INFLUENCE OF HERBICIDES AND TIME OF APPLICATION ON PEANUT (*Arachis hypogaea* L.) INJURY AND YIELD

By

JAMES A. BOYER

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2009

To my wife, Kelle, she has always had the patience and kindness to always love me regardless of my faults; and our children, Katherine and Nathan, for understanding and supporting me through this journey. I love you all and look forward to growing old with you.

ACKNOWLEDGMENTS

For their support and guidance at the University of Florida, I wish to express sincere appreciation to my graduate committee: Dr. Greg MacDonald, Dr. Jay Ferrell, Dr. Barry Brecke and Dr. Barry Tillman. Special thanks go to committee chair member Dr. Greg MacDonald, for providing the opportunity to further my education and Dr. Jay Ferrell, for keeping me on schedule and continual guidance. Without their gentle prodding and constant encouragement, I never would have achieved this degree. Thank you to Dr. Daniel Colvin, my supervisor at the Plant Science Research and Education Unit, for allowing me to pursue this degree and supporting my efforts over the past 2 ½ years in graduate school and 14 years throughout my career.

I would also like to acknowledge Carl Vining and Michael "Bucky" Dobrow. Carl was extremely instrumental in my data collection and spray applications and Bucky provided many moments of comic relief while encouraging me through graduate school. Most of the field research would not have been possible without the support and hard work of the PSREU staff.

My mother and father have been supportive, along with my brothers Willet and Rob and their families; thank you for providing encouragement and a refuge for me when I needed relief.

TABLE OF CONTENTS

LIST OF TABLES

Table page

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

INFLUENCE OF HERBICIDES AND TIME OF APPLICATION ON PEANUT (*Arachis hypogaea* L.) INJURY AND YIELD

By

James A. Boyer

August 2009

Chair: Greg MacDonald
Major: Agronomy

Dramatic changes in peanut weed management due to the development of herbicide resistant weed populations and shifts in weed spectrum have forced many southeastern peanut growers to consider the use of alternative herbicide programs. Most of these alternative programs utilize traditional herbicides that were common prior to 1996. These herbicides were primarily contact in activity, and resulted in a certain degree of foliar burn, with little to no peanut yield loss. Furthermore, these herbicides were researched extensively on Florunner variety, which is now no longer grown. Currently, a wide range of new varieties with greater yield potential and disease tolerance dominate the southeastern peanut growing region, but the impact of the older herbicide programs has not been evaluated on the new varieties.

Project I evaluated the effect of paraquat application timing with and without bentazon on two peanut varieties. Varieties were AP-3 and Florida-07 and treatments included paraquat and paraquat + bentazon applied 14, 21, 28, 35 or 42 days after cracking (DAC). All treatments resulted in a delay in canopy closure but this delay was not always followed by yield reduction for either variety. The addition of bentazon reduced injury for some treatments in both years, but foliar injury appeared to be related to application timing rather than addition of bentazon.

Project II evaluated the effects of paraquat applications as a function of variety, herbicide combinations, timing and application. Varieties were Andru II, AP-3 and C-99R and treatments included paraquat, paraquat + bentazon, paraquat + metolachlor and paraquat + bentazon + metolachlor applied 14 or 28 DAC. Bentazon lessened foliar injury while metolachlor increased foliar injury. Treatments applied 14 DAC exhibited 1/4 to 1/3 less injury than the 28 DAC treatments. Within an application timing, there appeared to be little difference between paraquat alone and combinations of metolachlor and/or bentazon with paraquat. There was little impact of any treatment on peanut yield.

Project III evaluated the effect of lactofen and acifluorfen applications as a function of variety and timing. Varieties were Andru II (2007), ViruGard (2008), AP-3 and C-99R and treatments included lactofen and acifluorfen applied 4, 6, 8 or 10 weeks after planting (WAP). Delay in canopy closure did not necessarily result in reduced yield. Injury at 14 days after treatment (DAT) appeared to be related to yield in 2008 but not in 2007. Yield loss was observed for treatments with ≥ 15% injury 14 DAT, which included lactofen applied 8 and 10 WAP and acifluorfen at 10 WAP.

In conclusion, there appeared to be a delay in foliar injury with paraquat + metolachlor combinations, but this effect was ameliorated by the addition of bentazon. However, there appeared to be little relation between herbicide treatment and peanut yield. Therefore, producers should consider the proper herbicide mixture that will provide economical and effective weed control, and not base herbicide selection on potential yield loss and/or foliar injury. It is likely that environmental conditions at the time or shortly after treatment plays a more important role in peanut injury than timing of application.

CHAPTER 1
THE EFFECT OF PARAQUAT ALONE AND IN COMBINATION WITH BENTAZON ON PEANUT INJURY AND YIELD AS A FUNCTION OF APPLICATION TIMING

Introduction

Weed management in peanuts prior to the mid 1990s relied heavily on early postemergence herbicide applications (Wehtje et al. 1992a; Wilcut et al. 1990b; Wilcut et al. 1994a; Wilcut et al. 1994b; Wilcut et al. 1994c). The herbicides used were primarily contact in activity, and peanut injury was common and was accepted by growers (*D.L. Colvin - personal communication*). Paraquat is a widely used contact herbicide in the southeastern United States that has been used for many years in early-season weed control in peanuts (Johnson et al. 1993; Senseman 2007). Peanuts sustain considerable foliar injury, but generally recover within 2-3 weeks of application (Wehtje et al. 1991a; Wehtje et al. 1992c). This herbicide continues to be widely used because of broad-spectrum weed control and relatively low cost (Cardina et al. 1987; Wehtje et al. 1986; Wilcut et al. 1987a; Wilcut et al. 1987b; Wilcut et al. 1989; Wilcut et al. 1990a).

Paraquat affects the light reactions in photosynthesis where it causes the formation of reactive oxygen (Fedtke 1982). This results in cell membrane disruption that can be observed soon after application (Senseman 2007). Paraquat affects both peanut and weeds, but generally weeds are damaged and killed whereas peanuts only sustain moderate defoliation and leaf burn (Wehtje et al. 1986). This potential for leaf burn limits applications to 28 days after emergence. To alleviate some of the phytotoxicity, bentazon is commonly added to paraquat (Grey et al. 1992; Wilcut et al. 1993).

In the late 1980s, growers began utilizing the combination of bentazon and paraquat, as it was observed that less peanut injury occurred. Researchers confirmed this phenomenon; the safening effect of bentazon is due to reduced paraquat uptake (Wehtje et al. 1992a) and possibly from interactions in photosynthetic electron flow prior to paraquat activity (Pfister et al. 1974; Suwanketnikom et al. 1982).

Since the registration of imazapic in 1996, many peanut producers have reduced paraquat usage in their production systems. The broad spectrum foliar and soil activity of imazapic allowed growers to rely almost exclusively on this herbicide for postemergence weed control. In addition to controlling many of the most common weeds in southeastern peanut production, it results in little to no visual injury (Dotray et al. 2001; Matocha et al. 2003).

However, the past decade of intense imazapic usage has led to the increasing occurrence of weed resistance and a shift in weed spectrum. The two most noteworthy species that will escape imazapic are acetolactate synthase (ALS)-resistant Palmer amaranth (*Amaranthus palmeri* S. Watson) and Bengal dayflower (*Commelina benghalensis* L.). Normally, imazapic controls Palmer amaranth with both preemergence and postemergence activity. ALS resistant Palmer amaranth exhibits high levels of resistance to imazapic and has been found across the southeastern United States (Vencill et al. 2002).

Bengal dayflower is tolerant to imazapic and displays little or no change in growth after application (Steptoe et al. 2006). Bengal dayflower is an exotic invasive weed species that has become widely distributed across the southeastern United States over the past five years (Webster et al. 2005). These weed problems have forced many growers to reconsider contact herbicides, but there has been limited research with new varieties. Even if growers do not have ALS resistant palmer amaranth, alternative herbicides are highly recommended to avoid resistant biotypes from developing or becoming endemic (Sellers et. al 2008). Paraquat is one of the leading contact postemergence herbicides available to combat resistance issues.

Paraquat and bentazon have a long record of effective weed control, but peanut tolerance and potential yield reduction continues to be a question for growers. The current label recommendations for paraquat were based on data collected on the Florunner variety, which is no longer grown. Florunner was a mid-season variety that reached maturity approximately 134 days after planting (Norden et al. 1969). Currently, a wide range of new varieties with greater yield potential and disease tolerance dominate the southeastern peanut growing region. The new peanut varieties differ in maturity that ranges from 120 to 145 days after planting.

The emergence of herbicide resistant weeds and exotic weed species will likely increase the use of paraquat across the peanut growing regions of the south. However, the current label recommendation, which is 28 days after peanut emergence, is in question. Some growers believe that the intense paraquat injury is more likely to reduce peanut yield as applications near 28 days after emergence. Conversely, in times of slow weed emergence, others believe that paraquat applications beyond 28 days are warranted and not yield limiting. Therefore, the objectives of this research were 1) to determine whether peanut yield reduction is likely to occur if paraquat is applied before or after 28 days after emergence to two recently released mid-season maturity peanut cultivars and 2) to determine the safening effect of bentazon compared to paraquat alone.

Materials and Methods

Field experiments were conducted in 2007 and 2008 at the Plant Science Research and Education Unit in Citra, Florida, on a Sparr fine sand (loamy, siliceous, hyperthermic Grossarenic paleudult) with 1% organic matter. All experiments were initiated using a conventional tillage regime.

Plots were 3.0 m wide, 7.6 m long and contained four rows spaced 76.2 cm apart. Plots received optimum irrigation, fertility, insecticide and fungicide treatments as directed by the Florida Cooperative Extension Service. Seeds were planted at a depth of 5 cm with a seeding density of 17 seeds per meter of row (Wright et al. 2006). Planting occurred on May 23, 2007 and May 6, 2008. Each year aldicarb was applied in furrow at 3.2 kg ai/ha. The experimental area received a preemergence broadcast application of pendimethalin (0.92 kg ai/ha) + diclosulam (0.42 kg ai/ha), and a postemergence application of imazapic (0.07 kg ai/ha). Supplemental hand-weeding was performed as needed to maintain weed-free conditions throughout the growing season.

The experimental design was a randomized complete block with a split-plot treatment arrangement and four replications. Peanut cultivar was the whole plot factor and herbicide treatments were subplots. Cultivars included medium-season peanut cultivars (137-140 days), AP-3 (Gorbet 2007) and Florida-07 (Gorbet and Tillman 2009). Ten herbicide treatments consisting of paraquat at 0.14 kg/ha or paraquat at 0.14 kg/ha + bentazon at 0.28 kg/ha applied to each variety at 14, 21, 28, 35 or 42 days after cracking (DAC). An untreated check was included for each cultivar. All herbicide treatments included a non-ionic surfactant at 0.25% v/v.

All experimental treatments were applied using a CO_2 backpack sprayer calibrated to deliver 187 L/ha. Peanut foliar injury was visually evaluated and peanut canopy width was measured 7, 14, and 28 days after application. Visual estimations of injury were rated on a scale from 0% to 100% with 0% = no injury and 100% = complete plant necrosis. Days to canopy closure (when no soil was visible between the two center rows) was also recorded.

The center two rows of each plot were dug according to maturity using a conventional digger-shaker-inverter. Maturity was determined by the hull scrape method for each cultivar (Johnson 1987; Johnson et al. 1993; Sholar et al. 1995). Peanuts were allowed to field dry for approximately 3 days and commercial harvesting equipment was used to harvest each plot.

Peanut yields (adjusted to moisture conditions of 9%) were determined and converted to a kg/ha basis.

Data were subjected to analysis of variance to test treatment effects and interactions. Means were separated using Fisher's Least Significant Difference (LSD) test at the $p<0.05$ level.

Results and Discussion

Treatment by year and treatment by variety interactions for all parameters measured were significant and prevented pooling of data (Table 1-1). Therefore, data is presented by year and variety.

AP-3

In 2007, the level of injury ranged from 19% to 55% 7 days after treatment (DAT) but peanuts fully recovered with no injury evident 28 DAT (Table 1-2). Paraquat injury to AP-3 ranged between 10% and 55% 14 DAT while paraquat + bentazon caused between 10% and 40% injury. Paraquat applications applied 14 and 21 DAC resulted in greater peanut injury than the 28, 35 and 42 DAC application. At 14 DAT, similar levels of injury were observed with paraquat alone and paraquat + bentazon for each application timing. The exception was the 21 DAC treatment where the addition of bentazon significantly reduced the injury compared to paraquat alone.

Paraquat alone resulted in significantly delayed canopy closure compared to the untreated check except for 35 DAC, but the delay was not observed with any bentazon combinations. In 2007, the yield of AP-3 was significantly reduced when paraquat was applied 14 DAC and 42 DAC and when paraquat + bentazon were applied 14 and 21 DAC. There were significant reductions in yield compared to the untreated check for paraquat alone at 14 and 42 DAC, and for paraquat + bentazon at 14 and 21 DAC.

In 2008, there was significant foliar injury for all treatments when evaluated 7 DAT (Table 1-3). Addition of bentazon did not affect differences in injury compared to paraquat alone. At 14 DAC, injury from all treatments was greatly reduced, much more so than observed in 2007. Once again applications on or before 28 DAC, resulted in greater injury compared to applications made 35 and 42 DAC. Peanuts fully recovered from foliar injury by 28 DAT, but nearly all treatments slowed canopy closure by up to 12 days. The addition of bentazon to paraquat reduced peanut injury and canopy closure delay, but no trends were observed and few conclusions can be drawn relative to the benefits of bentazon.

The greatest delays in canopy closure were observed in 2007. Paraquat at 14 and 42 DAC delayed canopy closure by 16 and 17 days, respectively, compared to the untreated control. The greatest delay in 2008 canopy closure was 12 days from paraquat applications applied 14 and 21 DAC. No application timing or herbicide combination resulted in yield reduction for AP-3 in 2008.

The addition of bentazon reduced injury for some treatments in both years. All treatments resulted in a delay in canopy closure for both years and yield reductions were observed in 2007 for paraquat and paraquat + bentazon combinations. Paraquat is labeled for use up to 28 days after emergence, but 2007 applications applied 14 DAC caused significant yield loss. It is unknown why yield reduction was observed with treatments applied 14 DAC and not at 35 DAC.

Florida-07

In 2007, all treatments applied to Florida-07 caused injury that ranged from 10% to 51% at 7 and 14 (DAT) (Table 1-4). Substantial injury was observed 7 DAT for all treatments. Measured 7 DAT, all treatments resulted in ≥40% injury with the exception of paraquat alone or in combination with bentazon applied at 35 DAC. Interestingly, these two treatments resulted in greater foliar injury 14 DAT compared to 7 DAT, while all other treatments showed much reduced injury.

As with AP-3, foliar injury appeared to be more closely associated with application timing than with the addition of bentazon. For example Florida-07 at 14 DAT, peanut treated 28 DAC exhibited significantly less injury compared to all other treatments, regardless of whether bentazon was included. This was also noted for AP-3 in 2007. Peanuts showed no foliar injury by 28 DAT for any treatment and only the paraquat alone 42 DAC resulted in a significant delay in canopy closure. The only two treatments that resulted in significant yield reductions were paraquat applied alone 14 DAC and paraquat + bentazon applied 42 DAC.

In 2008, all treatments resulted in >30% foliar injury 7 DAT but peanuts recovered more quickly in 2008, with ≤ 20% injury when evaluated one week later 14 DAT (Table 1-5). No injury was observed 28 DAT, but all treatments caused a delay in canopy closure, regardless of the addition of bentazon. In 2007, Florida-07 had canopy closure quicker than the AP-3 and paraquat applied 42 DAC caused the greatest delay in canopy closure for Florida-07. Florida-07 had slower canopy closure than AP-3 in 2008, and all applications caused significant delays in days to canopy closure compared to the untreated. The longest delay in canopy closure was observed following paraquat applied 14 DAC. No significant yield reduction was observed for any treatment in 2008. The yield loss in 2007 is noteworthy because the 14 DAC application is within the label recommendations.

Discussion

Overall, there was no relationship between delay in canopy closure and yield reduction. Bentazon reduced visual injury in some of the treatments, but lessened injury did not always lead to increased yield. These data indicate that some varieties are more sensitive to paraquat treatments, and the earlier growth stages are sometimes the most susceptible to paraquat injury.

Other research has shown some similarities and differences from these results. English pea (*Pisum sativum* L.) injury from paraquat was reduced when bentazon was added, similar to what was observed in the study reported here. Paraquat alone produced more visual injury than paraquat plus bentazon, but the English pea recovered by 21 DAT (Bellinder et al. 1997). English pea yield was not reduced with either treatment if the plant had adequate time to recover from herbicide injury before flower development and pod filling (Bellinder et al. 1997).

Grey et al. (1995) reported the addition of bentazon reduced visual injury ratings by 25% from paraquat alone in peanut. In two of the three years, peanut yield was higher in an early-postemergence paraquat application compared to paraquat plus bentazon.

Other research has shown that peanut tolerance is acceptable if the paraquat application is made prior to 28 days after emergence and that foliar injury did not lead to yield loss (Wehtje et al.1991b; Wilcut et al. 1989; Wilcut et al. 1994a). These data indicate that delaying paraquat applications until 21 to 35 days after emergence might allow the peanut to better recover from paraquat injury.

Wehtje showed the addition of bentazon did not improve peanut yield as compared to paraquat alone (Wehtje et al. 1992a). His work also showed that weeds sensitive to paraquat were not controlled with the addition of bentazon indicating that it safens weeds to paraquat injury similar to the way it safens peanut foliage (Wehtje et al. 1992a).

Another trend is the differences between 2007 and 2008. If you look at recovery from foliar burn, this was much more evident in 2008 compared to 2007. There was also no yield loss in 2008 from the treatments. This suggests that growth conditions in the first 2-3 weeks after paraquat applications are critical to yield. If the peanuts, in general, show >15% foliar injury 14 DAT, then a loss in yield could be observed – regardless of bentazon or timing of application.

Weeds compete with peanut for light, water, nutrients and physical space. If producers are making a decision on whether to use a contact herbicide, they have need to weigh the benefit of a herbicide with potential yield loss against the amount of yield loss due to weed pressure. Paraquat or paraquat + bentazon are useful tools for peanut growers, but the application decisions need to made on a case by case basis.

Table 1-1. ANOVA table for the effect of paraquat alone and in combination with bentazon on peanut injury and yield as a function of application timing.

Class Variable	DF[1]	--------------% injury[2]-------------			Days to Closure[2]	Yield[2]
		7 DAT[3]	14 DAT	28 DAT		
variety (maturity)	1	0.4557	0.4742	0.0291	0.0019	<0.0001
year (2007/2008)	1	0.0003	<0.0001	0.0291	<0.0001	<0.0001
treatment	10	<0.0001	<0.0001	0.1388	<0.0001	<0.0001
replication	3	0.9704	0.2829	0.1873	0.0007	0.5694
year * variety	1	0.1600	0.0112	0.0291	<0.0001	<0.0001
year * treatment	10	<0.0001	<0.0001	0.1388	0.0029	0.2976
year * variety * treatment	20	0.1491	0.0155	0.0846	0.5613	0.9728

[1] DF = degrees of freedom. [2] Pr > F. [3] DAT = days after treatment.

Table 1-2. Influence of paraquat and paraquat + bentazon herbicides on percent injury, days to row closure, and yield of AP-3 peanut in 2007.

Herbicide Treatment[3]	Timing DAC[4]	--------------% injury[1]-------------			Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
		7 DAT[5]	14 DAT	28 DAT		
paraquat	14	54a[6]	38bc	0a	88a	2810cd
paraquat	21	53a	55a	0a	84a-c	3180a-c
paraquat	28	39cd	10de	0a	86ab	3280ab
paraquat	35	19e	28bc	0a	70d	3240ab
paraquat	42	44bc	26b-d	0a	89a	2750d
paraquat + bentazon	14	55a	40ab	0a	79a-d	3060b-d
paraquat + bentazon	21	49ab	23cd	0a	83a-d	3080b-d
paraquat + bentazon	28	34d	10de	0a	74b-d	3310ab
paraquat + bentazon	35	19e	28bc	0a	70d	3370ab
paraquat + bentazon	42	44bc	25b-d	0a	84a-c	3240ab
untreated	0	0f	0e	0a	72cd	3510a

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha. [4] DAC = days after cracking. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 1-3. Influence of paraquat and paraquat + bentazon herbicides on percent injury, days to row closure, and yield of AP-3 peanut in 2008.

Herbicide Treatment[3]	Timing DAC[4]	--------------% injury[1]------------			Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
		7 DAT[5]	14 DAT	28 DAT		
paraquat	14	56a[6]	13ab	0a	63a	7010cd
paraquat	21	50bc	14a	0a	63a	7690a-c
paraquat	28	26e	10ab	0a	58b	8130a
paraquat	35	34d	6bc	0a	58b	8010ab
paraquat	42	49bc	6bc	0a	58b	6770d
paraquat + bentazon	14	54ab	10ab	0a	56b	7410b-d
paraquat + bentazon	21	54ab	11ab	0a	63a	7380b-d
paraquat + bentazon	28	29de	11ab	0a	54bc	7740ab
paraquat + bentazon	35	28e	9ab	0a	58b	7620a-c
paraquat + bentazon	42	46c	6bc	0a	51c	7010cd
untreated	0	0f	0c	0a	51c	7300b-d

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha. [4] DAC = days after cracking. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 1-4. Influence of paraquat and paraquat + bentazon herbicides on percent injury, days to row closure, and yield of Florida-07 peanut in 2007.

Herbicide Treatment[3]	Timing DAC[4]	--------------% injury[1]------------ 7 DAT[5]	14 DAT	28 DAT	Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
paraquat	14	48ab[6]	35ab	0a	70ab	2730b
paraquat	21	48ab	24c	0a	68ab	3380ab
paraquat	28	40c	13d	0a	67b	3300ab
paraquat	35	23d	29bc	0a	65b	3480ab
paraquat	42	44bc	28c	0a	77a	3040ab
paraquat + bentazon	14	51a	39a	0a	65b	3380ab
paraquat + bentazon	21	45bc	26c	0a	68ab	2890ab
paraquat + bentazon	28	41c	10d	0a	63b	3700ab
paraquat + bentazon	35	19d	28c	0a	67b	3300ab
paraquat + bentazon	42	45bc	28c	0a	72ab	2760b
untreated	0	0e	0e	0a	63b	3870a

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha. [4] DAC = days after cracking. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 1-5. Influence of paraquat and paraquat + bentazon herbicides on percent injury, days to row closure, and yield of Florida-07 peanut in 2008.

Herbicide Treatment[3]	Timing DAC[4]	--------------% injury[1]------------ 7 DAT[5]	14 DAT	28 DAT	Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
paraquat	14	59a[6]	16ab	3a	68a	5610c
paraquat	21	53bc	13ab	0b	67a	6280ab
paraquat	28	33e	11ab	1ab	63a	6560ab
paraquat	35	36de	16ab	0b	67a	6330ab
paraquat	42	48c	11ab	0b	63a	5570c
paraquat + bentazon	14	56ab	20a	0b	63a	6210ab
paraquat + bentazon	21	51bc	15ab	1ab	63a	6090a-c
paraquat + bentazon	28	31e	13ab	0b	66a	6630a
paraquat + bentazon	35	34e	14ab	0b	63a	6420ab
paraquat + bentazon	42	41d	9bc	0b	63a	6040bc
untreated	0	0f	0c	0b	54b	6110a-c

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha. [4] DAC = days after cracking. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer’s Least Significant Difference (LSD) test.

CHAPTER 2

THE EFFECT OF PARAQUAT ALONE AND IN COMBINATION WITH METOLACHLOR AND/OR BENTAZON ON PEANUT INJURY AND YIELD FOR THREE DIFFERING MATURITY CULTIVARS

Introduction

Peanut producers in the southeastern United States relied heavily on contact postemergence herbicides for weed control prior to 1996 (Wehtje et al. 1992a; Wilcut et al. 1990b; Wilcut et al. 1994a; Wilcut et al. 1994b; Wilcut et al. 1994c). Dinoseb was the principle postemergence herbicide treatment for 25 years until the EPA cancelled all registrations in 1986 (Wilcut et al. 1989). Dinoseb was one of the most economical and effective weed control measures used at that time (Buchanan et al. 1983). After the cancellation of dinoseb, paraquat was registered for peanut use in 1988 and became the standard for at-cracking weed control in southeastern peanut production (Wehtje et al. 1991a).

Paraquat is quickly absorbed into leaf tissue, producing oxygen-free radicals (Fedtke 1982). This formation of reactive oxygen destroys cells and cell membranes (Fedtke 1982; Senseman 2007). Paraquat works primarily by contact but can be translocated in the xylem (Brian 1969; Thrower et al. 1965). Even though xylem mobility is possible, the application method limits movement in the xylem.

Paraquat provides acceptable control of grass and many broadleaf weeds found in peanuts when applied within three weeks of ground cracking (Wehtje et al. 1986; Wilcut et al. 1989). Ground cracking is when the peanut plant is between the emergence of the hypocotyl and the appearance of first true leaves (Boote 1982). Paraquat causes foliar injury when applied postemergence, but the peanuts overcome leaf defoliation with no impact to yield (Wehtje et al. 1986). Peanuts are tolerant to this leaf defoliation if the application is made prior to pegging and pod development, which is approximately four weeks after emergence (Wehtje et al. 1986). The paraquat label allows applications up to 28 days after peanut emergence (Anonymous 2009). But, as stated previously, this application can result in temporary defoliation (Wehtje et al. 1986). To alleviate some of the phytotoxicity, bentazon is commonly added to paraquat (Grey et al. 1992; Wilcut et al. 1993).

In the late 1980s, researchers confirmed the combination of paraquat and bentazon lessened peanut injury (Wehtje et al. 1992a; Wehtje et al. 1992b). The safening is due to the bentazon interference of paraquat absorption (Wehtje et al. 1992a).

In contrast, peanut producers believe that metolachlor increases paraquat injury to peanut (*D.L. Colvin - personal communication*). Metolachlor is an effective tool in controlling Bengal dayflower (Culpepper et al. 2004; Prostko et al. 2005; Webster et al. 2006). Metolachlor is a growth inhibitor that can be used on a wide range of crops including peanut, corn, potato, soybean and cotton (Senseman 2007). Despite the injury potential, metolachlor was widely used to control certain broadleaf weeds and yellow nutsedge in peanuts (Cardina and Swann 1988; Wehtje et al. 1988; Wilcut et al. 1989; Wilcut et al. 1990b; Wilcut et al. 1994a).

Many peanut producers have reduced paraquat, metolachlor and bentazon usage in their production systems since the registration of imazapic. Imazapic is a broad spectrum herbicide that has foliar and soil activity. This compound was registered in 1996, and has allowed growers to rely on imazapic for postemergence weed control. Imazapic controls many of the most commonly occurring weeds in peanut with little visual injury and no yield reduction (Dotray et al. 2001; Matocha et al. 2003).

The past 13 years of repeated imazapic usage has led to the increasing occurrence of weed resistance and a shift in weed spectrum. The two problematic species are acetolactate synthase (ALS)-resistant Palmer amaranth (*Amaranthus palmeri* S. Watson) and Bengal dayflower

(*Commelina benghalensis* L.). Normally, imazapic controls Palmer amaranth with both preemergence and postemergence activity, but ALS resistant Palmer amaranth has quickly become one of the most troublesome weeds in the southeastern United States. High levels of Palmer amaranth resistance to imazapic have been found across the southeastern United States (Vencill et al. 2002).

Bengal dayflower is an exotic invasive weed species that has increased in distribution over the past five years (Webster et al. 2005). Bengal dayflower is tolerant to imazapic and glyphosate (Steptoe et al. 2006; Webster et al. 2005). Glyphosate-resistant crops such as cotton, soybean and corn have aided the spread of this weed due to the ineffectiveness of glyphosate on Bengal dayflower (< 55% control with glyphosate) (Culpepper et al. 2004). The lack of residual herbicides and reduced tillage systems favored in glyphosate-resistant crop programs has allowed the prevalence of this weed to increase (Brecke et al. 2005, Spader and Vidal 2000; Webster et al. 2005, 2006).

To combat these issues, growers have been forced to reconsider the use of residual herbicides such as metolachlor and contact herbicides such as paraquat (Webster et al. 2007). Even if growers do not have resistant weed populations, alternative herbicides are highly recommended to avoid resistance (Sellers et. al 2008). It is also important to rotate herbicides of various mechanisms of action, incorporate non-chemical controls such as cultivation and not allow resistant weeds to reproduce (Jordan et al. 2007).

Peanut tolerance to paraquat, bentazon and metolachlor continues to be a concern of growers, especially with the new peanut varieties. There is limited research on yield impact of these herbicides on new varieties, and the current label recommendations for paraquat were based on data collected in the 1980s on the Florunner variety. Florunner was a mid-season maturity variety that reached maturity in approximately 134 days after planting (Norden et al. 1969), but is no longer grown in the southeastern United States. Currently, a wide range of new varieties with greater yield potential and disease tolerance dominate the southeastern peanut growing region. The newer peanut varieties differ in maturity requiring from 120 to 145 days after planting to reach maturity.

Herbicide resistant weeds and exotic invasives will likely increase the use of paraquat and metolachlor across the peanut growing regions. Some producers believe that the intense paraquat injury is more likely to reduce peanut yield as applications approach the 28 days after emergence label restriction. The objectives of this research were to determine 1) whether peanut yield reduction is likely to occur when paraquat is applied before 28 days after emergence, 2) whether bentazon reduces any negative yield impact of paraquat alone, and 3) whether metolachlor increases the injury potential of paraquat.

Materials and Methods

Field experiments were conducted in 2006 and 2007 at the Plant Science Research and Education Unit in Citra, Florida on a Sparr fine sand (loamy, siliceous, hyperthermic Grossa-renic paleudult) with 1% organic matter. All experiments were initiated using a conventional tillage regime.

Plots were 3.0 m wide, 7.6 m long and contained four rows spaced 76.2 cm apart. Plots received optimum irrigation, fertility, insecticide and fungicide treatments as directed by the Florida Cooperative Extension Service. Seeds were planted at a depth of 5 cm with a seeding density of 17 seeds per meter of row (Wright et al. 2006). Planting occurred on May 17, 2006, and June 14, 2007. Each year aldicarb was applied in furrow at 3.2 kg ai/ha. The experimental area received a preemergence broadcast application of pendimethalin (0.92 kg ai/ha) + diclosulam (0.42 kg ai/ha), and a postemergence application of imazapic (0.07 kg ai/ha).

Supplemental hand-weeding was performed as needed to maintain weed-free conditions throughout the growing season.

The experimental design was a randomized complete block with a split-plot treatment arrangement and four replications. Peanut cultivar was the whole plot factor and herbicide treatments were subplots. Cultivars included early (Andru II), mid (AP-3) and late (C-99R) season peanut cultivars (Gorbet 2006; Gorbet 2007; Gorbet and Shokes 2002). Eight herbicide treatments consisting of paraquat at 0.14 kg/ ha, paraquat at 0.14 kg/ ha + bentazon at 0.28 kg/ ha, paraquat at 0.14 kg/ ha + metolachlor at 1.42 kg/ ha or paraquat at 0.14 kg/ ha + bentazon at 0.28 kg/ ha + metolachlor at 1.42 kg/ ha applied to each variety at 14 or 28 days after cracking (DAC). An untreated check was included for each cultivar. All herbicide treatments included a non-ionic surfactant at 0.25% v/v.

All experimental treatments were applied using a CO_2 backpack sprayer calibrated to deliver 187 L/ha. In 2006, visual ratings of peanut foliar injury were performed 7 days after application. In 2007, peanut foliar injury was visually rated and peanut canopy width measured 7, 14, and 28 days after application. Injury was visually rated on a scale from 0% to 100% with 0% = no injury and 100% = complete plant necrosis. Days to canopy closure (when no soil was visible between the two center rows) was also recorded.

The center two rows of each plot were dug according to maturity by a conventional digger-shaker-inverter. Maturity was determined by the hull scrape method for each cultivar (Johnson, 1987; Johnson et al. 1993; Sholar et al. 1995). Peanuts were allowed to field dry for approximately 3 days and commercial harvesting equipment was used to harvest each plot. Peanut yields (adjusted to moisture conditions of 9%) were determined and adjusted to a kg/ha basis.

Data were subjected to analysis of variance to test treatment effects and interactions. Means were separated using Fisher's Least Significant Difference (LSD) test at the $p<0.05$ level.

Results and Discussion

Statistical analysis detected a significant treatment by year and treatment by variety interaction (Table 2-1). Therefore, data were not pooled and the results are presented by year and variety.

Early Maturity Peanut (Andru II)

In 2006, significant differences in peanut injury were detected 7 days after treatment (DAT) (Table 2-2). Injury resulting from treatment applications ranged from 9% to 18% 7 DAT. Overall, applications 28 DAC were more injurious than 14 DAC treatments, regardless of paraquat combination. All treatments had significant yield reductions compared to the untreated control. The combination of paraquat plus metolachlor applied 28 DAC resulted in the largest yield reduction of 1440 kg/ha. Paraquat alone applied 14 and 28 DAC caused the next largest yield reduction of 1060 and 1010 kg/ha, respectively. Paraquat + bentazon + metolachlor applied 14 or 28 DAC resulted in the least yield reduction of 660 and 700 kg/ha, respectively. This indicates the safening effect of bentazon is more pronounced with later applications of paraquat + metolachlor.

In 2007, much greater injury was observed 7 DAT from applications made at 28 DAC compared to 14 DAC (Table 2-3). There also appeared to be no differences between paraquat alone and combination with either metolachlor or bentazon or the three-way combination, within an application timing. Interestingly, this trend did not continue when evaluated 14 DAT, where 28 DAC treatments showed injury levels similar to the 14 DAC treatments. Injury actually increased for all 14 DAC from 7 DAT to the 14 DAT evaluation period, but by 28 DAT, no injury was observed from any treatment.

Canopy closure was significantly delayed for all applications and ranged from 13 to 27 days longer than the untreated control. The longest delay in canopy closure resulted from paraquat applied 28 DAC. Paraquat + bentazon applied 28 DAC was the second longest delay of 24 days. Significant reductions in peanut yield were observed with paraquat alone applied 14 and 28 DAC, paraquat + bentazon applied 28 DAC, paraquat + metolachlor applied 14 DAC ranging from 630 to 890 kg/ha. In general, the larger yield reductions occurred with the 14 DAC treatments. This is interesting considering that the least visual injury ratings 7 DAT had the most yield reduction in this early maturity cultivar. Even though the most visual injury was observed with the 28 DAC treatments, the peanuts recovered quicker and had no loss in yield compared to the 14 DAC treatments.

Medium Maturity Peanut (AP-3)

In 2006, AP-3 exhibited minimal injury ranging from 4% to 11% (Table 2-4). As previously observed, the peanuts had generally recovered from the foliar injury by 28 DAT (data not shown). AP-3 yields were not reduced by any treatment in 2006.

AP-3 in 2007 was injured most from the 28 DAC treatments with injury ranging from 10% to 43% 7 DAT (Table 2-5), and peanut recovered by 28 DAT with no foliar injury visible from any treatment. At 7 DAT, injury levels were similar within each application timing. In general, the 14 DAC applications showed 1/4 to 1/3 less injury compared to the 28 DAC application. However, by 14 DAT, the injury from the 14 DAC treatment increased compared to 7 DAT, while the injury from the 28 DAC decreased, resulting in similar levels of injury for both application timings. There appeared to be little difference between paraquat alone or the combination of metolachlor and/or bentazon with paraquat. Row closure was delayed the most (>20 days) by paraquat applied 28 DAC, paraquat + metolachlor applied 28 DAC and paraquat + bentazon + metolachlor applied 14 DAC, and the least (1 day) by paraquat alone applied 14

DAC. Paraquat + bentazon did not safen injury effects compared to paraquat alone, paraquat + metolachlor, or paraquat + bentazon + metolachlor. AP-3 yields were not reduced by any treatments in 2007.

Late Maturity Peanut (C-99R)

In 2006, C-99R was injured 10% to 15% 7 DAT, with few differences among herbicide treatments or timings of application (Table 2-6). Paraquat (14 and 28 DAC), paraquat + metolachlor (14 and 28 DAC), paraquat + bentazon (14 DAC), and paraquat + bentazon + metolachlor (28 DAC) reduced C-99R yield by 610 to 860 kg/ha.

C-99R in 2007 was injured the most (39% to 49%) from 28 DAC treatments (Table 2-7). As previously observed, peanut injury was less severe 7 DAT from treatments applied 14 DAC compared to those applied 28 DAC. However, injury increased from 7 DAT to 14 DAT for herbicides applied 14 DAC but decreased for applications 28 DAC. Peanut recovered from foliar injury by 28 DAT. There were no differences in injury among the herbicide treatments.

Canopy closure was significantly delayed by all treatments with paraquat applied 28 DAC and paraquat + metolachlor applied 14 and 28 DAC causing the longer delay (22 days). Similar to AP-3, the least delay in canopy closure was paraquat applied 14 DAC and the greatest delay was paraquat applied 28 DAC. The only treatment that reduced yield was paraquat applied 28 DAC.

These results are similar to those reported for other cultivars. Less injury was observed for 14 DAC treatments at 7 DAT but increased injury by 14 DAT. Higher initial (7 DAT) injury was evident for the 28 DAC application but decreased by 14 DAC.

Discussion

There is a limited amount of published research describing the impact on peanut of paraquat and metolachlor combinations. Grey reported that bentazon and paraquat tank mix reduced foliar injury up to 25% (Grey et al. 1995). In the same study, paraquat alone yielded higher in 2 of the 3 years compared to paraquat and bentazon (Grey et al. 1995).

Richburg et al. reported that imazethapyr plus metolachlor applied preplant incorporated (PPI) followed by paraquat plus metolachlor at cracking reduced yield by 200 kg/ha averaged over a 3-year experiment compared with the same PPI followed by paraquat plus bentazon at cracking (Richburg et al. 1995).

Johnson et al. reported that alachlor mixed with paraquat followed by a paraquat application caused peanut to have early-season leaf reduction, later pod set and delayed maturity (Johnson et al. 1993). When peanuts were allowed to fully mature with delayed maturity from herbicide applications, peanut yield was not impacted (Johnson et al. 1993). Knauft et al. reported similar effects on peanut maturity (Knauft et al. 1990).

In conclusion, there appeared to be a delay in foliar injury with paraquat + metolachlor combinations, but this effect was ameliorated by the addition of bentazon. However, there appeared to be little impact of herbicide treatment on peanut yield. Therefore, producers should consider the proper herbicide mixture that will provide economical and effective weed control, and not base herbicide selection on potential yield loss and/or foliar injury. It is likely that environmental conditions at the time or shortly after treatment plays a more important role in peanut injury than timing of application.

Weeds compete with peanut for light, water, nutrients and physical space. If producers are making a decision on whether to use a contact herbicide, they have need to weigh the benefit of a herbicide with potential yield loss against the amount of yield loss due to weed pressure. Paraquat, bentazon and metolachlor are useful tools for peanut growers, but the application decisions need to made on a case by case basis.

Table 2-1. ANOVA table for the effect of paraquat alone and in combination with metolachlor and/or bentazon on peanut injury and yield for three differing maturity cultivars.^

Class Variable	DF[1]	--------------% injury[2]-------------			Days to Closure[2]	Yield[2]
		7 DAT[3]	14 DAT	28 DAT		
variety (maturity)	3	<0.0001	.	.	.	<0.0001
year (2006/2007)	1	<0.0001	.	.	.	<0.0001
treatment	8	<0.0001	.	.	.	<0.0001
replication	3	0.2298	.	.	.	0.0631
year * variety	2	0.4542	.	.	.	<0.0001
year * treatment	8	<0.0001	.	.	.	0.2250
year * variety * treatment	32	<0.0001	.	.	.	0.0323

^ Parameters including 14 DAT, 28 DAT and Days to Closure were not taken in 2006, therefore values could not be calculated. [1] DF = degrees of freedom. [2] Pr > F. [3] DAT = days after treatment.

Table 2-2. Influence of paraquat, paraquat + bentazon, paraquat + metolachlor and paraquat + bentazon + metolachlor herbicides on percent injury, days to row closure, and yield of Andru II peanut in 2006.

Herbicide Treatment[1]	Timing DAC[3]	% injury[2] 7 DAT[4]	Yield (kg/ha)
paraquat	14	9d[5]	4250bc
paraquat	28	16ab	4300bc
paraquat + bentazon	14	11cd	4550b
paraquat + bentazon	28	13b-d	4470b
paraquat + metolachlor	14	8d	4610b
paraquat + metolachlor	28	18a	3870c
paraquat + bentazon + metolachlor	14	11cd	4650b
paraquat + bentazon + metolachlor	28	15a-c	4610b
untreated	0	0e	5310a

[1] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha; metolachlor – 1.42 kg/ha. [2]Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [3] DAC = days after cracking. [4] DAT = days after treatment. [5] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 2-3. Influence of paraquat, paraquat + bentazon, paraquat + metolachlor and paraquat + bentazon + metolachlor herbicides on percent injury, days to row closure, and yield of Andru II peanut in 2007.

Herbicide Treatment[3]	Timing DAC[4]	-------------% injury[1]------------- 7 DAT[5]	14 DAT	28 DAT	Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
paraquat	14	21c[6]	26a	0a	81ab	2980c
paraquat	28	43a	14b	0a	86a	3050c
paraquat + bentazon	14	16c	20ab	0a	72b	3470a-c
paraquat + bentazon	28	36b	19b	0a	83ab	3240bc
paraquat + metolachlor	14	19c	20ab	0a	81ab	3100c
paraquat + metolachlor	28	41ab	14b	0a	79ab	3350a-c
paraquat + bentazon + metolachlor	14	16c	18b	0a	74b	3320a-c
paraquat + bentazon + metolachlor	28	39ab	20ab	0a	79ab	3820ab
untreated	0	0d	0c	0a	59c	3870a

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha; metolachlor – 1.42 kg/ha. [4] DAC = days after cracking. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 2-4. Influence of paraquat, paraquat + bentazon, paraquat + metolachlor and paraquat + bentazon + metolachlor herbicides on percent injury, days to row closure, and yield of AP-3 peanut in 2006.

Herbicide Treatment[1]	Timing DAC[3]	% injury[2] 7 DAT[4]	Yield (kg/ha)
paraquat	14	9a[5]	5590a
paraquat	28	9a	5450a
paraquat + bentazon	14	9a	5510a
paraquat + bentazon	28	6ab	6035a
paraquat + metolachlor	14	11a	5610a
paraquat + metolachlor	28	8ab	5410a
paraquat + bentazon + metolachlor	14	9a	5570a
paraquat + bentazon + metolachlor	28	4bc	5880a
untreated	0	0c	5350a

[1] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha; metolachlor – 1.42 kg/ha. [2]Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [3] DAC = days after cracking. [4] DAT = days after treatment. [5] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 2-5. Influence of paraquat, paraquat + bentazon, paraquat + metolachlor and paraquat + bentazon + metolachlor herbicides on percent injury, days to row closure, and yield of AP-3 peanut in 2007.

Herbicide Treatment[3]	Timing DAC[4]	-------------% injury[1]------------- 7 DAT[5]	14 DAT	28 DAT	Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
paraquat	14	10c[6]	16cd	0a	74cd	2670ab
paraquat	28	40ab	18b-d	0a	96a	2070d
paraquat + bentazon	14	11c	18b-d	0a	83bc	2330b-d
paraquat + bentazon	28	40ab	25a	0a	83bc	2410a-d
paraquat + metolachlor	14	11c	20bc	0a	81b-d	2720a
paraquat + metolachlor	28	43a	14d	0a	95a	2080d
paraquat + bentazon + metolachlor	14	11c	22ab	0a	95a	2530a-c
paraquat + bentazon + metolachlor	28	38b	18b-d	0a	84b	2400b-d
untreated	0	0d	0e	0a	73d	2230cd

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha; metolachlor – 1.42 kg/ha. [4] DAC = days after cracking. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 2-6. Influence of paraquat, paraquat + bentazon, paraquat + metolachlor and paraquat + bentazon + metolachlor herbicides on percent injury, days to row closure, and yield of C-99R peanut in 2006.

Herbicide Treatment[1]	Timing DAC[3]	% injury[2] 7 DAT[4]	Yield (kg/ha)
paraquat	14	10b[5]	4330bc
paraquat	28	13ab	4270bc
paraquat + bentazon	14	10b	4240bc
paraquat + bentazon	28	10b	4450a-c
paraquat + metolachlor	14	10b	4260bc
paraquat + metolachlor	28	15a	4120c
paraquat + bentazon + metolachlor	14	11ab	4670ab
paraquat + bentazon + metolachlor	28	10b	4080c
untreated	0	0c	4940a

[1] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha; metolachlor – 1.42 kg/ha. [2]Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [3] DAC = days after cracking. [4] DAT = days after treatment. [5] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 2-7. Influence of paraquat, paraquat + bentazon, paraquat + metolachlor and paraquat + bentazon + metolachlor herbicides on percent injury, days to row closure, and yield of C-99R peanut in 2007.

Herbicide Treatment[3]	Timing DAC[4]	--------------% injury[1]-------------			Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
		7 DAT[5]	14 DAT	28 DAT		
paraquat	14	13d[6]	23ab	0a	79b	3200a
paraquat	28	45ab	24ab	0a	88a	2250b
paraquat + bentazon	14	14d	26a	0a	83ab	3210a
paraquat + bentazon	28	43bc	25a	0a	83ab	3340a
paraquat + metolachlor	14	11d	24ab	0a	88a	3160a
paraquat + metolachlor	28	49a	20b	0a	88a	2970a
paraquat + bentazon + metolachlor	14	14d	24ab	0a	84ab	3290a
paraquat + bentazon + metolachlor	28	39c	20b	0a	86ab	3560a
untreated	0	0e	0c	0a	66c	3540a

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: paraquat – 0.14 kg/ha; bentazon – 0.28 kg/ha; metolachlor – 1.42 kg/ha. [4] DAC = days after cracking. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

CHAPTER 3
THE EFFECT OF LACTOFEN AND ACIFLUORFEN APPLICATION TIMING ON PEANUT INJURY AND YIELD FOR THREE VARYING MATURITY CULTIVARS

Introduction

Peanut weed management has always relied heavily on postemergence herbicides in the southeastern United States (Wehtje et al. 1992a; Wilcut et al. 1990b; Wilcut et al. 1994a; Wilcut et al. 1994b; Wilcut et al. 1994c). Prior to 1996, herbicides were primarily contact in activity, and peanut injury was common and accepted by growers (*D.L. Colvin - personal communication*). Prior to 1986, dinoseb was the most widely utilized herbicide for weed control in peanut systems (Buchanan et al. 1983). The Environmental Protection Agency cancelled all registrations of dinoseb in October of 1986, which removed one of the most effective, economical herbicide choices for peanut producers (Buchanan et al. 1983). With the cancellation of dinoseb, researchers looked for replacement herbicides that provided similar weed control (Wilcut et al. 1989)

Lactofen is a contact herbicide that is labeled for postemergence applications in peanut and soybean (Senseman 2007). Lactofen inhibits the enzyme protoporphyrinogen oxidase (Protox) which leads to the accumulation of protoporphyrin IX (PPIX) causing the formation of singlet oxygen. Singlet oxygen destroys cell membranes, resulting in rapid desiccation and disintegration (Duke 1991). Symptoms include chlorosis initially and then necrosis within two days (Senseman 2007). The current lactofen product label allows minimum time from application to harvest of 45 days (Anonymous 2008).

Acifluorfen is also a contact herbicide that is labeled for postemergence weed control in peanut and soybean (Senseman 2007). This herbicide acts in a similar manner to lactofen, with peanut leaves exhibiting chlorosis and eventually necrosis. The current acifluorfen product label allows minimum time from application to harvest of 75 days (Anonymous 2004).

The loss of dinoseb prompted the use of lactofen and acifluorfen for mid-season weed control, generally following an initial at-cracking paraquat application. Following the registration of imazapic in 1996, however, many peanut producers reduced lactofen and acifluorfen usage in their weed control systems. The broad spectrum foliar and soil activity of imazapic allowed growers to rely almost exclusively on imazapic for postemergence weed control. Imazapic controls many of the most commonly occurring weeds in peanuts without resulting in any visual injury or yield reduction (Dotray et al. 2001; Matocha et al. 2003).

However, the past decade of intense imazapic usage has led to an increase in resistant weeds and a shift in weed spectrum. The two most noteworthy species are acetolactate synthase (ALS)-resistant Palmer amaranth (*Amaranthus palmeri* S. Watson) and Bengal dayflower (*Commelina benghalensis* L.). Normally, imazapic controls Palmer amaranth with both preemergence and postemergence activity. High levels of resistance to imazapic have been found across the southeastern United States in ALS resistant Palmer amaranth (Vencill et al. 2002). ALS resistant Palmer amaranth has quickly become one of the most troublesome weeds in the southeastern United States. Bengal dayflower is an exotic invasive weed species that has increased in distribution over the past five years and is tolerant to imazapic (Webster et al. 2005).

These weed problems have forced many growers to reconsider the use of contact herbicides. Even if growers do not have resistant weed populations, alternative herbicides are recommended to avoid resistance (Sellers et. al 2008). Acifluorfen and lactofen are some of the leading contact postemergence herbicides to combat resistance issues.

Acifluorfen and lactofen have a long record of effective weed control, but peanut tolerance and yield reduction continue to be a concern. The label recommendations for acifluorfen and lactofen are mainly based on data collected on the Florunner variety, which is no longer grown.

Florunner was a mid-season maturity variety that reached maturity in approximately 134 days after planting (Norden et al. 1969). Currently, a wide range of new varieties with greater yield potential and disease tolerance dominate the southeastern peanut growing region. The new peanut varieties have differing maturity dates that range from 120 to 145 day maturity.

With the emergence of herbicide resistant weeds and new weed species, the use of lactofen and acifluorfen will likely increase across the peanut growing regions of the south. Therefore, the objective of this research was to determine the effect of lactofen and acifluorfen herbicides, applied across a wide growing period, on peanut injury and yield. Within this objective three peanut cultivars with varying maturity were evaluated.

Materials and Methods

Field experiments were conducted in 2007 and 2008 at the Plant Science Research and Education Unit in Citra, Florida on a Sparr fine sand (loamy, siliceous, hyperthermic Grossa-renic paleudult) with 1% organic matter. All experiments were initiated using a conventional tillage regime.

Plots were 3.0 m wide, 7.6 m long and contained four rows spaced 76.2 cm apart. Plots received optimum irrigation fertility, insecticide and fungicide treatments as directed by the Florida Cooperative Extension Service to ensure optimum growth. Seeds were planted at a depth of 5 cm with a seeding density of 17 seeds per meter of row (Wright et al. 2006). Planting occurred on June 14, 2007 and May 6, 2008. Each year aldicarb was applied in furrow at 3.2 kg ai/ha. The later than normal planting date in 2007 occurred because an outbreak of *Aspergillus niger* resulted in near total stand loss and replanting was required. The experimental area received a preemergence broadcast application of pendimethalin (0.92 kg ai/ha + diclosulam (0.42 kg ai/ha), and a postemergence application of imazapic (0.07 kg ai/ha). Supplemental hand-weeding was performed as needed to maintain weed-free conditions throughout the growing season.

The experimental design was a randomized complete block with a split-plot treatment arrangement and four replications. Peanut cultivar was the whole plot factor and herbicide treatments were the subplots. Cultivars included early (Andru II – 2007 and ViruGard – 2008), mid (AP-3 – 2007 and 2008) and late (C-99R – 2007 and 2008) season peanut cultivars (Gorbet 2006; Garcia y Garcia et al. 2007; Gorbet 2007; Gorbet and Shokes 2002). Andru II seed was not available in 2008. Eight herbicide treatments consisting of acifluorfen at 0.42 kg/ha or lactofen at 0.21 kg/ha were applied to each variety at 4, 6, 8 or 10 weeks after planting (WAP). An untreated check was included for each cultivar. All herbicide treatments included a crop oil concentrate at 1% v/v.

All experimental treatments were applied with a CO_2 backpack sprayer calibrated to deliver 187 L/ha. Visual ratings of peanut foliar injury and peanut canopy width were performed at 7, 14, and 28 days after application. Visual estimations of injury were rated on a scale from 0% to 100% with 0% = no injury and 100% = complete plant necrosis. Days to canopy closure (where no soil was visible between the two center rows) was also recorded.

The center two rows of each plot were dug according to maturity by a conventional digger-shaker-inverter. Maturity was based on the hull scrape method for each cultivar (Johnson 1987; Johnson et al. 1993; Sholar et al. 1995). Peanuts were allowed to field dry for approximately 3 days and commercial harvesting equipment was used to harvest each plot. Peanut yields (adjusted to moisture conditions of 9%) were determined and adjusted to a kg/ha basis.

Data were subjected to analysis of variance to test treatment effects and interactions. Means were separated using Fisher's Least Significant Difference (LSD) test at the $p<0.05$ level.

Results and Discussion

Statistical analysis detected a significant treatment by year and treatment by variety interaction (Table 3-1). Therefore, data will be presented by year and variety.

Early Maturity Peanut (Andru II and ViruGard)

In 2007, significant differences in peanut injury were detected 7 days after treatment (DAT) (Table 3-2). Peanut injury resulting from lactofen and acifluorfen applications ranged from 19% to 49% at 7 DAT. Overall, applications made at 4 and 6 WAP were more injurious than later applications, but regardless of application timing, almost complete recovery of Andru II was observed by 28 DAT. The 4 WAP injury persisted more than other treatments. The 14 DAT evaluation of the 8 WAP treatment showed a lower degree of recovery compared to the other treatments, regardless of herbicide used. Lactofen applications made 4 and 6 WAP and acifluorfen applications 4 WAP delayed canopy closure by 7 to 12 days. However, applications made 8 and 10 WAP did not influence canopy closure. This can partially be explained by the fact that the 8 and 10 WAP applications were made to peanuts that were already at, or near row closure.

No differences in canopy closure rate were observed between acifluorfen and lactofen and application timing seems to be the most important criteria for predicting delayed canopy closure. Regardless of foliar injury and canopy closure delay, no differences in yield were noted for the Andru II variety in 2007.

ViruGard injury in 2008 was similar to Andru II (Table 3-3). At 7 DAT, visual estimation of injury ranged from 26% to 51% for both lactofen and acifluorfen. Lactofen applied at 4 and 8 WAP was the most injurious ($\geq$50%). Canopy closure was significantly delayed with all applications except lactofen applied 10 WAP. This was due to row closure occurring prior to the 10 WAP application to ViruGard. The longest delay in canopy closure was 14 days for lactofen applied 6 and 8 WAP, and acifluorfen applied 8 and 10 WAP. ViruGard has a more erect growth habit than Andru II, and might explain the extended days to canopy closure in 2008.

Significant reductions in peanut yield, ranging from 500 to 1270 kg/ha, were observed as a result of lactofen applied 6, 8 and 10 WAP and acifluorfen applied 8 and 10 WAP. By 14 DAT, some recovery from foliar damage was observed for all treatments, but more rapid recovery occurred from the earlier application timings. For example, the 4 WAP application showed a 40% and 35% reduction in injury for lactofen and acifluorfen, respectively. However, for 10 WAP the level of recovery for lactofen and acifluorfen was 6% and 7%, respectively. By 28 DAT, all treatments showed minimal injury. Therefore, the loss in yield appeared to be more associated with injury 14 DAT, where treatments exhibiting ≥18% injury resulted in yield reductions compared to the untreated control.

Medium Maturity Peanut (AP-3)

In 2007, AP-3 exhibited a wide range of injury with visual estimation ratings from 13% to 49% (Table 3-4). At each application timing acifluorfen caused less injury than lactofen. As previously observed, plants had generally recovered from the foliar injury by 28 DAT with 8% or less injury remaining. Once again, the greatest injury was observed when either herbicide was applied 4 WAP, and this continued to be evident 14 DAT. However, there appeared to be little difference in the level of recovery between the two herbicides regardless of application timing. In addition, there were no differences between the herbicides within application timing.

Canopy closure was significantly delayed by the 4 WAP applications (16 days for lactofen and 20 days for acifluorfen). No other application timings resulted in delayed canopy growth. The only application that resulted in a significant reduction in yield compared to the untreated was lactofen and acifluorfen applied 8 WAP.

AP-3 in 2008 had the highest injury rating with early application (Table 3-5). Visual injury ratings ranged from 21% to 55%, and plants recovered by 28 DAT. At 7 DAT, all treatments showed significant foliar injury, with lactofen applied at 4 WAP resulting in >50% injury. Once again lactofen was more injurious than acifluorfen at each application timing. Peanuts recovered much quicker in 2008, although the level of damage still evident at 14 DAT was greater for the 8 and 10 WAP applications for both herbicides. This trend continued in the 28 DAT observation, where only 3 treatments resulted in significant injury, and this was ≤5%. Row closure was delayed at 4 and 6 WAP for both herbicides up to 12 days. In general, yield loss was observed in these treatments showing >15% injury 14 DAT, these being lactofen at 8 and 10 WAP and acifluorfen at 10 WAP.

Late Maturity Peanut (C-99R)

In 2007, when evaluated 7 DAT, lactofen caused greater injury than acifluorfen in C-99R when applied 6, 8 or 10 WAP (Table 3-6). No differences between acifluorfen and lactofen treatments were detected for the 4 WAP application, where the injury from both herbicides was nearly 50%. The lowest level of injury for both herbicides was observed with the 6 WAP timing. As with the other varieties in 2007, recovery was slower for the 4 WAP treatments. By 14 DAT, few differences were observed between herbicides applied at the same timing. Less than 5% injury was observed by 28 DAT.

Canopy closure was delayed following application of either lactofen or acifluorfen at 4 WAP. None of the other treatments affected canopy closure. None of the treatments resulted in a yield reduction compared to the untreated.

In 2008, visual injury estimation was similar for lactofen and acifluorfen (Table 3-7). In general, more injury was observed with the 4 WAP treatments and less injury following applications 10 WAP. In both years, the 28 DAT visual injury rating was 6% or less. High levels of injury were noted for all treatments 7 DAT, with lactofen showing greater injury compared to acifluorfen at all application timings. Significant delays in canopy closure were observed following lactofen applied 4 and 6 WAP and acifluorfen applied 6 WAP. All treatments recovered rapidly with <20% injury by 14 DAT. The only exception was lactofen applied 10 WAP, and this was the only treatment that resulted in significant yield loss. Another interesting observation was that the only treatments that significantly delayed canopy closure (lactofen applied 4 and 6 WAP, acifluorfen applied 6 WAP) also resulted in yields greater than the untreated control. In 2007, no significant yield reduction was observed in any of the treatments, but 2008 yield reduction was observed for lactofen applied 10 WAP.

Discussion

Canopy closure did not appear to relate with yield reduction, while lactofen injury at 14 DAT related with yield in 2008 but not in 2007. The current lactofen label allows for a preharvest interval of 45 days, but these data indicate that lactofen applications at 8 and 10 weeks after cracking (within preharvest interval) may result in yield loss for some cultivars. The current acifluorfen label allows for a preharvest interval of 75 days, but these data indicate that acifluorfen might impact yield at 8 and 10 weeks with some cultivars. Overall, yield loss was more with lactofen than acifluorfen from later applications.

Previous research has shown that both early and late-season applications of lactofen and acifluorfen reduced peanut yield, but the reasons for these reductions were not clear (Grichar 1997). Additionally, Wilson and Hines (1987) showed that snap bean yield was reduced more when acifluorfen was applied at the 1 to 2 leaf stage rather than the treatment at the 4 to 8 leaf stage. The injury rating for the 1 to 2 leaf stage was 81% in comparison to 22% at the 4 to 8 leaf stage (Wilson and Hines 1987).

In general, yield reduction increased with the later application timings in this experiment. This is interesting considering that the lowest visual injury ratings had the most yield reduction in the early maturity cultivar. It is hypothesized that these late-season applications had the greatest impact on yield since the herbicide caused stress, including substantial foliar loss, to the plant during the pod-fill and maturation phase of development. Previous research has shown that water stress, fertility, or plant stress during pod fill impacted yield more than when these stresses occurred early in plant development (Knauft et al. 1990).

Weeds compete with peanut for light, water, nutrients and physical space. If producers are making a decision on whether to use a contact herbicide, they have need to weigh the benefit of a herbicide with potential yield loss against the amount of yield loss due to weed pressure. Acifluorfen and lactofen are useful tools for peanut growers, but the application decisions need to made on a case by case basis. Caution should be used when making late season application even if the label allows for those applications.

Table 3-1. ANOVA table for the effect of lactofen and acifluorfen application timing on peanut injury and yield for three varying maturity cultivars.

Class Variable	DF[1]	--------------% injury[2]-------------			Days to Closure[2]	Yield[2]
		7 DAT[3]	14 DAT	28 DAT		
variety (maturity)	2	0.0027	0.0001	0.3112	<0.0001	<0.0001
year (2007/2008)	1	<0.0001	0.0014	<0.0001	<0.0001	<0.0001
treatment	8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
replication	3	0.0153	0.0294	0.1718	0.7679	0.0078
year * variety	2	0.1831	0.7717	0.1862	<0.0001	<0.0001
year * treatment	8	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
year * variety * treatment	32	0.0127	0.0010	0.3789	0.0005	0.0576

[1] DF = degrees of freedom. [2] Pr > F. [3] DAT = days after treatment

Table 3-2. Influence of lactofen and acifluorfen herbicides on percent injury, days to row closure, and yield of Andru II peanut in 2007.

Herbicide Treatment[3]	Timing WAP[4]	--------------% injury[1]------------- 7 DAT[5]	14 DAT	28 DAT	Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
lactofen	4	49a[6]	31a	5a	74a	3220a
lactofen	6	21cd	11c	4ab	69ab	3540a
lactofen	8	26c	19b	5a	64bc	2860a
lactofen	10	25c	9cd	5a	59cd	3130a
acifluorfen	4	46a	28a	4ab	72a	3070a
acifluorfen	6	21cd	8cd	1bc	64bc	3540a
acifluorfen	8	26c	16b	3a-c	61cd	3620a
acifluorfen	10	19de	5d	5a	57d	3550a
untreated	0	0f	0e	0c	62cd	3010a

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: lactofen – 0.21 kg/ha; acifluorfen – 0.42 kg/ha. [4] WAP = weeks after planting. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 3-3. Influence of lactofen and acifluorfen herbicides on percent injury, days to row closure, and yield of ViruGard peanut in 2008.

Herbicide Treatment[3]	Timing WAP[4]	--------------% injury[1]-------------- 7 DAT[5]	14 DAT	28 DAT	Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
lactofen	4	51a[6]	11de	1bc	75a	6360a-c
lactofen	6	44bc	18bc	0c	77a	5910cd
lactofen	8	50ab	28a	6a	77a	5680de
lactofen	10	34e	28a	0c	65b	5330e
acifluorfen	4	41cd	6e	1bc	72a	6450ab
acifluorfen	6	35de	13cd	0c	74a	6400ab
acifluorfen	8	41cd	23ab	4ab	77a	5830d
acifluorfen	10	26f	19b	0c	77a	6100b-d
untreated	0	0g	0f	0c	63b	6600a

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: lactofen – 0.21 kg/ha; acifluorfen – 0.42 kg/ha. [4] WAP = weeks after planting. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 3-4. Influence of lactofen and acifluorfen herbicides on percent injury, days to row closure, and yield of AP-3 peanut in 2007.

Herbicide Treatment[3]	Timing WAP[4]	--------------% injury[1]-------------			Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
		7 DAT[5]	14 DAT	28 DAT		
lactofen	4	49a[6]	29a	5ab	79ab	2700a
lactofen	6	18e	8d	3b-d	66c	2360a-c
lactofen	8	34c	18b	5ab	62c	2020c
lactofen	10	26d	8d	8a	64c	2480ab
acifluorfen	4	41b	26a	4bc	83a	2630a
acifluorfen	6	13f	10cd	1cd	71bc	2380a-c
acifluorfen	8	25d	14bc	0d	69bc	2220bc
acifluorfen	10	15ef	5de	5ab	66c	2490ab
untreated	0	0g	0e	0d	63c	2630a

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: lactofen – 0.21 kg/ha; acifluorfen – 0.42 kg/ha. [4] WAP = weeks after planting. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 3-5. Influence of lactofen and acifluorfen herbicides on percent injury, days to row closure, and yield of AP-3 peanut in 2008.

Herbicide Treatment[3]	Timing WAP[4]	--------------% injury[1]--------------			Days to Closure[2]	Yield
		7 DAT[5]	14 DAT	28 DAT	76.2 cm rows	(kg/ha)
lactofen	4	55a[6]	11ef	5a	63a	7910ab
lactofen	6	44b	15c-e	0b	65a	7850a-c
lactofen	8	44b	21ab	5a	53b	7200d
lactofen	10	30d	25a	0b	54b	6490e
acifluorfen	4	44b	9f	0b	61a	8360a
acifluorfen	6	39c	13d-f	0b	63a	8110ab
acifluorfen	8	38c	18bc	4a	54b	7590b-d
acifluorfen	10	21e	16cd	0b	53b	7280cd
untreated	0	0f	0g	0b	53b	7940ab

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: lactofen – 0.21 kg/ha; acifluorfen – 0.42 kg/ha. [4] WAP = weeks after planting. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 3-6. Influence of lactofen and acifluorfen herbicides on percent injury, days to row closure, and yield of C-99R peanut in 2007.

Herbicide Treatment[3]	Timing WAP[4]	--------------% injury[1]-------------- 7 DAT[5]	14 DAT	28 DAT	Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
lactofen	4	48a[6]	31a	4ab	79a	3420ab
lactofen	6	19de	10b	4ab	74a-c	3090bc
lactofen	8	33b	10b	1bc	70bc	3030c
lactofen	10	24cd	6c	4ba	69c	3270a-c
acifluorfen	4	49a	29a	4ba	77ab	3340a-c
acifluorfen	6	11f	10b	1bc	72a-c	3400ab
acifluorfen	8	25c	6c	0c	70bc	3110a-c
acifluorfen	10	16ef	5c	5a	70bc	3450a
untreated	0	0g	0d	0c	67c	3100bc

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: lactofen – 0.21 kg/ha; acifluorfen – 0.42 kg/ha. [4] WAP = weeks after planting. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

Table 3-7. Influence of lactofen and acifluorfen herbicides on percent injury, days to row closure, and yield of C-99R peanut in 2008.

Herbicide Treatment[3]	Timing WAP[4]	-------------% injury[1]------------- 7 DAT[5]	14 DAT	28 DAT	Days to Closure[2] 76.2 cm rows	Yield (kg/ha)
lactofen	4	54a[6]	15bc	1b	63a	6330ab
lactofen	6	43bc	15bc	0b	63a	5980a-c
lactofen	8	41c	19ba	6a	56de	5510cd
lactofen	10	30de	23a	0b	56de	5060d
acifluorfen	4	46b	10c	1b	62ab	5690c
acifluorfen	6	28e	10c	0b	63a	6470a
acifluorfen	8	34d	15bc	5a	58cd	5910bc
acifluorfen	10	23f	13bc	0b	54e	5620c
untreated	0	0g	0d	0b	60bc	5730c

[1] Visual assessment of peanut foliar damage and stunting based on the following scale: 0 = no foliar burn or stunting; 100 = complete plant necrosis. [2] Number of days required to achieve complete canopy closure between 76.2 cm wide row spacing. [3] Rates for herbicides are as follows: lactofen – 0.21 kg/ha; acifluorfen – 0.42 kg/ha. [4] WAP = weeks after planting. [5] DAT = days after treatment. [6] Values reflect the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level according to Fischer's Least Significant Difference (LSD) test.

LIST OF REFERENCES

Anonymous. 2004. Ultra Blazer® herbicide product label. EPA Registration 70506-60. Trenton, NJ: United Phosphorus Inc. 6 p.

Anonymous. 2008. Cobra® herbicide supplemental label. EPA Registration 59639-34. Walnut Creek, CA: Valent U.S.A. Corporation. 5 p.

Anonymous. 2009. Gramoxone Inteon® herbicide product label. EPA Registration 100-1217. Greensboro, NC: Syngenta. 55 p.

Bellinder, R. R., R. W. Wallace, and G. L. Jordan. 1997. English Pea (*Pisum sativum*) tolerance to paraquat and paraquat plus bentazon. Weed Technol. 11:39-44.

Boote, K. J. 1982. Growth stages of peanut. Peanut Sci. 9:35-40.

Brecke, B. J., D. O. Stephenson, and K. Hutto. 2005. Impact of tillage and herbicides on tropical spiderwort. Proceedings of the Tropical Spiderwort Symposium. Web page: http://mulch.cropsoil.uga.edu/weedsci/tsw2005/index.html. Accessed: June 25, 2009.

Brian, R. C. 1969. The influence of darkness on the uptake and movement of diquat and paraquat in tomatoes, sugar beet, and potatoes. Ann. Appl. Biol. 63:117-126.

Buchanan, G. A., D. S. Murray, and E. W. Hauser. 1983. Weeds and their control in peanuts. Pages 206-209 *in* H. E. Pattee and C. T. Young, (eds.). Peanut Science and Technology. American Peanut Research and Education Society, Yoakum, TX 77995.

Cardina, J. and C. W. Swann. 1988. Metolachlor effects on peanut growth and development. Peanut Sci. 15:57-60.

Cardina, J., A. C. Mixon, and G. R. Wehtje. 1987. Low-cost weed control systems for close-row peanuts (*Arachis hypogaea*). Weed Sci. 35:700-703.

Culpepper, A. S., J. T. Flanders, A. C. York, and T. M. Webster. 2004. Tropical spiderwort (*Commelina benghalensis*) control in glyphosate-resistant cotton (*Gossypium hirsutum*). Weed Technol. 18:432-436.

Dotray, P. A., T. A. Baughman, J. W. Keeling, W. J. Grichar, and R. G. Lemon. 2001. Effect of imazapic application timing on Texas peanut (*Arachis hypogaea*). Weed Technol. 15:26-29.

Duke, S. O., J. Lydon, J. M. Becerril, T. D. Sherman, L. P. Lehnen, Jr. and H. Matsumoto. 1991. Protoporphyrinogen oxidase-inhibiting herbicides. Weed Sci. 39:465-473.

Fedtke, C. 1982. Biochemistry and physiology of herbicide action. Berlin: Springer-Verlag. 202 pp.

Garcia y Garcia, A., L. C. Guerra, A. Suleiman, J. O. Paz, and G. Hoogenboom. 2007. Peanut water use under optimum conditions of growth and development: a simulation approach. Proceedings of the 2007 Georgia Water Resources Conference. Web page: http://cms.ce.gatech.edu/gwri/uploads/proceedings/2007/5.6.4.pdf. Accessed: July 8, 2009.

Gorbet, D. W. 2006. Registration of 'Andru II' peanut. Crop Science.46:2712-2713.

Gorbet, D. W. 2007. Registration of 'AP-3' peanut. Journal of Plant Registrations. 1:126-127.

Gorbet, D. W. and B. L. Tillman. 2009. Registration of 'Florida-07' peanut. Journal of Plant Registrations. 3:14-18.

Gorbet, D. W. and F. M. Shokes. 2002. Registration of 'C-99R' peanut. Crop Science. 42:2207.

Grey, T. L., G. R. Wehtje, R. H. Walker, and K. P. Paudel. 1995. Comparison of imazethapyr and paraquat-based weed control systems in peanut (*Arachis hypogaea*). Weed Technol. 9:813-818.

Grey, T. L., J. W. Wilcut, and G. R. Wehtje. 1992. Weed control in peanuts utilizing imazethapyr, bentazon, and paraquat. Proceedings Southern Weed Science Society. 45:105.

Grichar, W. J. 1997. Influence of herbicides and timing of application on broadleaf weed control in peanut (*Arachis hypogaea*). Weed Technol. 11:708-713.

Johnson III, W. C. 1987. The hull scrape method to assess peanut maturity. Georgia Cooperative Extension Service Bulletin. 958.

Johnson III, W. C., J. R. Chamberlin, T. B. Brenneman, J. A. Todd, B. G. Mullinix, Jr., and J. Cardina. 1993. Effects of paraquat and alachlor on peanut (*Arachis hypogaea*) growth, maturity, and yield. Weed Technol. 7:855-859.

Jordan, D., D. Prostko, P. Dotray, J. Wilcut, T. Baughman, B. Brecke, J. Chapin, J. Faircloth, W. Faircloth, J. Ferrell, T. Grey, J. Grichar, G. MacDonald, and C. Medlin. 2007. Managing herbicide-resistant weeds in peanuts in the United States. North Carolina State University and A&T State University Cooperative Extension Service. AG-692.

Knauft, D. A., D. L. Colvin, and D. W. Gorbet. 1990. Effect of paraquat on yield and market grade of peanut (*Arachis hypogaea*) genotypes. Weed Technol. 4:866-870.

Matocha, M. A., W. J. Grichar, S. A. Senseman, C. A. Gerngross, B. J. Brecke, and W. K. Vencill, 2003. The persistence of imazapic in peanut (*Arachis hypogaea*) crop rotations. Weed Technol. 17:325-329.

Norden, A. J., R. W. Lipscomb, and W. A. Carver. 1969. Registration of florunner peanuts. Crop Sci. Volume 9, November-December. p. 850.

Pfister, K., C. Buschmann, and H. K. Lichtenthaler. 1974. Inhibition of the photosynthetic electron transport by bentazon. Proceedings of the 3rd International Congress on Photosynthesis. Pp. 675-681.

Prostko, E. P., A. S. Culepper, T. M. Webster, and J. T. Flanders. 2005. Tropical spiderwort identification and control in Georgia field crops. Tifton, GA: University of Georgia Cooperative Extension Service Bulletin. http://pubs.caes.uga.edu/caespubs/pubs/PDF/c884.pdf. Accessed: June 25, 2009.

Richburg III, J. S., J. W. Wilcut, and E. F. Eastin. 1995. Weed management in peanut (*Arachis hypogaea*) with imazethapyr and metolachlor. Weed Technol. Volume 9:807-812.

Sellars, B. A., J. A. Ferrell, and G. E. MacDonald. 2008. Managing against the development of herbicide resistant weeds: Sugarcane. University of Florida Cooperative Extension Service, SS-AGR-244.

Senseman, S. A. 2007. Herbicide Handbook. 9th edition. Lawrence, KS: Weed Science Society of America. Pp. 12, 132-133, 188-192, & 209-210.

Sholar, J. R., R. W. Mozingo, and J. P. Beasley, Jr. 1995. Peanut cultural practices. Pages 354-382 *in* H. E. Pattee and H. T. Stalker (eds.). Advances in Peanut Science. American Peanut Research and Education Society, Inc., Stillwater, OK. 614 p.

Spader, V. and R. A. Vidal. 2000. Response curve of *Commelina bengalensis* to EPSPS enzyme inhibitory herbicides. Pest. Rev. Tec. Cien. 10:125-135.

Steptoe, P. J., W. K. Vencill and T. L. Grey. 2006. Influence of moisture stress on herbicidal control of an invasive weed, Benghal dayflower (*Commelina benghalensis*). J. Plant Dis. Protect. XX:907-914.

Suwanketnikom, R., K. K. Hatzios, D. Penner, and D. Bell, 1982. The site of electron transport inhibition by bentazon (3-isopropyl-(1*H*)-2,1,3-benzothiadiazin-(4)-(3*H*)-one-2,2-dioxide) in isolated chloroplasts. Can. J. Botany. 60:409-412.

Thrower, S. L., N. D. Hallam, and L. B. Thrower. 1965. Movement of diquat dibromide in leguminous plants. Ann. Appl. Biol. 55:253-260.

Vencill, W. K., E. P. Prostko, and T. E. Webster. 2002. Is Palmer amaranth (*Amaranthus palmeri*) resistant to ALS and dinitroaniline herbicides? Proceedings Southern Weed Science Society. 55:189.

Webster, T. M., M. G. Burton, A. S. Culpepper, A. C. York, and E. P. Prostko. 2005. Tropical Spiderwort (*Commoelina benghalensis*): A tropical invader threatens agroecosystems of the southern United States. Weed Technol. 19:501-508.

Webster, T. M., M. G. Burton, A. S. Culpepper, J. T. Flanders, T. L. Grey, and A. C. York. 2006. Tropical spiderwort (*Commelina bengalensis*) control and emergence patterns in preemergence herbicide systems. Journal Cotton Science. 10:68-75.

Webster, T. M., W. H. Faircloth, J. T. Flanders, E. P. Prostko, and T. L. Grey. 2007. The critical period of Bengal dayflower (*Commelina bengalensis*) control in peanut. Weed Sci. 55:359-364.

Wehtje, G. R., J. A. McGuire, R. H. Walker, and M. G. Patterson. 1986. Texas panicum (*Panicum texanum*) control in peanuts (*Arachis hypogaea*) with paraquat. Weed Sci. 34:308-311.

Wehtje, G. R., J. W. Wilcut, and J. A. McGuire. 1992a. Influence of bentazon on the phytotoxicity of paraquat to peanuts (*Arachis hypogaea*) and associated weeds. Weed Sci. 40:90-95.

Wehtje, G. R., J. W. Wilcut, and J. A. McGuire. 1992b. Paraquat behavior as influenced by 2,4-DB in peanut (*Arachis hypogaea*) and selected weeds. Peanut Sci. 19:51-55.

Wehtje, G. R., J. W. Wilcut, and J. A. McGuire. 1992c. Paraquat phytotoxicity absorption, and translocation in peanut and selected weeds as influenced by chloramben. Weed Sci. 40:471-476.

Wehtje, G. R., J. W. Wilcut, D. P. Dylewski, J. A. McGuire, and V. T. Hicks. 1991a. Antagonism of paraquat phytotoxicity in peanuts (*Arachis hypogaea*) and selected weed species by naptalam. Weed Sci. 39:634-639.

Wehtje, G. R., J. W. Wilcut, J. A. McGuire, and T. V. Hicks. 1991b. Foliar penetration and phytotoxicity of paraquat as influenced by peanut cultivar. Peanut Sci. 18:67-71.

Wehtje, G. R., J. W. Wilcut, T. V. Hicks, and J. A. McGuire. 1988. Relative tolerance of peanut to alachlor and metolachlor. Peanut Sci. 15:53-56.

Wilcut, J. W., A. C. York, and G. R. Wehtje. 1993. The control and interaction of weeds in peanut (*Arachis hypogaea*). Rev. Weed Sci. 6:151-176.

Wilcut, J. W., A. C. York, and G. R. Wehtje. 1994a. The control and interaction of weeds in peanut (*Arachis hypogaea*). Rev. Weed Sci. 6:177-205.

Wilcut, J. W., G. R. Wehtje, and M. G. Patterson. 1987. Economic assessment of weed control systems for peanuts (*Arachis hypogaea*). Weed Sci. 35:433-437.

Wilcut, J. W., G. R. Wehtje, and R. H. Walker. 1987. Economics of weed control in peanuts (*Arachis hypogaea*) with herbicides and cultivations. Weed Sci. 35:711-715.

Wilcut, J. W., G. R. Wehtje, T. A. Cole, T. V. Hicks, and J. A. McGuire. 1989a. Postemergence weed control systems without dinoseb for peanuts (*Arachis hypogaea*). Weed Sci. 37:385-391.

Wilcut, J. W., G. R. Wehtje, T. V. Hicks, and T. A. Cole. 1990a. Postemergence weed management systems for peanuts (*Arachis hypogaea*). Weed Technol. 4:239-244.

Wilcut, J. W., G. R. Wehtje, T. V. Hicks, and T. A. Cole. 1990b. Postemergence weed management systems for peanuts. Weed Technol. 4:76-80.

Wilcut, J. W., J. S. Richburg, III., E. F. Eastin, G. R. Wiley, F. R. Walls, Jr., and S. Newell. 1994b. Imazethapyr and paraquat systems for weed management in peanut (*Arachis hypogaea*). Weed Sci. 42:601-607.

Wilcut, J. W., J. S. Richburg, III., G. R. Wiley, F. R. Walls, Jr., S. R. Jones, and M. J. Iverson. 1994c. Imidazolinone herbicide systems for peanut (*Arachis hypogaea*). Peanut Sci. 21:23-28.

Wilson, H. P. and T. E. Hines. 1987. Snap bean (*Phaseolus vulgaris*) and common lambsquarters (*Chenopodium album*) response to acifluorfen. Weed Technol. 1:18-21.

Wright, D. L., B. Tillman, E. Jowers, J. Marois, J. A. Ferrell, T. Katsvairo and E. B. Whitty. 2006. Management and cultural practices for peanuts. University of Florida Cooperative Extension Service, SS-AGR-74.

BIOGRAPHICAL SKETCH

James A. Boyer grew up in Weirsdale, FL. He is the son of Mr. and Mrs. Willet (Bud) Boyer, a retired citrus grower. He attended Ocala Christian Academy and graduated in 1995. After graduation, he attended the University of Florida while working part-time for the Agronomy Department. He graduated with a Bachelor of Science in Agricultural Operations Management in 1999 and pursued a job opportunity in Punta Gorda, FL managing a 3,000-acre sod farm. The beginning of 2001, he accepted a position as Coordinator of Research Programs at the Plant Science Research and Education Unit in Citra, FL and soon after married Kelle McRae on August 18th. Jim's family expanded in March 2006 with Katherine and October 2008 with Nathan. They inspired him to pursue his master's degree, something he had always wanted. The fall of 2007 he was accepted into the graduate program at the University of Florida, pursuing a Master of Science degree in agronomy with a concentration in weed science under the supervision of Greg MacDonald. Jim has presented at the Florida Weed Science Society, presented for two years at the Southern Weed Science Society and played an active role in hosting the Southern Weed Science Society weed contest. He also won the paper contest at the Florida Weed Science Society in 2009. Following completion of his Master of Science degree, he plans to continue working at the Plant Science Research and Education Unit.