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Short Title: Fomesafen + Terbacil + Sorghum

Grain Sorghum Response to Simulated Fomesafen and Terbacil Carryover from Watermelons in Georgia

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Abstract

Georgia growers can benefit from double-cropping grain sorghum following watermelon to maximize land use and add economic value to their operations. However, capitalizing on the economic advantages of harvesting two crops within a single season must account for potential herbicide injury to rotational crops. An integrated weed management strategy that includes a preplant application of fomesafen and terbacil is recommended for weed control in watermelon production systems. However, currently labeled plant-back restrictions for grain sorghum require a minimum of 10 and 24 months for fomesafen and terbacil, respectively. Therefore, this research aimed to determine the tolerance of grain sorghum to fomesafen and terbacil following soil applications applied 90 to 100 d before planting (DBP). Experiments were conducted at the University of Georgia Ponder Research Farm from 2019 to 2023. The experimental design was a randomized complete block with 4 replications. Five rates of fomesafen (35, 70, 140, 210, 280 g ai ha^{-1}), four rates of terbacil (3.5, 7.0, 10.5, 14.0 g ai ha^{-1}) and a non-treated control, were evaluated. In 2019, fomesafen caused significant sorghum leaf necrosis, plant density reductions, height reductions, and yield reductions of at least 16%, especially when applied at rates $\geq$ 210 g ai ha^{-1}. Terbacil had little to no effect on sorghum injury, density, height, or yield in any year. These results suggest that sorghum has sufficient tolerance to terbacil when applied 90-100 DBP. In 4 of 5 years, sorghum had an acceptable tolerance to fomesafen when applied 90 to 100 DBP. However, yield losses observed in 2019 suggest that caution should be taken when fomesafen is applied 90 to 100 DBP grain sorghum at $\geq$ 210 g ai ha^{-1}.

Nomenclature: fomesafen; terbacil; grain sorghum, *Sorghum bicolor* (L); watermelon, *Citrullus lanatus* (Thunb.) Matsum. & Nakai],

Keywords: Carryover; crop rotation; degradation; double-cropping, herbicides

Introduction

Grain sorghum is a hardy warm season annual crop and one of the most important cereal grains in the world (Ottman and Olsen 2009). Commonly used throughout the U.S. in double-cropping systems, sorghum displays many attributes highly sought after when compared to other fall rotational crops, including quick establishment, drought tolerance, water-use efficiency, and minimal production inputs (Bennett et al. 1990; Peerzada et al. 2017; Sanford et al. 1973). For analogous reasons, producers in the Coastal Plains Region of South Georgia often double-crop sorghum following watermelon. This is a novel method for increasing production per unit of land within one growing season (Brandenberger et al. 2007; Crabtree et al. 1990; Lewis and Phillips 1976). Sorghum is well documented to tolerate a wide range of harsh environments, making it a suitable option to handle the mid-summer planting after watermelon harvest, where extreme temperatures and intermittent drought can otherwise limit production (Stahlman and Wicks 2000; Saballos 2008). However, residual herbicides commonly used in watermelon production systems have the potential to influence sorghum growth and yield negatively (Cobucci et al. 1998; Kratky and Warren 1973; Tweedy et al. 1971).

Watermelon is considered one of the primary specialty crops in Georgia, with 6,799 planted hectares in 2023 (USDA 2024). Weeds that emerge in watermelon within the first 4 to 5 weeks can significantly reduce yield from unwanted competition (Stall 2009). Thus, critical components for maximizing weed control and yield include crop rotations, tillage, and a robust herbicide program (Culpepper and Vance 2020). One of the current recommended weed control strategies is a preplant or preemergence (PRE) application of fomesafen (Reflex®, Syngenta, Greensboro, NC) and terbacil (Sinbar®, Tessenderlo Kerley, Phoenix, AZ) utilized in transplant bareground, seeded bareground, and most used transplant small-bed polyethylene (plastic) mulch production system (University of Georgia Pest Management Handbook 2024). Fomesafen (210 g ai ha^{-1}) and terbacil (14 g ai ha^{-1}) at the current recommended labeled rate can be applied either before plastic mulch installation or over-the-top before punching transplant holes (Culpepper and Vance 2020).

Fomesafen is an effective tool by providing extended residual control of problematic small-seeded broadleaf weeds, such as Palmer amaranth (*Amaranthus palmeri* Watson), in watermelon and other agronomic crops (University of Georgia Pest Management Handbook

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2024). Fomesafen could also be considered a favorable option for limiting non-target herbicide exposure with its relatively low off-site movement. As a week acid (pKa = 2.7), this diphenyl ether and protoporphyrinogen oxidase inhibitor (PPO), exhibits strong adsorption potential with half-life values (DT_{50}) ranging between 80 and 128 d in sandy soils of the Coastal Plains Region of Georgia (Li et al. 2018; Potter et al. 2016; Silva et al. 2013). Soil characteristics such as pH, and organic matter (OM) are significant factors that can influence the behavior of fomesafen in the soil profile and cause differential retention (sorption potential) (Li et al. 2018; Silva et al. 2013). Similar adsorption characteristics were observed for terbacil; which also displays lengthy residual activity with a DT_{50} value of 120 to 180 d in a silt loam soil (Jensen and Kimball 1982; Rahman 1977). As a photosystem II inhibitor in the uracil family, terbacil can have an average phytotoxic residue of 18 to 24 months (Jensen and Kimball 1982; Rahman 1977). Both fomesafen and terbacil not only exhibit high levels of persistence, but also relatively high water solubility, which leads to increased suspension in the soil solution (Kratky and Warren 1973; Silva et al. 2013). In terms of weed management, such circumstances are most often desirable. However, elevated mobility of fomesafen and terbacil and resuspension into the soil solution can increase successive crop injury, including grain sorghum.

Previous research has reported that significant injury to grain sorghum can occur from carryover of fomesafen and terbacil, leading to reductions in grain yield (Cobucci et al. 1998; Kratky and Warren 1973; Tweedy et al. 1971). Although, studies concluded that sorghum yield losses can be avoided if planting was delayed 100 to 179 d after a fomesafen application at a rate of 250 g ai ha^{-1} (Cobucci et al. 1998). Similar research for terbacil has not been explored. This recommendation coincides with typical sorghum planting intervals immediately following watermelon harvest ~100 d. However, this falls outside the labeled plant-back interval for fomesafen and terbacil at 10 and 24 months, respectively (Anonymous 2019; Anonymous 2022).

Mitigating losses in grain sorghum from herbicide carryover is critical. No studies have directly investigated the effects of fomesafen and terbacil carryover on grain sorghum in Georgia. Reviewing sorghum's tolerances with 10,117 planted hectares valued at US$12,000,000 will provide valuable information for sorghum management decisions when implemented into watermelon double-cropping systems (USDA 2024). Therefore, this research

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aims to determine the tolerance of grain sorghum to simulated carryover of fomesafen and terbacil.

Materials and Methods

Description of Research Site

This research was conducted at the University of Georgia Ponder Farm near TyTy, GA, (31°51' N, 83°66' W, 105 m elevation) from 2019 through 2023. The experimental site is nearly level (< 2% slope) and primarily composed of Tifton loamy sand with 96% sand, 2% silt, 2% clay, 1.2% organic matter, and an average soil pH of 6.0 (Web Soil Survey 2023).

Experimental Design and Treatments

The experimental site consisted of plots arranged in a randomized complete block design with four replications. Treatments were randomly assigned to 2 m x 7.62 m plots. The experimental site began in March of each year by utilizing both conventional tillage and a combination of burndown herbicides commonly used in agronomic systems to maintain plots weed-free. Following typical production patterns for watermelon in the Coastal Plains region of Georgia, applications of fomesafen (Reflex® 2SL, Syngenta, Greensboro, NC) and terbacil (Sinbar® 80WG, Tessenderlo Kerley, Phoenix, AZ) were made in April to bare soil. Rates included terbacil at 3.5, 7, 10.5, and 14 g ai ha^{-1} and fomesafen at 35, 70, 140, 210, and 280 g ai ha^{-1}. A nontreated control was also included for comparison. Treatments were applied utilizing a CO_2-pressurized backpack sprayer and TeeJet AIXR11002 nozzles (TeeJet Technologies Inc., Glendale Heights, IL) calibrated to deliver 140 L ha^{-1}. Immediately following application, overhead irrigation was administered at 12.7 mm to activate these herbicide treatments, which is a standard practice in watermelon production (University of Georgia Pest Management Handbook 2024). The experimental field was maintained weed-free up until sorghum planting with multiple applications of glyphosate, glufosinate, or paraquat as needed.

Grain sorghum ('Dekalb DKS 36-07' in 2019 and 'Dekalb DKS 40-76' in 2020-2023), treated with fluxofenim (Concep® III, Syngenta, Greensboro, NC) was planted in July of each year, using a Monosem two-row planter, 91 cm row spacing, 4 cm deep at a rate of 214,890 seeds ha^{-1}. Plots were maintained weed-free using a PRE application of paraquat at 774 g ai ha^{-1} (Gramoxone® 2SL, Syngenta, Greensboro, NC) and *s*-metolachlor at 1,402 g ai ha^{-1} (Dual

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Magnum® 7.62EC, Syngenta, Greensboro, NC) at planting. Atrazine at 1,121 g ai ha^{-1} (Aatrex® 4L, Greensboro, NC) and *s*-metolachlor at 1,402 g ai ha^{-1} were applied postemergence (POST) approximately 15 d after planting (DAP). Management decisions for all other fertility, insect, and disease were made according to University of Georgia Extension recommendations (University of Georgia Pest Management Handbook 2024).

A complete listing of herbicide application dates, sorghum planting dates, and rainfall totals from application to planting are presented in Table 1.

Data Collection

Visual estimates of sorghum injury in the form of leaf necrosis were obtained 14 DAP using a scale of 0 = no injury to 100 = complete plant death. Above-ground fresh weight biomass data was collected 14 DAP by hand-harvesting and weighing the number of plants/0.9 m^{-1}. Sorghum density data was collected 21 DAP by counting the number of plants/0.9 m^{-1}. Sorghum height data was collected 21 and 60 DAP. Yield data was obtained using a small-plot combine with grain moisture adjusted to 13%.

Statistical analyses

Data were subjected to PROC GLIMMIX in SAS 9.4 (Littell et al. 2006). Conditional residuals for control were used for checking assumptions of normality, independence of errors, homogeneity, and multiple covariance structures. Fixed effects included year and herbicide treatments. Trials and replicates represented random effects. Means were compared using LSMEANS procedure with a Fisher's protected LSD test for pairwise comparison ($P \leq 0.1$). The $P < 0.1$ value was chosen prior to trial initiation because it has been the authors' experience that biologically or practically significant differences in data are often overlooked when $P < 0.05$. The authors also feel that growers, the ultimate end users of this data, are willing to accept a slightly less stringent *P*-value in order to capture real-world differences that could result in greater economic returns at the farm level.

Results and Discussion

Grain Sorghum Leaf Necrosis

There was a year-by-treatment interaction for leaf necrosis; thus, data are presented by year (P < 0.1) (Table 2). In all years, terbacil did not affect sorghum leaf necrosis. However, leaf necrosis from applications of fomesafen varied by year, with the greatest injury observed in 2019. In 2019, fomesafen at the three highest rates (140, 210, 280 g ai ha^{-1}) caused significant necrosis compared to the nontreated control (NTC). In subsequent years (2020-2023), leaf necrosis never exceeded 15% with any rate of fomesafen.

Grain Sorghum Above-Ground Biomass

A significant year-by-treatment interaction was observed for grain sorghum above-ground biomass 14 DAP data. Therefore, years (2019) with treatment effects were separated, and the remaining were combined across years (P < 0.01) (Table 3). In 2019, above-ground biomass ranged from 17 to 56 g 0.9 m^{-1} across all treatments. Fomesafen at rates ≥ 140 g ai ha^{-1} reduced above-ground biomass by 40 to 64% compared to the NTC. However, fomesafen did not affect biomass from 2020-2023. Terbacil did not affect sorghum above-ground biomass when compared with the NTC. However, in 2019, differences were observed between rates of terbacil at 7.0 and 10.5 g ai ha-1, with 56 and 38 g 0.9 m^{-1}, respectively. Overall, above-ground biomass was greater in 2019 than in 2020 to 2023, which could be a result of the differences in variety or other environmental factors, including differences in degree days.

Grain Sorghum Density

A significant year-by-treatment interaction was observed for grain sorghum density 21 DAP; therefore, years were separated (P < 0.1) (Table 4). In 2019, fomesafen applied at 280 g ai ha^{-1} reduced sorghum density 16% when compared with the NTC (18 plants 0.9 m^{-1}). Results in 2020 and 2022 indicated no differences in density between treatments (P > 0.1). In 2023, sorghum density was reduced by 3.5 g ai ha^{-1} of terbacil compared with the NTC with 14 and 16 plants 0.9m^{-1}, respectively.

Grain Sorghum Height

There was a significant year-by-treatment interaction for grain sorghum heights 21 DAP; therefore, years with treatment interactions were separated and the remaining were combined across years ($P < 0.01$) (Table 5). In 2019, sorghum heights followed similar trends to leaf necrosis whereby fomesafen at the three highest rates caused significant height reductions relative to the NTC (Table 5). However, no other height reductions were observed from fomesafen at 21 d or 60 d. Terbacil did not reduce sorghum plant heights at any time when compared with the NTC, however, differences were observed between 3.5 and 7.0 g ai ha^{-1} with 16 and 14 cm, respectively.

Grain Sorghum Yield

A significant year-by-treatment interaction was observed with respect to yield. Yield data for 2019 is presented separately from pooled 2020-2023 yield data (Table 6). In 2019, grain sorghum yield ranged from 3,657 to 4,781 kg ha^{-1}. Fomesafen applied at the labeled rate for watermelons (210 g ai ha^{-1}) and the highest rate (280 g ai ha^{-1}) caused significant yield reductions when compared with the NTC (4,642 kg ha^{-1} compared to 3,897 and 3,657 kg ha^{-1}, respectively (Table 6)). Yields from other treatments did not differ from the NTC. In 2020-2023, there were no treatment differences regardless of herbicide and rate with yields ranging from 2,874 to 3,450 kg ha^{-1} (Table 6).

Overall, grain sorghum exhibited varied responses and was dependent on herbicide, rate, and year. Regardless of application rate, terbacil did not negatively impact vegetative growth or final yield in any year. These results were in contrast to previous studies whereby sorghum plants were severely injured from soil treated with terbacil, although, at much higher rates (1.12 kg ha^{-1}) (Tweedy et al. 1971). Terbacil exhibits a high level of persistence in the soil profile with DT_{50} concentration of 5-7 months in sandy loam soils (Marriage et al. 1977; Rahman 1976). However, terbacil is considered a highly mobile herbicide in soils with low organic matter (< 0.7%), regularly exceeding depths > 30 cm (Marriage et al. 1977; Gardiner et al. 1969; Rhodes et al. 1970; Skroch et al. 1971; Swan 1972). During the course of this experiment, rainfall accumulation between treatment application and planting (~100 d) totaled 188-434 mm over 2019-2023 (Table 1). Therefore, leaching below grain sorghum rooting zone is a probable cause

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for nonsignificant responses from terbacil treatments as approximately 86% of total root biomass is in the upper 30 cm of the soil profile (Mayaki et al. 1976; Rhodes et al. 1970).

In contrast to terbacil treatments, grain sorghum exhibited negative responses to fomesafen applications but was dependent on rate and year. In 2019, both the labeled rate of fomesafen for watermelon (210 g ai ha^{-1}), and the highest rate (280 g ai ha^{-1}), resulted in sustained injury throughout the growing season reducing density, above-ground biomass, height, and yield. This supports previous work whereby sorghum injury from fomesafen (250 g ai ha^{-1}) is likely when planting < 100 DAA (Cobucci et al. 1998). Under aerobic conditions in a laboratory setting, Potter et al. (2016) reported DT_{50} of fomesafen 100 ± 20 d. Field observations would support these findings as well with common PPO symptomology identified throughout the growing season including tissue bronzing, streaking, chlorosis, and significant leaf necrosis (Table 2) (Ahrens 1994). However, grain sorghum response to fomesafen in subsequent years (2020-2023) indicated no substantial negative responses when compared with the NTC ($P > 0.1$).

One hypothesis leading to the differences in fomesafen response between 2019 and 2020-2023 could be variety sensitivity (Abit et al. 2009). This is a plausible hypothesis but would require further investigation. Other contributing factors seem more likely to be the physiochemical properties of fomesafen and the environmental conditions at application and thereafter until planting (Costa et al. 2014; Ying and Williams 2000). Across all site years, rainfall totals from herbicide application until sorghum planting were never below the long-term average (Table 1). Studies have indicated that soil characteristics such as organic matter (OM), pH, sand, silt, and clay content are all significant contributors to adsorption, water solubility, and leaching (Costa et al. 2014; Li et al. 2018; Guo et al. 2003). Li et al. (2018) reported that when fomesafen was applied at 280-560 g ai ha^{-1} to a Tifton loamy sand, DT_{50} values were 4-6 d, on average, and residuals were not detected > 26 DAT. Because the experimental site consisted of similar sandy loam soil with low organic matter (< 0.1%), coupled with consistent rainfall, the moderate mobility of fomesafen most likely led to leaching through the soil profile.

Other environmental variables that account for the absence of distinctions between fomesafen treatments and the NTC for the years 2020-2023, during grain sorghum planting around 100 DAA, involve swift herbicidal breakdown via photolysis and microbial degradation

(Li et al. 2018). Previous studies suggest that these mechanisms notably diminish concentrations and mitigate crop response (Li et al. 2018). Nonetheless, they fail to elucidate the variances between 2019 and 2020-2023, except for potential disparities in hybrids or other unidentified factors.

This research concentrated on a simulated watermelon production system in an open-field environment. However, it is noteworthy to acknowledge that many farmers opt for polyethylene plastic mulch (Li et al. 2018; University of Georgia Pest Management Handbook 2024). Growers employ both small- and large-bed plastic mulch for watermelon cultivation. In such cases, fomesafen application can occur post-bed formation but before plastic mulch installation (AS Culpepper, personal communication). The persistence of fomesafen in the field has been shown to remain elevated when applied beneath plastic mulch before planting, as the mulch hindered photolysis, volatilization, and runoff from rain (Li et al. 2018; Reed et al. 2018). Consequently, it's plausible to speculate that the residual harm to grain sorghum around 100 DAA may be more pronounced in large-bed plastic mulch systems where fomesafen is applied to the bed before mulch installation. Hence, further exploration is warranted to assess fomesafen degradation and grain sorghum reaction under these conditions.

Practical Implications

The combination of fomesafen and terbacil plays a crucial role in weed management within watermelon production systems. Commonly known for their lengthy residual and soil persistence, these PRE herbicides are effective at limiting the most troublesome weeds for much of the growing season. As a result, growers that intend to pursue these niche integrated production systems should be mindful of the risks. Double-cropping grain sorghum will most likely continue to be a method utilized in Georgia to optimize land use during the summer growing season. Therefore, the following research will help growers implement their weed management strategy and limit any potential negative responses from herbicide carryover.

While terbacil applied to bareground at 14 g ai ha^{-1} poses minimal risk to grain sorghum planted 90-100 days after application, fomesafen applied at rates $\geq$ 210 g ai ha^{-1} has demonstrated the potential to induce notable sorghum injury and yield reduction. Injury caused by fomesafen to double-cropped grain sorghum applied 90-100 DBP at rates $\geq$ 210 g ai ha^{-1} could vary depending on variety. Nevertheless, adverse environmental conditions are likely the

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most influential factor impeding herbicide degradation. It is also important to note once again that this research was conducted on bare-ground. A common practice in watermelon production systems is to utilize some level of polyethylene mulching in addition to herbicides for weed suppression. As a natural consequence of reduced exposure to environmental factors under these mulching conditions, differences in herbicide persistence would be expected that could increase injury. For this reason, future research would require investigating grain sorghum response to fomesafen and terbacil in mulch production systems.

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Competing Interests

No competing interests have been declared.

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Table 1. Herbicide application dates, planting dates, rainfall totals for fomesafen and terbacil grain sorghum field trials, University of Georgia Ponder Farm near TyTy, GA, 2019-2023.[a]

Year	Variety	Herbicide application date	Grain sorghum planting date	Rainfall (from application to planting)	Long-term average
				---------- mm ----------	
2019	DKS 37-07	Apr 10	Jul 9	287	271
2020	DKC 40-76	Apr 17	Jul 20	382	294
2021	DKC 40-76	Apr 17	Jul 12	434	292
2022	DKC 40-76	Apr 4	Jul 6	188	278
2023	DKC 40-76	Apr 13	Jul 5	374	278

[a] Long-term historical (1981-2016) average. Data obtained from Georgia Weather Network (http://www.georgiaweather.net).

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Table 2. Leaf necrosis 14 d after planting (DAP) following fomesafen and terbacil applied 90-100 d before planting, near TyTy, GA, 2019-2023.[a]

Herbicide	Rate	Necrosis									
		2019		2020		2021		2022		2023	
	g ai ha^{-1}	------------------------- % ---------------------------									
Nontreated control	----	0	c	0	b	0	c	0	c	0	c
Fomesafen	35	0	c	1	b	0	c	0	c	0	c
Fomesafen	70	4	c	1	b	0	c	0	c	0	c
Fomesafen	140	28	b	0	b	0	c	1	bc	1	bc
Fomesafen	210	38	a	1	b	5	b	5	b	3	b
Fomesafen	280	40	a	4	a	15	a	10	a	8	a
Terbacil	3.5	0	c	0	b	0	c	1	bc	0	c
Terbacil	7.0	0	c	0	b	0	c	0	c	0	c
Terbacil	10.5	0	c	0	b	0	c	0	c	0	c
Terbacil	14	0	c	0	b	0	c	1	bc	0	c

[a] Means in the same column with the same letter are not significantly different according to Fisher's protected LSD test $P \leq 0.1$.

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Table 3. Grain sorghum above-ground fresh weight biomass 14 d after planting (DAP) following fomesafen and terbacil applied 90-100 d before planting, TyTy, GA, 2019-2023.[a]

Herbicide	Rate	Biomass 2019		Biomass 2020-2023	
	g ai ha^{-1}	---------------- g 0.9 m^{-1} ------------------			
Nontreated control	----	47	ab	13	a
Fomesafen	35	35	bc	12	a
Fomesafen	70	38	bc	11	a
Fomesafen	140	28	cd	13	a
Fomesafen	210	18	d	14	a
Fomesafen	280	17	d	11	a
Terbacil	3.5	47	ab	11	a
Terbacil	7.0	56	a	12	a
Terbacil	10.5	38	bc	13	a
Terbacil	14	44	ab	12	a

[a] Means in the same column with the same letter are not significantly different according to Fisher's protected LSD test $P \leq 0.1$. A significant treatment by year interaction was observed, therefore, 2019 data were isolated from combined data for 2020-2023.

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Table 4. Grain sorghum density 21 d after planting (DAP) following fomesafen and terbacil applied 90-100 d before planting, near TyTy, GA, 2019-2023.[ab]

Herbicide	Rate	Density							
		2019		2020		2022		2023	
	g ai ha^{-1}	--------------------- 0.9 m^{-1} -------------------							
Nontreated control	----	18	ab	17	a	16	bc	16	bc
Fomesafen	35	19	ab	16	a	17	bc	15	cd
Fomesafen	70	20	a	15	a	18	a	16	bc
Fomesafen	140	17	b	17	a	16	bc	17	a
Fomesafen	210	18	ab	15	a	16	bc	17	ab
Fomesafen	280	15	c	14	a	17	bc	16	bc
Terbacil	3.5	19	ab	17	a	15	c	14	d
Terbacil	7.0	18	ab	17	a	17	ab	17	ab
Terbacil	10.5	19	ab	18	a	18	a	17	ab
Terbacil	14	19	ab	18	a	16	c	17	a

[a] Means in the same column with the same letter are not significantly different according to Fisher's protected LSD test $P \leq 0.1$.

[b] Density data was not captured for 2021.

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Table 5. Grain sorghum plant height 21 and 60 d after planting (DAP) following fomesafen and terbacil applied 90-100 d before planting, near TyTy, GA, 2019-2023.[abc]

		Height							
		21 d						60 d	
Herbicide	Rate	2019		2020		2021-2023		2020; 2022-2023	
	g ai ha^{-1}	-------------------- cm --------------------							
Nontreated control	----	26	ab	13	bc	23	a	93	a
Fomesafen	35	27	ab	14	ab	23	a	98	a
Fomesafen	70	23	ab	15	a	22	a	100	a
Fomesafen	140	20	c	15	a	22	a	99	a
Fomesafen	210	20	c	16	a	23	a	100	a
Fomesafen	280	13	d	14	ab	21	a	98	a
Terbacil	3.5	27	ab	14	ab	23	a	96	a
Terbacil	7.0	28	a	12	c	23	a	94	a
Terbacil	10.5	26	ab	13	bc	23	a	97	a
Terbacil	14	28	a	13	bc	23	a	96	a

[a] Means in the same column with the same letter are not significantly different according to Fisher’s protected LSD test $P \leq 0.1$.

[b] For 21 DAP, a significant treatment-by-year interaction was observed; therefore, 2019 and 2020 data were isolated from combined data for 2021-2023.

[c] Height data for 60 DAP was not collected in 2019 and 2021.

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Table 6. Grain sorghum yield response following fomesafen and terbacil applied 90-100 d before planting, near TyTy, GA, 2019-2023.[ab]

		Grain yield			
Herbicide	Rate	2019		2020-2023	
	g ai ha^{-1}	-------------- kg ha^{-1} -------------			
Nontreated control	----	4642	a	3061	a
Fomesafen	35	4417	ab	3385	a
Fomesafen	70	4363	ab	2936	a
Fomesafen	140	4736	a	3450	a
Fomesafen	210	3897	bc	3305	a
Fomesafen	280	3657	c	3268	a
Terbacil	3.5	4751	a	2972	a
Terbacil	7.0	4781	a	3007	a
Terbacil	10.5	4518	a	2950	a
Terbacil	14	4596	a	2874	a

[a] Means in the same column with the same letter are not significantly different according to Fisher's protected LSD test $P \leq 0.1$. A significant year-by-treatment interaction was observed. Therefore, 2019 data were isolated from combined data for 2020-2023.

[b] Final moisture adjusted to 13%.

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