Cutleaf Groundcherry (*Physalis angulata*) Density, Biomass and Seed Production in Peanut (*Arachis hypogaea* L.) Following Regrowth Due to Inadequate Control

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A field experiment evaluated simulated salvage herbicide application injury and injury timing on cutleaf groundcherry density, biomass, seed production, and crop yield in a peanut system. Treatments included: 1) a non-treated control; 2) hand pruning; 3) diclosulam applied preemergence (PRE) alone at 27 g/ha ; 4) paraquat applied at cracking early postemergence (EPOST) at 140 g/ha followed by bentazon at 560 g/ha late postemergence (POST) alone or mixed with 5) 2,4-DB at 220 g/ha; 6) acifluorfen at 280 g/ha; 7) imazapic at 70 g/ha; or 8) chlorimuron ethyl at 9 g/ha. Hand pruning and POST herbicide treatments were performed at 1-week intervals for four weeks beginning in June of each year. Herbicide treatments do not reflect current peanut herbicide recommendations but were chosen based on likely differential cutleaf groundcherry biomass and subsequent seed production. Diclosulam applied PRE provided season-long cutleaf groundcherry control; imazapic applied POST in combination with bentazon also provided excellent control. Use of bentazon alone or mixed with chlorimuron ethyl, or hand pruning resulted in similar cutleaf groundcherry biomass and subsequent seed production compared to the non-treated control in almost all comparisons. Peanut yield reflected early-season weed interference and late season cutleaf groundcherry control. Highest yields were recorded for diclosulam PRE and POST applications containing 2,4-DB and imazapic with 6040, 5990, and 6430 kg/ha, respectively. When early-season weed control efforts fail to completely control cutleaf groundcherry, it is crucial to have effective late season herbicide options for salvage treatments in order to prevent additions to the seed bank.

Nomenclature: Acifluorfen, bentazon, chlorimuron ethyl, diclosulam, imazapic, paraquat, 2,4-DB, cutleaf groundcherry, *Physalis angulata* (L.) PHYAN, peanut, *Arachis hypogaea* (L.).

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Cutleaf groundcherry (*Physalis angulata* L.), a summer annual weed in the nightshade family, Solanaceae, is found throughout the southeastern United States primarily on disturbed sites and agricultural lands. This weed species can reach 1m in height and produces shallow-germinating seed within a many-seeded berry (Bell and Oliver 1979; Hall et al. 1991). Previous reports indicate cutleaf groundcherry to be a common weed species of rice (*Oryza sativa* L.), cotton (*Gossypium hirsutum* L.), and soybean (*Glycine max* L.) in several regions of the United States (Bell and Oliver 1979; Thomson and Witt 1987; Arslan et al. 2005). Groundcherry species have also been listed among the most troublesome weeds in peanut (*Arachis hypogaea* L.) production in Alabama and Mississippi; however, there is relatively little research dealing with control of cutleaf groundcherry (Anonymous 2005). The increasing appearance of this weed in peanut acreage, without effective control, presents the potential for peanut yield loss from cutleaf groundcherry competition. Peanut quality may also be affected when cutleaf groundcherry is present during harvest due to the difficulty in separating the groundcherry seed pod from harvested seed as well as the difficulty in removing groundcherry seed should the calyx rupture, which has been reported in soybean (Thomson and Witt 1987). Moreover, cutleaf groundcherry is recognized as a host species for the peanut root-knot nematode [*Meloidogyne arenaria* (Neal) Chitwood] which can severely reduce peanut yield (Rich and Tillman 2007; Rich et al. 2010).

Strategies for effective management in peanut generally rely on several herbicide applications to reduce weed pressure (Wilcut et al. 1995). Although previous research has reported acceptable control of cutleaf groundcherry in certain crops such as soybean (Arslan et al. 2005), early-season control can prove difficult to achieve due to the numerous seed deposits into the seedbank as well as cutleaf groundcherry's tolerance to preemergence (PRE) applied dinitroanilines (Bell and Oliver 1979).

Table 1. Herbicide treatment rates for 2009 and 2011 at Gulf Coast Research Center, Fairhope, AL.

Treatment	Rate
	g/ha
PRE	
Diclosulam	27
POST	
Paraquat[a] fb[b] bentazon	140 fb 560
Paraquat fb bentazon + 2,4-DB	140 fb 560 +220
Paraquat fb bentazon + acifluorfen	140 fb 560 + 280
Paraquat fb bentazon + imazapic	140 fb 560 + 70
Paraquat fb bentazon + chlorimuron ethyl	140 fb 560 + 9

[a]Paraquat applications applied at cracking.
[b]fb, followed by.

Additionally, cutleaf groundcherry can continue successful germination even in dry conditions which increases the need for post emergence control options (Thomson and Witt 1987). Limited information is available for cutleaf groundcherry control in peanut; however, current herbicide recommendations may only provide fair control of this weed species (Ferrell et al. 2009).

Use of inefficient postemergence (POST) herbicides can result in compensatory regrowth of weed species not completely controlled by herbicide applications (Mager et al. 2006). This increase in plant growth as a result of plant injury has been associated with several mechanisms for regrowth such as increased photosynthetic rate, reallocation of plant resources, and more efficient water use (Andreasen et al. 2002). Regrowth due to defoliation from herbivory or herbicide use has shown that some species are able to reestablish some or all lost plant biomass with varying degrees of fitness costs depending on the plant environment and timing of defoliation (Mabry and Wayne 1997; Tiffin 2001; Andreasen et al. 2002; Sun et al. 2009; Soti and Volin 2010). If cutleaf groundcherry is successful in regrowth after sub-lethal herbicide applications, peanut yield could potentially be reduced in current production systems while increased cutleaf groundcherry seed is added to the seed bank for germination in subsequent years (Baysinger and Sims 1992; Sikkema et al. 2004; Mager et al. 2006). Postemergent options along with application timing need to be further evaluated for effectiveness of cutleaf groundcherry control and extent of regrowth when not fully controlled.

Given the potential for regrowth of cutleaf groundcherry if not completely controlled, it is necessary to understand the effect of herbicides and application timing under conditions where cutleaf groundcherry is injured but not fully controlled. Therefore, research objectives were to evaluate cutleaf groundcherry population, biomass, seed production, and peanut yield in response to different application timing and herbicide applications designed to provide less than complete control.

Materials and Methods

A field study was conducted in 2009 and 2011 at the Gulf Coast Research and Extension Center in Fairhope, AL on a Malbis sandy loam soil (fine-loamy, siliceous, subactive, thermic Plinthic Paleudults) to investigate cutleaf groundcherry control by herbicides and timing of application in peanut production. Growing practices for peanut followed the Alabama Cooperative Extension System recommendations (Anonymous 2009).

The runner-type peanut cultivar Georgia 06G was planted on May 21, 2009 and June 8, 2011 at a rate of 160 kg/ha into a field with a natural population of cutleaf groundcherry. Prior to planting, the field was disked and field cultivated in April to prepare a smooth uniform seedbed. The experimental site was rotated to cotton during the 2010 growing season. Herbicide treatments were arranged in a randomized complete block design with three replications of each treatment. Plots were 3.9 m wide and 9.1 m long with 4 single rows per plot. Herbicide treatments included are listed in Table 1. Herbicide treatments do not reflect current peanut herbicide recommendations but were chosen based on likely differential cutleaf groundcherry biomass and subsequent seed production. Crop oil concentrate (COC) at 1% v/v was included in all bentazon treatments while applications of paraquat included a non-ionic surfactant (NIS) at 0.25% v/v. A 5-cm hand pruning (to simulate incomplete control from a contact herbicide, thus releasing axillary bud growth) treatment

Table 2. Herbicide application dates for 2009 and 2011 at the Gulf Coast Research Center, Fairhope, AL.

	Date of application	Date of application
Herbicide application	2009	2011
Diclosulam (PRE)	21-May	9-June
Paraquat[a]	5-June	24-June
POST treatments[b] 4 WAP[c]	23-June	8-July
POST treatments 5 WAP	1-July	15-July
POST treatments 6 WAP	7-July	22-July
POST treatments 7 WAP	15-July	29-July

[a]Paraquat was applied at cracking.

[b]Postemergence (POST) treatments included bentazon alone or in combination with 2,4-DB, acifluorfen, imazapic, or chlorimuron.

[c]WAP, weeks after planting.

was included as well as a non-treated control in the study. Hand pruning and POST herbicides were applied at four weekly intervals beginning four weeks after planting (WAP) on June 23, 2009 and on July 8, 2011 (Table 2). Sethoxydim plus COC was applied at 200 g/ha each year to control annual grasses. All applications were made with a CO_2 pressurized sprayer at 147 kPa.

On September 2, 2009 and September 25, 2011 (15 WAP), all aboveground cutleaf groundcherry biomass was removed from the entire plot and population density was recorded. Plot biomass was combined and dried at 60 C (until weights remained unchanged), weighed, and seed pod number were determined for each plot. Peanuts were inverted on October 21, 2009 and October 19, 2011 and harvested on November 5, 2009 and November 4, 2011, respectively. Peanut yield was determined from the center two rows of each plot.

Data analysis was performed with ANOVA (P=0.05) in SAS (Statistical Analysis Software®, version 9.2, SAS Institute Inc., Cary, NC) with means separated by Fisher's Protected LSD.

Results and Discussion

The data is presented by year due to a significant (P≤0.05) year effect being noted for cutleaf groundcherry seed pod production and peanut yield. Significant interactions were not observed in the data; therefore, main effects only are discussed.

Cutleaf groundcherry density, biomass and seed pod production. Cutleaf groundcherry populations were lowest with a PRE application of diclosulam and POST treatments of paraquat fb bentazon plus imazapic in 2009 with 180 and 500 plants/ha, respectively; however, these densities were not reduced in comparison to non-treated plots (Table 3). In 2011, diclosulam provided the lowest cutleaf groundcherry density, 390 plants/ha, among herbicide treatments; however, the PRE treatment did not decrease density compared to the no herbicide control treatment. In both years, increased densities were observed with the hand-pruned treatment over several herbicide treatments and, in 2011, the hand-pruned treatment had a greater density than that of the non-treated likely due to lack of intraspecific cutleaf groundcherry competition within these treatments.

Cutleaf groundcherry biomass production reflected density with diclosulam and POST applications that included imazapic producing lower biomass than other treatments in both years, as would be expected. The low biomass levels observed with diclosulam (21 kg/ha) and bentazon + imazapic (46 kg/ha) in 2011; however, levels were not reduced in comparison with the non-treated (110 kg/ha) or any other POST herbicide application except the application of paraquat plus bentazon alone which produced 130 kg/ha. Biomass levels of POST applications with acifluorfen in 2011 also resulted in lower biomass levels similar to those observed with diclosulam. Biomass levels for hand-pruned treatments were slightly higher than some treatments, though not significant; however, this indicates that cutleaf groundcherry is capable of regrowth after defoliation.

In 2009, seed pod production for herbicide treatments resulted in fewer seed pods per hectare following diclosulam and bentazon + imazapic treatments with 34,150 and 2090 pods/ha, respectively (Table 3). Seed pod production for POST applications of paraquat fb bentazon alone or plus chlorimuron resulted in elevated pod counts over the PRE and bentazon + imazapic treatments and were similar to counts observed in the non-treated and hand-pruned treatments. Seed pod counts in 2011 did not reveal a significant difference between most treatments; diclosulam and POST applications including imazapic once again resulted in lower pod counts at 32,910 and 320 pods/ha,

Table 3. Cutleaf groundcherry population, dry biomass, seed pod production, and peanut yield response to herbicide treatment in 2009 and 2011 at the Gulf Coast Research Center, Fairhope, AL.

Herbicide treatment		Population density		Dry biomass		Seed pods	
		2009	2011	2009	2011	2009	2011
		plants/ha		kg/ha		pods/ha	
	Non-treated	3370**ab**[a]	2690**b**	80**a**	110**ab**	260,270**a**	98,590**ab**
PRE	Diclosulam	180**b**	390**b**	10**bc**	20**b**	34,150**b**	32,910**b**
	Bentazon	5140**a**	4250**ab**	100**a**	130**a**	274,440**a**	179,250**a**
	Bentazon + 2,4-DB	3120**ab**	4150**ab**	70**ab**	80**ab**	167,460**ab**	110,990**ab**
POST[b]	Bentazon + acifluorfen	3610**ab**	3220**ab**	50**abc**	20**b**	147,870**ab**	6800**b**
	Bentazon + imazapic	500**b**	2910**b**	0**c**	50**ab**	2090**b**	320**b**
	Bentazon + chlorimuron ethyl	6270**a**	2370**b**	80**a**	60**ab**	250,070**a**	75,530**ab**
	Hand-pruned	4180**a**	7370**a**	110**a**	110**ab**	289,640**a**	84,920**ab**

[a]Means within a column followed by the same letter are not significant (P=0.05).
[b]POST treatments included a paraquat application at cracking.

respectively. POST applications containing acifluorfen also resulted in low seed pod production which was in agreement with the low level of biomass observed for this treatment in 2011. Seed pod production under hand-pruning was not negatively affected in either year with 290,000 and 85,000 pods/ha in 2009 and 2011, respectively. Seed pod counts were similar to non-treated counts in each year with a slight elevation in seed pod production in 2009, which may indicate the potential for increased seed production in cutleaf groundcherry with sub-lethal herbicide applications, as has been observed in a limited number of other weed species (Fawcett and Slife 1978; Sikkema et al. 2004). Seed pod production was highly related to cutleaf groundcherry plant biomass (Figure 1).

In both years of the study, diclosulam and treatments with imazapic had similarly low cutleaf groundcherry populations and biomass levels. Low seed pod production was observed for both treatments; however, POST treatments containing imazapic resulted in pod counts lower than diclosulam. Given the similar biomass levels and population densities of the treatments, differences in seed pod counts may indicate the potential to reduce seed production by cutleaf groundcherry when treated with a POST application that includes

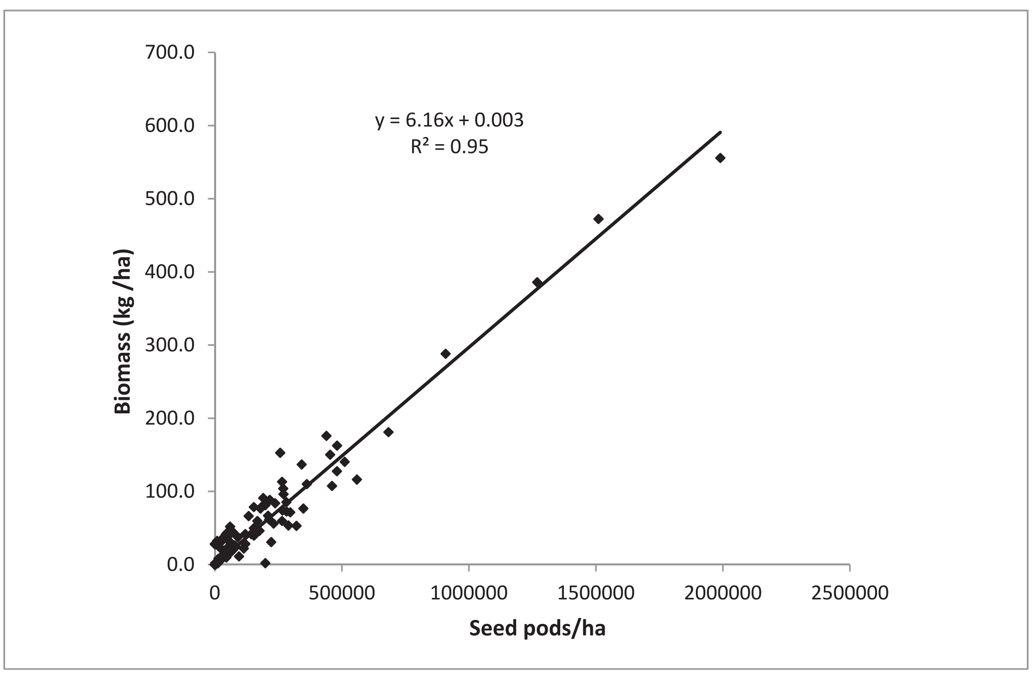

Fig. 1. Seed pod production as influenced by cutleaf groundcherry plant biomass. Increased seed pod production (seed pods/ ha) is positively correlated with increased plant biomass (kg/ha) averaged over all treatments and both years of the study.

Table 4. Cutleaf groundcherry population, dry biomass, and seed pod production response to postemergence application timing in 2009 and 2011 at the Gulf Coast Research Center, Fairhope, AL.

	Population density		Dry biomass		Seed pods	
	2009	2011	2009	2011	2009	2011
Post application	plants/ha		plants/ha		plants/ha	
4 WAP[a]	2800**b**[b]	6710**a**	50**b**	110**a**	170,910**b**	152,540**a**
5 WAP	1290**b**	1330**b**	30**b**	40**a**	60,740**b**	28,590**b**
6 WAP	5740**a**	2340**b**	120**a**	40**a**	340,510**a**	42,810**b**
7 WAP	3350**ab**	3300**b**	50**b**	90**a**	140,830**b**	70,710**ab**

[a]WAP, weeks after planting.
[b]Means within a column followed by the same letter are not significant (P=0.05).

imazapic compared to diclosulam. In peanut production with high populations of cutleaf groundcherry, imazapic applied in conjunction with paraquat may provide season-long control with reduced seed addition to the seedbank. However, when rotating to cotton, imazapic use is not feasible due to the rotation restriction, but PRE applications of diclosulam would also provide good cutleaf groundcherry suppression (Anonymous 2011).

Cutleaf groundcherry population density for the four weekly herbicide applications starting at 4 WAP resulted in lowest populations observed at 4 and 5 WAP in 2009 with 2800 and 1290 plants/ha, respectively (Table 4). Applications at 6 WAP resulted in increased density over the previous POST applications with 5740 plants/ha. In 2011, cutleaf groundcherry density response to application timing differed from 2009 with 4 WAP counts increased over later applications by 3400 plants/ha or more. As would be expected, the trend in density with respect to POST application intervals for each year was also observed in cutleaf groundcherry biomass levels and seed pod production. Measured biomass levels and seed pod production in 2009 was increased at 6 WAP over each of the other application weeks. The lowest biomass and seed pod counts occurred at 5 WAP with 30 kg/ha and 60,740 pods/ha. Cutleaf groundcherry biomass and pod counts in 2011 were increased at 4 WAP over 5 and 6 WAP but were similar to applications made at 7 weeks. Lowest measured biomass and seed pod production were recorded at 5 WAP with biomass levels of 40 kg/ha and pod counts at 28,590 pods/ha.

Peanut yield. Yields recorded in 2009 reflected a level of early-season weed interference and late season cutleaf groundcherry control (Table 5). The hand-pruned treatment yielded similar results to that of the non-treated with 4140 kg/ha. Highest yields were recorded for diclosulam PRE and POST applications containing 2,4-DB and imazapic with 6040, 5990, and 6430 kg/ha, respectively. Numerous previous studies have reported successful peanut production utilizing these herbicides due to excellent weed control as well as limited peanut injury (Grichar 1997; Wehtje et al. 2000; Scott et al. 2001; Brecke et al. 2002). In 2011, treatments with PRE applications of diclosulam outperformed all other treatments producing 4270 kg/ha, 1600 kg/ha or more than other treatments revealing that early-season weed interference was likely decreasing yield potential. Similar results with other weed species have also reported reduced peanut yields when certain weeds are present at peanut emergence. Florida beggarweed [(*Desmodium tortuosum* (Sweet) DC)] has been shown to be competitive with peanut when emerging early in the season with noted yield reduction (Hauser et al. 1982; Grey and Bridges 2005; Grey at al. 2009). Reduced peanut yield has also been reported with early-season interference by fall panicum (*Panicum dichotomiflorum* Michx.), sicklepod (*Senna obtusifolia* L.), and wild poinsettia (*Euphorbia heterophylla* L.) (Bridges et al. 1992; Hauser et al. 1982; York and Coble 1977). Mixed populations of weed species can also reduce peanut yield if not controlled in the first 8 wk after planting (Everman et al. 2008). Regardless of level of cutleaf groundcherry control, no other treatment improved peanut yield over the non-treated in 2011.

Weekly application intervals, starting at 4 WAP, resulted in similar yields for all weekly applications in 2009; however, yields were lower at 5 WAP than 4 WAP (Table 5). In 2011, applications at 5 WAP again resulted in reduced yields compared to 4 WAP as well as 6 and 7 WAP applications. Given that all applications were made during recommended time frames for peanut application and no interactions with any one herbicide were detected, it is likely that some other unknown factor increased peanut damage with applications made at 5 WAP, thus yield loss was sustained in both years in this application timing.

Results reveal that cutleaf groundcherry control influences subsequent biomass and seed pod production. Injured cutleaf groundcherry will likely recover and mature to produce seed pod numbers

Table 5. Peanut yield response to postemergence application timing and herbicide treatment in 2009 and 2011 at the Gulf Coast Research Center, Fairhope, AL.

		Yield	
		2009	2011
	Post application	kg/ha	
	4 WAP[a]	5490**a**[b]	2780**a**
	5 WAP	4810**b**	2250**b**
	6 WAP	5370**ab**	2740**a**
	7 WAP	5370**ab**	2850**a**
	Herbicide		
	Non-treated	3620**E**	2480**BC**
PRE	Diclosulam	6040**AB**	4270**A**
	Bentazon	4900**CD**	2130**C**
	Bentazon + 2,4-DB	5990**AB**	2320**BC**
POST[c]	Bentazon + acifluorfen	5590**BC**	2560**BC**
	Bentazon + imazapic	6430**A**	2680**B**
	Bentazon + chlorimuron ethyl	5360**BC**	2370**BC**
	Hand-pruned	4150**DE**	2450**BC**

[a]WAP, weeks after planting.
[b]Means within a column followed by the same letter are not significant (P=0.05).
[c]POST treatments included a paraquat application at cracking.

equivalent to non-treated plants. When early-season weed control efforts fail to completely control cutleaf groundcherry, it is crucial to have effective late season herbicide options for salvage treatments in order to prevent additions to the seed bank. In addition, results indicated that both herbicide applications of diclosulam as well as postemergent application regimes containing imazapic provide effective cutleaf groundcherry control and reduced seed production without decreased peanut yield. Diclosulam use, in particular, provided consistently effective weed control throughout the study. Although the use of both diclosulam PRE or POST applications including imazapic might provide excellent cutleaf groundcherry suppression, combining these two herbicides may increase the risk of resistance development (Anonymous, 2011).

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