and 1 X rates of glyphosate plus dicamba while the 90 DAP only resulted in a lower grade with the 1 X rate of glyphosate plus dicamba. In 2015, as in 2014, no grade differences were noted at the 30 DAP application (Table 2) All rates reduced grade with the 60 DAP application while at the 90 DAP application glyphosate plus dicamba at 1/16 and 1/8 X reduced grade from the untreated check

Conclusions

The use of herbicides such as Xtendimax®, FeXapan®, or Engenia® could impact the growth of peanut in close proximity to spray drift or improper spray tank cleanout. A big concern with the application of auxin herbicides such as dicamba in the current production systems has been the sensitivity that many other plant species have to these herbicides [29]. For some broadleaf species, the sensitivity is such that major injury can be observed at sub-lethal or drift rates [23,26,29]. To reduce the possibility of off-target movement of these type of herbicides, specific application requirements must be followed. Labels denote specific environmental conditions for application, buffer zones must be established between tolerant and susceptible crops, and applicator tractor speeds, boom height, and nozzle type and size, and tank-mix partners and additives are specified. For example, by increasing droplet size, an applicator can reduce the number of fine droplets that are considered driftable [30-33]. Care should be taken to avoid dicamba drift, sprayer contamination, and volitization. Growers should always read and follow all directions on the herbicide label.

Data Availability

Any of this data can be obtained from the corresponding author at w-grichar@tamu.edu.

Conflicts of Interest

There are no conflicts of interest.

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