IMPROVING PEANUT (*ARACHIS HYPOGAEA* L.) PRODUCTION STRATEGIES THROUGH USE OF COVER CROPS AND ORGANIC MANAGEMENT

by

DYLAN QUINCY WANN

(Under the Direction of R. Scott Tubbs)

ABSTRACT

Peanut (*Arachis hypogaea* L.) production is typically dependent on numerous chemical inputs for fertilization and pest control. Field trials were conducted to observe decomposition and nutrient effects of three cover crops on a subsequent peanut crop. All displayed potential for releasing significant amounts of nutrients and increasing nutrient uptake by the peanut crop, but there was little impact on peanut yield and crop quality under standard management. Field trials were also conducted to evaluate eleven peanut cultivars and three approved fungicide formulations for foliar disease management and six cultivation regimes for weed control in peanut under organic management. Florida-07, Georgia-06G, and Tifguard exhibited the best combination of disease resistance and yield potential, while all fungicide treatments improved yields over the control only under heavy disease pressure. All levels of tine cultivation (plus sweep cultivation and hand-weeding) provided sufficient weed control and profit maximization over the control.

INDEX WORDS: *Bacillus subtilis*, copper sulfate, cultivation, decomposition, early leaf spot, late leaf spot, non-chemical weed control, nutrient release, nutrient uptake, organic agriculture, strip-tillage, tine weeder.

IMPROVING PEANUT (*ARACHIS HYPOGAEA* L.) PRODUCTION STRATEGIES

THROUGH USE OF COVER CROPS AND ORGANIC MANAGEMENT

by

DYLAN QUINCY WANN

B.S. Abilene Christian University, 2008

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment

of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2011

IMPROVING PEANUT (*ARACHIS HYPOGAEA* L.) PRODUCTION STRATEGIES THROUGH USE OF COVER CROPS AND ORGANIC MANAGEMENT

by

DYLAN QUINCY WANN

Major Professor: R. Scott Tubbs

Committee: Albert K. Culbreath
Glendon H. Harris
John P. Beasley, Jr.

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
May 2011

DEDICATION

This effort is dedicated to my wonderful family: Dad, Mom, and Alejandro. Thank you for everything you have given me—the endless encouragement, love, and support that you've continually poured out have carried me through this entire crazy journey. But, most of all, I dedicate this to my incredible wife, Andrea, who has literally supported my every effort in this program. Thank you for seeing the absolute best and worst of me, yet loving me all the more. You are a shining example of God's love and I would be nowhere without you.

ACKNOWLEDGEMENTS

A humongous "thank you" to all of my phenomenal committee members: Dr. Albert Culbreath, Dr. Glen Harris, and Dr. John Beasley. Thank you all for your guidance and insight and for helping shape me into what I've become today. Not to mention, thanks for the good music, the great reads, and the occasional squirrel stew. A long-standing thanks to Dr. Kent Gallaher, formerly of Abilene Christian University, who first sparked the wild-hair idea, years ago, to embark on this journey. More than anyone, however, thank you so much, Dr. Tubbs, for all of the time, energy, and instruction that you've given me. You've poured into me more than any other graduate professor that I've seen and I couldn't be more grateful for your teaching and guidance. Thank you for encouraging me to always reach my potential. Most of all, thanks for taking a chance on a kid from Wyoming.

Many, many thanks to Chad Abbot, Corey Brooke, Corey Thompson, Katie Davis, Josh Ott, Justin Moss, Paige Adams, and Will Vance for their outstanding technical assistance. Without all of you, literally none of this research would have been possible. Thank you for helping me sample the bejeebers out of those nutrient cycling tests and for pulling so many weeds. Y'all are fantastic.

Finally, I want to acknowledge and thank my Lord and Savior, Jesus Christ, in whom all things are possible. Thank You for Your love, strength, guidance and, above all, the gift of salvation that You afforded all through Your death on a cross. "I have been crucified with Christ. It is no longer I who live, but Christ who lives in me. And the life I now live in the flesh, I live by faith in the Son of God, who loved me and gave Himself for me." – Galations 2:20.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

As global populations continue to increase, greater pressure is placed on agricultural producers to meet the food and fiber demands of an ever-flourishing populace. In light of concerns regarding limited natural resources, more pressure is placed on producers to also increase the efficiency of their production. Over 27% of the world's land and 25% of U.S. land is devoted to permanent crop or pasture land. Also, over 70% of water consumed by humans is used in agricultural production. Of the water consumed in the U.S., 68% is devoted to agriculture alone (FAO, 2009). Thus, the impact of agriculture on land and water quality worldwide is enormous. In the last 20 years, however, land use efficiency of U.S. agricultural lands has improved dramatically. In maize (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), soybean (*Glycine max* [L.] Merr.), and wheat (*Triticum aestivum* L.), soil loss per hectare has significantly decreased (by 69%, 34%, 49%, and 50%, respectively), while yield per hectare has increased (by 41%, 31%, 29%, and 19%, respectively). Irrigation water use per hectare and energy use per output in maize, soybean, and cotton have also shown a marked decrease (Keystone, 2009). Many techniques and approaches have been utilized to confer increased efficiency, most of which focus on conservation-based production. The Food and Agriculture Organization of the United Nations (FAO) has widely advocated the use of conservation practices worldwide that reduce production inputs while promoting the long-term health and viability of cropping systems. Two such techniques are cover cropping and conservation ("reduced") tillage (FAO, 2008).

Cover cropping is a technique that has been implemented in the production of many different crops worldwide, including peanut (*Arachis hypogaea* L.). Cover crops are primarily used to reduce soil erosion in the periods between cash crops, but they also provide numerous other benefits, including weed suppression, soil moisture retention, and addition of organic matter and recycled nutrients to soils (SAN, 2005). Cover cropping has been implemented in peanut production, due to the highly-erodible nature of the sandy soils on which peanut is typically grown (Gallaher and Hawf, 1997).

Conservation tillage is an appealing option because it significantly reduces soil losses via wind and water erosion and subsequently improves the long-term quality and productivity of soil. It also aids in reducing soil compaction and evaporation of soil moisture, increases soil organic matter (SOM), and can improve water infiltration into the soil. From a production standpoint, conservation tillage also requires fewer trips across the field, reducing equipment needs and fuel costs (Bauer et al., 2004; Derpsch, 2003; Gallaher and Hawf, 1997; Gebhardt et al., 1985; Johnson et al., 2001; Rowland et al., 2006; Simoes et al., 2009; Wright et al., 2009). In the Southeast, adoption of conservation-tillage practices has occurred in maize, soybean, and cotton production, and is now occurring with peanut (Banerjee et al., 2007; Gallaher and Hawf, 1997; Sholar et al., 1995; Wright et al., 2009).

With the adoption of cover cropping and conservation tillage practices in the southeastern U.S., there is budding interest among growers in the nutrient cycling capabilities of various cover crop species used in peanut production. Thus, there is a distinct need for information regarding the nutrient cycling potential of cover crops and their respective impacts on peanut nutrition and productivity. This information would be extremely beneficial to growers by providing information that could possibly allow them to reduce costly fertilizer inputs to their cropping systems.

Demand for and production of certified organic crops has also become prominent in U.S. agriculture (Gaskell et al., 2000). Though they typically produce lower overall yields than conventionally-produced crops, organics typify the image of low-input, conservation-oriented agriculture through elimination of costly and potentially hazardous synthetic chemical and energy inputs (Kuepper and Gegner, 2004). In the southeastern U.S., weed and disease control have consistently proven to be the main inhibitory factors to organic production. Organic peanut faces the same obstacles. Organic peanut production is largely localized in the southwestern U.S., where issues with weeds and plant diseases are less prevalent in the predominantly arid climate. Enormous potential exists in organic peanut markets for Georgia, the nation's most prolific peanut producer (NASS, 2009), since much of the industry's infrastructure is already established. However, little information is available to growers regarding effective, affordable methods of disease and weed control for organic peanut.

CHAPTER 2

LITERATURE REVIEW

Conservation-Tillage in Peanut

The Conservation Technology Information Center (CTIC) defines “conservation tillage” as any tillage and planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water. Where soil erosion by wind is the primary concern, a conservation tillage system is one that maintains at least 1120 kg ha^{-1} of flat, small grain residue equivalent on the surface throughout the critical wind erosion period (CTIC, 2011). Gebhardt et al. (1985) described conservation tillage as any tillage practice that reduces soil or water loss when compared to moldboard plowing. “Reduced-tillage” is classified as a form of tillage which consists of disturbing the entire soil surface prior to and/or during planting, leaving 15-30% residue cover after planting or 560-1120 kg ha^{-1} of small grain residue equivalent during the critical period of erosion. Alternatively, “conventional-tillage” is classified as tillage that disturbs the entire soil surface before and/or during planting and other numerous tillage trips, leaving less than 15% (or 560 kg ha^{-1}) of residue cover on the soil surface (CTIC, 2011). Of the approximately 112 million cultivated hectares in the U.S., 70 million (62%) are in some form of conservation or reduced-tillage, compared to 42 million (38%) in conventional-tillage (CTIC, 2004).

There are many types of conservation-tillage systems, but strip-tillage tends to be the most-implemented type in peanut production in the southeastern U.S., due largely to characteristic layers of soil compaction in the top 15-20 cm of soils on which peanut is typically grown (Wright et al., 2009). Strip-tillage utilizes minor tillage (usually with subsoiling) of a 7- to 30-cm band of soil to break apart the compaction layers, with little disturbance of crop residue between rows. Seeds are then planted into the tilled bands, allowing for good seed-to-soil contact while leaving the soil between drill rows relatively undisturbed (CTIC, 2011; Derpsch, 2003; Gallaher and Hawf, 1997; Johnson et al., 2001; Logan, 1990). Strip-tilling ensures that a significant amount of crop residue is present on the soil surface in the row middles, providing a number of different benefits to the soil and subsequent crop.

The benefits of strip-tillage are numerous. Strip-tillage requires fewer trips across the field than the multiple passes required in a conventional-tillage system. This allows for quicker land preparation in the spring, thus allowing for timelier planting. Economically, strip-tillage also requires less equipment, combined with fewer trips across the field, reducing equipment and fuel costs for the farmer (Gallaher, 1980; Gallaher and Hawf, 1997; Teare, 1989; Wright et al., 2009). Agronomically, the presence of crop residue between rows significantly reduces soil erosion from wind and water, and decreases the rate of soil water evaporation after rainfall events. This is extremely valuable in the Southeast, an area of historic highly-erodible soils (Durham, 2003; Gallaher and Hawf, 1997; Gebhardt et al., 1985; Jordan et al., 2001; Siri-Prieto et al., 2007). Subsoiling and residual cover crop roots aid in alleviating soil compaction (Schomberg et al., 2006; Simoes et al., 2009; Siri-Prieto et al., 2007). This effect improves water infiltration into the soil, increasing the overall availability of soil moisture in strip-tillage scenarios (Rowland et al., 2006). Cover crop production also provides significant organic matter additions to the soil, which further improves overall soil quality (Bauer et al., 2004; Siri-Prieto et al., 2007). In peanut, the presence of cover crop residues suppresses early leaf spot (*Cercospora arachidicola* S. Hori) epidemics (Cantonwine et al., 2007) and significantly reduces the incidence of tomato spotted wilt (*Tospovirus*) (TSWV), the most limiting disease for peanut production in the Southeast over the last 15 years (Baldwin and Hook, 1998; Johnson et al., 2001; Jordan et al., 2003; Marois and Wright, 2003; Wright et al., 2000).

Mechanical weed control is one of the main purposes of conventional-tillage for peanut and a reduction in tillage typically results in decreased weed control. Additionally, the minor amount of soil disturbance in strip-tillage systems can result in greater weed germination in the drill row. Herbicide inputs, therefore, are typically higher in conservation-tillage systems (Gallaher and Hawf, 1997; Gebhardt et al., 1985; Johnson et al., 2001, 2002; Wilcut et al., 1990; Wright et al., 2009). However, some studies have reported little differences in weed control inputs between conservation-tillage and conventional-tillage crops (Brecke and Stephenson, 2006; Price et al., 2007; Wright et al., 2009).

There have been some concerns regarding potentially reduced yields in strip-tillage versus conventional-tillage peanut. Though some results have reported lower pod yields in strip-tillage (Jordan et al., 2001, 2003; Grichar, 2006; Wilcut et al., 1990), strip-tillage peanut yields are often equivalent to conventional-tillage yields (Colvin et al., 1988; Jordan et al., 2003; Tubbs and Gallaher, 2005; Rowland et al., 2006; Wright et al., 2000). In long-term strip-tillage scenarios, increased SOM, reduced soil losses, and improved tilth could result in consistently equal or higher strip-tillage pod yields versus conventional-tillage yields (Johnson et al., 2001; Jordan et al., 2008).

Benefits of Cover Cropping

The use of cover crops is another method of improving resource conservation in cropping systems. Cover crops are temporary crops that are grown during the time between growth periods of a main cash crop. They are utilized primarily to provide “cover”, preventing erosion of topsoil (Gallaher and Hawf, 1997; Sainju et al., 2002; SAN, 2007; Truman and Williams, 2001). Prior to planting the cash crop, a cover crop is typically killed with rolling, mowing, a non-selective herbicide application. Cover crops can also provide some level of weed suppression in addition to herbicide use, either through physical suppression of germination or chemical weed suppression via allelopathy. Cereal rye (*Secale cereale* L.) and wheat both have some allelopathic properties that can aid in reducing weed germination (Phatak, 1998; Price et al., 2007; SAN, 2007). However, high-biomass residues can sometimes limit the efficacy of dinitroaniline herbicides applied post-emergence in strip-tillage peanut, by reducing the amounts of herbicide that actually reach the soil (Johnson et al., 2002). Cover crop use can also aid in conserving soil moisture during the growing season. As mentioned previously, cover crops roots can improve water infiltration to soil through root channels during rainfall events. Also, surface soil beneath crop residue is typically cooler than exposed soil, which slows water evaporation after rainfall events (Bauer and Busscher, 1993; Coppens et al., 2006; Marois and Wright, 2003; Munawar et al, 1990; Rowland et al., 2006; Simoes et al., 2009; Williams and Weil, 2004; Wright et al., 2009). However, cover crops can also drain much-needed soil moisture prior to planting of the subsequent crop in dry years and can retain excessive moisture in wet years, both of which can be harmful to the subsequent crop (Collins et al., 2011).

Cover cropping also aids in protecting surface water quality. By reducing erosion and surface runoff from agricultural areas, cover crops reduce non-point-source sediment and chemical inputs to nearby surface water. They also scavenge excess nitrates and prevent them from leaching into groundwater (Coppens et al., 2006; Dabney et al., 2001; Doran and Smith, 1991; Truman and Williams, 2001; Sainju et al., 1997; SAN, 2007; Tubbs, 2003). Cover crop residues, whether incorporated or left on top of the soil, improve soil quality and subsequent crop yields by providing significant additions of SOM. Residual cover crop roots also become SOM. Greater amounts of SOM increase soil cation exchange capacity (CEC), provide carbon (C) energy sources for microorganisms, and cycle nutrients back into the soil as the organic matter decomposes (Coppens et al., 2006; Dabney et al., 2001; Kuo et al., 1997; Sainju et al., 2002; Sarrantonio, 2007; Somda et al., 1991; Williams and Weil, 2004; Wright et al., 2009).

Typical cover crops used in peanut production are small cereal grain crops like wheat and rye (Wright et al., 2009). Both are high biomass producers with thick diffuse root systems, although rye typically produces the greatest aboveground biomass and root density (Kuo et al., 1997; Sainju et al., 1997; Williams and Weil, 2004). High biomass accumulation is beneficial because it minimizes the time that a soil is exposed and ensures a thick residue cover during the subsequent peanut crop. It also provides quick and effective weed suppression (SAN, 2007). However, these cover crops do not provide total weed suppression alone in strip-tillage peanut. They must be used in concert with pre- and post-emergence herbicide applications to provide sufficient weed control (Price et al., 2007). Both grain species are also effective at scavenging residual nutrients left over from previous fertilizer applications, especially nitrogen (N), phosphorus (P), and potassium (K) (Brandi-Dohrn et al., 1997; Sainju et al., 1997; SAN, 2007; Tubbs, 2003).

Organic Matter Decomposition and Nutrient Cycling

Cover crops can enhance the nutrient cycling capabilities of a cropping system. By reducing soil erosion, they reduce surface P loss and the loss of other nutrients adsorbed to eroded soil particles. Cover crops also absorb and assimilate nutrients from the soil that would otherwise leach out of the soil. This is especially valuable in winter months, when the risk of leaching is greatest. Nitrogen (as nitrate [NO_3^-]), calcium (Ca^{2+}), and K^+ are all water-soluble and tend to leach (especially NO_3^-). However, cover crop roots can draw these nutrients up from deeper soil layers and prevent them from leaching out of the soil profile (Dabney et al., 2001; Sarrontonio, 2007; Tubbs, 2003). Though, in sandy soils, nitrates typically leach faster than cover crop roots can be established (Gallaher and Hawf, 1997; Marois and Wright 2003). The absorption of water by cover crops also reduces the amount of water in the soil, thus reducing the medium by which soluble nutrients could leach. Some cover crops can improve the availability of P for plant uptake by secreting acids that increase its solubility (Sarrontonio, 2007). As previously mentioned, rye and wheat are effective at scavenging N, P, and K from the soil and are both used as cover crops in peanut (SAN, 2007; Wright et al., 2009). Rye is especially useful for scavenging P and K from Coastal Plain soils (Tubbs, 2003). Leguminous cover crops provide significant N additions to the soil through biological N-fixation, which can be beneficial to a subsequent non-legume cash crop, but can also absorb significant amounts of Ca on Coastal Plain soils (SAN, 2007; Tubbs, 2003). The N-fixation ability of peanut plants reduces the need for residual soil N in peanut cropping systems (Cox et al., 1982).

When cover crops are killed prior to peanut planting, they will gradually decompose and release many of their assimilated nutrients back into the soil. This process is primarily facilitated by soil microorganisms. The C from the residue provides an energy source for these microbes, which subsequently consume and mineralize other nutrients present in the decaying residue. This process adds valuable humic substances to the soil and results in the slow release of mineralized nutrients to the soil and the subsequent crop. In fact, the major source of N, P, sulfur (S), and many micronutrients in cropping systems is SOM. Wheat residues provide significant amounts of N and K to soil through decomposition (Schomberg et al., 1994). Because the addition of crop residues also increases the CEC of the soil, it increases the ability of the soil to adsorb and retain many nutrients that would otherwise leach out of the profile.

Decomposition rates of crop residues are determined largely by the chemical composition of the residue. Since decomposition is a biological process, residues with the highest concentrations of nutrients beneficial to soil microorganisms typically break down very quickly. Early in the decomposition process, easily-digestible simple sugars and amino acids are decomposed rapidly. Polysaccharides, proteins, and lipids are broken-down at much slower rates (Schomberg et al., 1994). Lignin is a complex carbohydrate that is difficult for microbes to digest. Thus, greater amounts of lignin in residue typically result in slower microbial degradation. The C:N ratio of crop residue is also an effective indicator of decomposition rates. Greater amounts of N in residue (low C:N ratio) are more beneficial to microorganisms and are consumed very quickly. Similarly, residues with low lignin:N ratios generally decompose faster than those with high lignin:N ratios (Melillo et al., 1982; Quemada and Cabrera, 1995; Sarrantonio, 2007). This facilitates rapid breakdown of high-N residues. Thus, leaf residues, with a low overall C:N ratio, tend to decompose more rapidly than stem and root residues. Immobilization ("binding-up") of many nutrients by microbes usually occurs at C:N ratios >20. When residues are <20, net mineralization will occur and nutrients will be released into the soil solution (Coppens et al., 2006; Douglas and Rickman, 1992; Quemada and Cabrera, 1995; Sarrantonio, 2007; Schomberg et al., 1994; Somda et al., 1991; Wagger et al., 1998).

Wheat, rye, and oat all have whole-plant C:N ratios that are >20. Crimson clover (*Trifolium incarnatum* L.), a cool-season legume, has a C:N ratio that is <20. Therefore, wheat, rye, and oat typically have slower rates of decomposition than crimson clover, based on their respective C:N ratios (Doran and Smith, 1991; SAN, 2007; Somda et al., 1991). Because wheat, rye, and oat have higher C:N ratios, they are more effective than legumes at increasing soil C (Sainju et al, 2002). Rapid decomposition results in a rapid release of nutrients to the soil. In a cover cropping scenario, it is ideal to facilitate residue decomposition and nutrient release at a rate that accommodates nutrient uptake by the subsequent crop. This can be problematic if the subsequent crop isn't fully established to where it can take full advantage of the nutrients. However, wheat, rye, and oat residues tend to facilitate slower rates of nutrient release throughout the growing season, providing a slower flow of nutrients to the subsequent crop (SAN, 2007; Sarrantonio, 2007).

Water and temperature also influence microbial activity. Increased soil water content and increased soil temperature generally facilitate faster decomposition. Soil microorganisms function at temperatures from 0-60ºC, with maximum activity at 25-35ºC. Optimum microbial breakdown of wheat residues occurs between 30-35 ºC (Schomberg et al., 1994). Also, microbial activity peaks when soil pore spaces are 60% filled with water. At water values above or below 60%, activity tends to decline (Sarrantonio, 2007).

Residue placement in relation to the soil surface has a significant impact on its rate of decomposition. In conventional-tillage management, crop residues are incorporated directly into the soil. In strip-tillage management, they are left on the soil surface as cover. Incorporated residues typically break down faster because of more direct contact with soil microbes that facilitate decomposition. Residue is also chopped to smaller particle sizes during incorporation, resulting in greater surface area available for reactivity with microorganisms. In addition, microbial activity increases with greater oxygen (O_2) availability, contributing to faster rates of decomposition in cultivated soils (Derpsch, 2003; Gallaher and Hawf, 1997; Sarrantonio, 2007; Schomberg et al., 1994).

Peanut Nutrition

In peanut production, soil conditions and residues that favor the availability of P, K, Ca, magnesium (Mg), S, boron (B), manganese (Mn), and zinc (Zn) are optimum. However, peanut yields tend to be most limited by Ca deficiencies. Calcium is required for sufficient pod-filling; deficiencies result in the production of “pops,” or aborted or shriveled fruit. Therefore, the availability of Ca heavily impacts final pod yields. Boron is also essential for kernel development and can significantly impact the final quality of the crop. Boron deficiencies prevent the peanut kernels from forming properly, resulting in a damaged state called “hollow heart.” Thus, B does not affect yield quantity, but more yield quality. Soil test levels of <0.05 mg B kg^{-1} in the Southeast will cause B deficiency symptoms in peanut. Phosphorus tends to be the most commonly deficient nutrient for peanut worldwide, simply because it does not naturally occur at high levels in soils that have never been fertilized. However, P deficiencies are easily-remedied for peanuts by phosphate applications. Phosphorus fixation to soils is also minimal, since peanut is typically grown in sandy soils with minimal clay content. Soil P levels as low as 4 mg kg^{-1} have been shown to be sufficient for peanut production. Cobalt (Co) is a micronutrient that is essential to N-fixation by rhizobia, though not directly essential to the peanut plant itself. Cobalt can be applied either as a seed treatment or a foliar spray. Potassium, S, Mg, Mn, and Zn are also necessary for peanut growth, but do not have a dramatic effect on pod yield or quality. Lime ($CaMg[CO_3]_2$) applications are typically in the southeastern U.S. required to maintain a soil pH (between 6.0 and 7.0) that maximizes the availability of these nutrients, without raising toxicity concerns (Cox et al., 1982; Hallock et al., 1971).

Organic Crop Production

The concept of "organic" agricultural production has existed since 1940, when the term was first coined by J.I. Rodale. In the last 70 years, organic production has increased rapidly, led largely by increases in market demand for organic products (Boudreau et al., 2008; Gaskell et al., 2000). The National Organic Standards Board (NOSB) defines organic agriculture as "an ecological production management system . . . based on minimal use of off-farm inputs and on management practices that restore, maintain, and enhance ecological harmony" (Kruepper and Gegner, 2004). Organic farming systems rely on cultural and biological pest management, excluding the use of synthetic chemicals (USDA, 2005). Organic agriculture typifies the image of low-input production by significantly reducing chemical and energy inputs for production systems, compared to conventional agricultural systems (Pimental et al., 2005).

In 1990, the Organic Foods Production Act was passed, representing the first piece of legislation designed to establish national standards for defining organic production and certifying organic operations in the U.S. Therefore, by USDA definition, a certified organic product must be:

- Produced and handled without the use of synthetic chemicals.
- Not produced on land to which any prohibited substances, including synthetic chemicals, have been applied during the 3 years immediately preceding the harvest of the agricultural products.

- Produced and handled in compliance with an organic plan agreed to by the producer and handler of such product and certifying agent (USDA, 2005).

Organic production has seen the greatest adoption in fruit and vegetable crops, which accounted for 37% of U.S. organic food sales in 2008 (USDA-ERS, 2008). However, organic production has also expanded to numerous field crops, including maize, soybean, cotton, rice (*Oryza sativa* L.), alfalfa (*Medicago sativa* L.), and many others (Kruepper and Gegner, 2004; Hively and Cox, 2001; Pimentel et al., 2005). Much of the impetus for increased organic production has been an overwhelming market demand for organic products. Dimitri and Greene reported in 2002 that organic food sales in the U.S. had increased 20-25% annually since the early 1990s. Projected certified organic hectarage in 2008 totaled more than 1.6 million hectares in the U.S., encompassing over 14,000 individual farms. Total farm commodity sales were also projected to be over $3 billion.

Increased organic food sales and market demand for organic products have also translated to U.S. peanut production. The demand for organic peanut products is widely regarded as the fastest-growing sector of the entire peanut industry (Lamb et al., 2007; Puppala, 2007). The growing demand for organic peanuts has subsequently resulted in market premiums for certified organic versus conventional peanuts. In the Valencia markets of the southwestern U.S., premiums for organic peanut typically average \$990 Mg^{-1}, whereas conventional peanut ranges close to \$610 Mg^{-1} (Puppala, 2007). In the Southeast, organic runner-type premiums occur up to \$1100 Mg^{-1}, versus \$720 Mg^{-1} contracts for conventional peanut (N.B. Smith, personal communication, 2010). Significant price incentives exist for peanut growers who are interested in pursuing some organic production in the runner market. However, organic production is severely limited in the humid climatic conditions of the southeastern U.S. by heavy weed and disease pressure (Cantonwine et al., 2008; Johnson and Mullinix, 2008). Therefore, identifying effective methods of weed and disease control for organic peanut is essential for establishing commercial levels of production in the southeastern region.

Non-Chemical Weed Control

Weed control is a major inhibitory factor to most organic cropping systems, where synthetic herbicide applications are prohibited for the direct control of weed escapes (Baldwin, 2006; Bàrberi, 2002; Bond and Grundy, 2001; Boudreau et al., 2008; Guerena and Adam, 2008). Approved herbicide options are available for weed control in organic peanut, but are often expensive and limited in scope and efficacy (Johnson and Mullinix, 2008; Johnson et al., 2008). Therefore, many innovative, non-chemical techniques have been used to provide weed control in organic cropping systems. Research has been conducted to identify integrated weed management programs including: crop rotation, cover cropping, false/stale seedbed techniques, steaming, propane flame-weeding, mulching, solarization, cultivation, intercropping, and the use of various crop cultivars. Of those techniques, however, tillage and hand-weeding are the most effective methods of control (Bàrberi, 2002; Bond and Grundy, 2001; Caamal-Maldonado, 2001; Gopinath et al., 2009; Johnson, 2006; Kruepper and Gegner, 2004). Johnson (2006) also reported that frequent cultivation and hand-weeding, along with stale seedbed tillage, provides a high degree of weed control in organic peanut.

The potential of cultivation for weed control in peanut has been shown in both organic and conventional production systems (Ferrell et al., 2009; Johnson and Mullinix, 2008). Cultivation is only possible until the peanut canopy reaches 50-75% closure, before the gynophores begin to fully develop. Therefore, intensive cultivation in the few weeks after planting could reduce the amount of supplemental hand-weeding that is necessary later in the season. Additionally, weeds have the greatest impact on peanut yields within the first 3-8 wk after planting (Everman, 2008). Therefore, providing intensive cultivation during this critical weed control period could significantly reduce yield losses due to weeds.

Sweep cultivation is an effective method of removing inter-row weeds in row crops, and is used in conventional peanut production (Ferrell et al., 2009; Wilcut et al., 1987). Sweep cultivation consists of using flat, triangular blades that travel below the top 2-4 cm of soil to cut weeds below their growing points to kill them. Sweeps are effective for controlling inter-row weeds, but are unable to reach weeds close to the peanut rows without causing significant damage to the peanut plants themselves. These weeds, which are much closer to the row, compete more directly for resources and must be effectively reduced or controlled to ensure adequate peanut production (Bowman, 1997; Johnson and Mullinix, 2008; Smith et al., 2000). A proven method of reducing weeds close to crop rows is tine cultivation. Tine cultivation utilizes an implement that drags flexible, metal tines across the soil surface. As they drag, the tines vibrate rapidly and mechanically disrupt the top 3 cm of soil. This soil disruption both uproots and buries germinating weed seedlings, providing some level of weed control. The tines, along with their capacity to bend and flex, are also adjustable, which allows them to disrupt weeds close to crop rows without damaging the plants. This method of cultivation could be beneficial for organic weed control in peanut, which has a low, spreading growth habit that is typically vulnerable to damage by cultivation.

Little information is currently available for growers regarding effective, affordable weed control techniques for use in organic peanut. There is a distinct need for information that identifies cultivation regimes that are not only effective, but also provide the greatest financial return to growers interested in organic peanut production.

Disease Management for Organic Peanut

In the Southeast, the predominately warm, humid climate further exacerbates disease control issues in organic crops. Peanut is a prime example. The bulk of organic peanut production in the U.S. is localized in the arid Southwest (Guerena and Adam, 2008; NASS, 2007). However, commercial organic peanut production is only marginal in the southeastern U.S. The most limiting diseases to organic peanut are early leaf spot and late leaf spot (*Cercosporidium personatum* [Beck & Curtis] Deighton) diseases, both foliar diseases that cause significant defoliation by the end of the growing season. If left untreated, leaf spot diseases alone can result in up to 50% yield loss at harvest (Smith, 1984). Leaf spot control is maintained in conventional production through several synthetic fungicide applications every 10-14 days during the growing season (Kemerait et al., 2009). However, in certified organic cropping systems, synthetic agrichemical use is prohibited by USDA guidelines (USDA, 2005).

Some organically-approved fungicides are available and have shown some potential on peanut, but are inconsistently effective. Cantonwine et al. (2008) reported that copper sulfate, copper sulfate + *Bacillus subtilis*, copper sulfate + sulfur, sulfur, cupric hydroxide, and cupric hydroxide + *B. subtilis* fungicide applications reduced defoliation from leaf spot compared to the unsprayed control. However, only copper sulfate and cupric hydroxide improved pod yields over the control. Shew et al. (2006) also reported that copper sulfate applications significantly reduced leaf spot incidence compared to the unsprayed control, but did not improve final pod yield. Additionally, fungicides in the form of seed treatments have shown little potential for suppressing disease or improving pod yields in organic peanut. Puppala (2007) reported that Capsicum oleoresin and garlic extracts did not reduce disease incidence on peanut compared to the control. Ruark and Shew (2008) evaluated 22 organic and synthetic seed treatments on peanut in North Carolina. In one of the three years of the study, the *B. subtilis* and copper hydrate seed treatments increased seedling survival over the untreated check. However, there were no differences among treatments in the other two years of the study. These studies indicate that there is some potential for improving organic peanut production with approved fungicides. However, they also indicate that disease-resistant cultivar selection is paramount in managing diseases for organic peanut.

Koike et al. (2000) and Van Bruggen and Termorshuizen (2003) explained that cultivar selection was the most important factor for managing plant diseases in organic cropping systems. Use of disease-resistant cultivars has also been an essential component of disease management in conventional peanut systems for years (Brown et al., 2007; Wynne et al., 1991). Desirable characteristics for such cultivars include: resistance to foliar and soil-borne diseases, good germination and seedling vigor, strong stand establishment, and high yield and grade potential. Stand establishment is crucial for reducing TSWV incidence and improving competition with weeds and overall yield potential. Viable candidate cultivars have been identified for the Virginia- and Valencia-type markets (Coker et al., 2007; Guerena and Adam, 2008), but little cultivar information is available for the predominantly runner-type markets of the southeastern U.S. In Georgia, Branch and Culbreath (2008) identified Georgia-01R and Georgia-05E as multiple-pest-resistant cultivars that produced substantial yields without fungicide or insecticide inputs. However, both of these cultivars are no longer commercially available.

With recent improvements in cultivars, disease management for organic peanut is showing promise in the Southeast (Boudreau et al., 2008; Branch and Culbreath, 2008; Gorbet and Tillman, 2009; Holbrook and Culbreath, 2008; Holbrook et al., 2008a). Boudreau et al. (2008) reported that the Georganic cultivar exhibited impressive resistance against early leaf spot and late leaf spot diseases, TSWV, and southern stem rot (*Sclerotium rolfsii* Sacc.). Branch and Culbreath (2008) also identified a number of different peanut cultivars that displayed exceptional resistance to TSWV, southern stem rot, and leaf spot diseases in the absence of fungicide and insecticide applications.

Research is needed to provide growers with the most successful cultivar options for disease management in organic peanut and improving overall production. More research is necessary to provide supplemental information regarding effective organic fungicide options for use in peanut. Also, evaluating cultivars for yield potential and disease-resistance is crucial for identifying viable seed options for growers.

Objectives

Currently, little data has been reported comparing cover crop decomposition between conventional-tillage and strip-tillage peanut. Cover crops have been evaluated for weed suppression ability in conservation-till peanut, but there is a lack of published research regarding their decomposition and subsequent nutrient cycling potential for the crop. Such research would provide valuable knowledge about the rates at which nutrients cycle from cover crops to soil to a subsequent peanut crop. This information could help growers make more educated decisions regarding cover crops for the long-term fertility management of their cropping systems.

Rye and wheat are commonly-used cover crops in peanut production, but crimson clover is more commonly used to precede non-leguminous crops (Price et al., 2007; Quemada and Cabrera, 1995; SAN, 2007; Wright et al., 2009). Therefore, the first objective of this research is to monitor the decomposition and nutrient release of crimson clover, rye, and wheat cover crops, and determine the amounts of nutrients available for uptake by a subsequent peanut crop. This research will also evaluate the impact of each cover crop on overall peanut production, in both conventional- and strip-tillage systems.

Likewise, there is little research available regarding viable weed and disease control techniques applicable for organic peanut production. Therefore, this research is aimed to identify effective, affordable cultivation regimes for weed control in organic peanut. It will also evaluate an assortment of commercial, high-yielding peanut cultivars and approved fungicides for disease management and productive potential in an organic management scenario.

CHAPTER 3

COVER CROP DECOMPOSITION AND NUTRIENT CYCLING IN CONVENTIONAL- AND STRIP-TILLAGE PEANUT (*ARACHIS HYPOGAEA* L.)[1]

[1] Wann, D.Q., R.S. Tubbs, G.H. Harris, and J.P. Beasley, Jr. To be submitted to *Agronomy Journal*.

Abstract: Cover crops are commonly used in peanut production and could potentially provide some nutrient benefits to peanut as cover crop residues decompose. Therefore, the objective of this experiment was to evaluate the rate of decomposition and nutrient cycling potential of crimson clover, rye, and wheat cover crops grown in either conventional or strip-tillage and their impacts on a subsequent peanut crop. Field trials were conducted in Tifton, GA from 2008-2010. Crimson clover, rye, wheat, and no cover treatments were established in the fall preceding each year of the trial in conventional and strip-tillage. Soil and plant tissue samples from cover crop residues and peanut plants were collected at various points throughout the growing season and analyzed for nutrient concentration and biomass. Wheat residues displayed the sharpest decline in conventional-tillage both years, though not different from rye in 2010. Conventional-tillage resulted in sharper cover crop biomass decline than strip-tillage in 2009. Despite the sharper decline of wheat residues in 2009, crimson clover in conventional-tillage released the greatest amounts of N, P, K, Ca, Mg, B, and Zn that year. Soil nutrient levels varied little among cover crops and tillage at all sample dates, but levels did tend to increase within the first 60-90 days after cover crop burndown, as residues began to decompose. Cover crops did little to improve nutrient content in peanut vegetation and actually reduced uptake of K, Mn, and Zn compared to no cover in conventional-tillage in 2009 ($P \leq 0.05$). However, strip-tillage increased total N, K, Mg, S, Mn, and Zn content in peanut pods under drought-like conditions in 2010 ($P \leq 0.05$). There were almost no differences among treatments in vegetative peanut production, yield, or grade. These results indicate that cover crops have some impact on nutrient uptake of peanut, but have little impact on overall productivity. Tillage has some impact on nutrient uptake in pods, but was not consistent in both years of this experiment.

Introduction

The bulk of commercial peanut (*Arachis hypogaea* L.) production in the U.S. typically occurs on well-drained, coarse-textured soils. While these soils are well-suited for successful peanut production, they are highly vulnerable to wind and water erosion (Gallaher and Hawf, 1997; Henning, et al., 1982). Peanut production has traditionally been a tillage-intensive operation, which further exacerbates problems with erosion. However, many peanut growers have adopted conservation tillage and cover cropping techniques in an effort to reduce further soil losses to erosion and sustain the viability of their cropping systems (Gallaher and Hawf, 1997; Sorensen et al., 2010; Wright et al., 2009).

Because of compacted clay layers characteristic of Coastal Plain soils and tomato spotted wilt (*Tospovirus*) TSWV pressure, strip-tillage has become the most widely-adopted form of conservation tillage among growers in the Southeast (Schomberg et al., 2006; Wright et al., 2009). Strip-tillage involves cultivating and subsoiling a narrow 7-30 cm band of soil, leaving the rest of the soil between rows undisturbed. This not only breaks apart the layers of soil compaction but also leaves the majority of the soil undisturbed and less-vulnerable to erosion. Reduced soil disturbance and the presence of surface residues also aids in reducing thrips (Thysanoptera: Thripidae) activity on peanut, which are known vectors of TSWV. Economically, strip-tillage also requires fewer passes across the field for tillage operations than in conventional-tillage, reducing fuel, labor, and equipment inputs. Strip-tillage is typically combined with use of a winter cover crop, which further aids in reducing soil erosion losses (Derpsch et al., 2003; Gallaher and Hawf, 1997; Gebhardt et al., 1985; Johnson et al., 2001).

The benefits of cover crop usage are numerous and well-documented. Their primary purpose is to reduce soil losses to erosion by anchoring soil around the crops’ roots and reducing soil dispersion from rainfall by covering the soil surface with residue (Gallaher and Hawf, 1997; Sainju et al., 2002; SAN, 2007). Other benefits to soil of using cover crops include: increasing soil organic matter (SOM), alleviating soil compaction, improving water infiltration, and reducing soil moisture loss to evaporation, among many others (Coppens et al., 2006; Gallaher and Hawf, 1997; Rowland et al., 2006; Siri-Prieto, 2007; Williams and Weil, 2004; Wright et al., 2009). In peanut systems, cover crop use and strip-tillage have been documented to also reduce early leaf spot (*Cercospora arachidicola* S. Hori) (Cantonwine et al., 2007) and TSWV incidence (Baldwin and Hook, 1998; Johnson et al., 2001; Jordan et al., 2003; Marois and Wright, 2003), two significant diseases in peanut production. However, cover crops are also able to capture and cycle nutrients back to soils as their residues decompose. As cover crops actively grow in the winter, they take up plant nutrients and store them in their tissues. When the cover crops are terminated prior to tillage and planting of the subsequent crop, their residues decompose and can act similarly to a slow-release fertilizer, releasing those assimilated nutrients to the actively-growing crop plants (SAN, 2007; Schomberg et al., 1994; Siri-Prieto, 2007; Somda et al., 1991). Schomberg et al. (1994) reported that the major source of nitrogen (N), phosphorus (P), sulfur (S), and many micronutrients in cropping systems is from decaying soil organic matter (SOM). Leguminous cover crops are especially beneficial in providing significant amounts of nitrogen to a cropping system. Ibewiro et al. (2000) reported that maize (*Zea mays* L.) following mucuna (*Mucuna pruriens* [L.] *DC*. var. *utilis* [Wright] Bruck) or lablab (*Lablab purpureus* [L.] Sweet) was able to recover up to 47% of the total N contained in the preceding cover crop. Schomberg et al. (2006) observed significant N contributions of leguminous winter cover crops to a following cotton (*Gossypium hirsutum* L.) crop. Similarly, Ebelhar et al. (1984) reported that hairy vetch (*Vicia villosa* Roth.) increased inorganic soil N over rye (*Secale cereale* L.) and no cover in no-tillage and increased vegetative N and final grain yield of a subsequent maize crop.

Peanut, however, is a warm-season legume and fixes its own N. It is therefore important to examine the capability of cover crop species to cycle the other primary and secondary nutrients, as well as boron (B), manganese (Mn), and zinc (Zn). Rye and wheat (*Triticum aestivum* L.), two commonly-utilized cover crop species on Coastal Plain soils, are effective scavengers of P and potassium (K) from soils, especially rye (Tubbs, 2003). Decaying organic residues also release P to the soil in an organic form, which can increase the efficiency of its uptake by a subsequent crop (SAN, 2007). Peanut responds better to residual soil fertility than to direct fertilization, so decomposing cover crop residues could potentially provide a noticeable nutrient benefit to peanut (Henning et al., 1982). Crusciol and Soratto (2009) observed an increase in vegetative N in no-till peanut following a fertilized cover crop.

Little research has been published regarding the potential nutrient effects of cover crops on peanut. Additionally, since peanut is a legume, there could be potentially unique nutrient effects of a preceding leguminous cover crop (i.e. crimson clover) on the total nutrient content of peanut, since N is mostly provided for peanut plants through N-fixation. There is also little information that compares the decomposition and nutrient cycling of cover crops in conventional-tillage versus strip-tillage. This information could aid growers in making better, more educated decisions regarding the overall nutrient management of their peanut systems, especially on the low-fertility soils of the peanut-producing region of the U.S. The objectives of this research were to measure the decomposition and nutrient release of crimson clover (*Trifolium incarnatum* L.), rye, and wheat cover crop residues in conventional- and strip-tillage.

This research was also designed to evaluate the nutrient cycling of those three cover crops and their impact on the nutrient uptake and productivity of a subsequent peanut crop.

Materials and Methods

Field trials were conducted from 2008-2010 at the University of Georgia (UGA) Coastal Plain Experiment Station Lang-Rigdon Farm near Tifton, GA, on a Tifton loamy sand (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults). Crimson clover ('AU Robin' [van Santen et al., 1992]), rye ('Wrens Abruzzi' [Morey, 1970]), and wheat (AGS 2026) cover crops were planted 19 Nov. 2008 and 23 Dec. 2009 with a Tye no-till grain drill[1], at recommended seeding rates of 22 kg ha^{-1}, 99 kg ha^{-1}, and 99 kg ha^{-1}, respectively. Row spacing for all cover crops was 17.8 cm. Late-season rainfall and cold temperatures delayed harvest of the preceding crop and subsequent preparation of the 2009/2010 test site, resulting in a much later planting date. All plots were 7.3 m wide (8 peanut rows) x 12.2 m long in a randomized complete block design with four replications both years. The experiment consisted of a 4 x 2 factorial treatment arrangement each year: four cover crop treatments (crimson clover, rye, wheat, and no cover) and two tillage treatments (conventional- and strip-tillage). Cover crops were terminated with glyphosate[2] on 10 Apr. 2009 (1.40 kg a.i. ha^{-1}) and 26 Apr. 2010 (1.54 kg a.i. ha^{-1}).

In 2009, the soil pH of the test site was approximately 5.7, which prevented adequate germination and establishment of crimson clover, although both rye and wheat produced somewhat normal stands. An application of finely-ground dolomitic lime[3] ($CaMg[CO_3]_2$) was made on 17 Mar. (2240 kg ha^{-1}), as a fast-acting liming agent to try and salvage the crimson clover treatments. The finely-ground lime successfully raised soil pH at the test site to approximately 6.2 by burndown, but it was not timely enough to salvage crimson clover stands.

A single N application (38 kg N ha^{-1}) was also made on 30 Mar. 2009 to improve rye and wheat growth prior to burndown. Because of poor crimson clover stands, residues were cut and removed from a similar cover crop trial and applied to the conventional-tillage crimson clover treatment plots at a density of 4666 kg ha^{-1} dry matter (DM) ha^{-1} (which was the density in the field where it was respectively growing) on 16 Apr., prior to tillage operations. Crimson clover residues in 2009 were composed of both root and shoot residues, as the plants in the other trial were inverted with a 2-row digger-shaker-inverter[4] prior to collection. The strip-tillage crimson clover treatment was unsalvageable and subsequently abandoned. In 2010, crimson clover stands were non-existent as a result of late planting in 2009 and record cold temperatures that occurred from Dec. 2009 through Jan. 2010. Therefore, the same procedure was repeated in 2010: crimson clover residue was collected from another trial and spread on the conventional-tillage crimson clover plots at the same density as the previous year (4666 kg DM ha^{-1}) on 26 Apr., prior to tillage operations. However, unlike 2009, only the shoot residues were collected from the other trial, by cutting the crimson clover plants at ground level, because the crimson clover was grown in a bahiagrass (*Paspalum notatum* Flugge) sod that could not be disturbed. The 2010 strip-tillage crimson clover treatment was also subsequently abandoned.

Cover crop biomass samples were collected from all cover crop plots on 16 Apr. 2009 and 6 May 2010 to estimate total cover crop biomass production at burndown each year, prior to tillage operations. Soil samples were also collected at a depth of 5 cm and 20 cm from the biomass sample area in each plot to determine initial nutrient concentrations. Biomass samples were collected using a 0.5-m^2 quadrat (91 cm x 55 cm) that equally spanned either side of the drill row, clipping at ground level and collecting all of the biomass that fell within the quadrat area. The samples were subsequently desiccated in a forced-air oven until completely dried and then weighed. Dried residues were then placed in mesh litterbags composed of fiberglass screening[5] with 2.86 mm^2 $hole^{-1}$ (35 holes cm^{-2}) at equivalent densities to what was determined for each cover crop from the field (crimson clover = 14.0 g bag^{-1}, rye = 14.3 g bag^{-1}, and wheat = 9.9 g bag^{-1} in 2009). Dimensions of each bag were 15 cm x 20 cm (300 cm^2) (Wang et al., 2004). Rye and wheat biomass production in 2010 was much lower than in 2009 (as a result of the later planting date), resulting in very low amounts of residue to be placed in the litterbags. Because this would likely result in sampling problems later in the season (when residues are highly-decomposed and more difficult to quantify), the 2010 bags were filled with the same amounts of residue for each cover crop as in 2009. This ensured that enough residues would be present in each bag for accurate sampling later in the season.

Tillage operations occurred on 5-7 May 2009 and 21 May 2010. All conventional-tillage plots were tilled with a disc harrow, followed by tillage with a ripper-bedder to keep organic residues within sampling depth in the soil. Strip-tillage plots were tilled once each with a Rip/Strip in-row subsoiler[4]. Seven litterbags were buried in each conventional-tillage plot on 12 May 2009 and 26 May 2010, corresponding to the cover crop in each plot. Bags were buried at a depth of 15 cm to simulate incorporated residue in a conventional-tillage system.

All plots were subsequently planted with ‘Georgia-03L’ (Branch, 2004) and ‘Georgia-06G’ (Branch, 2007) peanut cultivars, two cultivars with excellent TSWV resistance and widespread commercial availability, on 9 June 2009 and 25 May 2010, respectively. All plots were planted using a 2-row precision air planter[6] at a seeding rate of 20 seed m^{-1} and a depth of 6 cm. Phorate[7] insecticide was also applied in-furrow at planting, at a rate of 1.4 kg a.i. ha^{-1}. All seed were treated with azoxystrobin[8] seed treatment fungicide. Georgia-03L seed was unavailable for the second year of this experiment. Georgia-06G is a common cultivar with widespread commercial hectarage and high yield potential and was therefore selected as an alternative large-seeded runner-type cultivar for the 2010 growing season.

Numerous spray fungicide applications were made to all plots both years for disease management. In 2009, applications of pyraclostrobin[9] (164 g a.i. ha^{-1}) were made on 9 Jul. and 20 Jul. and applications of prothioconazole[10] (84 g a.i. ha^{-1}) were made on 4 Aug., 20 Aug., and 3 Sept. In 2010, an application of pyraclostrobin[9] (164 g a.i. ha^{-1}) was made on 25 Jun. Azoxystrobin[11] applications (327 g a.i. ha^{-1}) were made on 23 Jul. and 20 Aug. and chlorothalonil[12] (1.26 kg a.i. ha^{-1}) applications were made on 9 Jul., 6 Aug., 3 Sept., and 17 Sept. Gypsum ($CaSO_4 \cdot 2H_2O$) was applied on 3 Aug. 2010 at 1100 kg ha^{-1} to provide calcium for pod-filling. Mid-season soil test calcium (Ca) at 7 cm in depth (the pegging zone) did not indicate a need for Ca fertilization in 2009. Boron[13] was also supplied to all plots mid-season at 0.4 kg B ha^{-1} via foliar applications made on 9 July 2009 and 25 June 2010 to ensure adequate peanut kernel development, as recommended by UGA. All other production practices were conducted according to UGA recommendations for irrigated peanut (Beasley et al., 1997).

Following the initial samplings, subsequent cover crop biomass and 5-cm and 20-cm soil samples were also collected on 1 May, 12 June, 13 July, 18 Aug., 22 Sept., and 15 Oct. in 2009 and on 6 May, 26 May, 22 June, 28 July, 18 Aug., 14 Sept., and 5 Oct. in 2010. One litterbag was also sampled from each conventional-tillage plot (except the plots with no cover) at each of the aforementioned sample dates. Peanut whole-plant samples were also collected within the 0.5-m^2 quadrat as plants began to develop. Peanut plants were uprooted using a pitchfork to loosen the soil, and then separated into root, aboveground vegetation, and pod components. All biomass samples were desiccated in a forced-air oven until dried and then weighed. After weighing, all tissue samples (excluding peanut roots) and soil samples were analyzed for nutrient concentrations at the UGA Soil, Plant, and Water Lab in Athens, GA. Phosphorus, K, Ca, Mg, B, Mn, and Zn were extracted from tissue samples by microwave-acid (HNO_3) digestion, using a CEM Mars5 Microwave Digestion System[14]. They were subsequently analyzed via inductively coupled plasma (ICP) spectroscopy with a Thermo Jarrell-Ash Enviro I ICAP Spectrometer[15]. Due to significantly higher costs for N and S analyses, however, only tissue samples from the initial and final sample dates were analyzed for N and S concentrations. Nitrogen and S concentrations were determined with the dry combustion method (Tabatabai and Bremner, 1991), using a LECO CNS-2000 Analyzer[16]. Due to circumstances beyond our control, some of the 2010 conventional-tillage cover crop samples were accidentally spilled during analysis. The remaining sample quantities were too small to be analyzed with the standard amounts of analytical compounds required to perform P, K, Ca, magnesium (Mg), B, Mn, and Zn analysis. Therefore, each sample was analyzed using half-rates of the necessary compounds. Total content of each nutrient in cover crop residues and peanut vegetation and pod tissues were calculated by multiplying the concentration of the specific nutrient by the respective biomass quantity. Subsequently, “total nutrient release” was determined for each cover crop by subtracting the total nutrient content of residues at the final sample date each year from the initial content at burndown. “Total nutrient uptake” indicates the total nutrient content of respective peanut tissues collected at the final sample date each year.

Soil P, K, Ca, Mg, Mn, and Zn were extracted using the Mehlich-1 extraction method (Mehlich, 1953) and analyzed via ICP spectroscopy with a Thermo Jarrell-Ash Enviro I ICAP Spectrometer[15]. Similar to tissue analyses, higher costs for NO_3-N and OM limited these analyses to those soil samples collected at the initial and final sample dates. Nitrate-N concentration was determined colorimetrically and organic matter concentration was determined using the Loss on Ignition (LOI) method (Ball, 1964). Soil pH for all samples was determined by $CaCl_2$ titration using an automated LabFit AS-3000 pH Analyzer[17].

Soil moisture data (% volumetric water content) were collected using a FieldScout TDR 300 Soil Moisture Meter[18], at a depth of 7.6 cm. Soil moisture readings were conducted by treatment at each sample date, beginning on 13 July 2009 and 22 June 2010. Plots were inverted 3 Nov. 2009 and 18 Oct. 2010 using a 2-row digger-shaker-inverter[4]. Two non-sampled rows were harvested from each plot on 9 Nov. 2009 and 22 Oct. 2010 using a 2-row small plot peanut combine. Yield and grade data were determined for each treatment, with pod yields adjusted to 7% moisture.

Statistical Analyses**.** Cover crop biomass decline was analyzed using the PROC NLIN function of SAS 9.2 software[19]. Biomass data were subjected to non-linear regression and responses were described by the exponential decay equation

$$y = B_0 e^{-B_1(x)}$$

where y is the response variable of treatment, B_0 is the value of the response variable (y) when x is equal to zero (kg DM ha^{-1}), B_1 is the rate of decline of cover crop biomass, and x is time (days after burndown [DAB]). Data for biomass decline by treatment were analyzed by ANOVA using the general linear model procedure in PROC NLIN in SAS 9.2 and means were separated using 95% asymptotic confidence intervals (Grey et al., 2007). All other data were analyzed by ANOVA using the PROC GLIMMIX function in SAS 9.2 and means were separated using pairwise t-tests at $P \leq 0.05$. Because of the unbalanced experimental design resulting from the abandoned strip-tillage crimson clover plots, however, nearly all analyses were separated by tillage treatment, except where data were pooled over rye, wheat, and no cover treatments for tillage comparisons.

Results and Discussion

Cover Crop Decomposition. All cover crop residues tended to display the greatest amount of decomposition in the first 60-90 DAB. In the conventional-tillage plots, wheat displayed the greatest rate of biomass decline among residues both years (Figs. 3.1a & 3.2a; Tables 3.1 & 3.2), although wheat and rye did not differ in 2010. This contrasts slightly with the literature that designates C:N ratio as the greatest indicator of decomposition rates: wheat has an average whole-plant C:N ratio of approximately 50:1, whereas crimson clover is approximately 21:1. However, in the first year of this experiment, wheat residues had an average C:N ratio of 22:1 at burndown, which was very close to that of crimson clover (Table 3.3). This could have resulted in a greater rate of wheat residue breakdown, although it is unable to fully explain why wheat decomposed so much more rapidly than the other cover crop residues. The relatively low C:N ratio of wheat in 2009 could have been a result of the spring N fertilization that year, which likely increased N uptake by cover crops prior to burndown. Likewise, both rye and wheat C:N ratios were lower in 2009 than 2010 (when no N fertilization was made). In a lab experiment, Quemada and Cabrera (1995) observed wheat residues to decompose as rapidly as crimson clover residues in soil columns. They also reported that the average C:N ratio of wheat leaves (13:1) is near that of crimson clover (10:1) (rye leaves are approximately 29:1), which could aid in accelerating whole-plant decomposition. Similarly, Collins et al. (1990) reported that the decomposition of incorporated wheat leaf and stem parts is 25% greater than the sum of decomposition from the individual plant parts. Therefore, because whole wheat plants were placed in the litterbags (stems + leaves), the leaf residues could have increased total wheat decomposition significantly, compared to wheat stems alone.

It is possible that lignin content of cover crop residues could have caused the somewhat counterintuitive distribution of decomposition rates among cover crop species. In addition to C:N ratios, lignin content and lignin:N ratios are also effective indicators of decomposition rates, in that greater amounts of lignin tend to slow decomposition (Douglas and Rickman, 1992; Melillo et al., 1982; Schomberg et al., 1994; Sarrantonio, 2007). Although crimson clover residues have relatively low C:N ratios, they can contain relatively high concentrations of lignin compared to wheat (Quemada and Cabrera, 1995). Additionally, lignin content of plants can vary at different stages of growth; the lignin content of crimson clover, for example, can increase by 87% from the late-vegetative to early seed-set stage (Ranells and Wagger, 1992). However, we did not collect lignin content or lignin:N data on cover crop residues in this experiment because of time considerations and cost limitations for lignin analysis.

Rate of decomposition did not differ between rye and wheat residues in the strip-tillage treatments both years (Figs. 3.1b & 3.2b; Tables 3.1 & 3.2). This was most likely due to less overall decomposition in the strip-tillage plots, which would minimize differences among treatments. All strip-tillage treatments also displayed lower rates of decomposition compared to conventional-tillage in 2009, but not in 2010 (despite different initial biomass amounts in 2010) (Figs. 3.1c & 3.2c; Table 3.4). This was likely due to less overall decomposition in all treatments in 2010, which would again reduce differences among treatments. Total soil moisture in 2010 was also much less than in 2009 ($P \leq 0.05$) (data not shown), because of less total rainfall from cover crop termination to final sampling date in 2010 (48 cm) versus 2009 (75 cm) and record-setting high temperatures during the 2010 season. Hot, dry soil conditions likely reduced soil microbial activity and residue decomposition. The greater rates of decomposition and differences among treatments in conventional-tillage in 2009 were likely due to greater soil/residue contact and soil aeration from incorporation, compared to the strip-tillage treatments (Douglas and Rickman, 1992).

Along with biomass, total cover crop nutrients tended to decline most rapidly in the first 60-90 DAB both years, when the greatest amount of cover crop decomposition was occurring. There were few treatment effects on soil nutrients at the 20-cm depth, therefore only the 5-cm soil data are reported below. Cover crops did not have a strong impact on total nutrient contents of peanut vegetation and pods, although some differences were apparent.

Nitrogen and Soil Organic Matter. Crimson clover residues in conventional-tillage released the greatest quantity of N in 2009 ($P \leq 0.05$), but were not different from wheat (Table 3.5). However, in 2010, total N release did not differ among cover crops, probably as a result of the lower overall rates of decomposition in 2010 (Table 3.6). In strip-tillage, total N release did not differ between rye and wheat in either year, likely due to the reduced decomposition in strip-tillage treatments mentioned above and less initial biomass that year. In conventional-tillage, rye resulted in greater soil N than no cover at 6 DAB in 2009 ($P \leq 0.10$) and crimson clover resulted in the greatest soil N at 10 DAB in 2010 ($P \leq 0.05$) (Tables 3.7 & 3.8). Because crimson clover is a legume, it is not surprising that it increased initial soil N levels in 2010. However, it is unclear as to why rye resulted in greater soil N in 2009, since the higher C:N ratio of rye residues would typically reduce N mineralization or result in N immobilization compared to the other cover crops. Rye produced the greatest amount of biomass in 2009, providing a thick cover for soil during winter and early spring. It is possible that this thick cover reduced NO_3^- leaching during that time, compared to the other treatments, resulting in greater soil NO_3-N.

Despite greater total N release from conventional-tillage crimson clover in 2009, rye resulted in the greatest soil N by the end of the season in 2009 and all cover crops resulted in greater soil N than no cover in 2010 ($P \leq 0.05$) (Tables 3.7 & 3.8). However, N levels were relatively low by that point each year. This indicates that the N released from crimson clover residues in 2009 was either lost via leaching or volatilization, or was taken up by the actively-growing peanut plants. However, N leaching and volatilization measurements were not conducted in this experiment. Soil N did not differ among cover crop treatments in strip-tillage at either point in the season. Soil organic matter also did not differ among cover crop or tillage treatments both years, at burndown or at the end of the season (Tables 3.7 & 3.8). In a long-term strip-tillage system, however, some organic matter buildup could occur, but we were unable to examine this within the short timeframe of our experiment. Long-term cropping systems that increase organic matter inputs to soil can increase soil biological activity, which subsequently increases the ability of the soil to cycle nutrients more rapidly (Dick, 1992).

Nitrogen content of peanut vegetation did not differ among cover crops in conventional- and strip-tillage either year (Tables 3.9 & 3.10). Because peanut is a legume, any cover crop effects on N uptake by peanut vegetation were likely masked by the ability to fix N. However, this conflicts with the results reported by Crusciol and Soratto (2009), who observed greater amounts of N in peanut vegetation as a result of conservation-tillage. Total N in peanut pods also did not differ among cover crop treatments in either tillage (Tables 3.11 and 3.12). However, strip-tillage in 2010 resulted in greater total N in pods ($P \leq 0.10$) than conventional-tillage (Table 3.13). This was probably due to the in-row subsoiling component of strip-tillage, which allows plant roots to travel much deeper soils with hardpan layers, in order to better-scavenge for water and nutrients. Additionally, the near-drought conditions in 2010 resulted in low water availability in soil, which could have caused deeper root growth by peanut plants. Greater root growth is a common response of peanut to drought conditions in the soil (Pandey et al., 1984; Beasley et al., 1997). Peanut also is also an inherently effective scavenger of residual soil nutrients because of its normally deep taproot growth (Beasley et al., 1997). Therefore, peanut roots in 2010 could have traveled much deeper in strip-tillage, scavenging significant amounts of additional N as pods developed late in the season.

Phosphorus. Cover crop P in conventional-tillage tended to decline most rapidly within the first 30 days after incorporation (30-60 DAB) both years, as residues came into direct contact with soil microorganisms (Figs. 3.3a & 3.4a). All cover crop species displayed a similar rate of P decline, despite the differing rates of biomass decline mentioned previously. However, by approximately 60 DAB, wheat residues contained lower amounts of P than crimson clover or rye, indicating that much of the P in wheat had been released during the first rapid period of decomposition each year. By the end of the season in 2009, crimson clover released the greatest total P ($P \leq 0.05$) (Table 3.5), although there were no differences in P release among cover crops in 2010 (Table 3.6). Despite greater total P release from crimson clover in 2009, there were no significant cover crop effects on soil P or P content of peanut vegetation and pods at any sample date in 2009 or 2010 (Figs. 3.3b-d & 3.4b-d; Tables 3.9, 3.10, 3.11, & 3.12).

In strip-tillage, rye and wheat varied little in cover crop P, although rye tended to contain slightly greater total P initially than wheat in 2009 (Fig. 3.5a). By the end of each season, neither differed in total P release (Tables 3.5 & 3.6). The greater biomass produced by rye in 2009 resulted in lower soil P initially than the no cover treatment (Fig. 3.5b), since much of the soil P was likely taken up and assimilated by rye. However, this did not hinder P uptake by peanut vegetation or pods (Figs. 3.5c-d; Tables 3.9 & 3.11). Wheat actually resulted in greater total P in pods in 2009 ($P \leq 0.10$). Total P did not differ among cover crops in 2010 (Fig. 3.6a) or soil, peanut vegetation, and pods at any sample date that year (Figs. 3.6b-d; Tables 3.10 & 3.12).

Potassium. Total K in cover crop residues showed a drastic decline in the first 60 DAB in conventional-tillage both years (Figs . 3.7a & 3.8a). By 60-90 DAB both years, almost all of the K had been released from cover crop residues. Crimson clover released the greatest amounts of K both years ($P \leq 0.05$) (Tables 3.5 & 3.6). Potassium release did not differ among rye and wheat in 2009 (Table 3.5), but rye released greater total K than wheat in 2010 (Table 3.6). Rapid K release from cover crop residues also appeared to affect soil K. Cover crops slightly increased soil K from 0-90 DAB in 2009 (Fig. 3.7b). Soil K eventually declined until approximately 120-165 DAB both years (as total K increased in peanut vegetation and pods), but then increased slightly in all cover crop treatments by the final sample dates (Fig. 3.7b & 3.8b). It is unclear as to why soil K increased at the end of the season, since nearly all of the cover crop K had been released by then. Total K in peanut vegetation was greater from wheat than rye at approximately 85 DAP in 2010. Otherwise, it did not differ among cover crop treatments at any other sample date each year, other than at the final sample date in 2009 (Figs. 3.7c & 3.8c; Tables 3.9 & 3.10). This was likely due to almost all cover crop K having been released by the time peanut plants were of significant size. No cover resulted in greater total vegetative K that year ($P \leq 0.05$), which indicates that, though cover crops released significant amounts of K to soil early on, the peanut plants were not large enough to take full advantage of that K. Total K in pods at 140 DAP was greater from crimson clover than from rye and no cover in conventional-tillage (Fig. 3.8d). Otherwise, total K in pods did not differ among cover crops either year at any other sample date (Figs. 3.7d & 3.8d; Table 3.11 & 3.12).

In strip-tillage, rye residues displayed a slightly greater rate of initial K decline than wheat both years (Figs. 3.9a & 3.10a), however they did not differ from one another in total K release both years (Tables 3.5 & 3.6). Both rye and wheat residues subsequently increased soil K over no cover by approximately 65-95 DAB in 2009 (Fig. 3.9b). Cover crop treatments did not differ in soil K at any sample date in 2010 (Fig. 3.10b). However, soil K both years followed the same trend as it did in the conventional-tillage treatments, where it declined until approximately 115-130 DAB as K uptake by peanut plants increased (Figs. 3.9c & 3.10c). Total K in peanut vegetation and pods did not differ among cover crop treatments at any sample date both years (Figs. 3.9c-d & 3.10c-d; Tables 3.9, 3.10, 3.11, & 3.12), however no cover resulted in greater total K in peanut vegetation ($P \leq 0.05$) at the end of the season in 2010 (Table 3.10). Alternatively, wheat resulted in greater total K in pods ($P \leq 0.10$) than no cover at the end of the season in 2009 (Table 3.11).

In 2010, strip-tillage resulted in a greater final pod K ($P \leq 0.05$) (Table 3.13), however this was not observed in 2009. Similar to pod N in strip-tillage, there was likely greater root growth in response to the drought conditions that occurred in 2010, allowing for potentially greater K uptake at greater soil depths. Because K is a relatively mobile nutrient in sandy soils, some amounts of K could have leached to greater soil depths, potentially providing additional amounts of K for uptake for peanuts with deeper roots.

***Calcium*.** Because Ca applications were made at some point during the trial both years, it is possible that some of the treatment effects on Ca uptake by peanut plants were masked (especially with the later Ca application in 2010), though not entirely. Crimson clover displayed potential for absorbing and assimilating large amounts of Ca, as evidenced by the greater total Ca in crimson clover residues than rye and wheat in conventional-tillage both years. All cover crops displayed a steady rate of decline in 2009, although crimson clover appeared to display a sharper decline than either rye or wheat (Fig. 3.11a). Cover crop calcium data in 2010, however, was nonsensical (Fig. 3.12a). There did not appear to be any decline in total Ca, although total biomass showed a consistent decline in all cover crops. The abnormal nature of the data was the result of the lab accident mentioned previously, where many of these samples were spilled and then analyzed at half-concentrations. This resulted in considerable variation in Ca concentrations among sample dates (Fig. 3.13a-b), which resulted in the counterintuitive trends observed in Fig. 3.12a. Total Ca release was greatest from crimson clover in 2009 ($P \leq 0.05$) (Table 3.5). Cover crop Ca in 2010 was too sporadic to confidently determine Ca release values (Table 3.6). Initial soil Ca in conventional-tillage was greater in 2009 than in 2010, because of the lime application made prior to peanut planting. However, soil Ca did not differ among cover crop treatments at any sample date, including the final sample date (Figs. 3.11b & 3.12b). In 2009, soil Ca in all cover crop treatments declined slightly from approximately 100-165 DAB, as peanut vegetation and pods increased in Ca content (Figs. 3.11c-d & 3.12c-d). This trend was not as strong in 2010, likely because of a combination of more limited Ca mobility from less soil moisture in 2010 and the gypsum application that occurred on 3 Aug. (99 DAB). The gypsum application caused a noticeable jump in soil Ca to over 400 mg Ca kg^{-1}. This soil Ca increase caused a resultant increase in vegetative Ca in peanut in the rye and wheat treatments at approximately 85 DAP (Fig. 3.12c), although it is unclear why this effect would not have been observed in all cover crop treatments. Alternatively, in 2009, wheat and no cover caused a slight increase in total vegetative Ca over crimson clover and rye at 140 DAP (Fig. 3.11c), as a result of less Ca being tied up by cover crop residues in those two treatments. Final vegetative Ca uptake did not differ among cover crop treatments both years (Tables 3.9 & 3.10). Additionally, though total Ca in pods was less in 2010, there were no differences in total pod Ca among cover crops at any sample date both years (Figs. 3.11d & 3.12d; Tables 3.11 & 3.12).

In strip-tillage, rye and wheat residues showed only minimal decline in Ca content all season in 2009 (Fig. 3.14a). The 2010 data was nonsensical (Figs. 3.15a) because of Ca concentrations (Fig. 3.13b), since the tissue samples related to these treatments and sample dates were also part of the accident mentioned above. Therefore, we were able to conclude little from the 2010 data, although the initial sample dates followed a similar trend as in 2009. Soil Ca in 2009 did not differ among cover crop treatments (Fig. 3.14b), however Ca levels in all treatments did decline slightly at approximately 165 DAB, when Ca in peanut vegetation was at its greatest. Soil Ca in 2010 did not follow this trend and varied minimally all season (Fig. 3.15b). Total Ca in peanut vegetation and pods varied little among treatments at any sample date each year (Figs. 3.14c-d & 3.15c-d; Tables 3.9-3.12).

Magnesium. Magnesium followed similar trends as Ca in cover crop residues, soils, and peanut tissues. Crimson clover contained the greatest total Mg at burndown in conventional-tillage in 2009 (Fig. 3.16a). Total Mg decline in cover crop residues was very similar among cover crop treatments, although wheat lost almost all of its Mg by approximately 130 DAB. Similar to Ca in conventional-tillage in 2010, total cover crop Mg data was nonsensical (Fig. 3.17a) because of significant variation in Mg concentrations among residues (Fig. 3.18), as many of the samples related to those data were included in the accident mentioned above. Therefore, we are also able to conclude little from cover crop Mg in 2010. Total Mg release from cover crops was greatest from crimson clover in 2009 ($P \leq 0.05$) (Table 3.5). However, because of the sporadic cover crop Mg, we were unable to confidently determine total Mg release. Because dolomitic lime was applied prior to cover crop burndown in 2009, initial soil Mg was greater in

2009 than in 2010 (Figs. 3.16b & 3.17b). However, there was little variation in soil Mg among cover crops in conventional-tillage both years (Figs. 3.16b & 3.17b), although there appeared to be a slight decline in soil Mg from 30-165 DAB in 2010. Magnesium in peanut vegetation and pods did not differ among cover crops at any sample date in 2009 (Figs. 3.16c & 3.16d; Tables 3.9 & 3.11). Rye and wheat resulted in slightly greater Mg in peanut vegetation than crimson clover and no cover at approximately 85 DAB in 2010 (Fig. 3.17c), although there were no differences at any other sample date or at the end of the season (Table 3.10). Similarly, crimson clover and wheat resulted in slightly greater total Mg in pods at the end of the season (Fig. 3.17d; Table 3.12), but differences were not significant.

In strip-tillage, total Mg in wheat displayed significant decline in 2009 (Fig. 3.19a). Rye and wheat residues in 2010, however, appeared to exhibit little difference in Mg decline (Fig. 3.20a), which was likely due to the much smaller quantities of cover crop biomass and subsequent Mg that were present at burndown. Neither rye nor wheat differed in total Mg release both years (Tables 3.5 & 3.6). Soil Mg varied little over the course of the season and did not differ among cover treatments both years (Figs. 3.19b & 3.20b). However, there was a slight decline in soil Mg from approximately 90-115 DAB in all treatments in 2010, as Mg increased in peanut vegetation (Fig. 3.20c). Total Mg in peanut vegetation and pods did not differ among cover crop treatments at any point in the growing season both years (Figs. 3.19c-d & Figs. 3.20c-d; Tables 3.9-3.12).

Similar to K and N, strip-tillage resulted in greater total Mg in peanut pods at the end of the season than conventional-tillage ($P \leq 0.10$) in 2010 (Table 3.13). This was also likely a result of deeper root growth of peanut plants in strip-tillage, where the hardpan had been disrupted in the drill row with in-row subsoiling.

***Sulfur*.** Sulfur release did not differ among cover crops in conventional- or strip-tillage in 2009 or 2010 (Tables 3.5 & 3.6). Subsequently, total S uptake by peanut vegetation was not different among all cover crop treatments both years (Tables 3.9-3.12). However, similar to K, Mg, and N, total S in pods was greatest in strip-tillage at the end of the season in 2010 ($P \leq 0.10$) (Table 3.13). Because SO_4^- is easily-leached in soils (Havlin et al., 2005), deeper root growth in the subsoiled strip-tillage plots likely allowed peanut plants to take advantage of SO_4^- that had leached to deeper portions of the soil profile.

***Boron*.** In conventional-tillage, crimson clover appeared to contain greater quantities of total B than rye and wheat at burndown in 2009 (Fig. 3.21a). Subsequently, crimson clover residues exhibited a slightly sharper B decline than both rye and wheat, culminating in greater total B release from crimson clover that year (Table 3.5). However, similar to Ca and Mg, cover crop B data in 2010 (Fig. 3.22a) were notably erratic because of variation in tissue B concentrations (Fig. 3.23a). Therefore, we are unable to report meaningful results for cover crop B that year. Total B in peanut vegetation was insignificant among cover crop treatments at all sample dates both years (Figs. 3.21b & 3.22b; Tables 3.9 & 3.10). Total B in pods appeared to be slightly greater from crimson clover than the other treatments at approximately 140 DAP in 2010 (Fig 3.22c), but was not significant. Otherwise, total pod B was insignificant among cover crops at all other sample dates in 2009 and 2010 (Figs. 3.21c & 3.22c; Tables 3.11 & 3.12).

In strip-tillage, wheat residues exhibited a slightly sharper B decline than rye in both 2009 (Fig. 3.24a), although the two cover crops did not differ in total B release (Table 3.5). Similar to the conventional-tillage treatments, cover crop B in 2010 (Fig. 3.25a) was nonsensical, because of sporadic B concentrations in tissues (Fig. 3.23b). Therefore, we also cannot confidently reach any conclusions regarding cover crop B or total B release for that year. Total

B in peanut vegetation and pods did not differ among cover crop treatments at any sample date in 2009 or 2010 (Figs. 3.24b-c & 3.25b-c; Tables 3.9-3.12). It is possible that the foliar B applications made in both years of this experiment may have masked potential treatment effects on B uptake by peanut plants. Future research could therefore focus on evaluating cover crop effects on B uptake, with and without B fertilization.

Manganese. Conventional-tillage wheat and rye cover crops appeared to contain the most initial Mn in 2009 (Fig. 3.26a), although rye did not appear to differ from crimson clover. Wheat also exhibited a sharp decline in total Mn over the course of the season in 2009. However, total Mn release did not differ among cover crop treatments (Table 3.5). Similar to B, Ca, and Mg, cover crop Mn in 2010 (Fig. 3.27a) was extremely erratic, due to significant variation in Mn concentrations among sample dates (Fig. 3.28). Again, the data were too sporadic to confidently calculate and report total Mn release from cover crop residues. Soil Mn did not differ among cover crops at each sample date both years (Figs. 3.26b & 3.27b), although overall soil Mn was greater in 2009 than 2010. A consistent decline in soil Mn occurred both years among all cover crops, indicating that any Mn contributions from cover crops were not enough to overcome Mn removal from soil by peanut plants. However, liming acidic soils decreases solution and exchangeable Mn^{2+} by precipitation as MnO_2 (Brady and Weil, 2002; Havlin et al., 2005), so some amounts of soil Mn could have been lost to precipitation, especially with the early-season lime application in 2009. Total Mn in peanut vegetation varied little among cover crops in 2009, but was greater in the no cover treatment at 135 DAP (Fig. 3.26c). However, final vegetative Mn was not different among cover crop treatments (Table 3.9). Vegetative Mn in 2010 was not different among cover crops at any sample date (Fig. 3.27c; Table 3.10). Similarly, total pod Mn was not different among cover crops at any point during the season in 2009 (Fig. 3.26d; Table 3.11). Crimson clover resulted in the greatest total pod Mn at approximately 140 DAB in 2010, but was not different among treatments at any other sample date (Fig. 3.27d; Table 3.12).

In strip-tillage in 2009, both rye and wheat residues exhibited similar rates of Mn decline (Fig. 3.29a). Rye appeared to display a sharp Mn decline in 2010 (Fig. 3.30a), although cover crop Mn amounts were much lower in 2010. By the end of the season in 2009, rye and wheat did not differ in total Mn release (Table 3.5), although rye exhibited greater total release in 2010 ($P \leq 0.05$) (Table 3.6). There were no differences in soil Mn among cover crop treatments in soil both years (Figs. 3.29b & 3.30b), although in both years we observed the aforementioned decline in soil Mn over time. Total Mn in peanut vegetation did not differ among cover crops in 2009 until approximately 160 DAP, where both rye and wheat resulted in greater total Mn than no cover ($P \leq 0.05$) (Fig. 3.29c; Table 3.9). Subsequently, wheat resulted in greater total pod Mn at the end of the season ($P \leq 0.05$) (Fig. 3.29d; Table 3.11). It is unclear as to why rye and wheat improved Mn uptake by peanut plants in 2009. It is possible that rye and wheat residues released Mn that was in a more plant-available form for uptake by the peanut plants. These effects were not observed in 2010, however—there were no differences in total Mn in peanut vegetation and pods among cover crops at any sample date (Figs. 3.29c-d & 3.30c-d; Tables 3.10 and 3.12). This was likely a result of the much drier soil conditions that occurred in 2010, as Mn^{2+} availability is greatly reduced in dry, aerated soil by precipitation as MnO_2 (Havlin et al., 2005). Total Mn in pods was also greater in strip-tillage than in conventional-tillage ($P \leq 0.05$) in 2010, similar to K, Mg, N, and S (Table 3.13).

Zinc. There were clear differences in total Zn content of cover crop residues in conventional-tillage at the beginning of the season in 2009 (Fig. 3.31a), with crimson clover appearing to contain the greatest total Zn. All three cover crops exhibited similar rates of Zn decline over the course of the season, although wheat released nearly all of its Zn by approximately 130 DAB. By the end of the season, crimson clover released the greatest total amount of Zn ($P \leq 0.05$) (Table 3.5). Similar to cover crop B, Ca, Mg, and Mn in 2010, cover crop Zn was notably sporadic because of significant variation in Zn concentrations among all sample dates (Figs. 3.32a & 3.33). Therefore, no conclusions were able to be made confidently regarding total Zn release from cover crop residues that year. Despite differences in total Zn release among cover crop residues, there were no significant treatment effects on soil Zn (Fig. 3.31b), total Zn in peanut vegetation (Fig. 3.31c; Table 3.9), or total Zn in pods (Fig. 3.31d; Table 3.11) at any sample date in 2009. In 2010, soil Zn did not differ among treatments at any sample date (Fig. 3.32b). Total Zn in peanut vegetation was apparently greater from rye than from crimson clover at approximately 85 DAP, but was not different among cover crops for any other sample date that year (Fig. 3.32c; Table 3.10). Similarly, total Zn in pods was not different among treatments for any sample date in 2010 (Fig. 3.32d; Table 3.12).

In strip-tillage, wheat exhibited a slightly sharper Zn decline in 2009 and 2010 (Figs. 3.34a and 3.35a). However, by the end of the season, both cover crops did not differ in total Zn release both years (Tables 3.5 & 3.6). Soil Zn concentrations also did not differ among cover crops at any point during the season either year (Figs. 3.34b & 3.35b). Total Zn in peanut vegetation did not vary among cover crops in 2009 until 160 DAB, when both rye and wheat resulted in greater vegetative Zn ($P \leq 0.05$) (Fig. 3.34c; Table 3.9). Similarly, rye and wheat resulted in greater total pod Zn than no cover at 160 DAB ($P \leq 0.05$) (Fig. 3.34d; Table 3.11). In 2010, total Zn in peanut vegetation and pods did not differ among cover crop treatments at any point in the season (Fig. 3.35c-d; Tables 3.10 & 3.12).

Strip-tillage also resulted in greater total Zn in pods than conventional-tillage in both 2009 and 2010 ($P \leq 0.10$), similar to K, Mg, Mn, N, and S (Table 3.13). It is unclear why this effect occurred, as Zn is considered relatively immobile and highly-resistant to leaching in Coastal Plain soils (Beasley et al., 1997). It is possible that deeper root growth increased the amount of soil Zn that came into direct content with the peanut roots that was subsequently absorbed.

Vegetative Peanut Production, Yield, and Grade. Despite varying cover crop effects on nutrient uptake, peanut vegetation did not differ among cover crop treatments in conventional- or strip-tillage at any point in the season both years (data not shown) and did not differ at the end of the season (Table 3.14). Total peanut root biomass at the end of the season was greatest in 2010 ($P \leq 0.05$), likely as a result of drought-like conditions causing greater root growth (Table. 3.14). Crimson clover in conventional-tillage did result in greater peanut root biomass ($P \leq 0.10$) than wheat and no cover, but was not different from rye. This could have been a result of the greater soil N present in crimson clover plots and numerically greater soil N in rye plots prior to peanut planting, which could have helped bolster early-season peanut root growth over the other treatments. Root biomass in strip-tillage wheat was also greater than no cover, although it was not different from rye. This effect also appeared to follow the trend of soil N among strip-tillage treatments in 2010, although soil N amounts were not different among cover crops that year. The greater overall root growth in 2010 could have also resulted in greater potential for differences among cover crop treatments, since differences among cover crops in either tillage were not apparent in 2009. Final peanut stands were greater in 2009 than 2010, but were not different among cover crop treatments in either tillage system both years (Table. 3.14).

Pod yields were not different among cover crop treatments in conventional- or strip-tillage both years, although mean yields were greater in 2009 than 2010 (Table 3.15). This was also likely the result of greater rainfall during the 2009 season. Strip-tillage rye resulted in a greater percentage of total sound mature kernels (TSMK) than no cover in 2009, although it was not different from wheat (Table 3.15). However, there were no other grade differences among cover crops in either tillage system both years. The cause of this effect in 2009 is unclear, since it was only observed in one tillage treatment in one year of the study.

Summary and Conclusions

The results of this experiment indicate that there are clear differences in rate of decomposition and nutrient release of cover crops among species and tillage system. However, these effects had only minor impacts on nutrient uptake in peanut vegetation and pods. Cover crop decomposition was greatest in the first 60-90 DAB and biomass decline was greatest in conventional-tillage in 2009. Wheat biomass exhibited the sharpest decline in conventional-tillage both years, but was not different from rye in 2010. This is somewhat contrary to the traditional method of using C:N as a predictor of decomposition, since wheat typically has a high C:N ratio. However, the whole-plant C:N ratio of wheat in 2009 was almost equivalent that of crimson clover, likely due to an N fertilization that was made in the winter prior to cover crop burndown that year. Lignin:N ratios are also effective predictors of decomposition and could have been a factor in the slower decomposition of crimson clover, which can contain large amounts of lignin. Lignin:N was not evaluated in these experiments because of time and financial limitations, but this indicates a need for future research evaluating lignin:N as an indicator of cover crop decomposition on a field scale.

Cover crops had little effect on SOM in the first 5 cm of soil, although the limited timeframe of these experiments precluded potential long-term cover crop effects on SOM buildup. Crimson clover and rye displayed potential for increasing soil N at burndown, which also appeared to increase peanut root biomass later in the season. Nutrient release varied significantly among cover crops and tillage systems. Despite the sharper decline of wheat residues, crimson clover residues in conventional-tillage released the greatest amounts of N, P, K, Ca, Mg, B, and Zn in 2009. However, wheat released equivalent amounts of total N that year as crimson clover. Nutrient release from cover crop residues resulted in some amount of soil nutrient increase, but was inconsistently apparent and varied by nutrient. Soil nutrients varied little among actual cover crop species and tillage.

Total nutrient content in peanut vegetation and pods varied little among cover crop and tillage both years, although some nutrient effects may have been masked by fertilizer applications. Cover crops in conventional-tillage actually reduced total K in peanut vegetation in conventional-tillage in 2009 and strip-tillage in 2010. Rye and wheat, however, increased total Mn and Zn in peanut vegetation and pods in strip-tillage in 2009. Strip-tillage wheat also resulted in greater total P and K in pods in 2009, although was not different from rye in total pod K. Strip-tillage resulted in greater N, K, Mg, S, Mn, and Zn uptake by pods under drought-like conditions experienced in 2010, likely because of in-row subsoiling and greater root growth in response to drought conditions. Strip-tillage can therefore improve the uptake of the more leachable nutrients by peanut under drought conditions. Despite these differences, however, there were few significant cover crop or tillage effects on vegetative peanut biomass production, final plant stand, yield or grade both years.

These results indicate that there is some nutrient benefit to peanut (however minimal) grown after crimson clover, rye, or wheat cover, although benefits vary based on tillage system. However, there are no apparent yield or grade advantages resulting from these nutrient benefits. In a long-term scenario, nutrient benefits might become more apparent over time, although peanut could not be grown in successive growing seasons because of pest limitations from the peanut root-knot nematode (*Meloidogyne arenaria*). More research is needed to evaluate cover crop effects on nutrient cycling in more long-term cropping scenarios. Since peanut is a leguminous crop, N effects from decomposing cover crop residues on peanut plants were not as dramatic as they would potentially be on a non-leguminous crop. Additionally, the significant fungicide inputs typically utilized in peanut systems could impede or restrict the activity of soil fungi in decomposing cover crop residues. Future research should therefore focus on the nutrient cycling effects of cover crops on non-legumes like maize and cotton, which typically receive almost no fungicide applications and are commonly grown in rotation with peanut on the Coastal Plain.

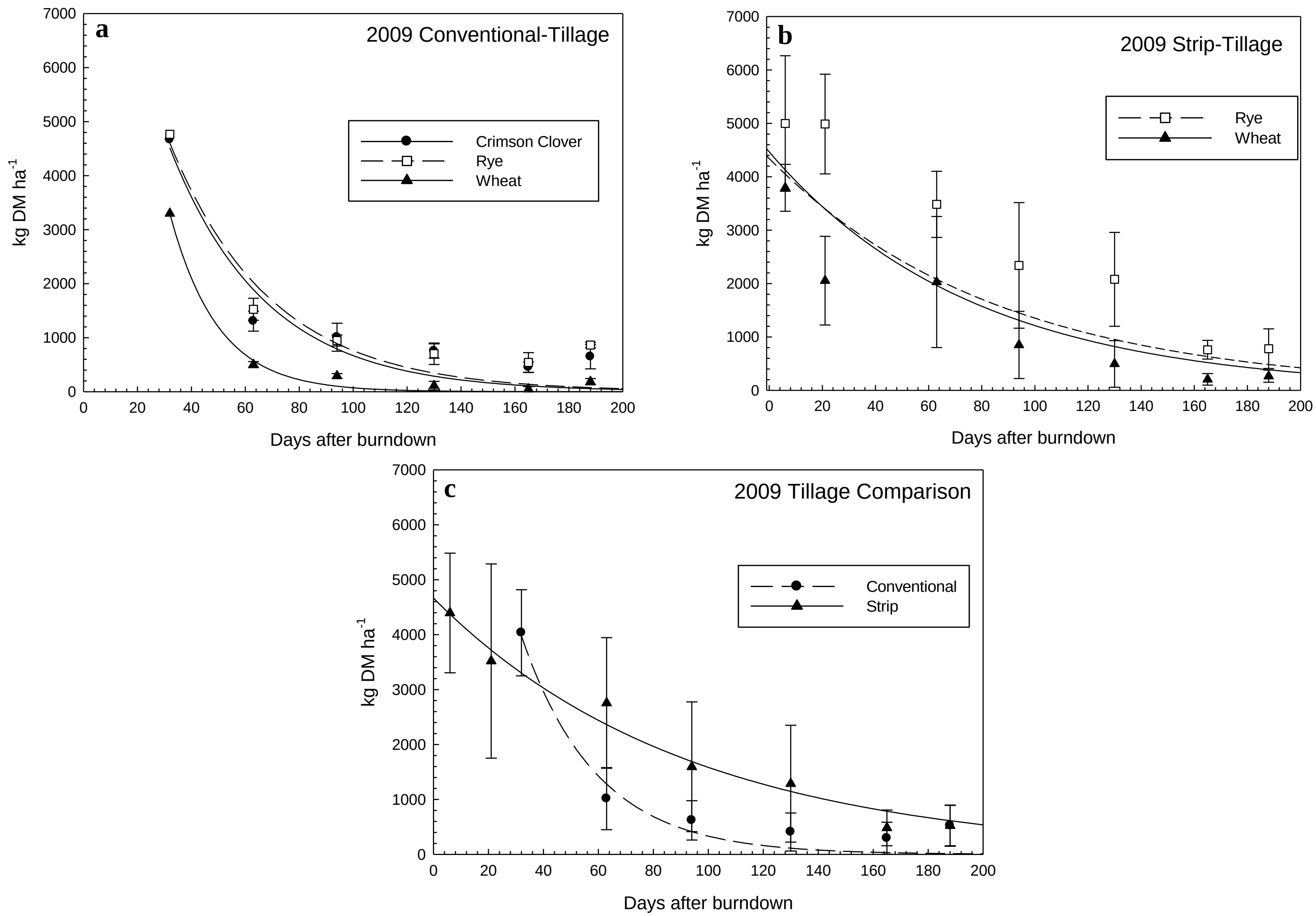

Figure 3.1. Biomass decline of three cover crop species in (a) conventional-tillage, (b) strip-tillage, and (c) among tillage treatments in Tifton, GA, 2009. Values for the tillage comparison were pooled over rye and wheat only.

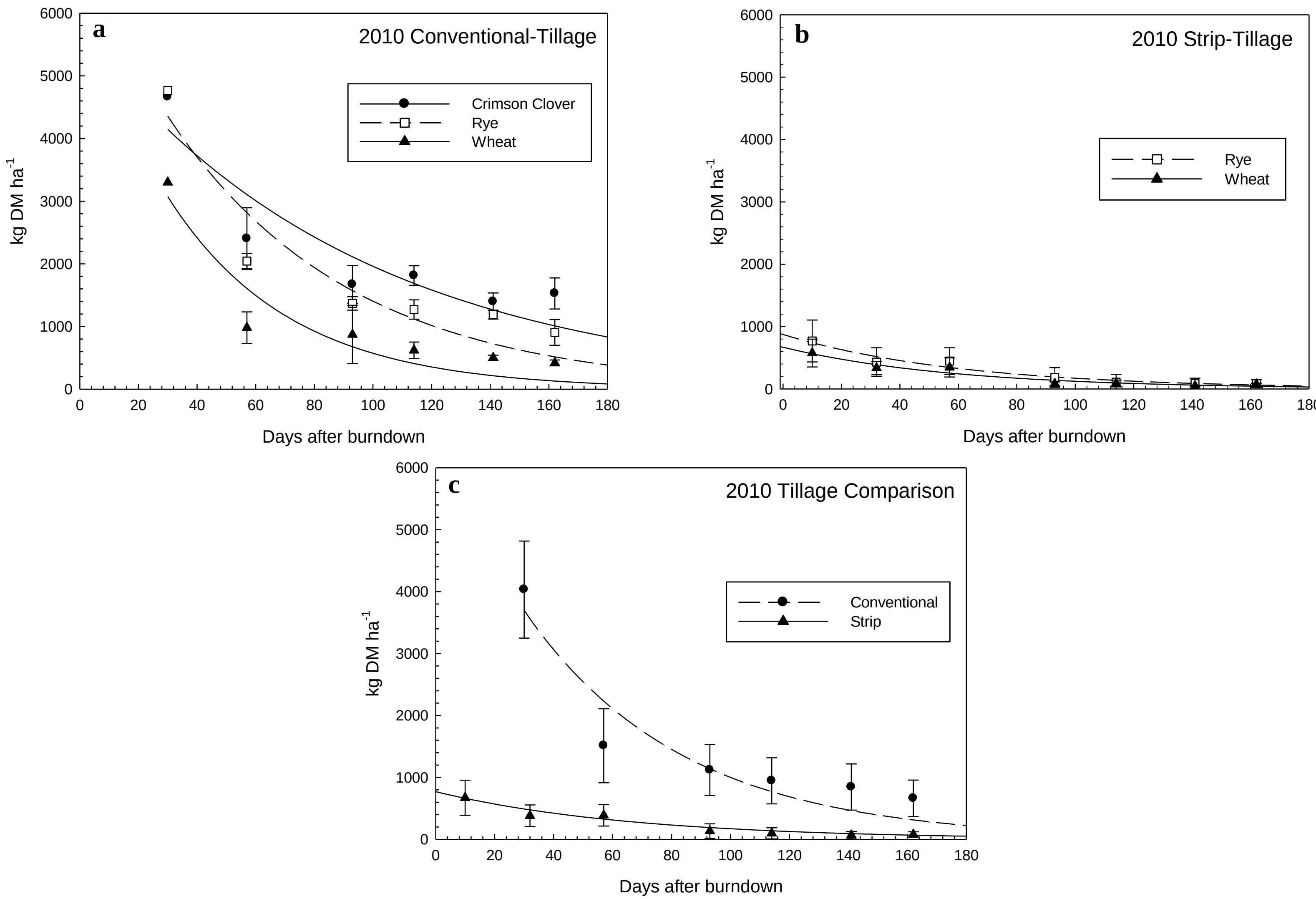

Figure 3.2. Biomass decline of three cover crop species in (a) conventional-tillage, (b) strip-tillage, and (c) among tillage treatments in Tifton, GA, 2010. Values for the tillage comparison were pooled over rye and wheat only.

Table 3.1. Interactive effects of tillage and crop species on rate of cover crop biomass decline in Tifton, GA in 2009.

		Rate of decline[b]			
Tillage	Cover Crop	B_1	95% CI	B_0	95% CI
Conventional				kg DM[a] ha^{-1}	
	Crimson Clover	0.0281 b	± 0.0064	11,089 b	± 2947
	Rye	0.0265 b	± 0.0059	10,750 b	± 2712
	Wheat	0.0562 a	± 0.0074	19,901 a	± 4968
Strip					
	Crimson Clover	---	---	---	---
	Rye	0.0091 a	± 0.0023	5675 b	± 763
	Wheat	0.0147 a	± 0.0053	3739 a	± 720

First-order rate constant means within a column followed by the same lowercase letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$; means were separated using a general linear model procedure with 95% asymptotic confidence intervals.

[a] Dry matter.

[b] Rate of biomass decline was determined with respect to time using non-linear regression and responses were described by the exponential decay equation $y = B_0 e^{-B_1(x)}$, where y is the response variable of treatment, B_0 is the value of the response variable y when x is equal to zero (kg DM ha^{-1}), B_1 is the rate of decline of cover crop biomass, and x is time (days after burndown).

Table 3.2. Interactive effects of tillage and crop species on rate of cover crop biomass decline in Tifton, GA in 2010.

		Rate of decline[b]			
Tillage	Cover Crop	B_1	95% CI	B_0	95% CI
Conventional				kg DM[a] ha^{-1}	
	Crimson Clover	0.0107 b	± 0.0025	5716 a	± 996
	Rye	0.0162 ab	± 0.0031	7086 a	± 1241
	Wheat	0.0240 a	± 0.0063	6312 a	± 1725
Strip					
	Crimson Clover	---	---	---	---
	Rye	0.0138 a	± 0.0077	879 a	± 307
	Wheat	0.0169 a	± 0.0058	668 a	± 147

First-order rate constant means within a column followed by the same lowercase letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$; means were separated using a general linear model procedure with 95% asymptotic confidence intervals.

[a] Dry matter.

[b] Rate of biomass decline was determined with respect to time using non-linear regression and responses were described by the exponential decay equation $y = B_0 e^{-B_1(x)}$, where y is the response variable of treatment, B_0 is the value of the response variable (y) when x is equal to zero (kg DM ha^{-1}), B_1 is the rate of decline of cover crop biomass, and x is time (days after burndown).

Table 3.3. Average carbon (C) and nitrogen (N) concentration and C:N ratios of crimson clover, rye, and wheat residues at burndown in Tifton, GA in 2009-2010.

	C		N		C:N	
Cover Crop	2009	2010	2009	2010	2009	2010
	----------------g kg^{-1}----------------					
Crimson Clover	370	380	18	14	20:1	26:1
Rye	410	390	13	8	32:1	44:1
Wheat	400	380	17	10	22:1	36:1

Table 3.4. Tillage effects on rate of cover crop biomass decline in Tifton, GA in 2009-2010.

Year	Tillage[a]	Rate of decline[c]			
		B_1	95% CI	B_0	95% CI
2009				kg DM[b] ha^{-1}	
	Conventional	0.0366 a	± 0.0085	12,830 a	± 4058
	Strip	0.0108 b	± 0.0030	4664 a	± 694
2010					
	Conventional	0.0187 a	± 0.0039	6480 a	± 1290
	Strip	0.0150 a	± 0.0054	770 b	± 175

First-order rate constant means within a column followed by the same lowercase letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$; means were separated using a general linear model procedure with 95% asymptotic confidence intervals.

[a] Pooled over rye and wheat treatments only.

[b] Dry matter.

[c] Rate of biomass decline was determined with respect to time using non-linear regression and responses were described by the exponential decay equation $y = B_0 e^{-B_1(x)}$, where y is the response variable of treatment, B_0 is the value of the response variable (y) when x is equal to zero (kg DM ha^{-1}), B_1 is the rate of decline of cover crop biomass, and x is time (days after burndown).

Table 3.5. Effects of species and tillage on total release of primary and secondary plant nutrients and select micronutrients from decaying cover crop residues in Tifton, GA in 2009.

Tillage	Cover Crop	N	P	K	Ca	Mg	S	B	Mn	Zn
		-------------------------------------				kg ha^{-1}				-------------------------------------
Conventional										
	Crimson Clover	70 a	9 a	141 a	33 a	8 a	5 a	0.100 a	0.09 a	0.11 a
	Rye	42 b	8 b	76 b	8 b	4 b	4 a	0.003 b	0.12 a	0.05 b
	Wheat	58 ab	8 b	64 b	8 b	4 b	5 a	0.001 b	0.20 a	0.07 b
	LSD[a]	19	1	13	8	2	3	0.011	0.11	0.02
Strip										
	Crimson Clover	---	---	---	---	---	---	---	---	---
	Rye	52 a	8 a	79 a	6 a	3 a	5 a	0.005 a	0.17 a	0.07 a
	Wheat	60 a	8 a	69 a	7 a	4 a	6 a	0.006 a	0.24 a	0.07 a
	LSD	13	2	29	9	2	1	0.003	0.07	0.02

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Least Significant Difference.

Table 3.6. Effects of species and tillage on total release of primary and secondary plant nutrients and select micronutrients from decaying cover crop residues in strip-tillage in Tifton, GA in 2010.

Tillage	Cover Crop	N	P	K	Ca	Mg	S	B	Mn	Zn
		--kg ha^{-1}--								
Conventional[a]										
	Crimson clover	32 a	3.7 a	131 a	---	---	2.7 a	---	---	---
	Rye	23 a	9.2 a	57 b	---	---	2.6 a	---	---	---
	Wheat	26 a	6.5 a	32 c	---	---	3.6 a	---	---	---
	LSD[b]	10	6.2	14	---	---	1.5	---	---	---
Strip										
	Crimson clover	---	---	---	---	---	---	---	---	---
	Rye	5 a	1.5 a	7 a	0.13 a	0.40 a	0.59 a	0.0003 a	0.010 a	0.007 a
	Wheat	4 a	0.9 a	4 a	0.03 a	0.40 a	0.46 a	0.0009 a	0.003 b	0.006 a
	LSD	2	0.9	3	0.1	0.11	0.25	0.0009	0.001	0.003

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Residues for the conventional-tillage treatments were artificially elevated to the 2009 densities, to ensure adequate residue for accurate sampling late in the season.

[b] Least Significant Difference.

Table 3.7. Effects of cover crop species and tillage on soil nitrogen (N) and soil organic matter (OM) in Tifton, GA in 2009.

		Soil N		Soil OM	
Tillage	Cover Crop	6 DAB[a]	188 DAB	6 DAB	188 DAB
		---------g kg^{-1}--------		----------g kg^{-1}--------	
Conventional					
	Crimson Clover	7.8 ab[b]	0.3 b	9.2 a	9.0 a
	Rye	11.3 a	0.4 a	10.1 a	9.2 a
	Wheat	5.9 ab	0.3 b	9.6 a	8.1 a
	No Cover	3.0 b	0.3 b	9.1 a	9.2 a
	LSD[c]	5.2	0.1	1.9	1.4
Strip					
	Crimson Clover	---	---	---	---
	Rye	7.5 a	0.3 a	9.4 a	9.5 a
	Wheat	7.4 a	1.3 a	10.4 a	10.1 a
	No Cover	4.1 a	0.3 a	9.4 a	8.9 a
	LSD	4.0	1.5	1.4	2.1

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Days after cover crop burndown.

[b] Significant at P = 0.10.

[c] Least Significant Difference.

Table 3.8. Effects of cover crop species and tillage on soil nitrogen (N) and soil organic matter (OM) in Tifton, GA in 2010.

		Soil N		Soil OM	
Tillage	Cover Crop	10 DAB[a]	162 DAB	10 DAB	162 DAB
		-----------g kg^{-1}---------		-----------g kg^{-1}--------	
Conventional					
	Crimson Clover	9.2 a	1.6 a	6.5 a	6.6 a
	Rye	3.4 b	1.2 a	6.3 a	7.4 a
	Wheat	1.5 b	1.2 a	6.7 a	7.6 a
	No Cover	1.5 b	0.5 b	5.7 a	8.1 a
	LSD[b]	4.7	0.5	1.8	4.5
Strip					
	Crimson Clover	---	---	---	---
	Rye	1.9 a	0.6 a	5.7 a	6.8 a
	Wheat	2.1 a	0.9 a	5.7 a	9.8 a
	No Cover	1.7 a	0.9 a	6.4 a	7.9 a
	LSD	1.9	0.5	1.2	4.0

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Days after cover crop burndown.

[b] Least Significant Difference.

Table 3.9. Total nutrient content of peanut vegetation as affected by four cover crop treatments and two tillage treatments in Tifton, GA in 2009[a].

Tillage	Cover Crop	N	P	K	Ca	Mg	S	B	Mn	Zn
		----------	----------	----------	----------	kg ha^{-1}	----------	----------	----------	----------
Conventional										
	Crimson Clover	66 a	4 a	94 b	46 a	12 a	5 a	0.08 a	0.13 a	0.10 a
	Rye	62 a	4 a	93 b	47 a	12 a	4 a	0.08 a	0.12 a	0.09 a
	Wheat	59 a	4 a	77 b	48 a	13 a	3 a	0.08 a	0.08 a	0.07 a
	No Cover	70 a	4 a	115 a	61 a	15 a	6 a	0.10 a	0.17 a	0.06 a
	LSD[b]	34	1.8	19	23	6	2	0.03	0.10	0.05
Strip										
	Crimson Clover	---	---	---	---	---	---	---	---	---
	Rye	71 a	4 a	105 a	53 a	12 a	4 a	0.09 a	0.17 a	0.12 a
	Wheat	74 a	4 a	103 a	54 a	12 a	4 a	0.09 a	0.15 a	0.11 a
	No Cover	65 a	4 a	84 a	47 a	13 a	4 a	0.08 a	0.06 b	0.05 b
	LSD	22	1	23	14	3	1	0.02	0.03	0.03

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at $P = 0.05$.

[a] Nutrient data determined from the final sample date that year (15 Oct. 2009).

[b] Least Significant Difference.

Table 3.10. Total nutrient content of peanut vegetation as affected by four cover crop treatments and two tillage treatments in Tifton, GA in 2010[a].

Tillage	Cover Crop	N	P	K	Ca	Mg	S	B	Mn	Zn
		----------------------------------	-------	-------	-------kg ha^{-1}-------	-------	-------	-------	-------	----------------------------------
Conventional										
	Crimson Clover	95 a	6 a	108 a	57 a	15 a	7 a	0.13 a	0.12 a	0.09 a
	Rye	91 a	5 a	93 a	56 a	20 a	7 a	0.14 a	0.20 a	0.11 a
	Wheat	91 a	5 a	71 a	57 a	17 a	6 a	0.14 a	0.13 a	0.09 a
	No Cover	54 a	4 a	50 a	40 a	13 a	5 a	0.09 a	0.10 a	0.07 a
	LSD[b]	43	3	62	25	10	3	0.06	0.14	0.05
Strip										
	Crimson Clover	---	---	---	---	---	---	---	---	---
	Rye	84 a	5 a	86 b	57 a	17 a	7 a	0.14 a	0.13 a	0.08 a
	Wheat	80 a	5 a	98 b	53 a	14 a	6 a	0.13 a	0.10 a	0.10 a
	No Cover	88 a	4 a	126 a	73 a	17 a	7 a	0.15 a	0.11 a	0.11 a
	LSD	19	1	16	25	8	1	0.04	0.05	0.03

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Nutrient data determined from the final sample date that year (5 Oct. 2010).

[b] Least Significant Difference.

Table 3.11. Total nutrient content of peanut pods as affected by four cover crop treatments and two tillage treatments in Tifton, GA in 2009[a].

Tillage	Cover Crop	N	P	K	Ca	Mg	S	B	Mn	Zn
		-----------------	-----------------	-----------------	-----------------	kg ha^{-1}	-----------------	-----------------	-----------------	-----------------
Conventional										
	Crimson Clover	211 a	15 a	40 a	3.6 a	8.7 a	9.7 a	0.09 a	0.11 a	0.14 a
	Rye	174 a	12 a	31 a	3.1 a	7.2 a	8.0 a	0.07 a	0.09 a	0.13 a
	Wheat	176 a	13 a	35 a	3.8 a	8.0 a	8.7 a	0.07 a	0.09 a	0.12 a
	No Cover	210 a	13 a	38 a	4.0 a	8.5 a	9.7 a	0.08 a	0.10 a	0.10 a
	LSD[b]	58	4	12	2.2	3.1	2.9	0.03	0.04	0.06
Strip										
	Crimson Clover	---	---	---	---	---	---	---	---	---
	Rye	210 a	14 b[c]	39 ab[c]	4.1 a	8.0 a	9.5 a	0.08 a	0.12 a	0.15 a
	Wheat	230 a	16 a	45 a	4.3 a	9.7 a	10.7 a	0.09 a	0.13 a	0.17 a
	No Cover	189 a	13 b	34 b	3.6 a	8.2 a	8.5 a	0.07 a	0.08 b	0.11 b
	LSD	66	3	11	1.9	2.2	3.4	0.03	0.07	0.09

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Nutrient data determined from the final sample date that year (15 Oct. 2009).

[b] Least Significant Difference.

[c] Significant at P = 0.10.

Table 3.12. Total nutrient content of peanut pods as affected by four cover crop treatments and two tillage treatments in Tifton, GA in 2010[a].

Tillage	Cover Crop	N	P	K	Ca	Mg	S	B	Mn	Zn
		-----------------------------------	------	------	------kg ha^{-1}------	------	------	------	------	-------------------
Conventional										
	Crimson Clover	102 a	7.7 a	20 a	1.8 a	4.2 a	6.2 a	0.03 a	0.04 a	0.10 a
	Rye	97 a	7.8 a	21 a	1.5 a	4.3 a	6.2 a	0.05 a	0.04 a	0.06 a
	Wheat	103 a	7.7 a	21 a	1.7 a	4.3 a	6.6 a	0.03 a	0.04 a	0.10 a
	No Cover	95 a	7.7 a	18 a	1.8 a	4.3 a	6.7 a	0.03 a	0.04 a	0.06 a
	LSD[b]	100	7.0	18	1.6	4.0	6.3	0.03	0.04	0.06
Strip										
	Crimson Clover	---	---	---	---	---	---	---	---	---
	Rye	126 a	9.5 a	28 a	2.2 a	5.6 a	8.2 a	0.05 a	0.06 a	0.07 a
	Wheat	132 a	9.7 a	26 a	2.0 a	5.4 a	8.3 a	0.04 a	0.06 a	0.08 a
	No Cover	130 a	9.8 a	29 a	2.1 a	5.8 a	8.5 a	0.04 a	0.06 a	0.09 a
	LSD	28	3.0	8	0.8	1.5	2.3	0.02	0.02	0.03

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Nutrient data determined from the final sample date that year (5 Oct. 2010).

[b] Least Significant Difference.

Table 3.13. Total nutrient content of peanut pods as affected by tillage in Tifton, GA in 2009-2010.

Year	Tillage	N	P	K	Ca	Mg	S	B	Mn	Zn
		----------	----------	----------	----------	kg ha^{-1}	----------	----------	----------	----------
2009										
	Conventional	187 a	13 a	35 a	3.6 a	7.9 a	8.8 a	0.08 a	0.09 a	0.12 b[a]
	Strip	209 a	14 a	39 a	4.0 a	8.6 a	9.5 a	0.07 a	0.11 a	0.14 a
	LSD[b]	48	3	7	1.8	2.3	2.4	0.03	0.03	0.02
2010										
	Conventional	98 b[a]	7.7 a	20 b	1.6 a	4.3 b[a]	6.5 b[a]	0.04 a	0.04 b	0.06 b[a]
	Strip	129 a	9.6 a	27 a	2.1 a	5.6 a	8.3 a	0.04 a	0.06 a	0.08 a
	LSD	31	2.4	6	0.6	1.3	2.0	0.01	0.01	0.02

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Significant at P = 0.10.

[b] Least significant difference.

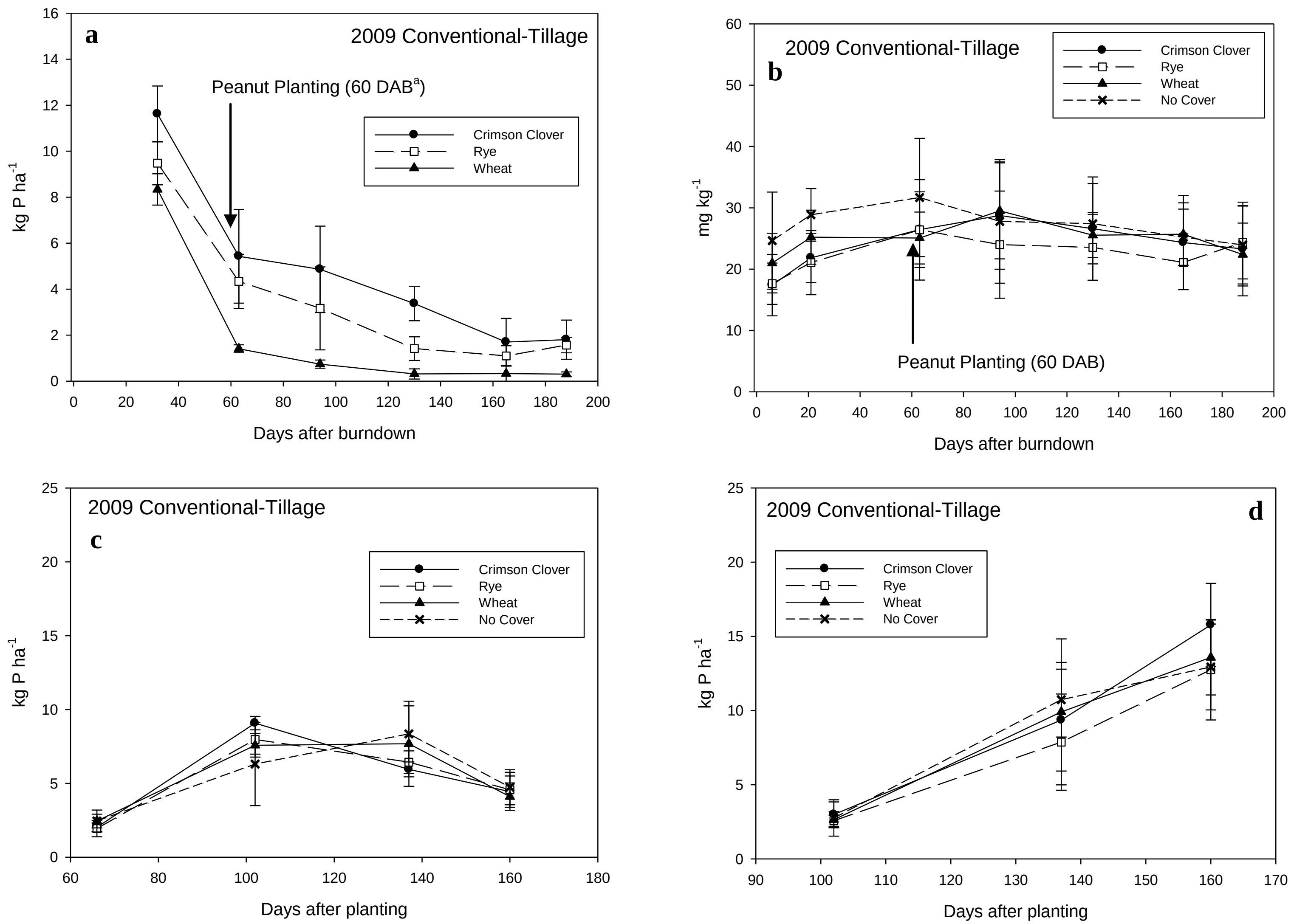

Figure 3.3. Phosphorus content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

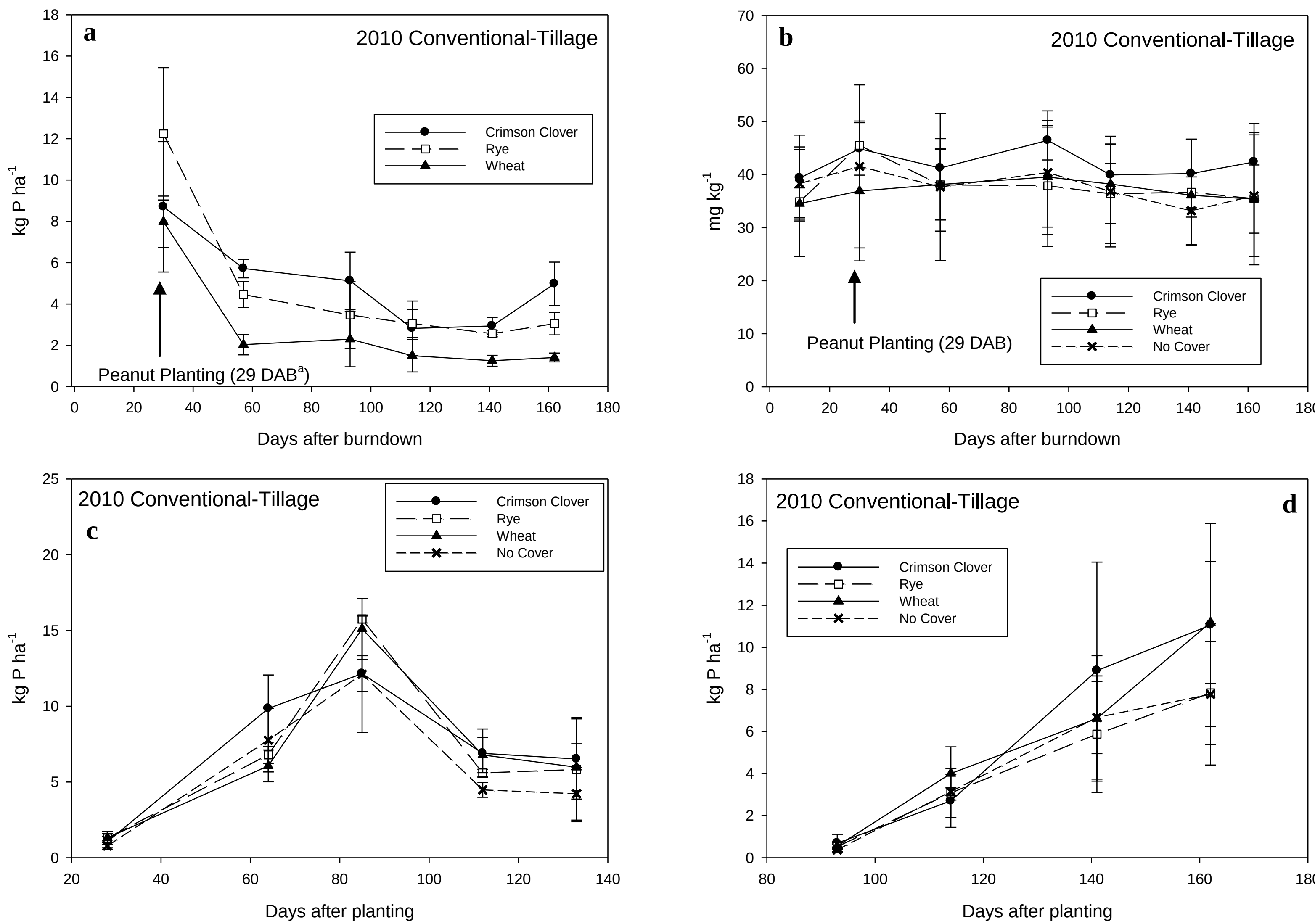

Figure 3.4. Phosphorus content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

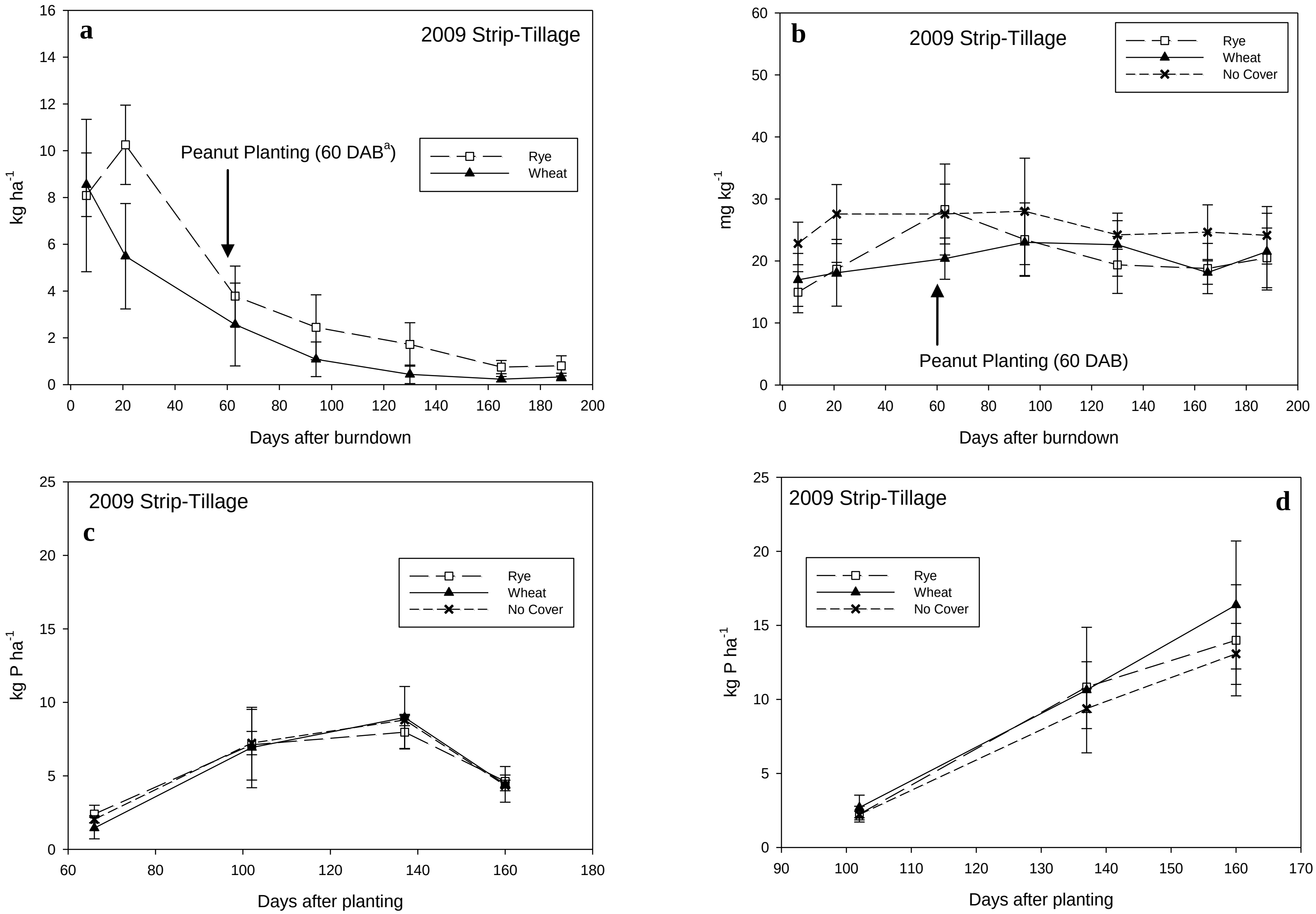

Figure 3.5. Phosphorus content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

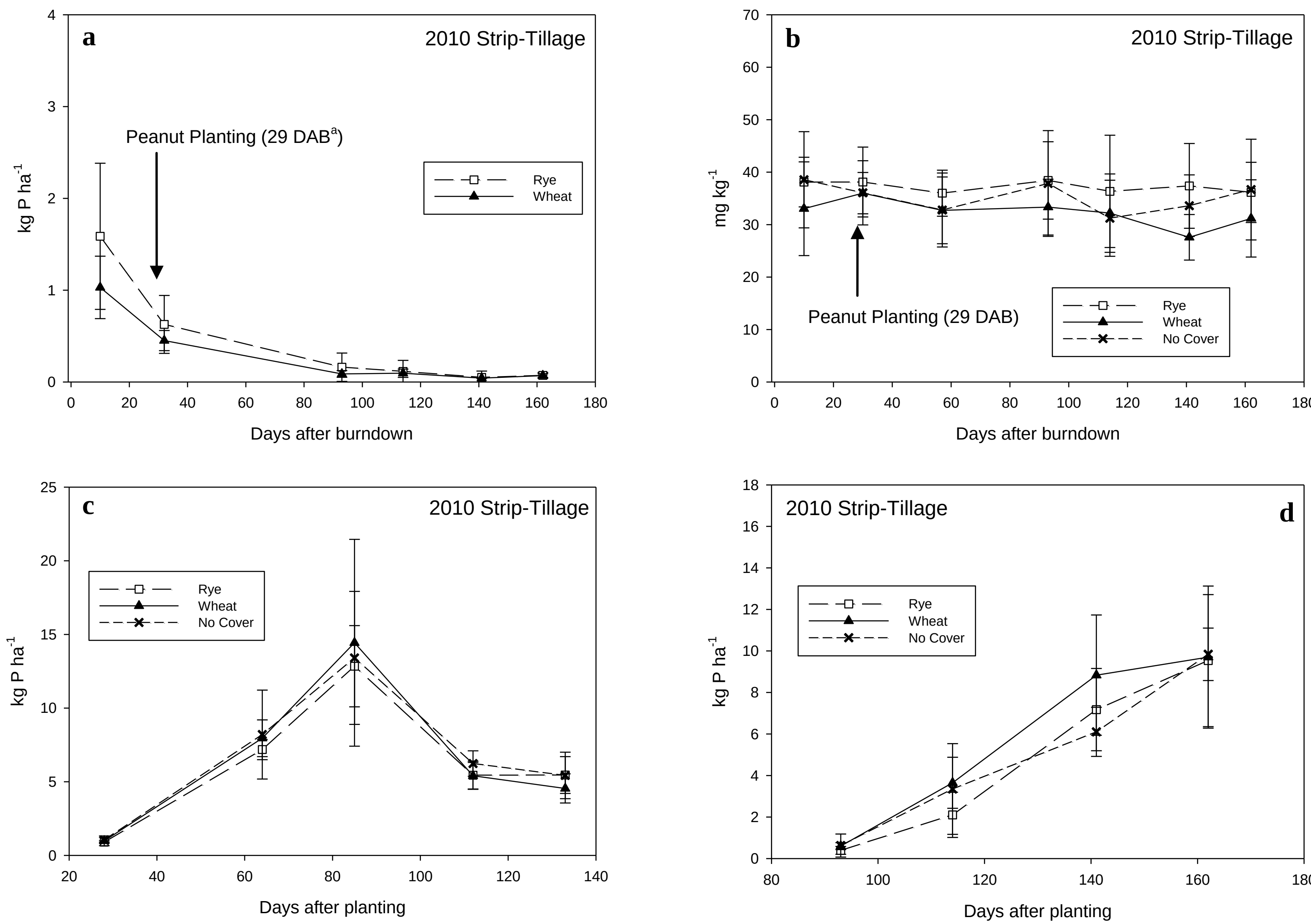

Figure 3.6. Phosphorus content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

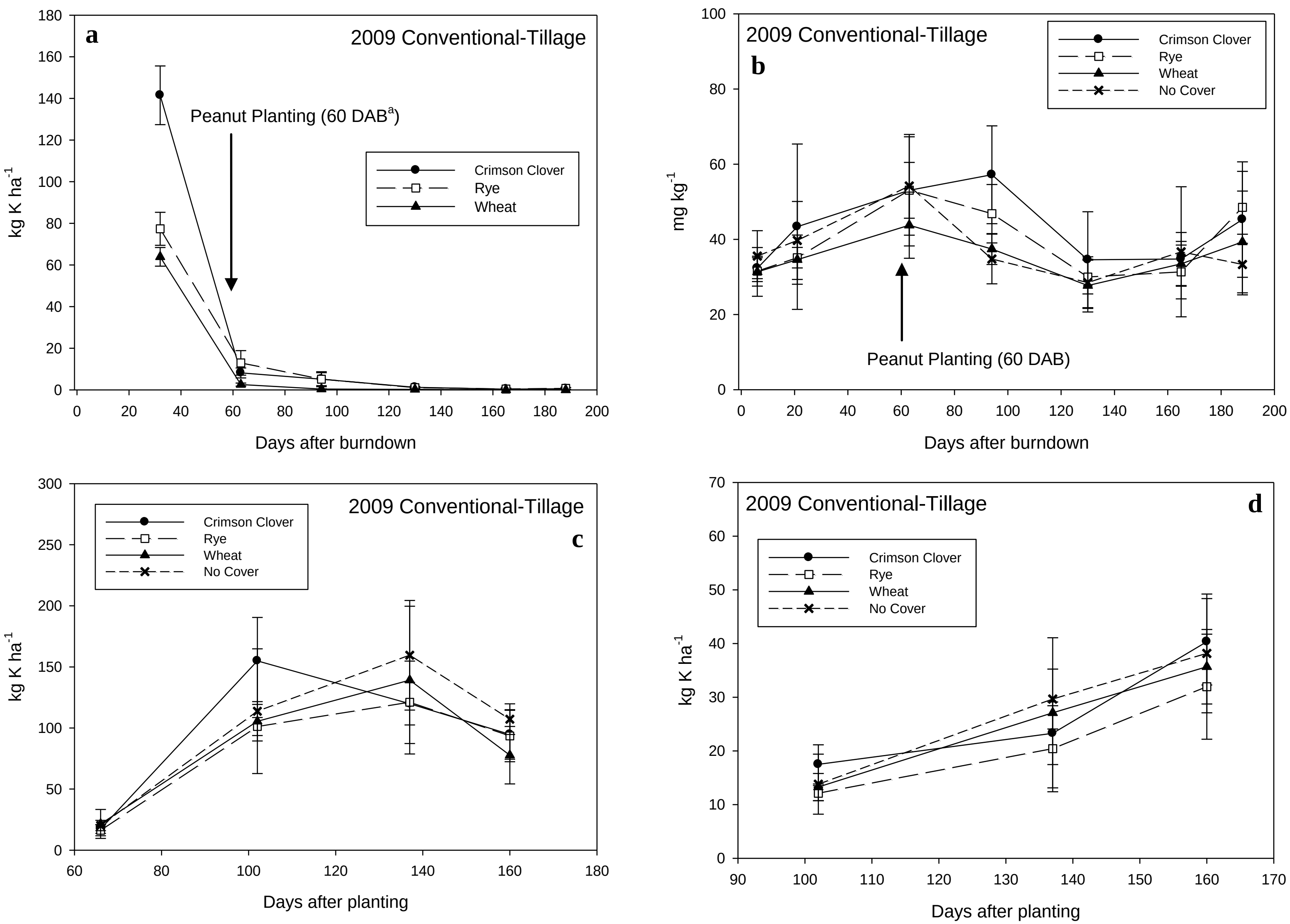

Figure 3.7. Potassium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

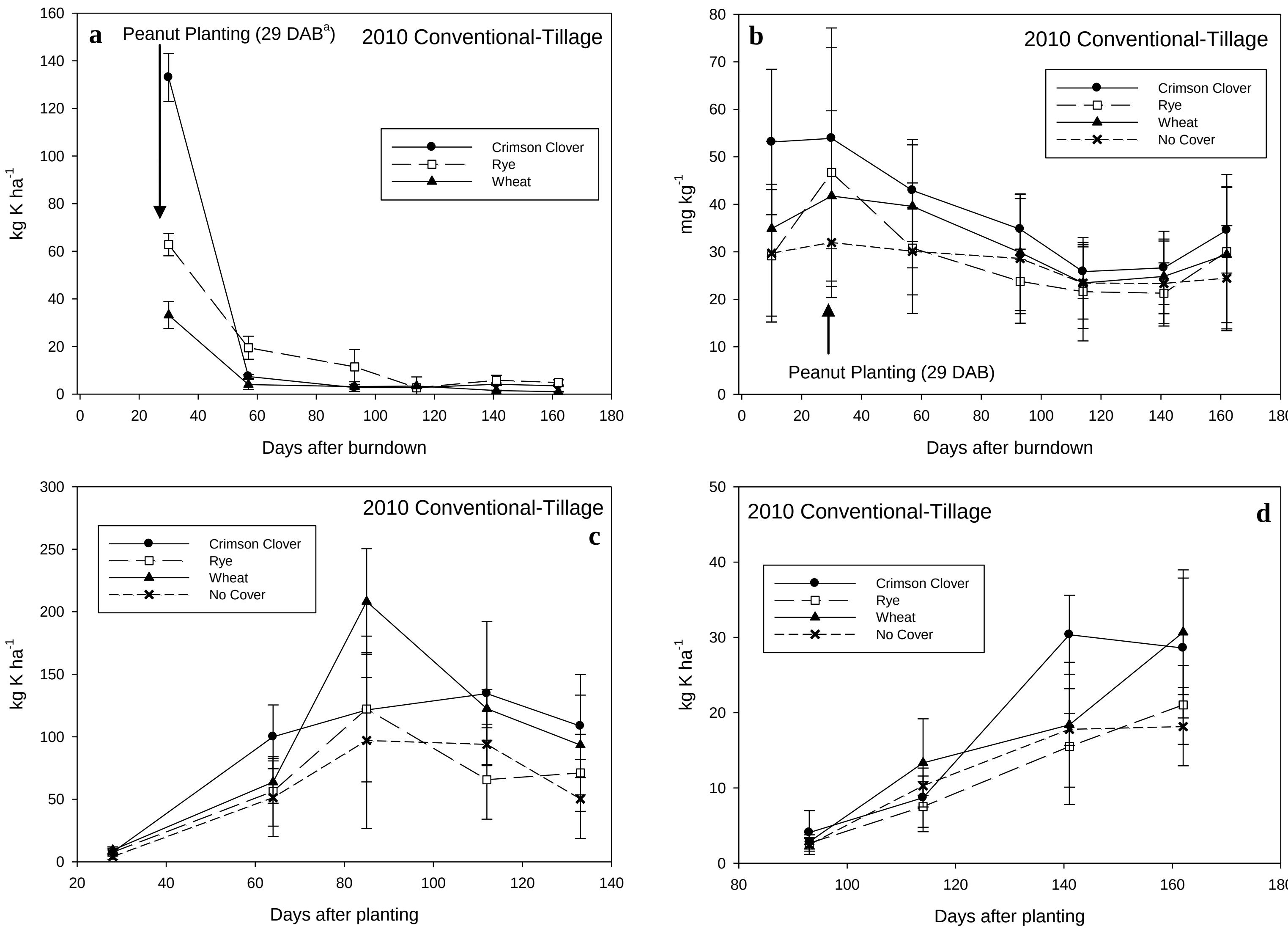

Figure 3.8. Potassium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

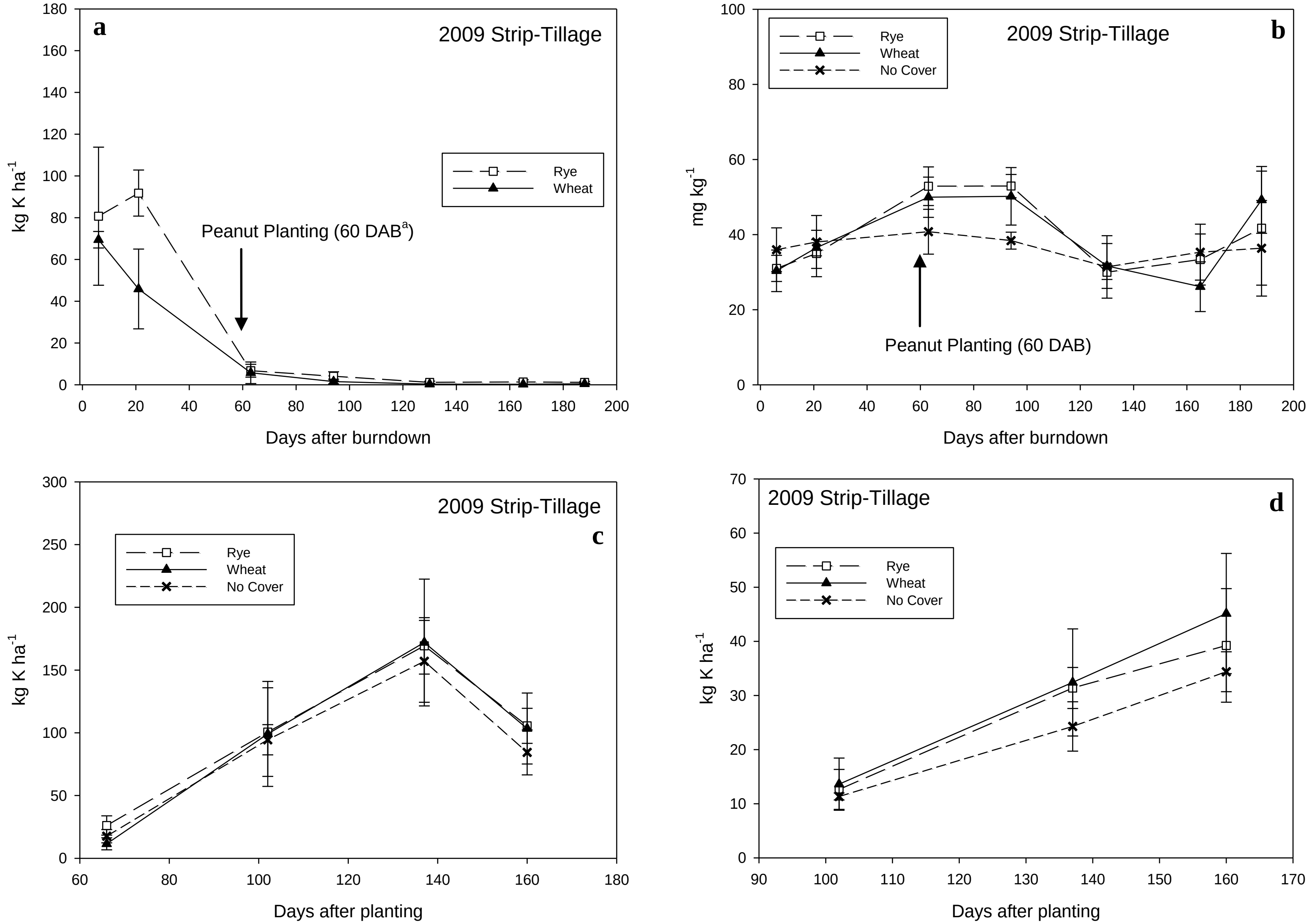

Figure 3.9. Potassium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

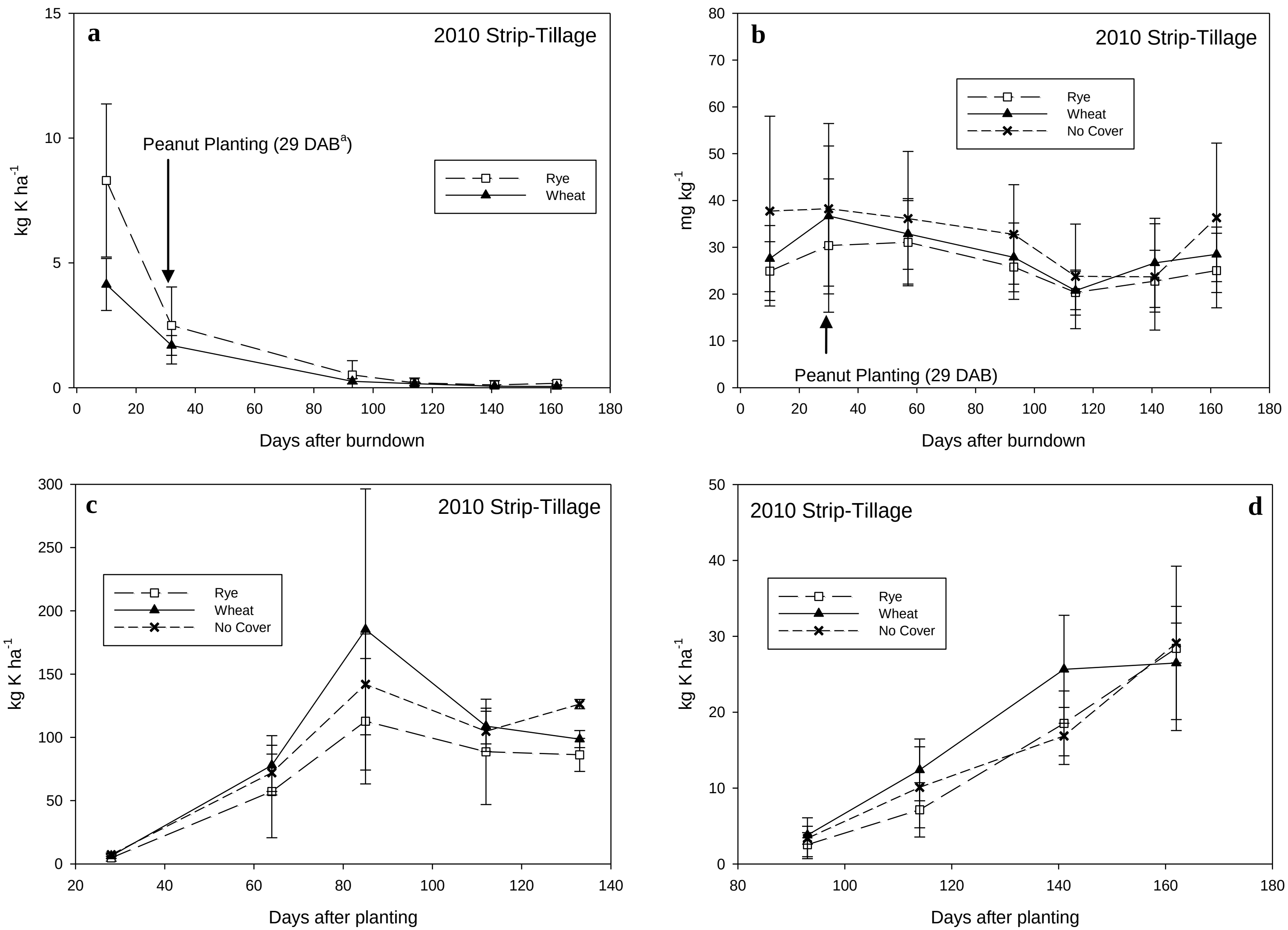

Figure 3.10. Potassium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

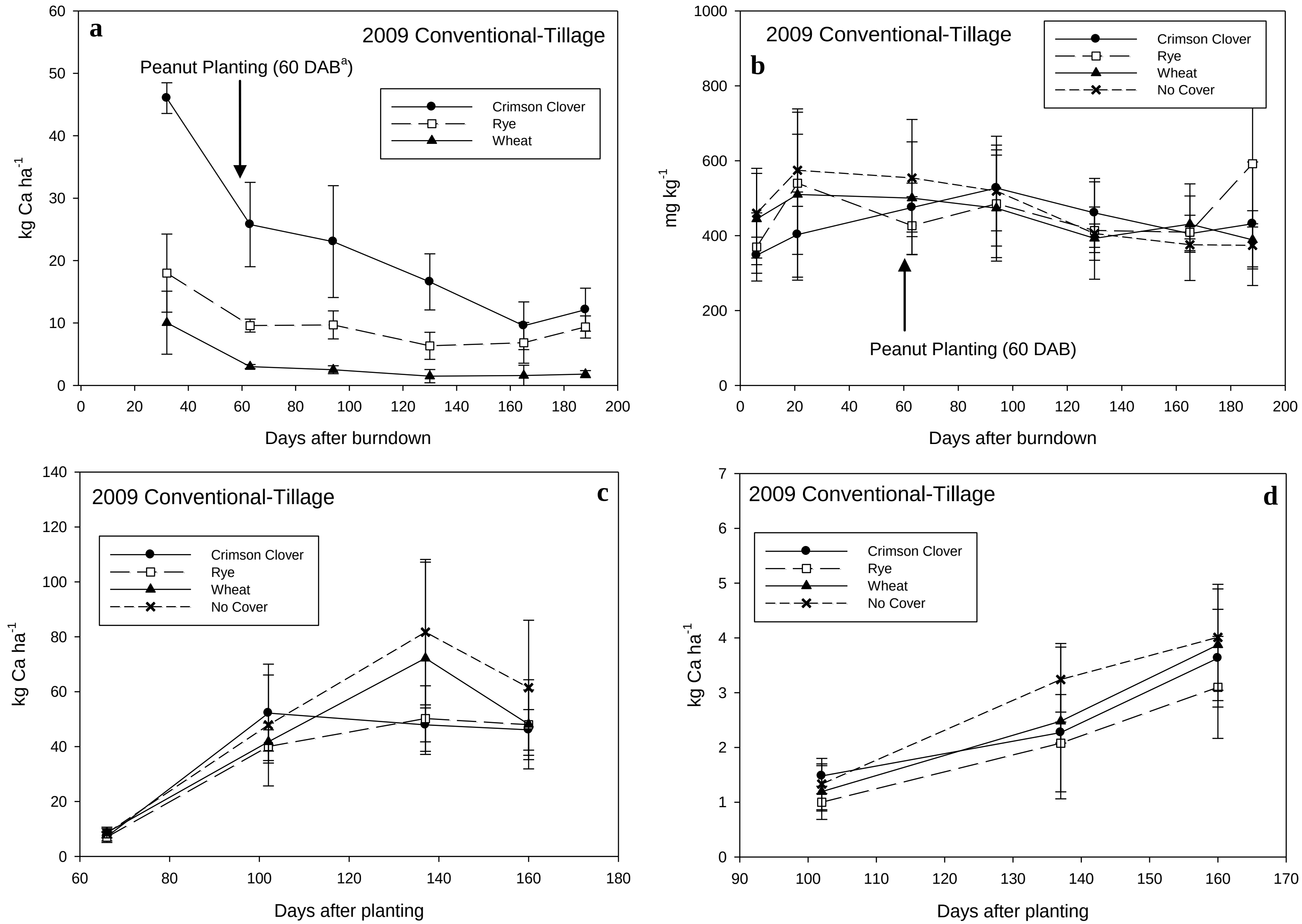

Figure 3.11. Calcium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

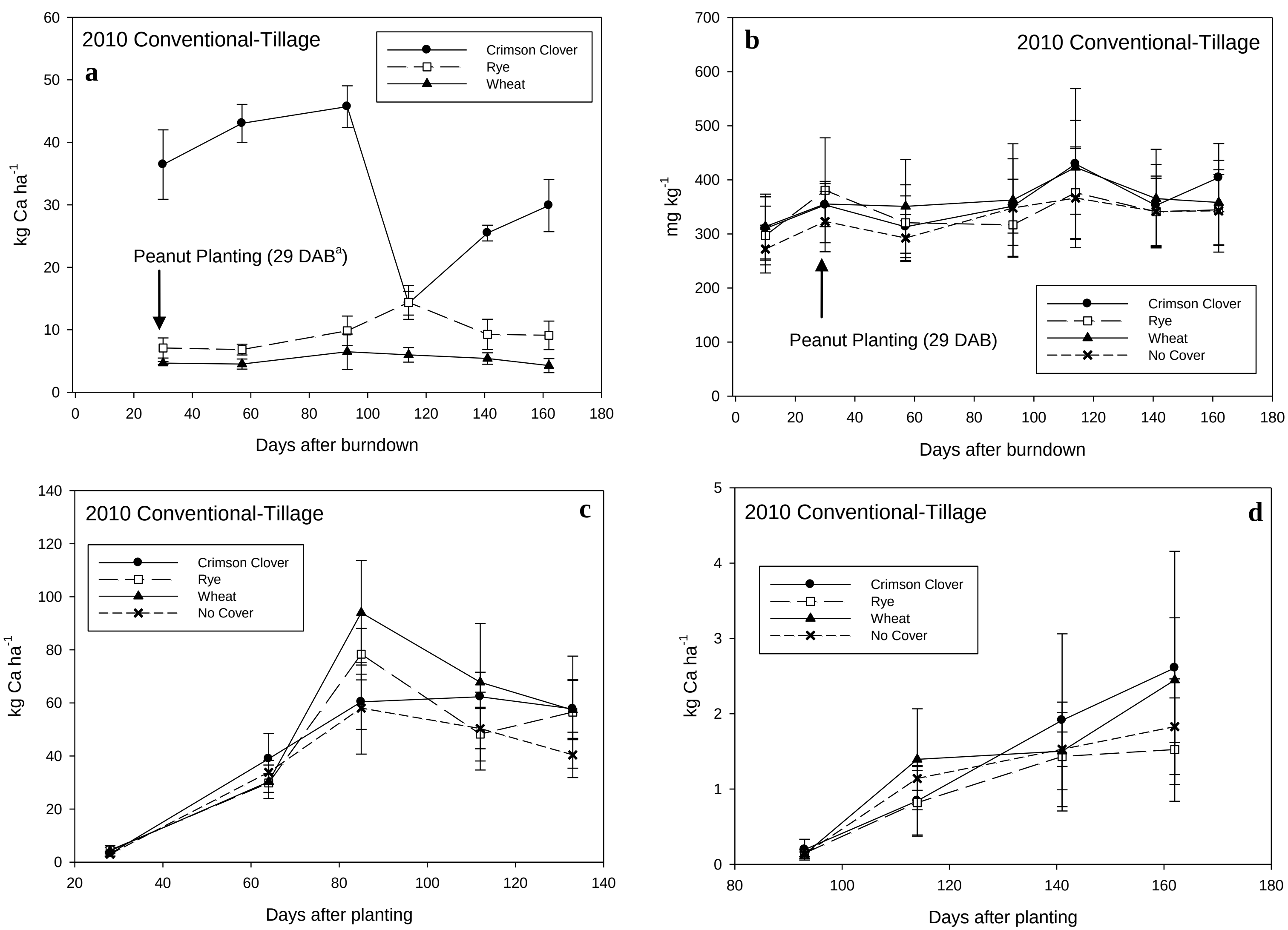

Figure 3.12. Calcium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

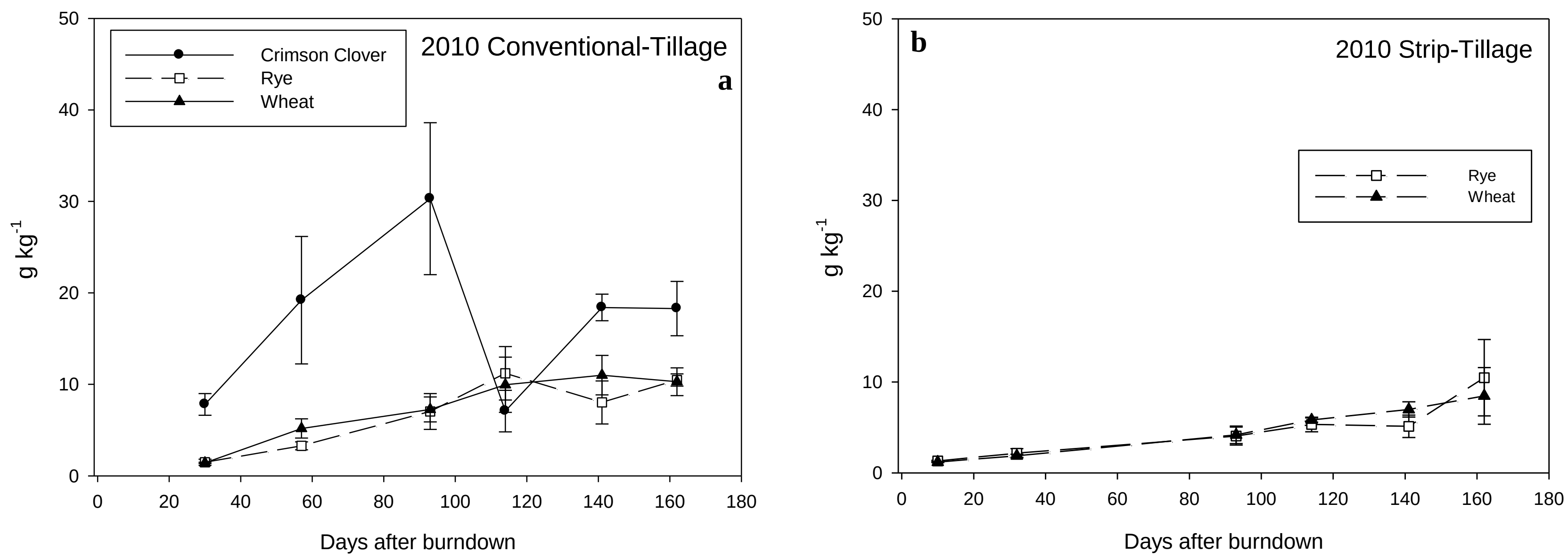

Figure 3.13. Calcium concentration of three cover crop residues in (a) conventional-tillage and (b) strip-tillage in Tifton, GA, 2010.

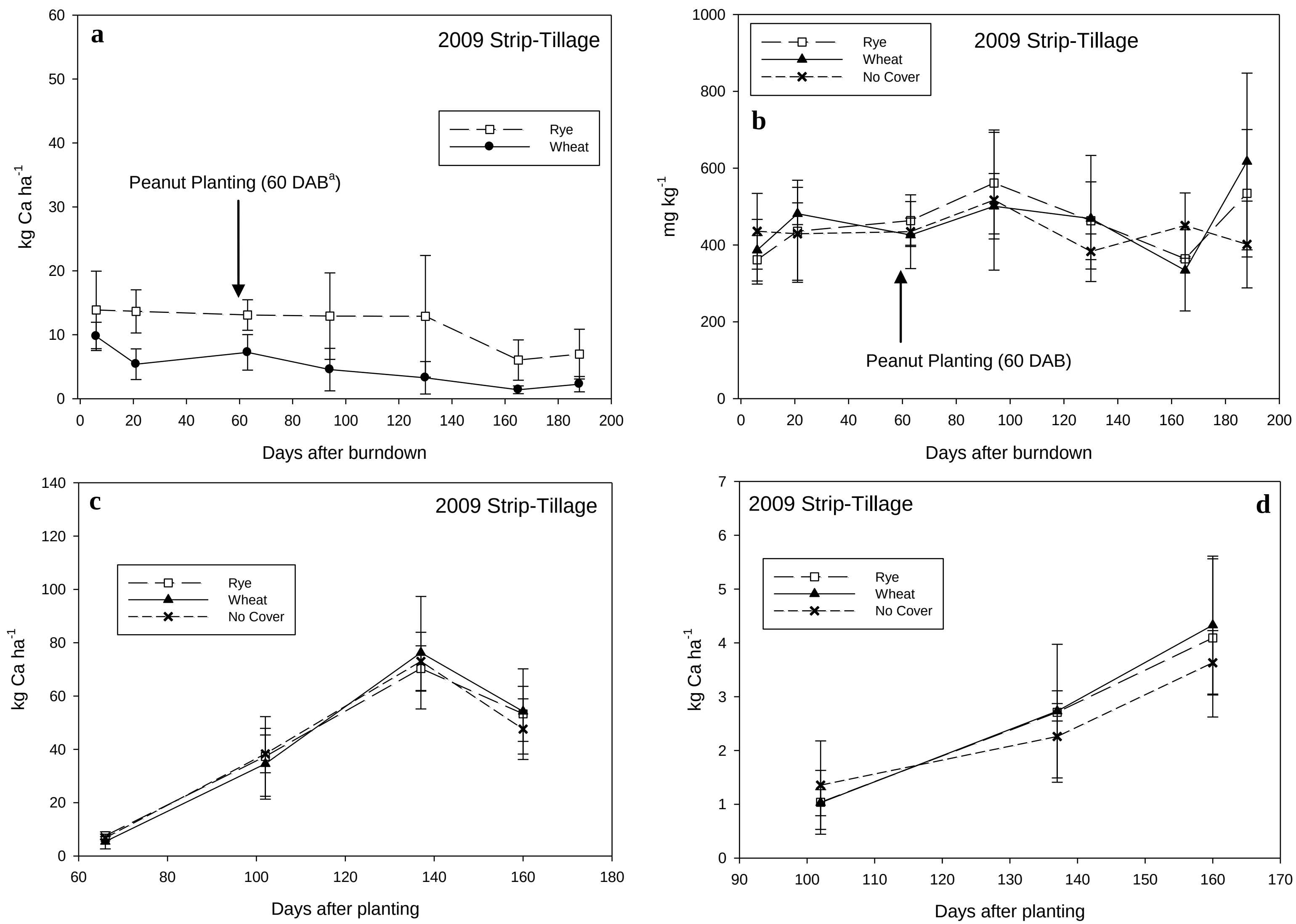

Figure 3.14. Calcium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

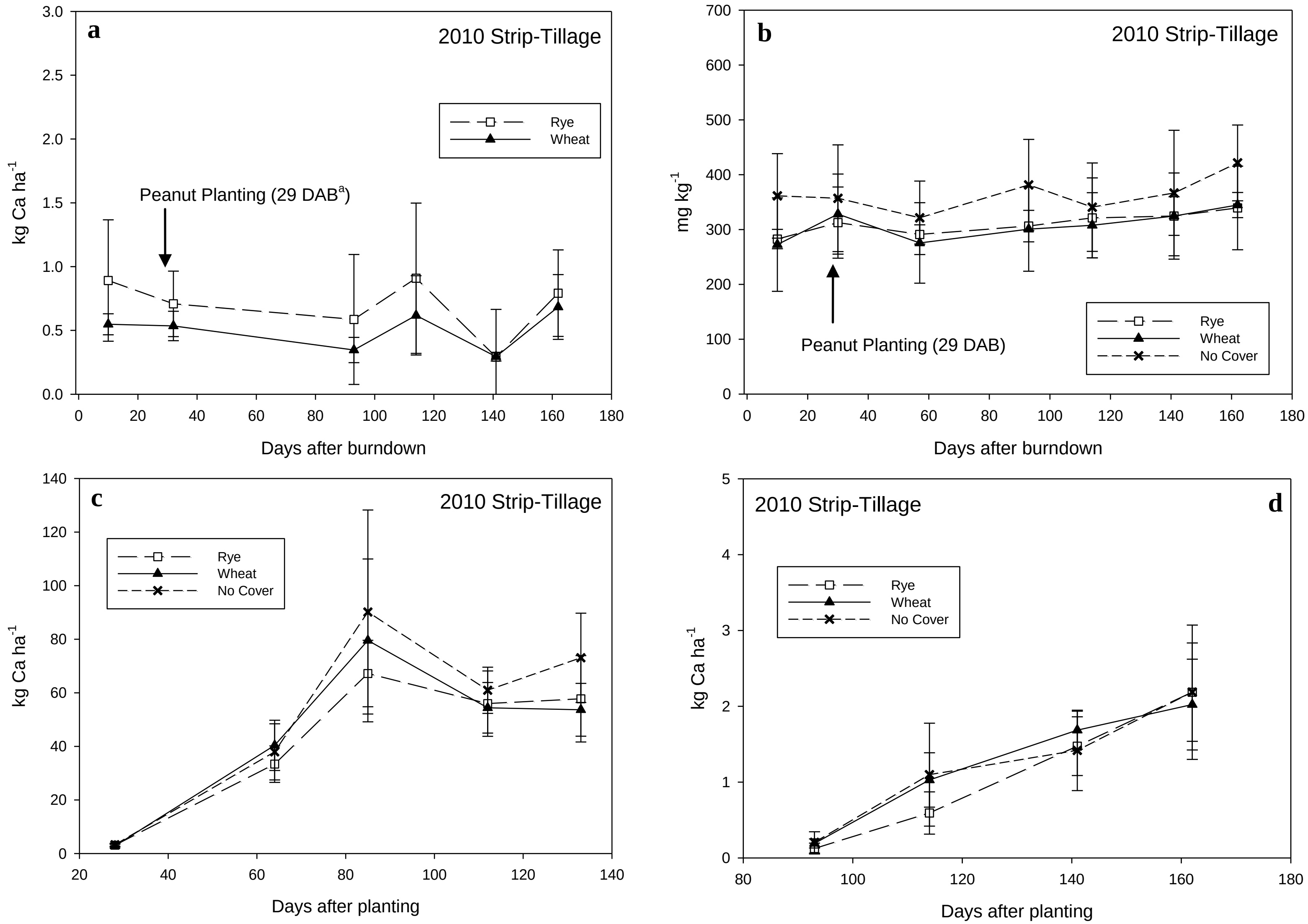

Figure 3.15. Calcium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

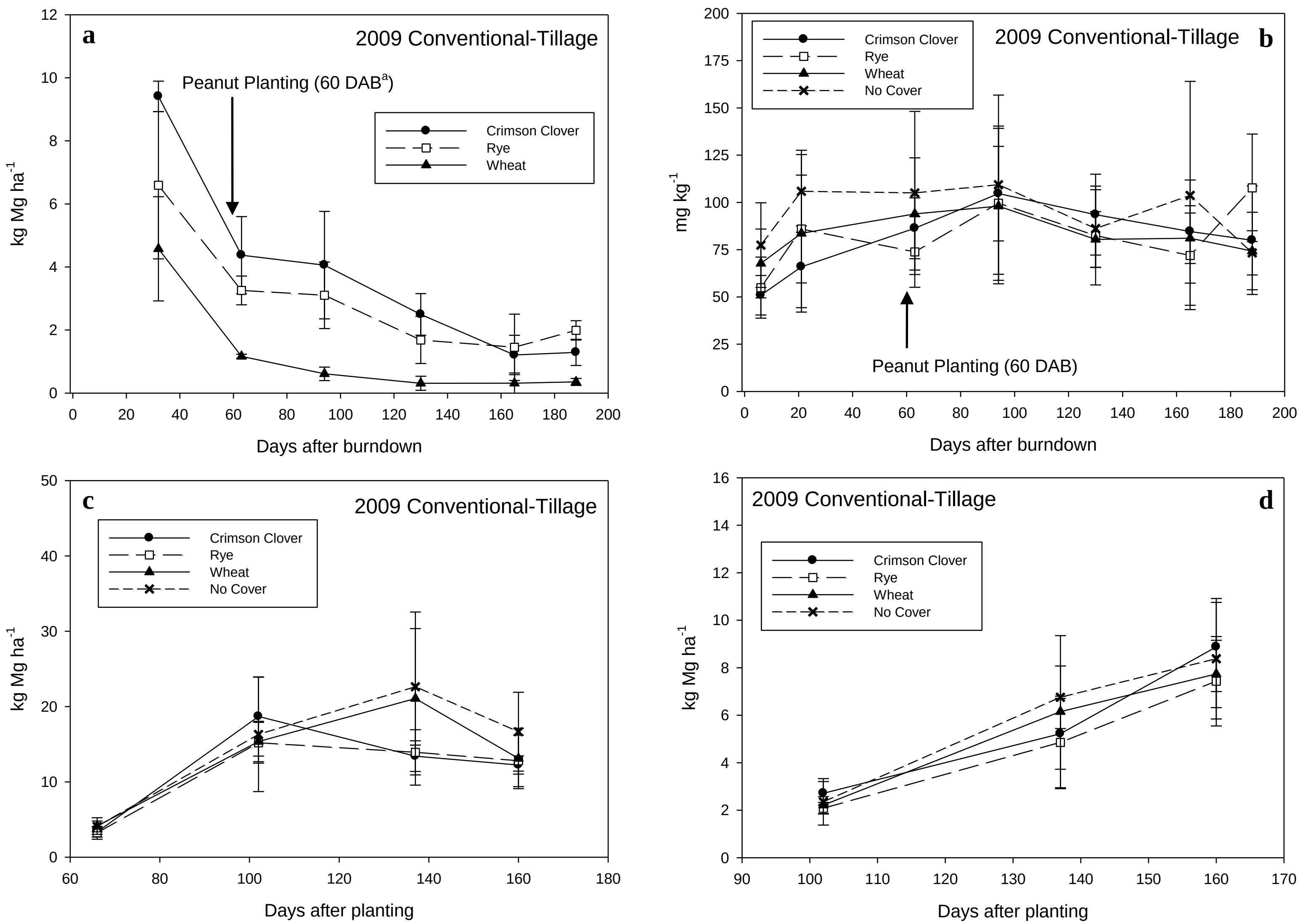

Figure 3.16. Magnesium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

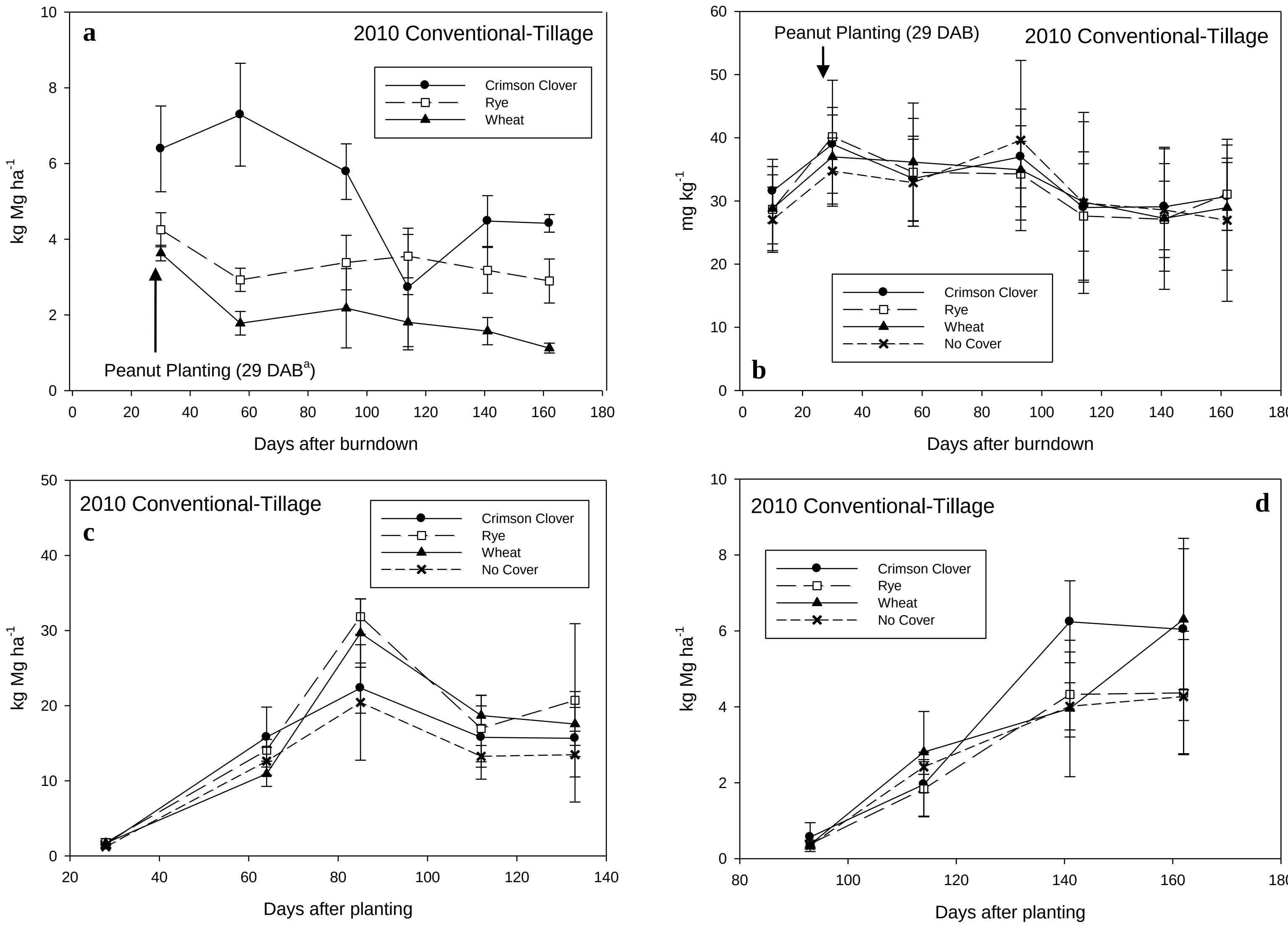

Figure 3.17. Magnesium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

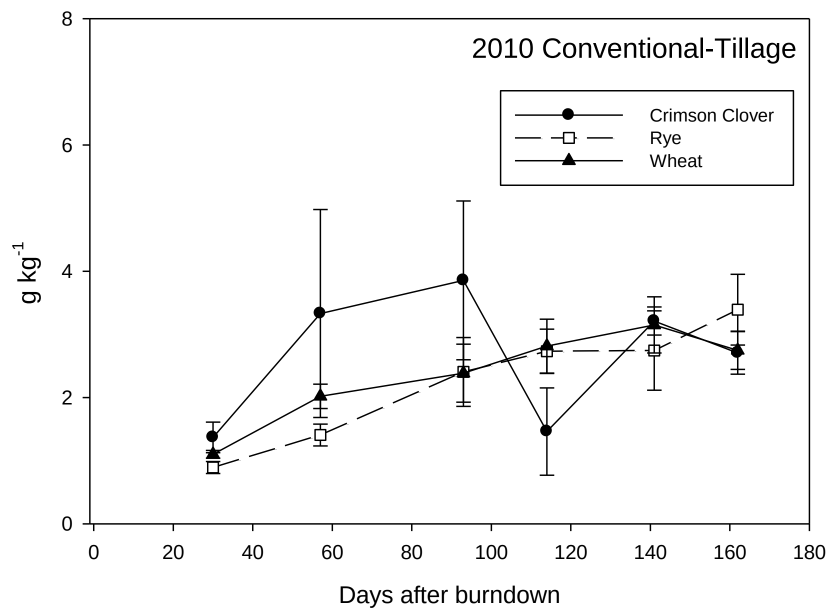

Figure 3.18. Magnesium concentration of three cover crop residues in conventional-tillage in Tifton, GA, 2010.

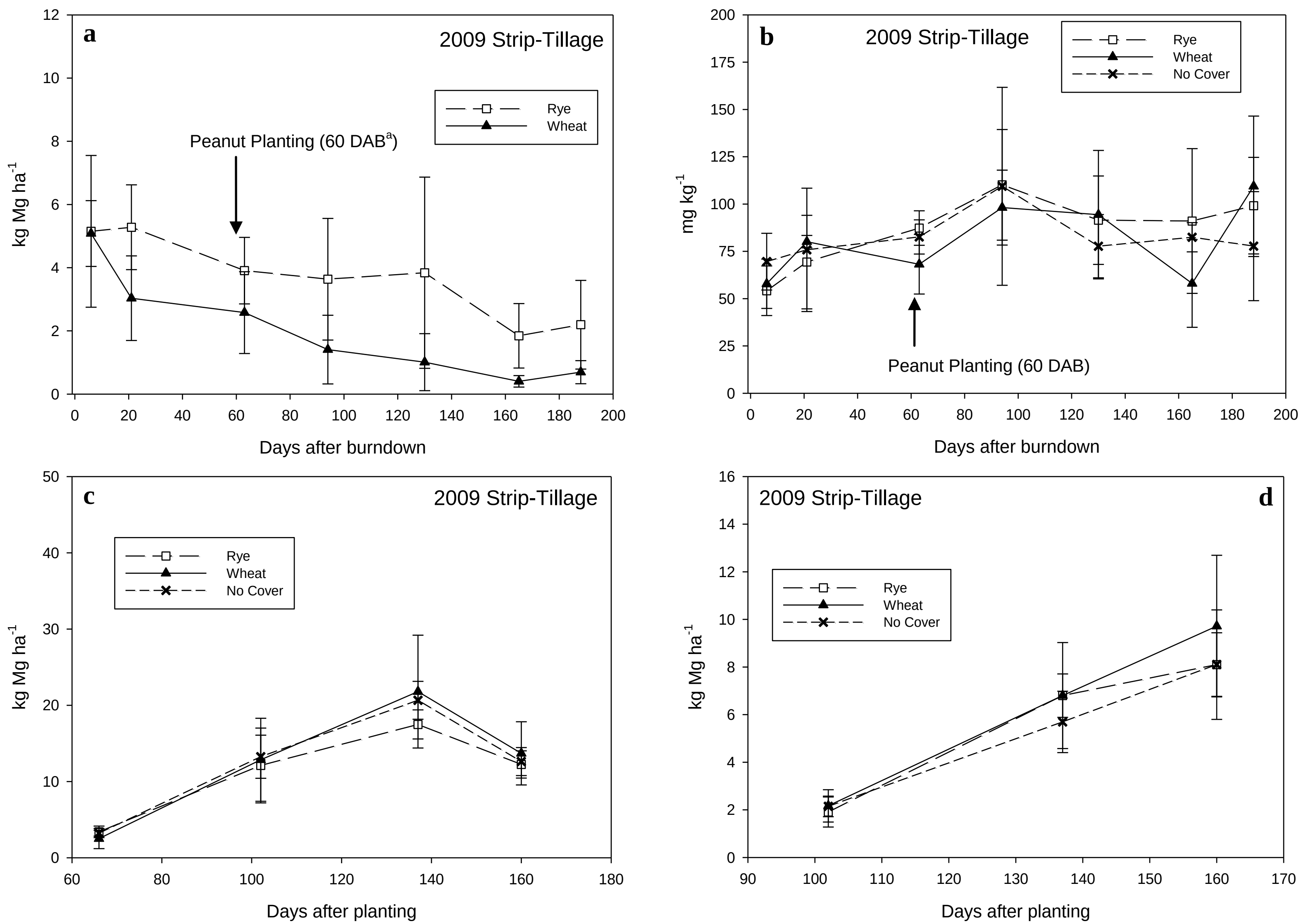

Figure 3.19. Magnesium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

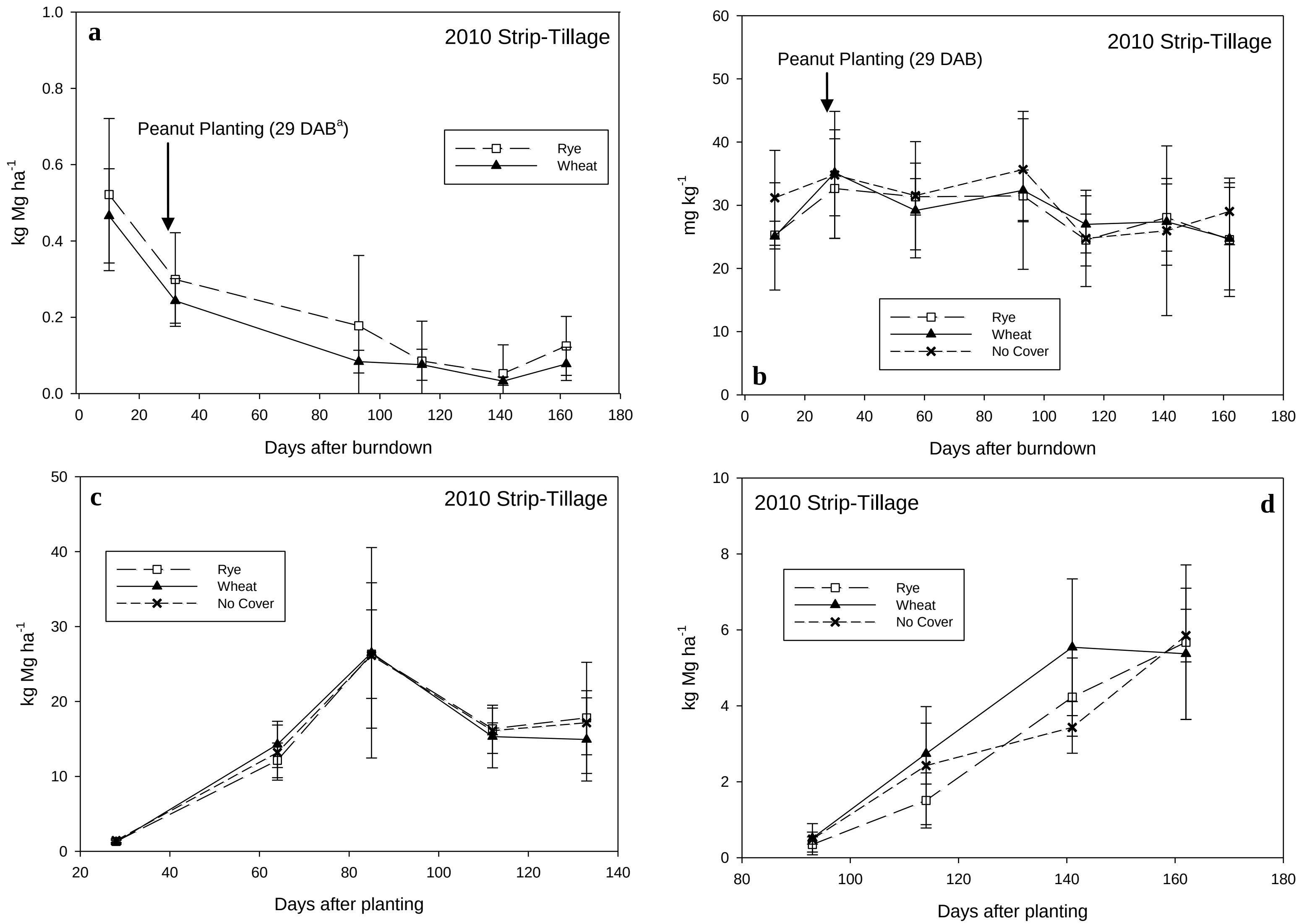

Figure 3.20. Magnesium content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

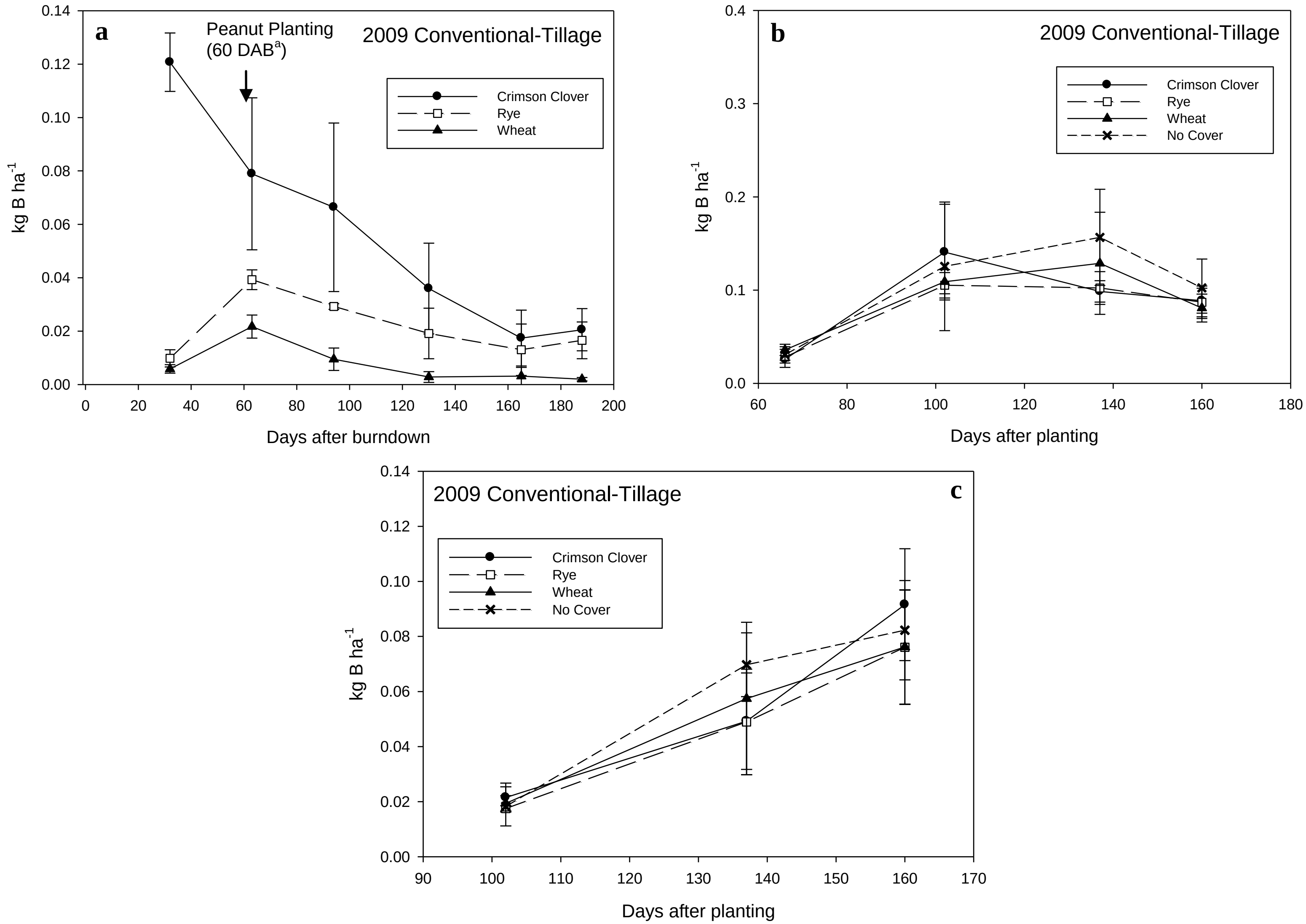

Figure 3.21. Boron content of (a) cover crop tissues and (b) peanut vegetation and (c) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

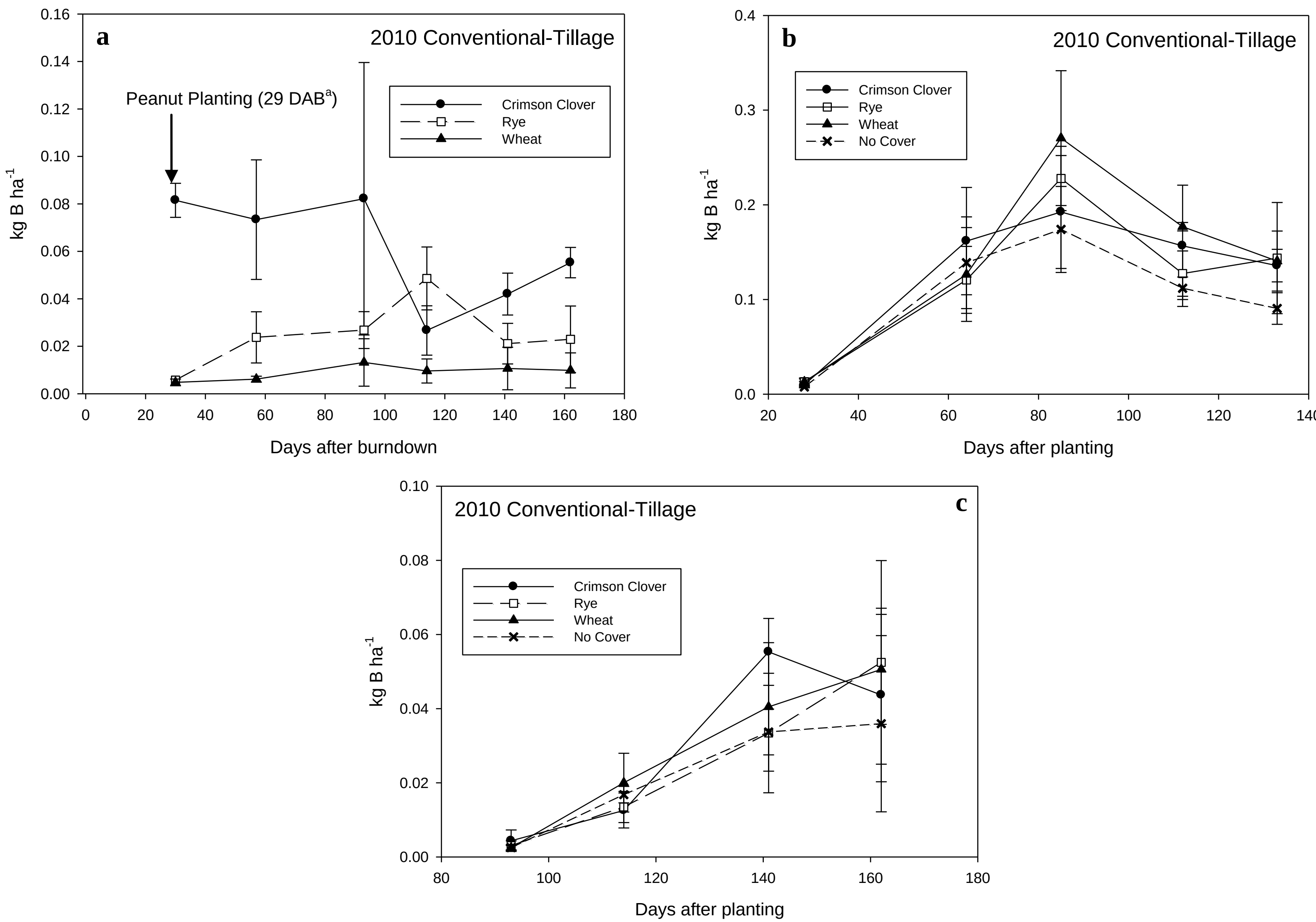

Figure 3.22. Boron content of (a) cover crop tissues and (b) peanut vegetation and (c) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

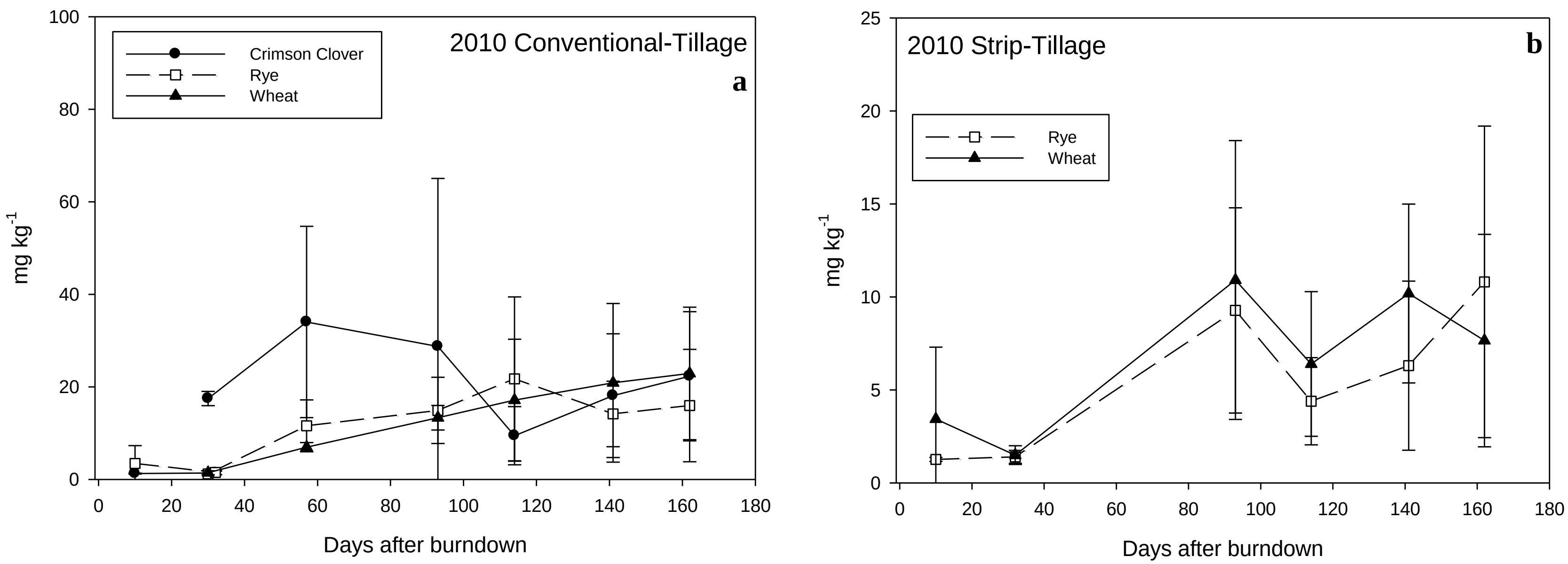

Figure 3.23. Boron concentration of three cover crop residues in (a) conventional-tillage and (b) strip-tillage in Tifton, GA, 2010.

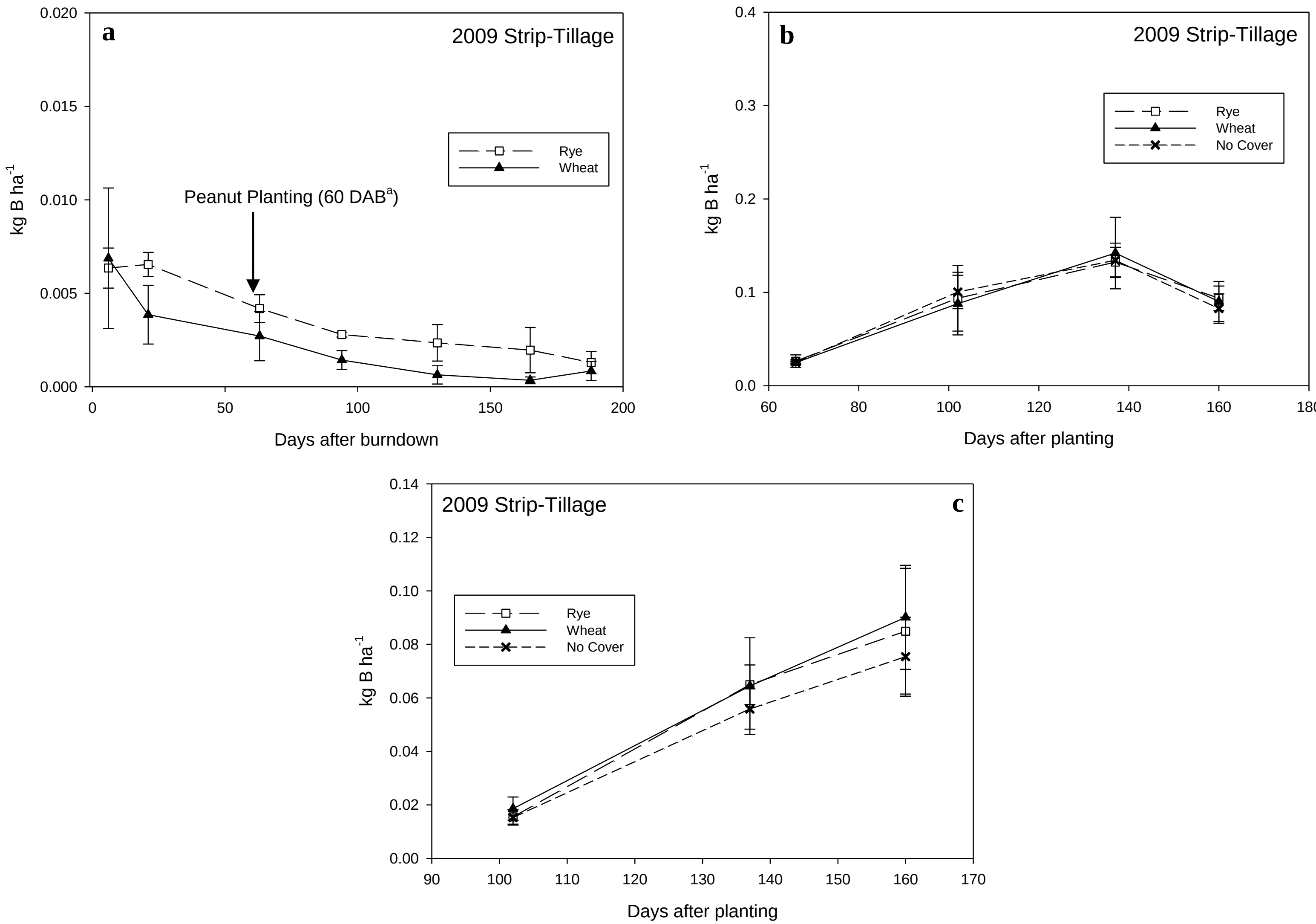

Figure 3.24. Boron content of (a) cover crop tissues and (b) peanut vegetation and (c) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

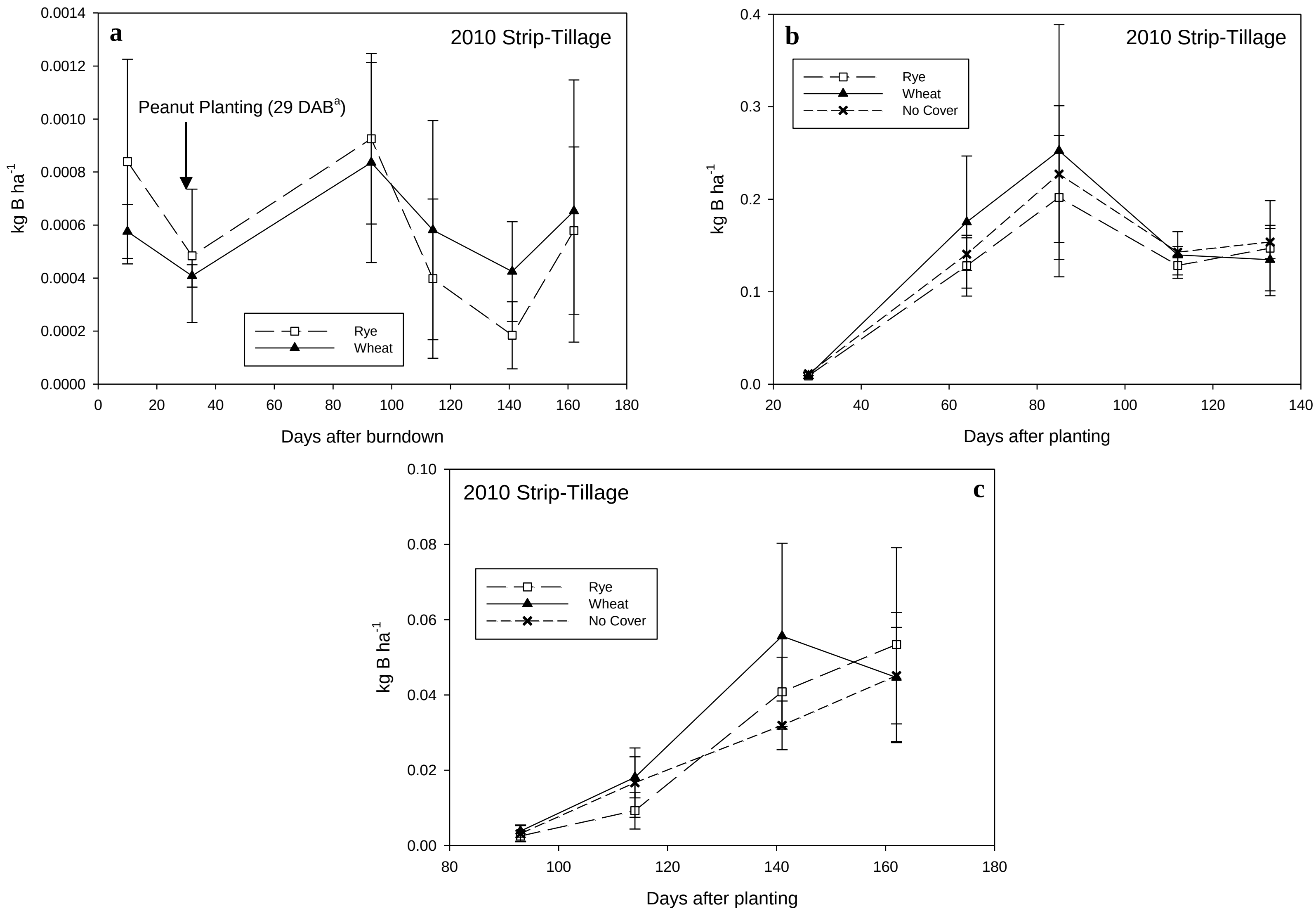

Figure 3.25. Boron content of (a) cover crop tissues and (b) peanut vegetation and (c) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

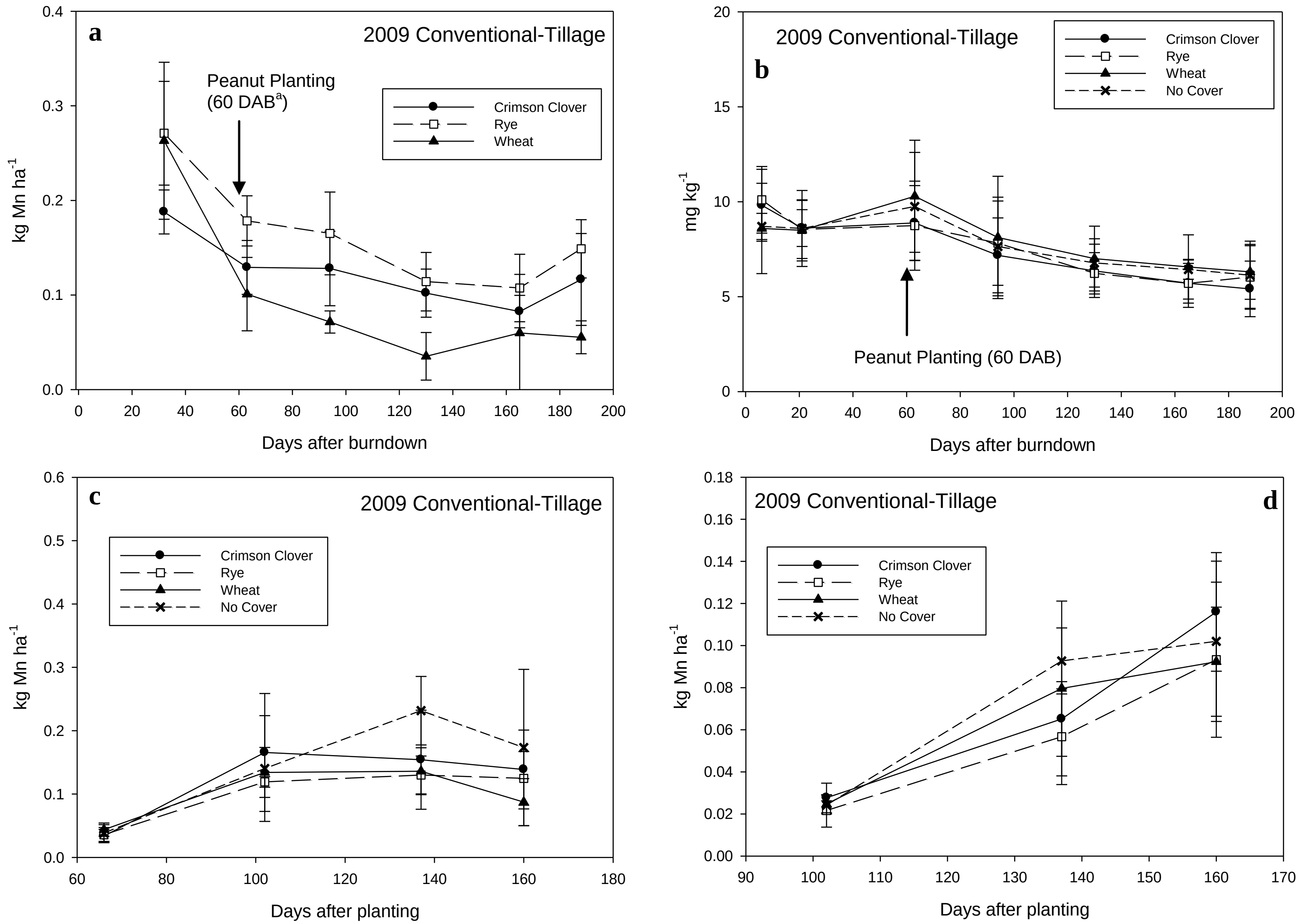

Figure 3.26. Manganese content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

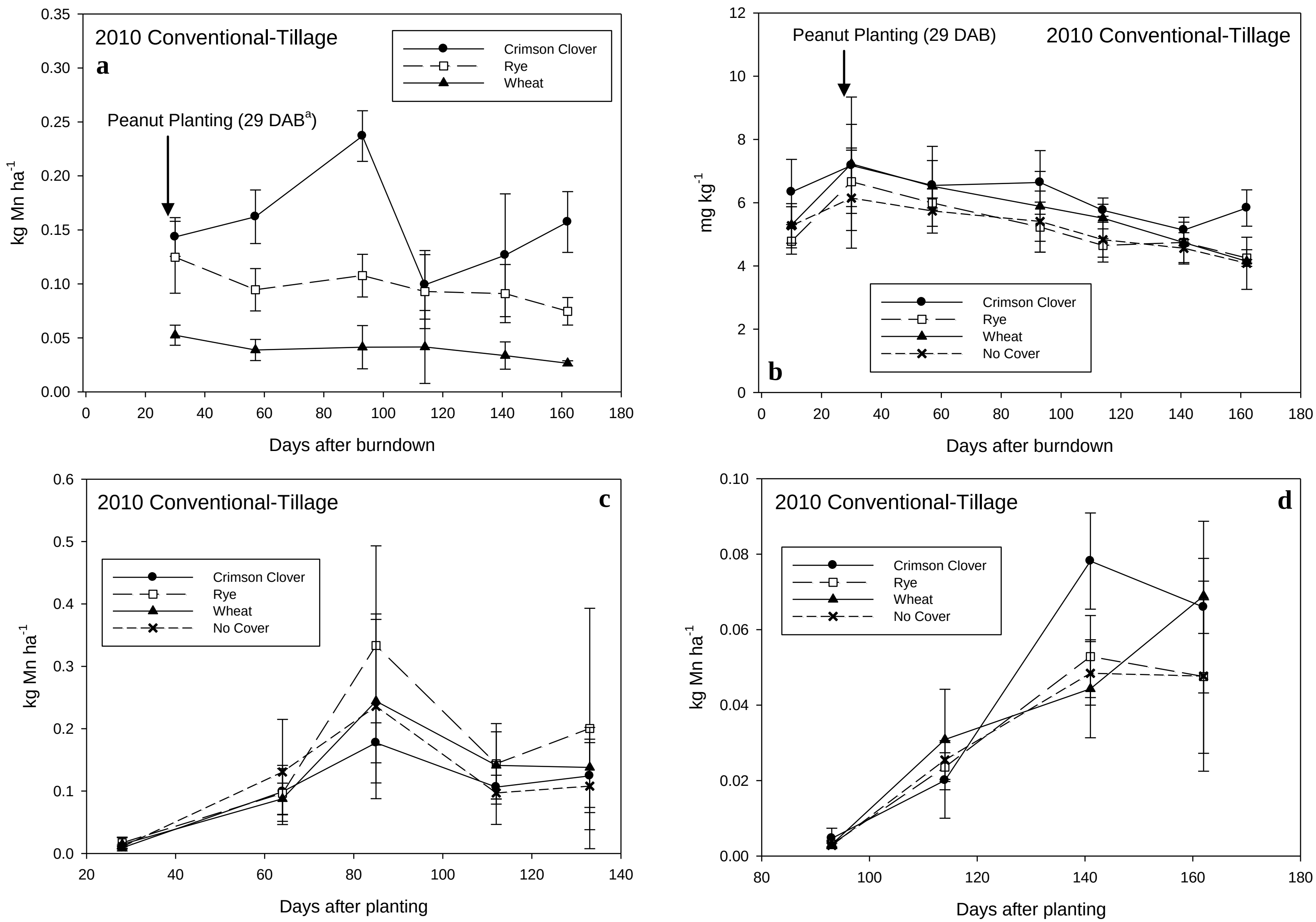

Figure 3.27. Manganese content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

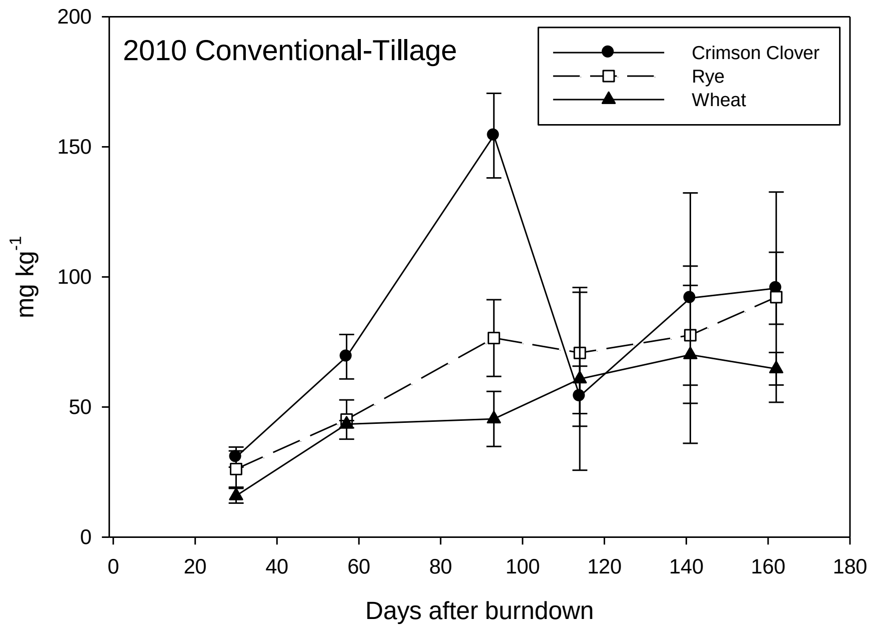

Figure 3.28. Manganese concentration of three cover crop residues in conventional-tillage in Tifton, GA, 2010.

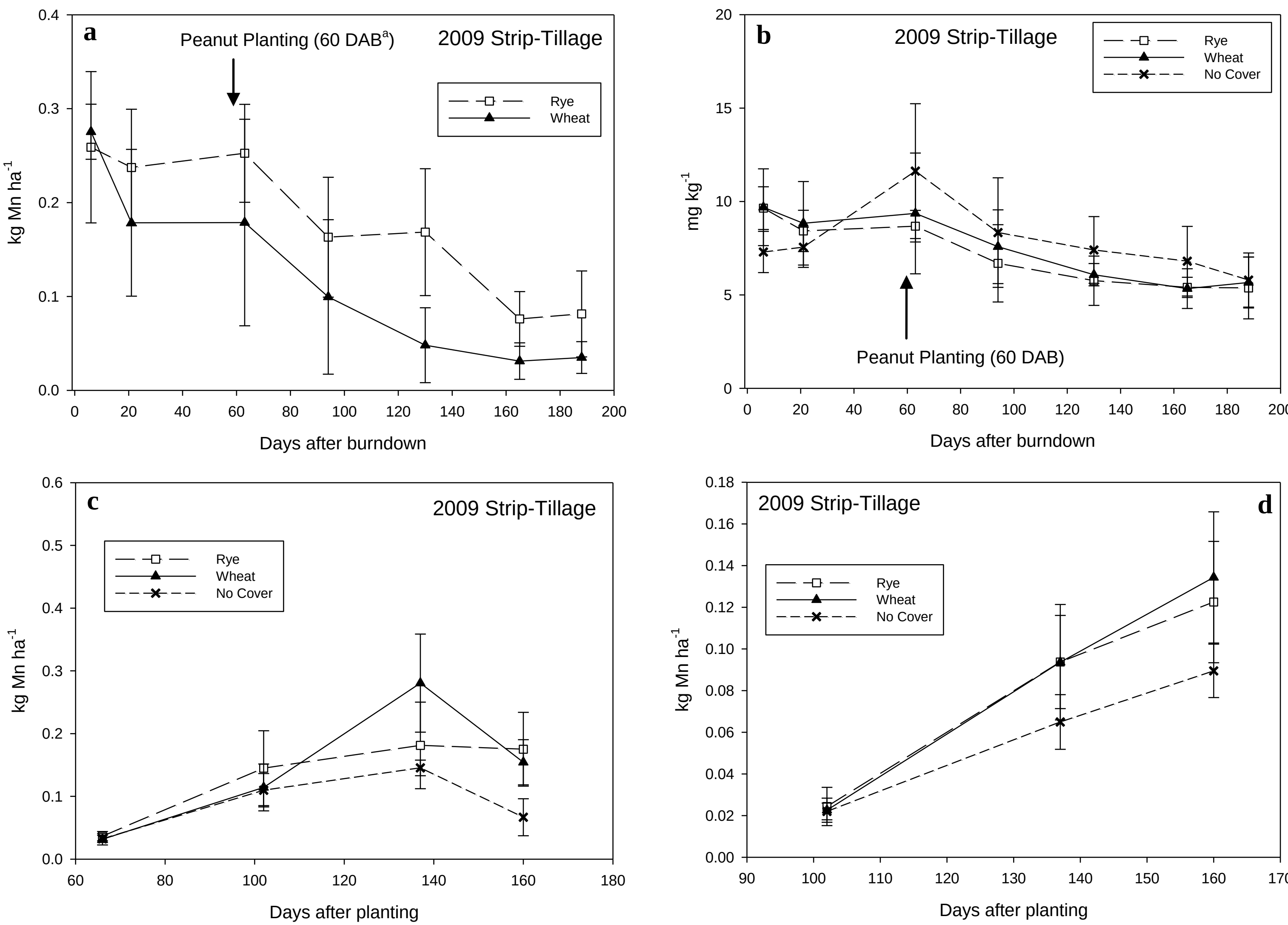

Figure 3.29. Manganese content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

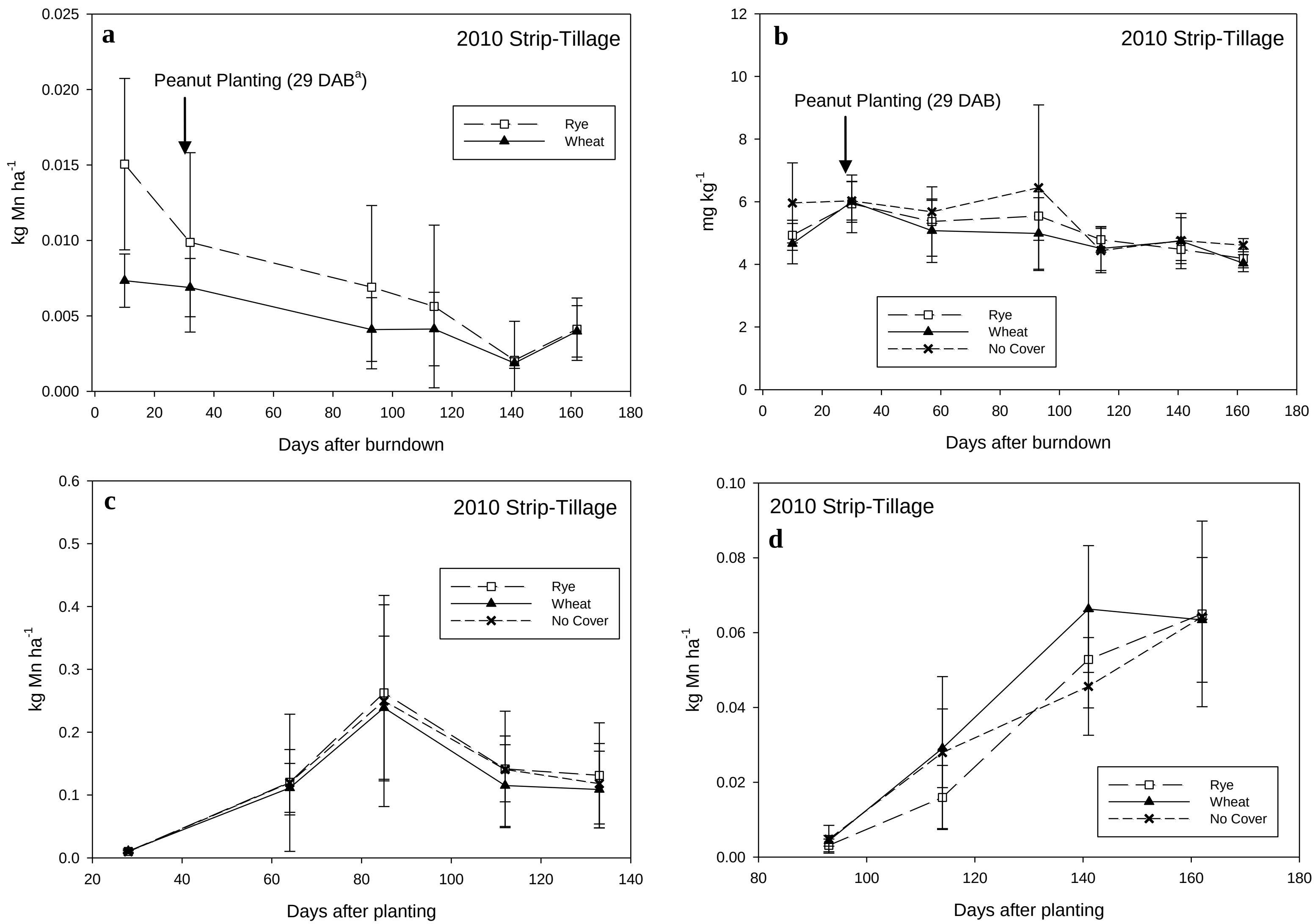

Figure 3.30. Manganese content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

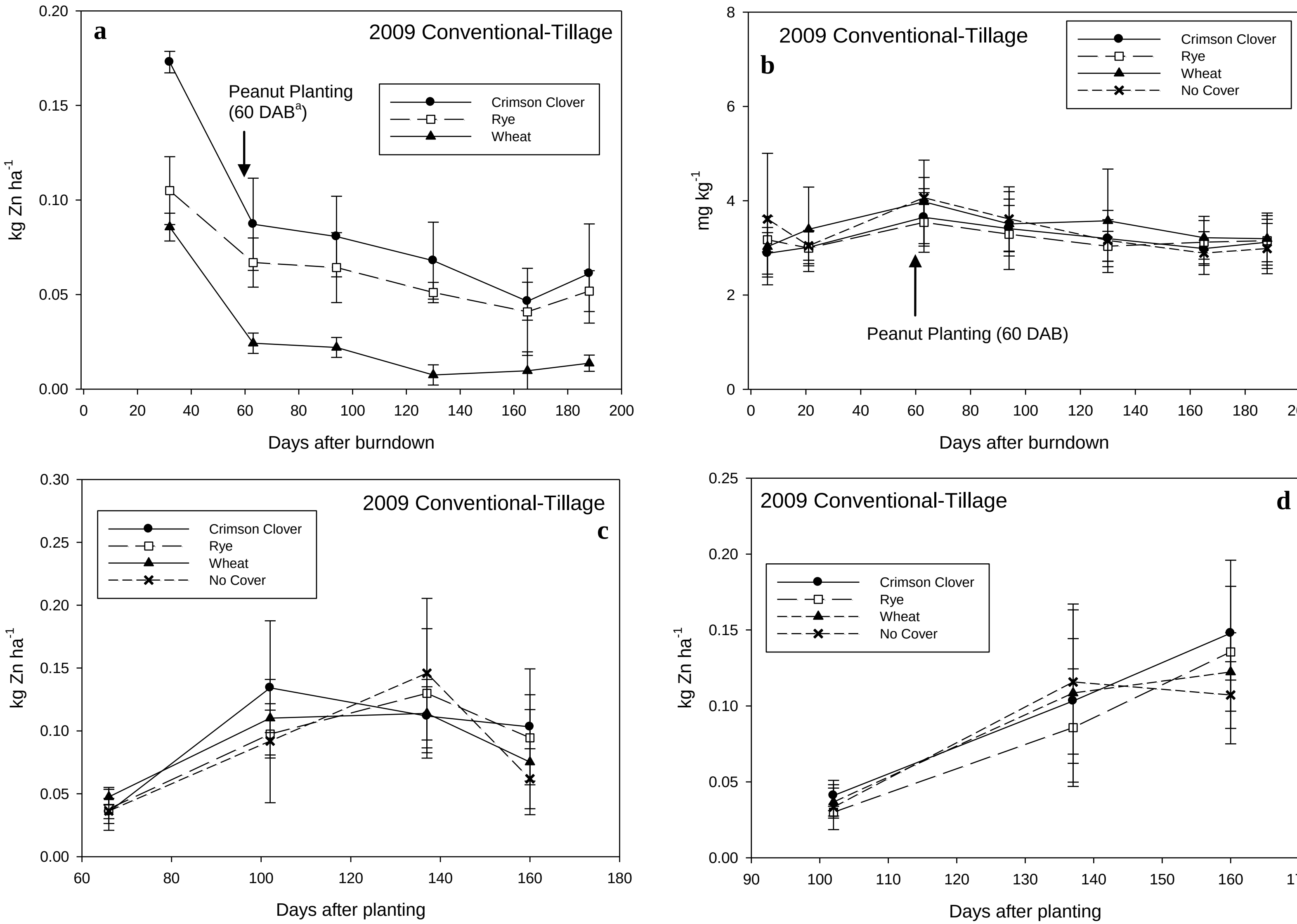

Figure 3.31. Zinc content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

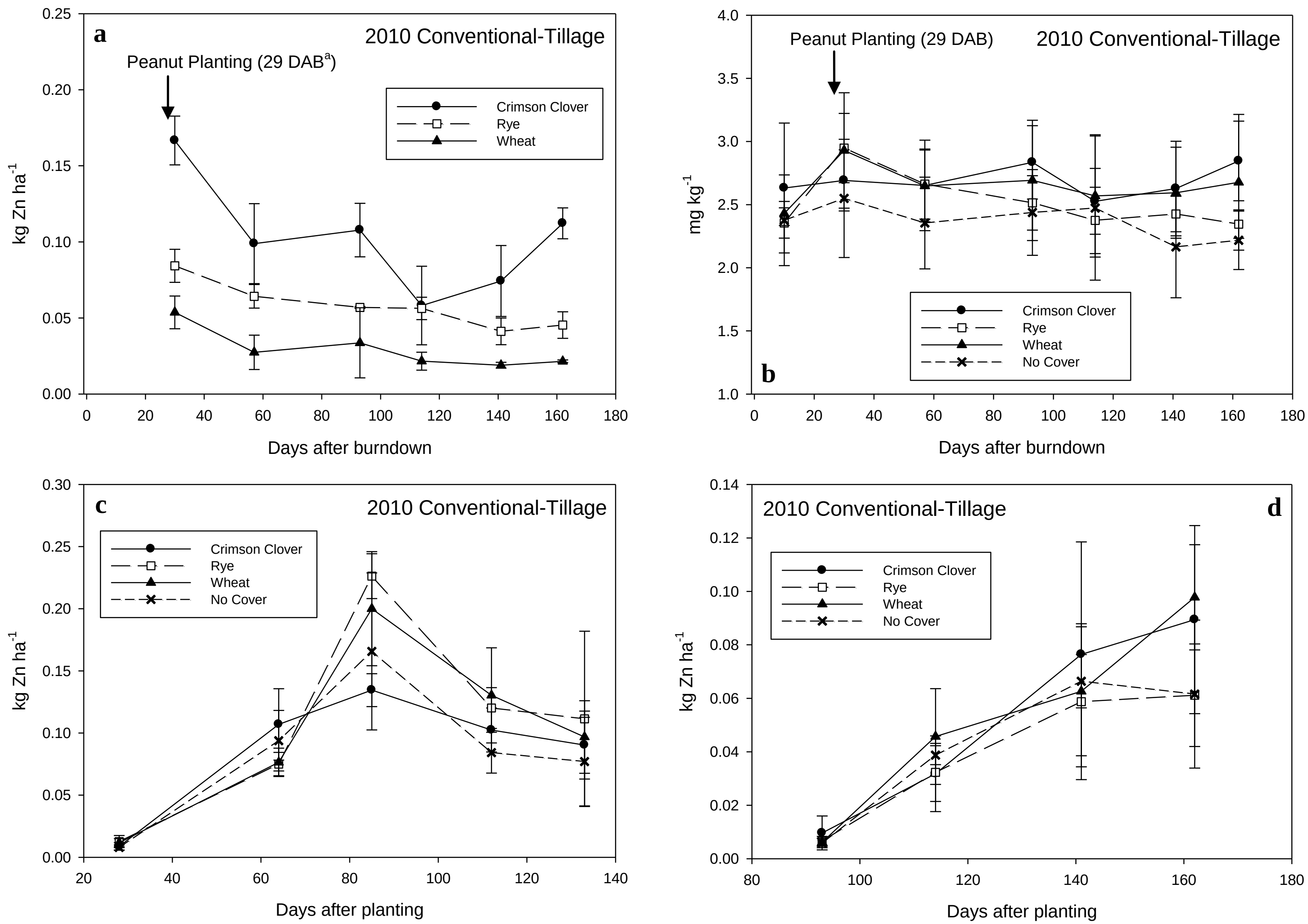

Figure 3.32. Zinc content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of four cover crop treatments in conventional-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

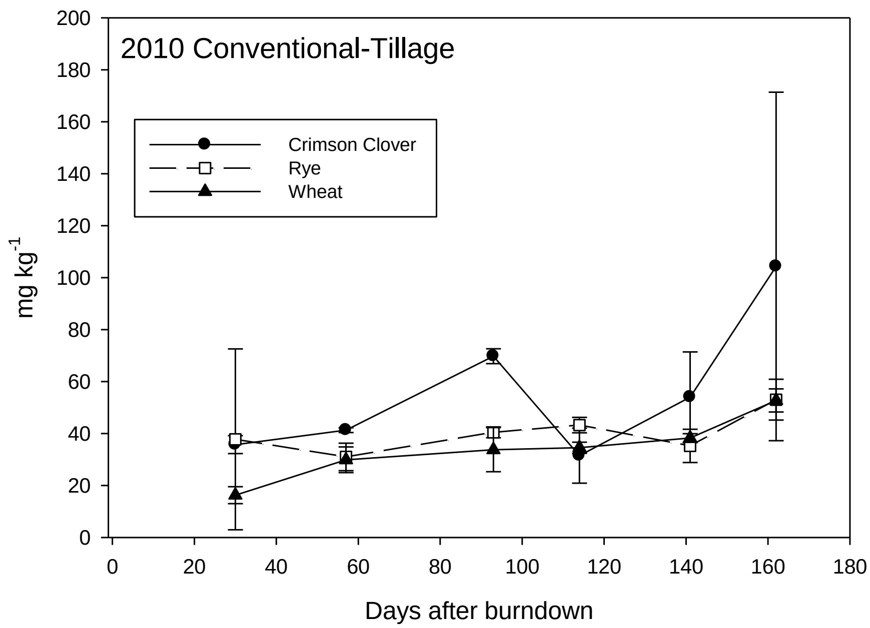

Figure 3.33. Zinc concentration of three cover crop residues in conventional-tillage in Tifton, GA, 2010.

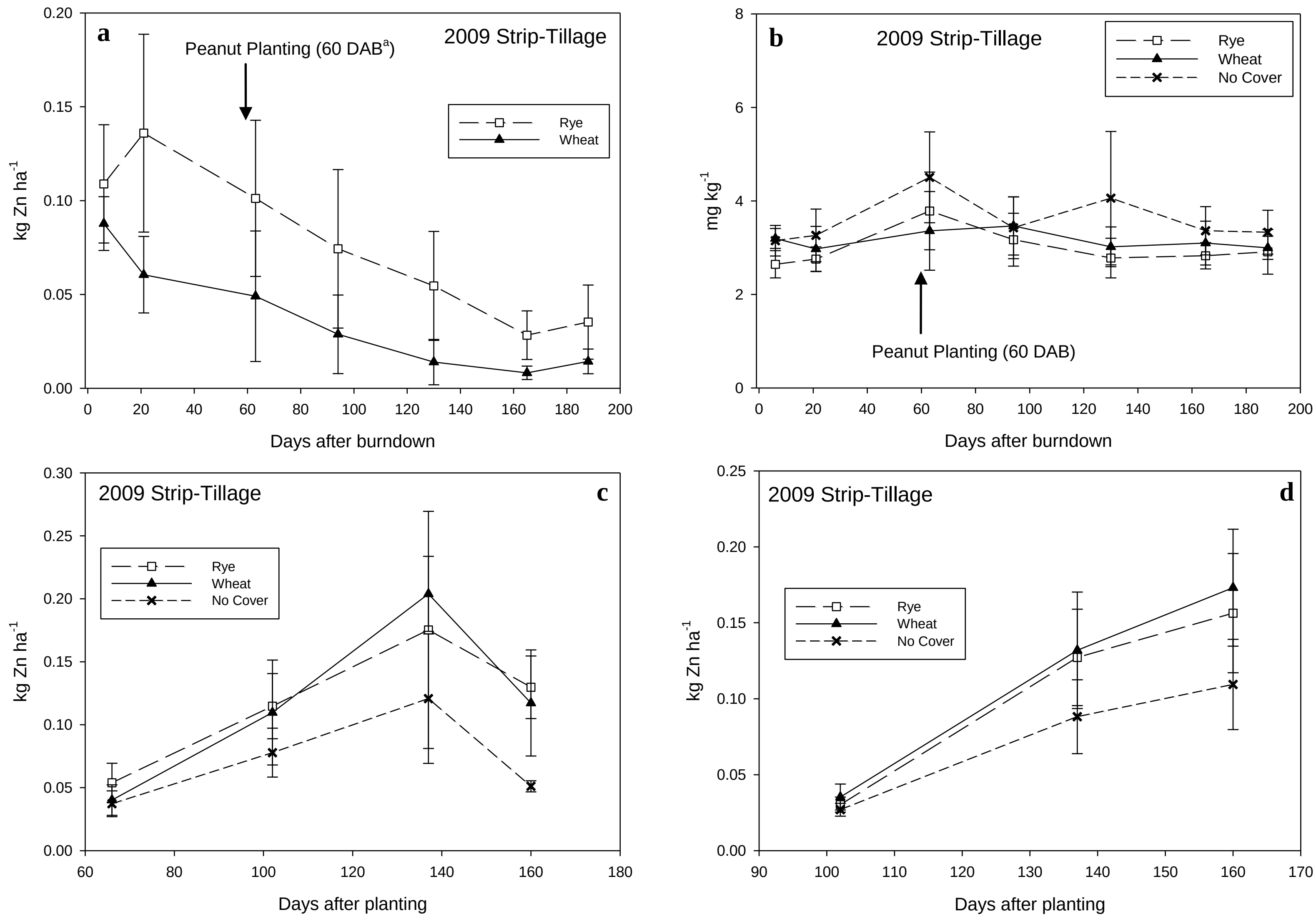

Figure 3.34. Zinc content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2009. [a] Days after burndown (DAB).

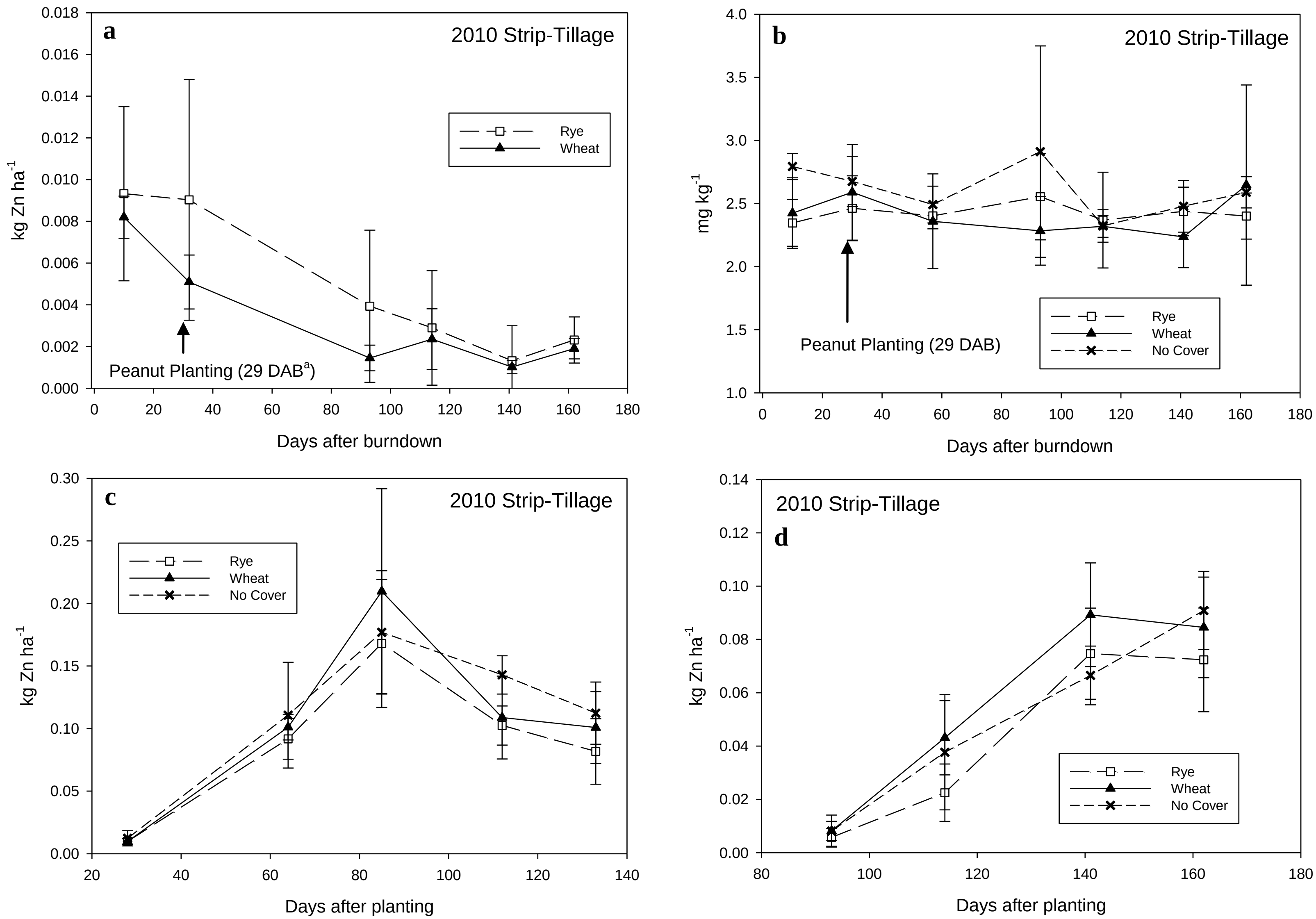

Figure 3.35. Zinc content of (a) cover crop tissues, (b) soil (5-cm depth), and (c) peanut vegetation and (d) pods as a result of three cover crop treatments in strip-tillage in Tifton, GA, 2010. [a] Days after burndown (DAB).

Table 3.14. Effects of cover crop and tillage on aboveground peanut vegetation, root biomass, and final plant stand of peanut in Tifton, GA in 2009-2010.

		Peanut Vegetation[a]		Root Biomass[a]		Final Stand[b]	
Tillage	Cover Crop	2009	2010	2009	2010	2009	2010
		------kg ha^{-1}------		------g $plant^{-1}$------		-----plants m^{-1}-----	
Conventional							
	Crimson Clover	3892 a	4978 a	1.2 a	3.1 a[c]	11.0 a	9.8 a
	Rye	3842 a	4449 a	1.1 a	2.2 ab	9.3 a	9.1 a
	Wheat	3597 a	4660 a	1.2 a	1.8 b	11.9 a	8.5 a
	No Cover	4162 a	3986 a	1.3 a	2.0 b	10.4 a	9.2 a
	LSD[d]	1122	1976	0.5	1.3	3.1	1.7
Strip							
	Crimson Clover	---	---	---	---	---	---
	Rye	4042 a	4552 a	1.4 a	2.1 ab[c]	9.5 a	10.3 a
	Wheat	4142 a	4544 a	1.1 a	2.5 a	9.5 a	9.7 a
	No Cover	3777 a	4578 a	1.3 a	1.8 b	10.5 a	8.6 a
	LSD	673	1565	0.6	0.7	1.4	2.0

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Aboveground vegetation and root biomass data collected from the final sample dates both years (15 Oct. 2009 and 5 Oct. 2010).

[b] Determined after peanut inversion, prior to harvest.

[c] Significant at $P = 0.10$.

[d] Least Significant Difference.

Table 3.15. Final pod yield and grade of peanut as affected by four cover crop treatments and two tillage treatments in Tifton, GA in 2009-2010.

Tillage	Cover Crop	Pod Yield		Grade	
		2009	2010	2009	2010
		-------kg ha^{-1}-------		-----%TSMK[a]------	
Conventional					
	Crimson Clover	5216 a	3625 a	75.2 a	71.6 a
	Rye	4608 a	3624 a	75.9 a	73.0 a
	Wheat	4706 a	3287 a	75.9 a	71.0 a
	No Cover	4898 a	3578 a	75.4 a	73.6 a
	LSD[b]	630	964	0.9	5.1
Strip					
	Crimson Clover	---	---	---	---
	Rye	4309 a	3161 a	75.9 a	71.0 a
	Wheat	4658 a	3573 a	75.2 ab	72.3 a
	No Cover	4224 a	3246 a	73.6 b	74.2 a
	LSD	760	1041	1.7	4.2

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Total sound mature kernels.

[b] Least Significant Difference.

CHAPTER 4

CULTIVAR AND APPROVED FUNGICIDE EVALUATION FOR LEAF SPOT MANAGEMENT IN ORGANIC PEANUT (*ARACHIS HYPOGAEA* L.) PRODUCTION[1]

[1] Wann, D.Q., R.S. Tubbs, and A.K. Culbreath. Submitted to *Plant Health Progress*, 2/25/2011.

Abstract: Growers interested in organic peanut production are in need of information to identify viable, disease-resistant cultivars and acceptable fungicides for control of early and late leaf spot diseases where inorganic pesticide applications are not permissible. Field trials were conducted in crop years 2008, 2009, and 2010 to evaluate eleven peanut cultivars for leaf spot resistance and yield potential in organic management. CRSP 983 and Georganic demonstrated the greatest resistance to early and late leaf spot diseases (18-59% and 34-52% defoliation, respectively), but Florida-07, Georgia-06G, and Tifguard produced the largest yields (2454-5424 kg ha^{-1}, 3758 kg ha^{-1}, and 1760-4030 kg ha^{-1}, respectively). Tifguard exhibited the best combination of stand establishment, disease resistance, and yield potential of all cultivars and would be a strong option for growers pursuing organic production, although Florida-07 and Georgia-06G are also formidable choices. A secondary objective of this experiment was to evaluate the efficacy of three approved fungicides for leaf spot control on peanut under organic management. Copper sulfate + *Bacillus subtilis* alone reduced leaf spot defoliation compared to the control. However, *B. subtilis*, copper sulfate, and copper sulfate + *B. subtilis* all improved yields when leaf spot pressure was heavy. Combining high-yielding, disease-resistant peanut cultivars and organic fungicide applications can significantly improve leaf spot management and yield potential of peanut under organic management.

Introduction

The bulk of U.S. organic peanut (*Arachis hypogaea* L.) production currently rests among the arid southwestern states of New Mexico and Texas. In 2008, Texas alone produced nearly 7000 Mg of certified organic peanuts, which constituted over 72% of national production that year (Guerena and Adam, 2008; NASS, 2007). The southeastern U.S., while producing the most conventional peanut regionally, has developed only marginal organic production, limited by the heavy disease pressure prevalent throughout the warm, humid region. Peanut is a natural host to a number of different foliar and soil-borne diseases, typically requiring several synthetic fungicide applications every 10-14 days during the growing season in conventional production. Early and late leaf spot diseases (*Cercospora arachidicola* S. Hori and *Cercosporidium personatum* [Beck & Curtis] Deighton) are particularly limiting to production by causing significant defoliation, and are typically found wherever peanut is grown (Smith, 1984). Without regular fungicide applications or other preventative practices, defoliation from leaf spot diseases alone can result in up to 50% yield losses at harvest (Kemerait et al., 2009; Smith, 1984).

The use of synthetic agrichemicals is prohibited in certified organic cropping systems by U.S. Department of Agriculture (USDA) definitions (USDA, 2005). Therefore, the use of disease-resistant cultivars is a main factor in managing leaf spot diseases and maximizing yields in organic peanut systems. The importance of genetic disease resistance has been recognized for other organic crops (Koike et al., 2000; Van Bruggen and Termorshuizen, 2003) and has been a crucial component for disease management in conventional peanut production for years (Brown et al., 2007; Wynne et al., 1991). Previous research with organically-acceptable fungicides, however, has shown marked potential for reducing leaf spot incidence and improving pod yields in organic peanut, along with using resistant cultivars. Cantonwine et al. (2008) reported that copper sulfate, copper sulfate + *Bacillus subtilis*, copper sulfate + sulfur, sulfur, cupric hydroxide, and cupric hydroxide + *B. subtilis* applications significantly reduced defoliation from leaf spot diseases compared to the unsprayed control. However, only copper sulfate and cupric hydroxide improved pod yields over the control. Shew et al. (2006) also reported that copper sulfate applications significantly reduced leaf spot incidence compared to the unsprayed control, but did not improve final pod yield.

There is a distinct need for information regarding cultivar options with strong disease resistance and high yield potential for conventional and organic peanut growers alike. However, little research has been published in this area. Desirable characteristics for cultivars include: resistance to foliar diseases, a high percentage of germination and low seedling mortality for establishment of an optimum stand, and high yield and grade potential. In Georgia, Branch and Culbreath (2008) identified Georgia-01R and Georgia-05E as strong, multiple-pest-resistant cultivars that produced substantial yields under organic management, however both of these cultivars are no longer commercially available. A number of additional disease-resistant cultivars have been released more recently that could have significant potential for improving organic peanut production (Branch, 2007; Gorbet and Tillman, 2009; Holbrook and Culbreath, 2008; Holbrook et al., 2008a). These new cultivars, along with timely applications of organic fungicides, have the potential to greatly improve management of leaf spot diseases for organic peanut growers. The primary objective of this research, therefore, was to evaluate leaf spot resistance and productivity of several peanut cultivars with current and future commercial relevance grown under organic management. A secondary objective was to supplement previous research regarding organic fungicides by evaluating three potentially-viable organic fungicide formulations for control of early and late leaf spot diseases in organic peanut.

Materials and Methods

Irrigated research trials were conducted at the University of Georgia (UGA) Horticulture Hill Farm in 2008 and Lang-Rigdon Farm in 2009 and 2010 near Tifton, GA. The soil was a Tifton loamy sand (fine-loamy, Kaolinitic, thermic Plinthic Kandiudults). Five peanut cultivars were planted in 2008 as preliminary research to evaluate leaf spot resistance and yield potential and the efficacy of three organic fungicide formulations on leaf spot under organic management. In 2009 and 2010, eleven different peanut cultivars (nine each year) were planted and evaluated for several different data parameters in addition to leaf spot resistance and pod yield. All cultivars planted over the three years of this experiment are listed in Table 4.1.

All plots were planted with untreated seed using 2-row precision air planter[6] on 12 June 2008, 6 June 2009, and 27 May 2010 at a depth of 6 cm, a seeding rate of 20 seed m^{-1}, and a standard row spacing of 91 cm. Plots were arranged in a randomized complete block design with five replications in 2008 and four replications in 2009 and 2010. All plot lengths in 2008 ranged from 36 m to 57 m, due to the triangular shape of the field. Plot lengths were therefore grouped by replication (Rep 1 = 57 m; Rep 2 = 54 m; Rep 3 = 48 m; Rep 4 = 45 m; and Rep 5 = 36 m). Plot dimensions in 2009 and 2010 were 7.3 m wide (8 rows) x 9.1 m long, although the harvested area comprised only the center peanut rows (3.7 m x 9.1 m). All ‘Florida-07’ (Gorbet and Tillman, 2009) plots were sub-divided into four two-row (1.8-m wide), equal-length sections (6.4-8.8 m and 9.1 m) in 2008 and 2009, respectively, to facilitate an evaluation of the three organic fungicide formulations. Data for comparison among cultivars were collected from the unsprayed control plots.

Production practices included conventional deep tillage with a moldboard plow to a depth of 30-35 cm prior to planting and irrigation as needed during the season, according to UGA recommendations for peanut. Gypsum applications of 1120 kg ha^{-1} (8 July 2008), 1344 kg ha^{-1} (30 July 2009), and 1120 kg ha^{-1} (4 Aug. 2010) were made to all plots based on soil test recommendations to meet calcium requirements for pod-filling. No herbicides, fungicides (including seed treatments), or insecticides were applied at any point during the season in order to follow approved USDA-certified organic production practices and to solely evaluate genetic differences among cultivars and experimental fungicide treatments. Weed control each year was maintained by a combination of tine cultivation, flat sweep cultivation, and hand-weeding.

Due to extremely poor plant stands, all CRSP 38 and 'Florida Fancy' plots were severely overrun by weeds in 2008 and were subsequently abandoned. Therefore, leaf spot and yield data were collected only from the Florida-07, 'Georganic' (Holbrook and Culbreath, 2008), and 'McCloud' (Tillman et al., 2008) plots in 2008. Additionally, availability of 'Georgia-03L' (Branch, 2004) was extremely limited in 2010 due to phasing-out of the cultivar and was therefore unavailable for the third year of this experiment. 'Georgia-06G' (Branch, 2007), a common cultivar with widespread commercial hectarage and high yield potential, was selected as an alternative large-seeded runner-type cultivar for the 2010 growing season.

Visual canopy development ratings were conducted on 15 June 2009 and 8 June 2010 (9 and 12 days after planting [DAP], respectively), utilizing a novel 4-point rating scale (1 = Poor; 2 = Moderately Poor; 3 = Moderately Good; 4 = Good). This factor was visually assessed as an average over the plot from a combination of plant stand, vegetation size, health status symptoms (i.e. wilting, necrosis, etc.) and overall canopy appearance plus the amount of visible bare space within the peanut rows. Emergent plant stand counts were conducted on 15 June and 2 July in 2009 (9 and 26 DAP, respectively) and on 7 June and 21 June in 2010 (11 and 25 DAP, respectively). Final plant stand counts were conducted for all plots prior to harvest after inversion. Lapping dates were collected for each cultivar, being the date when at least 50% of the plot had plant vines that touched or overlapped in the middle of the bed, in order to determine and compare rates of canopy closure among cultivars. These data indicate how quickly each cultivar achieves coverage of inter-row space, an important factor for competition with and suppression of weeds. Late-season visual ratings for combined early and late leaf spot severity were conducted on 22 Oct. 2008, 16 Oct. 2009, and 11 Oct. 2010, using visual estimates for percent defoliation.

Four fungicide treatments were applied to all Florida-07 plots, a cultivar susceptible to early and late leaf spot infestations, in 2008 and 2009, arranged in a randomized complete block design with four replications each year. Treated areas were each 1.8-m wide (2 rows) and varied from 6.4-8.8 m in length in 2008. Treated areas in 2009 each measured 1.8 m x 9.1 m. Fungicide treatments consisted of copper sulfate[20] (2.2 kg ha^{-1}), *B. subtilis*[21] (2.8 kg ha^{-1}), copper sulfate[20] (2.2 kg ha^{-1}) + *B. subtilis*[21] (2.8 kg ha^{-1}), and an unsprayed control. Spray applications of each fungicide were made by hand in 115 liters ha^{-1} of water at 345 kPa of pressure, using a backpack sprayer. Applications were made on 58 and 86 DAP in 2008 and at 90 DAP, 116 DAP, and 131 DAP in 2009, based on timing and severity of leaf spot epidemics. Visual estimates of defoliation from early and late leaf spot combined were conducted prior to peanut inversion on 22 Oct. 2008 and 16 Oct. 2009

Optimum digging date was determined each year using the standard Hull-Scrape Maturity Profile method (Williams and Drexler, 1981). Therefore, all plots in 2008, except for Georganic (which has the longest maturity range of the cultivars used in this experiment), were inverted on 31 Oct. using a 2-row digger-shaker-inverter[4] and harvested 6 Nov. using a 2-row small plot peanut combine. All Georganic plots were subsequently inverted on 7 Nov. and harvested 20 Nov. In 2009, all plots were inverted on 28 Oct., since consistently cool weather ceased development of all cultivars, including Georganic. Plots were then harvested 5 Nov. In 2010, temperatures were significantly warmer throughout the fall, again allowing for continued development of the late-maturing Georganic cultivar beyond the other cultivars. All plots (except Georganic) were inverted 15 Oct. and harvested 19 Oct., while Georganic plots were inverted 30 Oct. and harvested 8 Nov. Pod yields were collected for each cultivar and fungicide treatment and adjusted to 7% moisture. Grade data were only collected in 2009 and 2010 for the cultivar evaluation.

Statistical analyses were conducted using SAS 9.2 software[19]. Data were statistically analyzed by analysis of variance, using PROC GLIMMIX and means were separated using pairwise t-tests ($P = 0.05$).

Results and Discussion

Cultivar Performance Evaluation. There were significant Year x Cultivar interactions ($P \leq 0.05$) for each data parameter analyzed. Therefore, the data were separated by year and subsequently analyzed. Grade differences were not significant among cultivars in 2010 ($P \leq 0.05$), but differences were evident in all other data parameters.

Differences in late-season leaf spot incidence were strong among cultivars all three years ($P \leq 0.05$). Early and late leaf spot pressure was also more severe at the 2009 test site than the 2008 or 2010 sites. Georganic exhibited the least defoliation from leaf spot in 2008 (Table 4.2), while Florida-07 and McCloud exhibited the greatest defoliation. In 2009, Georganic and CRSP 983 resulted in the lowest defoliation from leaf spot, followed by Georgia-03L (Table 4.3). Florida-07 and McCloud again exhibited the greatest incidence with nearly complete defoliation by harvest. In 2010, 'C724-19-25' (Holbrook et al., 2008b) and CRSP 983 exhibited the lowest incidence of leaf spot, but were not significantly different from Georganic (Table 4.4). 'Georgia-08V' (Branch, 2009) had the highest incidence of leaf spot with near complete defoliation at harvest. These results were mostly consistent with the point values associated with the Peanut Disease Risk Index leaf spot incidence values for the respective cultivars (Culbreath et al., 2010), and also with Branch and Culbreath (2008) regarding the distribution of leaf spot resistance among Georganic, Georgia-03L, and Florida-07.

Plant stands among all cultivars were lower in 2009 than in 2010, which was likely due to multiple factors including level of soil-borne disease inoculum in respective field sites; growing conditions in previous year when source seed was produced; soil temperature, moisture, and edaphic status; and other conditions. In 2009, C724-19-25 and 'Tifguard' (Holbrook et al., 2008a) resulted in the greatest initial plant stands at 9 DAP, but were not significantly different from Georgia-03L (Fig. 4.1). Both C724-19-25 and Tifguard also the received the highest canopy development ratings at 9 DAP, exhibiting large, healthy-looking plants with minimal bare space within their respective plots (Table 4.3). At 26 DAP, Tifguard and C724-19-25 still had the greatest plant stands, followed closely by Georgia-03L, demonstrating low numbers of both post-emergent seedling mortality and also delayed emergence. By the end of the season, C724-19-25 and Tifguard retained the greatest plant stands, but Georganic stands had also increased to a level comparable with C724-19-25 and Tifguard. Georganic produced marginal emergent stands and received a low canopy development rating but eventually compensated by harvest. This was possibly due to the late-maturing nature of the Georganic cultivar, exhibiting a slower rate of germination early on but ultimately generating a substantial plant stand at full maturity.

In 2010, the stands of several of the cultivars displayed a significant decline from 11 DAP to 25 DAP and then a noticeable increase by harvest (Fig. 4.2). It is noted that the cultivars demonstrating this behavior are also the same cultivars which received canopy development ratings of 3.0 or higher (moderately good to good) (Table 4.4), which indicates that this was likely due to experimental error during the 25 DAP stand counts. Since the lateral peanut branches of vigorously growing peanut plants are thickly intertwined by that point in the season, the likelihood of mistaking two smaller adjoining plants as just one larger plant is greatly increased, resulting in falsely lower values at that time. Other cultivars exhibited a decline in plant stand from 11 to 25 DAP, but had visual canopy development ratings below 3.0, and likewise resulted in lower plant stands at harvest, demonstrating that there was likely greater levels of seedling mortality from disease and less occurrence of falsely low counts from experimental error since those plots were visually rated as less healthy to begin with.

Tifguard produced the greatest initial stands at 11 DAP, followed closely by Georgia-06G and Georgia-08V. Tifguard also received the highest visual canopy development rating at 12 DAP, along with Georgia-08V (Table 4.4). C724-19-25, however, produced one of the lowest initial plant stands and received one of the lowest canopy development scores, which could have been the result of poor seed quality or a different spectrum or pressure of soil-borne diseases at the 2010 site. At 25 DAP, there was little separation among the cultivars with acceptable stands, but CRSP 983 and McCloud had the sparsest stands which would be considered unacceptable for production. By harvest, Tifguard had the densest stand, followed closely by Georgia-06G and Georgia-08V. Georganic followed a similar trend as in 2009, with low initial canopy development ratings and plant stands in the early season but with improved stands at harvest. However, the contrast between early- and late-season stands was not as pronounced as in 2009. CRSP 983 had relatively low emergent plant stands among all ten cultivars both years and received very poor canopy development ratings, indicating that the cultivar may have poor seed quality or could be very susceptible to soil-borne diseases that prevent adequate germination and early-season stand establishment.

In the absence of a commercial pre-planting seed treatment, the effects of soil-borne disease are much more dramatic on germination and stand establishment and mere genetic differences can be more pronounced. When significant gaps in the peanut rows exist early on, weeds have the opportunity to quickly fill the bare space. The effects of competition with intra-row weeds on peanut are typically greatest during the first 3-8 weeks after planting (Everman et al., 2008). Therefore, early-season stand establishment is crucial in organic peanut systems for ensuring the ability of the crop to effectively compete with weeds and diseases and to increase the overall productivity of the system. Good plant stands also significantly reduce the risk of tomato spotted wilt (*Tospovirus*) (TSWV) incidence, a devastating viral pathogen in peanut (Culbreath et al., 2010). Of all cultivars evaluated in both years, Tifguard displayed the most consistent and notable early-season stand establishment and retained good stands in spite of not having a seed treatment prior to planting.

Differences in the number of days to lapping were significant among cultivars both years ($P \leq 0.05$). In 2009, Georganic required the fewest number of days to lap, despite exhibiting slower germination and initial stand establishment (Table 4.3). CRSP 983, however, required the greatest number of days to lap, which appeared to correspond to its poor early-season plant stands. In 2010, Florida-07 and Tifguard required the fewest number of days to lap, yet were statistically equivalent with Georgia-08V (Table 4.4). CRSP 983 again required the greatest number of days to lap. The rapid canopy closure exhibited by Tifguard and Florida-07 is a desirable trait in cultivar selection, because the quicker the peanut rows lap, the more effectively they can shade and suppress weeds. This is especially important in organic systems, where supplemental herbicide use for direct control of weed escapes is prohibited. Additionally, inadequate vegetative growth reduces the ability of the peanut plant to properly invert prior to harvest, limiting the ability of the peanut pods to properly dry, thus reducing the quality of the pods.

Mean yields in 2009 and 2010 were relatively low compared to conventional peanut yields. This is to be expected given no chemical inputs were applied. Florida-07 produced the greatest yields in 2008 and 2009 (Tables 4.2 & 4.3), despite heavy defoliation from leaf spot. In 2010, Tifguard, Georgia-06G, and Florida-07 produced the highest yields (Table 4.4). Conversely, CRSP 983 produced among the lowest yields in 2009 and 2010, in spite of exhibiting consistently exceptional leaf spot resistance. This was likely due to the poor stands generated by the cultivar both years. Tifguard exhibited high yield potential and moderate leaf spot resistance, whereas both Florida-07 and Georgia-06G displayed relatively poor leaf spot resistance but overcame by producing substantial pod yields. It is, therefore, important to select a cultivar that exhibits a strong balance between leaf spot resistance, stand establishment, and yield potential.

Grade data were only collected in 2009 and 2010. Differences among cultivars were significant in 2009 ($P \leq 0.05$) (Table 4.3), but not in 2010 (Table 4.4). McCloud, C724-19-25, and Tifguard all received the highest grades in 2009. Florida-07, Georgia-03L, Florida Fancy, and CRSP 983, however, all graded poorly. The grade score of a peanut crop, expressed as percent total sound mature kernels (%TSMK) indicates the level of quality of a peanut crop and how much of the crop is saleable at the highest price. Grade is a very important consideration for cultivar selection and can directly impact a grower's profit potential for the shelled market. Because McCloud graded the highest in 2009, there might be some potential for a grower to recoup his/her yield losses with a high %TSMK. Conversely, Florida-07 produced the greatest yield in 2009, but was among the poorest-grading cultivars, thus reducing the profit potential generated by high yields. Tifguard produced one of the highest yields with the second-highest %TSMK in 2009, representing the most profitable combination of yield and grade potential among all cultivars. In 2010, however, Tifguard produced the highest yield but a slightly lower grade would result in lower net returns than an equally high yielding cultivar with a better grade.

Organic Fungicide Evaluation. There was a significant Year x Fungicide treatment interaction for percent defoliation and yield data in 2008 and 2009 ($P \leq 0.05$). Therefore, the data were separated by year and subsequently analyzed. Leaf spot severity was greater in 2009 than 2008, although late leaf spot epidemics were more prevalent in 2009 and required later fungicide applications. There were no significant differences in defoliation among fungicide treatments in 2008 (Table 4.5). In 2009, copper sulfate + *B. subtilis* significantly reduced defoliation from leaf spot compared to all other fungicide treatments, including the unsprayed control. Copper sulfate and *B. subtilis* alone did not reduce defoliation compared to the control. The difference in fungicide efficacy between 2008 and 2009 is likely due to the varied leaf spot pressure between the two years. These results indicate that copper sulfate + *B. subtilis* can provide significant reductions in the incidence and severity of early and late leaf spot when pressure is heavy. However, it appears that copper sulfate + *B. subtilis* is unable to provide further leaf spot reductions when pressure is lighter. The effects of copper sulfate + *B. subtilis* on defoliation from leaf spot in this experiment were somewhat consistent with results by Cantonwine et al. (2008). However, the effects of copper sulfate alone were not consistent with

Cantonwine et al. (2008), likely due to the later, less-frequent fungicide applications made in this experiment.

Similar to the percent defoliation data, there were no significant differences in pod yield among fungicide treatments in 2008 (Table 4.5). This was again likely due to the lighter leaf spot pressure in 2008, since yields in 2008 were also significantly greater than in 2009. All fungicide formulations significantly improved yield compared to the control in 2009, however yields were not different among the sprayed treatments themselves. This was notable because the copper sulfate or *B. subtilis* plots each were almost completely defoliated by the end of the growing season. These results also correlate with the results for Florida-07 reported in the cultivar comparison experiment above, in that the cultivar still exhibits high yield potential in spite of significant defoliation from early and late leaf spot diseases. Similar to the results for defoliation in this experiment, it appears that the three fungicide formulations examined in this experiment all have significant potential for improving yields in sites with heavier leaf spot pressure, though the same effects are not apparent in areas of lower pressure.

Summary and Conclusions

There are a number of runner- and Virginia-type cultivar options available for peanut production in the southeastern U.S. However, the results of this experiment suggest that various commercial cultivars used in conventional peanut production can perform differently under organic management, in the absence of commercial pesticides or seed treatments. Tifguard displayed quick germination and a rapid vegetative growth habit, establishing dense plant stands early in the season and maintaining them throughout the growing season. Georgia-06G also displayed strong stand establishment during the one year it was grown. Stand establishment is an important consideration because it directly impacts TSWV incidence and yield potential and it has implications for long-term weed management in organic cropping systems. Reduced plant populations increase the risk of TSWV incidence and reduce the number of viable plants available to produce pods for harvest, thus directly reducing yield. Dense peanut stands can also aid in suppressing weed populations given their prostrate growth habit. This was not apparent within the two-year timeframe of this experiment, but it could have a lasting positive impact for the long-term over numerous successive growing seasons.

CRSP 983 consistently displayed the greatest resistance to early and late leaf spot diseases, but the resistance did not translate to significant yield improvement at the end of the season because of poor stands. Conversely, Florida-07, Georgia-06G, and Tifguard did not display the greatest leaf spot resistance but all three produced the highest yields and showed marked potential for organic production. This was also apparent for Florida-07 in the fungicide evaluation. Tifguard displayed the most optimum balance of rapid stand establishment, foliar disease resistance, and overall yield potential. At the time of this writing, Tifguard is also the only peanut cultivar available that has high host plant resistance to both TSWV and the peanut root-knot nematode (*Meloidogyne arenaria*) (Holbrook et al., 2008a). Therefore, Tifguard is a multiple-pest-resistant cultivar that would be a strong choice for growers pursuing organic production. However, the most widely planted conventional peanut cultivars in the U.S., Georgia-06 and Florida-07, are likewise compelling options under organic management due to their ability to overcome adverse conditions and still produce high yields.

Bacillus subtilis, copper sulfate, and copper sulfate + *B. subtilis* fungicides all have potential for use in organic peanut systems. Although copper sulfate + *B. subtilis* alone reduced defoliation from early and late leaf spot compared to the control, all three formulations displayed potential for significantly improving peanut yields. However, their effectiveness appears to be greater in areas with heavier leaf spot pressure or when they are applied at more frequent intervals earlier in the growing season. Combined with the high-yielding, disease-resistant cultivars identified in this experiment, organic and conventional peanut growers alike have a variety of important tools available to improve both the management of leaf spot in their cropping systems and the feasibility of organic production as a whole.

Table 4.1. Market type and years planted of eleven peanut cultivars evaluated under organic management in Tifton, GA, 2008-2010.

		Years Planted		
Cultivar	Market Type	2008	2009	2010
C724-19-25	Runner		*	*
CRSP 38	Runner	*		
CRSP 983	Runner		*	*
Florida-07	Runner	*	*	*
Florida Fancy	Virginia	*	*	*
Georganic	Runner	*	*	*
Georgia-03L	Runner		*	
Georgia-06G	Runner			*
Georgia-08V	Virginia		*	*
McCloud	Runner	*	*	*
Tifguard	Runner		*	*

Table 4.2. Leaf spot defoliation and pod yield of five peanut cultivars under organic management in Tifton, GA in 2008.

Cultivar	Leaf Spot Defoliation[a]	Pod Yield
	---------%---------	---kg ha^{-1}--
CRSP 38	---	---
Florida-07	65 a	5424 a
Florida Fancy	---	---
Georganic	46 b	3297 b
McCloud	71 a	3839 b
LSD[b]	15	825

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Values are based on visual estimates of percent defoliation from early and late leaf spot diseases.

[b] Least significant difference.

Table 4.3. Leaf spot defoliation, canopy development, days to lapping, and grade of nine peanut cultivars under organic management in Tifton, GA in 2009.

Cultivar	Leaf Spot Defoliation[a]	Canopy Development[b]	Days To Lapping	Pod Yield	Grade
	-------%--------			kg ha^{-1}	%TSMK[c]
C724-19-25	95 a	3.5 a	83 abc	1602 bc	72 abc
CRSP 983	59 c	1.2 c	91 a	546 f	67 f
Florida-07	98 a	2.2 b	82 bc	2454 a	70 c-f
Florida Fancy	91 a	1.7 bc	87 ab	1048 e	68 ef
Georganic	52 c	2.1 b	78 c	1757 b	70 b-e
Georgia-03L	77 b	2.3 b	81 bc	1399 cd	69 def
Georgia-08V	89 ab	1.8 bc	81 bc	957 e	71 bcd
McCloud	96 a	1.9 b	80 bc	1198 de	74 a
Tifguard	90 ab	3.6 a	82 bc	1760 b	73 ab
LSD[d]	13	0.6	6	292	3

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Values are based on visual estimates of percent defoliation from early and late leaf spot diseases.

[b] Values based on 1-4 visual rating scale (1 = Poor; 2 = Moderately Poor; 3 = Moderately Good; 4 = Good).

[c] Total sound mature kernels.

[d] Least significant difference.

Table 4.4. Leaf spot defoliation, canopy development, days to lapping, and grade of nine peanut cultivars under organic management in Tifton, GA in 2010.

Cultivar	Leaf Spot Defoliation[a]	Canopy Development[b]	Days To Lapping	Pod Yield	Grade
	------%-------			kg ha^{-1}	%TSMK[c]
C724-19-25	24 e	2.0 e	83 bc	2699 cd	72 a
CRSP 983	18 e	1.7 e	100 a	1847 e	71 a
Florida-07	88 ab	2.7 d	66 d	3424 abc	72 a
Florida Fancy	77 b	3.0 cd	92 ab	2910 bcd	72 a
Georganic	34 de	1.7 e	87 ab	2171 de	71 a
Georgia-06G	82 ab	3.3 bc	92 ab	3758 ab	71 a
Georgia-08V	99 a	3.6 ab	81 bcd	2554 de	72 a
McCloud	49 cd	2.8 d	86 ab	2332 de	68 a
Tifguard	56 c	3.8 a	68 cd	4030 a	69 a
LSD[d]	20	0.3	15	827	4

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Values are based on visual estimates of percent defoliation from early and late leaf spot diseases.

[b] Values based on 1-4 visual rating scale (1 = Poor; 2 = Moderately Poor; 3 = Moderately Good; 4 = Good).

[c] Total sound mature kernels.

[d] Least significant difference.

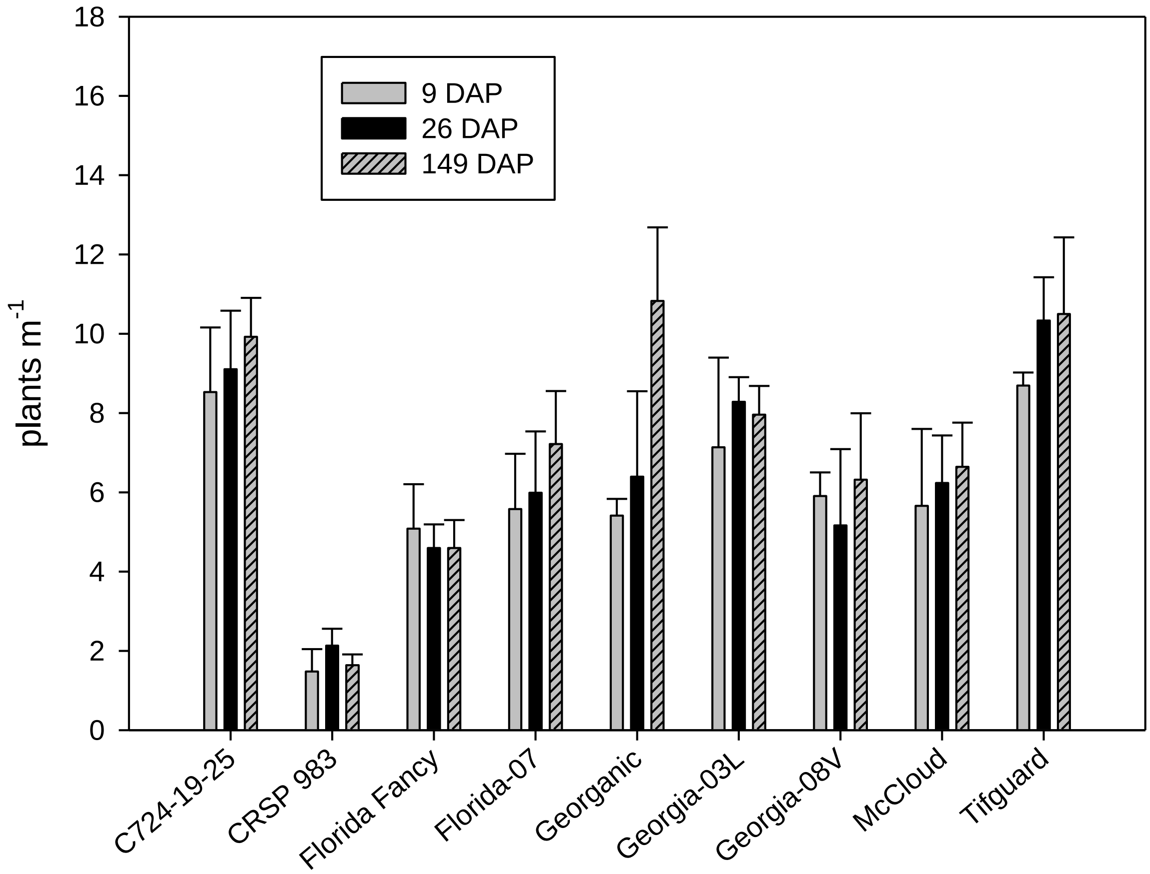

Figure 4.1. Plant stand counts at 9 days after planting (DAP), 26 DAP, and harvest of nine peanut cultivars under organic management in Tifton, GA, 2009. Error bars indicate one standard error above and below the mean and are for comparison among cultivars within a sample date.

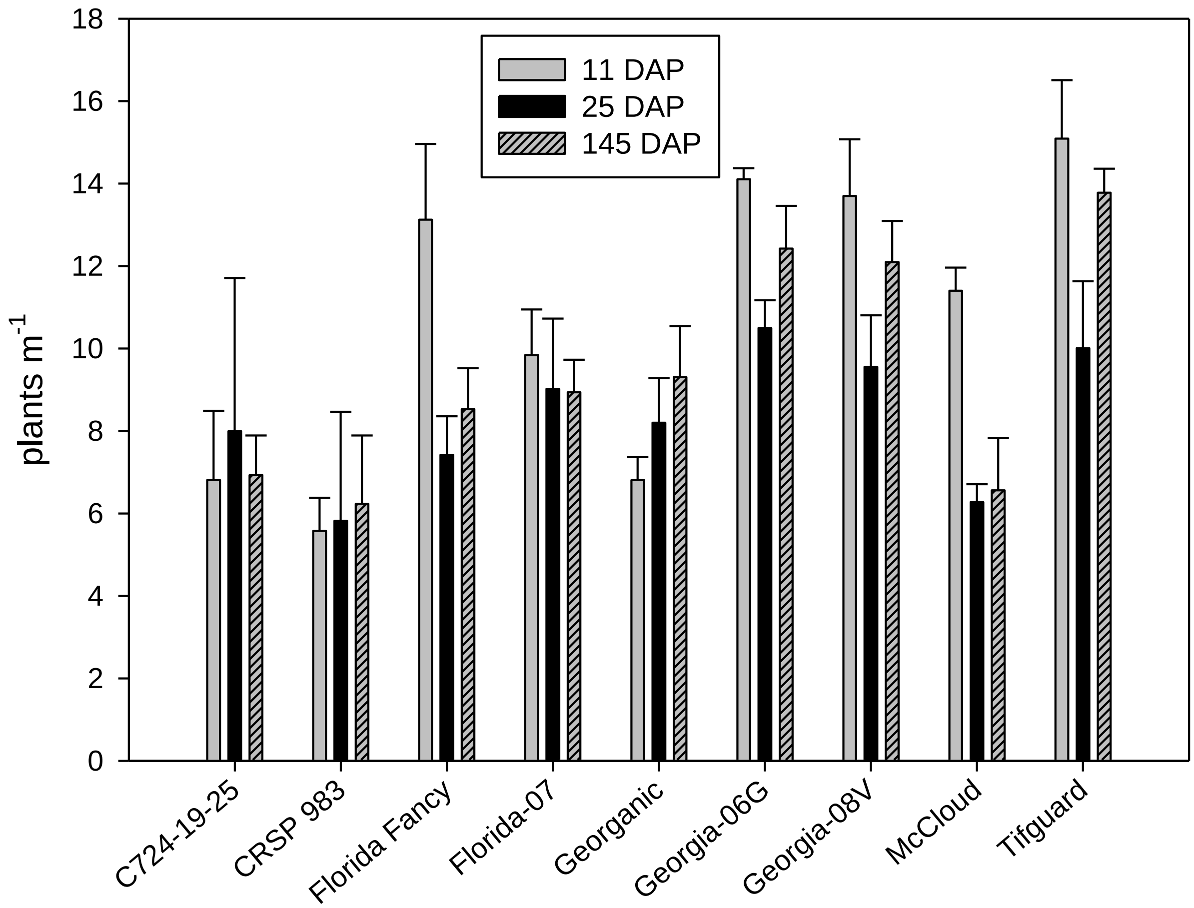

Figure 4.2. Plant stand counts at 11 days after planting (DAP), 25 DAP, and harvest of nine peanut cultivars under organic management in Tifton, GA, 2010. Error bars indicate one standard error above and below the mean and are for comparison among cultivars within a sample date.

Table 4.5. Leaf spot defoliation and yield of Florida-07 peanut as a result of four organic fungicide treatments under organic management in Tifton, GA in 2008-2009.

	Leaf Spot Defoliation[a]		Pod Yield	
Treatment	2008	2009	2008	2009
	--------%--------		-------kg ha^{-1}-------	
Control	65 a	98 a	5238 a	2454 b
Bacillus subtilis	65 a	92 a	5498 a	3354 a
Copper sulfate	55 a	96 a	5323 a	3218 a
Copper sulfate + *B. subtilis*	53 a	46 b	4989 a	3386 a
LSD[b]	25	6	624	421

Means within a column followed by the same lowercase letter are not significantly different according to pairwise t-tests at P = 0.05.

[a] Values are based on visual estimates of percent defoliation from early and late leaf spot diseases.

[b] Least significant difference.

CHAPTER 5

CULTIVATION FREQUENCY AND DURATION EFFECTS ON PRODUCTIVITY AND ECONOMICS OF PEANUT (*ARACHIS HYPOGAEA* L.) IN ORGANIC MANAGEMENT[1]

[1] Wann, D.Q., R.S. Tubbs, W.C. Johnson, III, A.R. Smith, N.B. Smith, and A.K. Culbreath. Submitted to *Peanut Science*, 10/18/2010.

Abstract: Identifying effective weed control regimes for organic peanut is paramount for improving the feasibility of organic production. Tine cultivation is a proven effective method for reducing in-row weed populations in several crops. Field trials were therefore conducted in 2008 and 2009 to assess the effects of various frequencies and durations of tine cultivation on weed control and overall peanut productivity of two peanut cultivars under organic management. Tine cultivation regimes consisted of two frequencies (once per week or twice per week) for three durations (3 wk, 4 wk, or 5 wk). All cultivation treatments were also cultivated with flat sweeps at least once and were hand-weeded during the growing season. A non-cultivated, non-weeded control was included for comparison. All cultivation treatments significantly reduced annual grass populations in 2008 and Florida pusley populations both years. Cultivated treatments also resulted in denser plant stands for peanut (9.2 plants m^{-1} to 13.2 plants m^{-1}) than the non-cultivated control (3.9 plants m^{-1} to 7.9 plants m^{-1}). Pod yields in cultivated treatments ranged from 3420 kg ha^{-1} to 4340 kg ha^{-1} and were all significantly greater than yields in the non-cultivated groups (1140 kg ha^{-1} and 2220 kg ha^{-1}). Also, net revenues generated by cultivated treatments ranged from \$3334 ha^{-1} to \$3638 ha^{-1} and were greater than that of the control (\$1795 ha^{-1}). These same revenues from cultivated treatments were at least 2x greater than those generated by an average conventional peanut crop. However, the differing effects of tine cultivation on weed control, plant stand, pod yield, and net revenue were largely insignificant among the various frequencies and durations of tine cultivation. These results indicate that tine cultivation at a minimum of once per week for at least 3 weeks can significantly reduce weed populations, improve plant stand, and increase peanut yields and net revenues in organically-managed peanut. There is also significant economic incentive for peanut growers interested in pursuing organic production, utilizing this cultivation regime.

Introduction

As demand for organic products has increased in the U.S. in recent years, the demand for organic peanuts has subsequently followed a similar upward trend (Dimitri and Greene, 2002; Lamb et al., 2007; Puppala, 2007). Demand for organic peanuts is generally regarded as the fastest growing sector of the entire U.S. peanut industry (Lamb et al., 2007; Parker, 2007; Puppala, 2007). Heightened demand for organic peanuts has translated to higher price premiums for certified organic versus conventional peanut. At the time of this writing, certified organic runner-type peanut prices were up to \$1100 Mg^{-1} (N.B. Smith, personal communication, 2010), compared to approximately \$720 Mg^{-1} for conventional runner peanut contracts. Therefore, economic incentives exist for peanut growers interested in pursuing organic production. However, these economic incentives are sometimes negated by additional costs associated with organic production, such as additional trips through the field for cultivation and hand-weeding.

Disease and weed pressure are significant limiting factors to organic peanut production, especially in the southeastern U.S. (Branch and Culbreath, 2008; Guerena and Adam, 2008; Johnson et al., 2008). However, numerous runner-type cultivars have been released in recent years that have displayed excellent disease resistance and productive capacity in organic production scenarios (Branch and Culbreath, 2008; Holbrook and Culbreath, 2008; Holbrook et al., 2008a). Therefore, identifying effective weed control regimes for organic peanut has become paramount for improving the feasibility of organic production.

Weed management in conventional peanut cropping systems is typically achieved via a combination of crop rotation and various cultural practices, as well as cultivation and herbicide use for direct control (Ferrell, et al., 2009; Hauser et al., 1973). In certified organic production, application of synthetically-derived herbicides is forbidden (USDA, 2005). There are herbicide options available for organically-grown crops that are derived from natural sources. However, these herbicides are limited in scope and efficacy and cost-prohibitive for organic peanut production (Johnson and Mullinix, 2008; Johnson et al., 2008). Therefore, focus has shifted to non-chemical methods for direct weed control in organic peanut. Numerous non-chemical weed control techniques are available for organic systems, including mechanical, thermal, mulching, and biological methods (Bond and Grundy, 2001), although these techniques have shown mixed results. Johnson and Mullinix (2008) reported that clove oil, citric acid + acetic acid, and broadcast propane flaming used for remedial weed control, combined with sweep cultivation, were ineffective against annual grasses and dicot weeds and resulted in decreased peanut yields in an organic production scenario.

Sweep cultivation can be an effective method of controlling both mature weeds and weeds between peanut rows (Böhrnsen, 1993; Bowman, 1997; Wilcut et al., 1987). However, sweep blades are unable to remove weeds in or near the actual peanut row, where the effects of weed competition are greatest on crop plants (Bowman, 1997; Johnson and Mullinix, 2008; Smith et al, 2000). Tine cultivation, utilizing a tine weeder with rigid or spring-loaded tines, is an effective method for reducing in-row weed populations with minimal damage to the crop. The metal tines vibrate vigorously, providing weed control by disrupting or burying germinating weed seedlings within the top 3 cm of soil. The tines are also able to cultivate much closer to the actual crop rows than sweep blades, thus improving weed control closest to the actual crops (Bowman, 1997; Reddiex et al., 2001). Therefore, integration of tine cultivation could be an effective method of mechanical in-row weed control for organic peanut. The objective of this study was to assess the effects of various frequencies and durations of tine cultivations on weed control and overall productivity of runner-type peanut grown under organic management.

Materials and Methods

Irrigated field trials were conducted on a Tifton loamy sand (fine-loamy, Kaolinitic, thermic Plinthic Kandiudults): 88% sand, 10% silt, 2% clay, and 0.56% organic matter (2008 site) and 90% sand, 6% silt, 4% clay, and 0.88% (2009 site). The trials were conducted at the University of Georgia (UGA) Horticulture Hill and Lang-Rigdon Farms near Tifton, GA in 2008 and 2009, respectively. All plots were planted 6 June 2008 and 5 June 2009 using a 2-row precision air planter[6] at a depth of 6 cm and a seeding rate of 20 seed m^{-1}. Production practices included conventional-tillage prior to planting and irrigation as needed during the season, according to UGA recommendations for peanut (Beasley et al., 1997). No herbicides, fungicides (including seed treatments), or insecticides were applied to the plots at any point during the season in order to follow approved USDA-certified organic production practices.

The experiment utilized a strip-plot design with a 2 x 7 treatment arrangement: two peanut cultivars and seven cultivation treatments. A strip-plot design was utilized to allow sufficient plot length to facilitate equipment operation at an optimum speed, thus allowing the metal tines to properly vibrate and disrupt the soil. Individual plot sizes were 1.8 m x 9.2 m, with a 0.9-m standard row spacing. Cultivars planted were ‘Georganic’ (Holbrook and Culbreath) and ‘Tifguard’ (Holbrook et al., 2008a), which have displayed strong host plant resistance to foliar diseases. Additionally, Tifguard has displayed significant resistance to the peanut root-knot nematode (*Meloidogyne arenaria*), making it a strong option for organic production. Cultivation treatments included two frequencies (once per week [1x] or twice per week [2x]) for three durations (3 wk, 4 wk, or 5 wk). A non-cultivated, non-weeded control treatment was also included for comparison. Tine cultivations were conducted using a tine weeder[22] and were initiated 10 days after planting (DAP) in 2008 and 9 DAP in 2009.

Cultivation with flat sweeps was conducted once on all cultivated plots at the 3 wk tine cultivation (24 DAP in 2008 and 23 DAP in 2009) to control inter-row weeds. All cultivated plots were hand-weeded twice in 2008 (23 June and 14 July) and once in 2009 (28 July) to remove escaped weeds. Hand-weeding times were recorded for each plot.

Late-season weed population estimates were conducted on 28 Oct. 2008 and 22 Oct. 2009 using a 0.5-m^2 quadrat (91 cm x 55 cm), counting individual plants within the quadrat. Despite different maturity ranges for Tifguard (approximately 135 DAP) and Georganic (approximately 150 DAP), all plots in 2008 were inverted using a 2-row digger-shaker-inverter[4] on 30 Oct. due to cool temperatures (four consecutive days of minimum temperatures below 8° C) causing continued development to cease, and harvested 6 Nov. using a 2-row small plot peanut combine. In 2009, Tifguard plots were inverted on 23 Oct. and Georganic plots on 28 Oct. (cool October temperatures again ceased additional development of the Georganic cultivar). All plots were harvested 4 Nov. 2009. Final plant stand, hand-weeding time, final pod yield, and weed population data were collected for each treatment. Pod yields were adjusted to 7% moisture. Final plant stand counts were conducted on 6 Nov. 2008 and 2 Nov. 2009, covering 3 m of row per plot.

Economic analysis was also conducted for each treatment. Input costs for organic production included hand labor, seed, equipment, and fuel costs. Revenue data were generated based on an \$1100 Mg^{-1} premium for organic peanut and a \$9.12 hr^{-1} wage for hand labor (NASS-GA, 2010). Data were calculated for conventional peanut systems based on UGA Extension budgets for irrigated conventional-tillage peanut (Smith and Smith, 2009), in order to compare net revenues between organic peanut and an average conventional peanut revenue (assuming a 4500 kg ha^{-1} yield and a \$390 Mg^{-1} contract price). Input costs for conventional revenues included seed, chemical, equipment, fuel, and labor costs. Adjusted net revenue (ANR) was determined as $ANR = Y * (P - M) - (S - R - D)$, where Y is yield (kg ha^{-1}), P is price (\$ ha^{-1}), M is marketing costs (e.g. checkoff funding) (\$ ha^{-1}), S is seed cost (\$ ha^{-1}), R is costs for repair, equipment, labor, and fuel (\$ ha^{-1}), and D is drying costs (\$ ha^{-1}) for each treatment. Organic/conventional revenue ratios were determined by dividing organic adjusted net revenues from each treatment by the conventional adjusted net revenue value (\$1613 ha^{-1}).

Statistical analysis was performed with SAS 9.2 software[19]. Data were statistically analyzed by analysis of variance, using PROC GLM and PROC GLIMMIX. Means were separated using Tukey's Honestly Significant Difference test or Tukey-Kramer Groupings where appropriate ($P = 0.05$).

Results and Discussion

Prevalent weed species differed significantly between the two years. Pressure from annual grass species and perennial nutsedges was noticeably greater in 2008 than 2009. Therefore, weed population estimates were performed on crowfootgrass (*Dactyloctenium aegyptium* [L.] Willd.), goosegrass (*Eleusine indica* [L.] Gaertn.), southern crabgrass (*Digitaria ciliaris* [Retz.] Koeler), and yellow nutsedge (*Cyperus esculentus* L.) in 2008 but not in 2009. Populations of these weed species were too sparse to legitimately estimate in 2009. Estimates of Florida pusley (*Richardia scabra* L.) and smallflower morningglory (*Jacquemontia tamnifolia* [L.] Griseb.) were performed both years.

A number of significant interactions occurred among year, cultivar, and cultivation treatment in our data analysis. Florida pusley and smallflower morningglory population, final plant stand, pod yield data, and hand-weeding time all displayed either a significant year x cultivar or year x cultivation treatment interaction, or both. All of the year x cultivar interactions were due to differing magnitudes of response between years, however there were differences between cultivars, so data were pooled over year and separated by cultivar. Annual grass and yellow nutsedge population data in 2008 were also pooled over cultivar.

***Annual Grass Control*.** The three grass species counted in 2008 were combined for analysis and are subsequently expressed as “annual grasses,” consisting of approximately 65% crowfootgrass, 25% southern crabgrass, and 10% goosegrass. All cultivation treatments significantly affected annual grass weed populations (Table 5.1) but did not affect yellow nutsedge populations (data not shown). Annual grass populations were significantly reduced by all six cultivation treatments compared to the control. However, there were no significant differences among the varying frequencies or durations of cultivation. There did appear to be a slight trend in effect of cultivation frequency on annual grass density. Twice weekly cultivations resulted in numerically lower grass populations than the weekly cultivation treatments, although differences were not statistically significant. Additionally, the 2x – 5 wk treatment resulted in a 65% reduction in annual grass weeds, compared to the 1x – 3 wk cultivation treatment. It therefore appears that additional cultivations can still provide weed reductions, although the least and greatest cultivation regimes were statistically equivalent in annual grass control in this experiment. Overall, any combination of tine cultivation, flat-sweep cultivation, and hand-weeding in this experiment proved effective in significantly reducing annual grass populations compared to the non-cultivated group.

***Dicot Weed Control*.** The effects of cultivation on Florida pusley varied statistically between 2008 and 2009 (Table 5.1), but this was due primarily to differing pressure between the two test sites. The greatest weed pressure at the 2008 site was from annual grass species, with relatively low baseline Florida pusley populations. However, Florida pusley was the dominant weed species at the 2009 site. Therefore, treatment differences in Florida pusley control were non-existent in 2008, but were very pronounced in 2009. Similar to the trends in annual grass control, all cultivated treatments significantly reduced Florida pusley populations compared to the control in 2009. Differences between cultivation frequencies/durations, however, were again insignificant. Based on these results, it appears that, when Florida pusley is predominant, these cultivation regimes significantly reduce Florida pusley populations. However, when baseline Florida pusley populations are relatively low, tine cultivation is mostly ineffective at further reducing populations. It is also possible that the more prostrate growth habit of Florida pusley caused it to be outcompeted by the more upright annual grass species in 2008, when annual grass pressure was heavier. Thus, the surviving number of Florida pusley plants could have been equalized by this effect in all treatments, including the non-cultivated plots.

The effects of the cultivated treatments on smallflower morningglory populations were varied, but largely insignificant (Table 5.1). In 2008, all but two cultivated treatments (2x – 3 wk and 1x – 4 wk) were ineffective at significantly reducing smallflower morningglory populations compared to the control. Additionally, in 2009, there were no significant smallflower morningglory reductions among any cultivated treatments compared to the control. Therefore, in this experiment, tine cultivation + sweep cultivation + hand-weeding appeared to have very minor efficacy in controlling smallflower morningglory.

***Hand-Weeding Times*.** Differences in hand-weeding times among cultivated treatments had few significant differences when pooled over both year and cultivar (Table 5.2). The 2x – 5 wk cultivation treatment resulted in a statistically greater hand-weeding time than the 1x – 4 wk treatment. All other differences were insignificant. However, there were trends of the 2x cultivation frequency requiring more hand-weeding than the 1x frequency. It is possible that the 2x frequency resulted in over-cultivation, actually accelerating additional weed growth by incorporating surface weed seeds back into the soil or uncovering buried weed seedlings from previous cultivations. A trend also seemed to exist in that hand-weeding time increased as cultivation durations increased. Thus, the 2x – 5 wk treatment resulted in the greatest hand-weeding time numerically, though it was only statistically greater than the 1x – 4 wk treatment. These trends suggest that over-cultivation might be possible with a tine weeder, in which weed growth could actually be encouraged by additional disturbance, rather than suppressed. This is a very important point to consider, as hand-weeding represents one of the costliest inputs to any organic cropping system.

Final Plant Stand and Peanut Yield. In 2008, all cultivated treatments resulted in greater peanut stands compared to the control (Table 5.1). However, in 2009, only the 1x – 4 wk and 2x – 4 wk cultivation treatments resulted in higher plant densities than the control. This is an important consideration in organic peanut systems, where proper stand establishment is crucial for ensuring adequate ground coverage and overall productivity in the system. Peanut stands in cultivated treatments were also greater in 2008 than in 2009, when annual grass weeds were more populous. This suggests that small-seeded annual grass species could be very sensitive to tine cultivation. Therefore, tine cultivation can be a good option for improving peanut stands in scenarios where annual grasses are predominant.

Pod yields followed the similar trend of final plant stands (Table 5.1). Tine cultivation, combined with sweep cultivation and supplemental hand-weeding, significantly improved peanut yields in both 2008 and 2009. All cultivated treatments resulted in higher yields than the control in 2008. The 1x – 5 wk treatment also resulted in a significantly higher yield than that of the 1x

– 4 wk treatment. Remaining cultivated treatment yields were not significantly different from one another. In 2009, all cultivated treatments resulted in higher yields than the control. Yields among cultivated treatments, however, were not different. These data suggest that all cultivation regimes in this experiment significantly improved final peanut yields compared to no cultivation, although there were few statistical trends to claim that an increase in either frequency or duration of cultivation passes improved yield (except between the 1x – 4 wk and 1x – 5 wk treatments in 2008). Notably, cultivation in 2008 resulted in a 250% overall yield increase over the non-cultivated treatments, compared to only a 60% yield increase in 2009. Johnson and Mullinix (2005) reported that Texas panicum (*Panicum texanum* Buckl.) densities of 2.2 plants m^{-2} reduced pod yields by 25% and that other annual grasses have a similar impact on peanut yields. Therefore, the greater density of annual grasses in 2008 likely caused heavy yield reductions in the control groups, where annual grasses occurred at approximately 12.3 plants m^{-2}. Subsequently, a positive yield response occurred in all cultivated treatments. Similar to final plant stand, these results suggest that tine cultivation, along with flat-sweep cultivation and supplemental hand-weeding, can result in high levels of annual grass control and a greater yield response in scenarios where annual grass species are predominant.

***Cultivar Comparison*.** Differences in final plant stand, hand-weeding time, and pod yield were also significant between Georganic and Tifguard in both 2008 and 2009 (Table 5.3). Tifguard plots produced denser plant stands than Georganic and resulted in lower hand-weeding times. Tifguard also produced greater yields than Georganic plots both years. The same pattern appeared in the economic analyses for the two cultivars. When pooled over year and cultivation treatment, Tifguard generated net revenue of \$4082 ha^{-1}, which was significantly greater than the \$2333 ha^{-1} generated by Georganic ($P \leq 0.05$). Additionally, Tifguard resulted in net revenue

2.5x greater than an average conventional peanut crop. Georganic net revenue was only 1.4x the revenue of a conventional crop. The rapid, lateral growth habit of Tifguard likely provides quicker coverage of the bed, aiding in suppressing weed growth and significantly reducing the amount of hand-weeding. Therefore, the lower hand-weeding times in Tifguard treatments, combined with significantly greater peanut stands and yields, resulted in a more profitable system than did the Georganic treatments. Including unique host plant nematode resistance and a shorter growing season than Georganic, Tifguard appears to be a strong option for maximizing both yield and profitability in an organic peanut system.

***Economic Results*.** Net revenues generated by each cultivation treatment followed a similar trend as much of the aforementioned data. Revenue values in cultivated treatments ranged from \$3638 ha^{-1} to \$3334 ha^{-1} and were all significantly greater than the non-cultivated control (\$1795 ha^{-1}) ($P \leq 0.05$). Differences in net revenue among frequency/duration of cultivation were not significant. The ratios of organic revenue/conventional revenue followed the same trend. Ratios varied among cultivated treatments (2.1 to 2.3), but differences were not significant ($P \leq 0.05$). However, all cultivated treatments resulted in greater ratios than the control (1.1).

These data suggest that there is no statistical difference in net revenue generated by the 1x – 3 wk or 2x – 5 wk cultivation regimes. Therefore, the 1x – 3 wk treatment was sufficient to achieve maximized profits, along with maximized yields and weed control, while minimizing time spent cultivating and hand-weeding. However, the 2x – 5 wk regime resulted in an additional \$300 ha^{-1} revenue. Though this was not enough to be considered statistically significant, it would still be beneficial for growers to utilize the 2x – 5 wk regime and take full advantage of the subsequent revenue generated. Additional cultivations tended to increase hand-weeding time among cultivated treatments but the yield response from the additional cultivations offset the greater hand-weeding costs to result in greater net revenue. All treatments also resulted in equivalent or greater revenues than an average conventional cropping system. Cultivated treatments consistently resulted in double the revenue generated by a conventional peanut crop. Even the control group, with no cultivation or hand-weeding all season, resulted in a revenue equivalent to that of a conventional crop. However, it should be understood that considerable time and effort in weed management was necessary for several years prior to peanut establishment in order to get weed seedbank populations to extremely low levels in the low weed pressure section of the 2008 experiment. This resulted in atypical sections of field where yields for the non-cultivated plots were substantially inflated compared to normal organic operations. Therefore, significant economic incentives exist for peanut growers who are interested in organic production, but those higher revenues are needed in order to offset low revenues associated with the transitional period before organic certification, when organic premiums are not offered, yet organic management must be strictly followed.

Summary and Conclusions

These results show that tine cultivation, combined with one flat-sweep cultivation and supplemental hand-weeding, can significantly improve the productivity and profitability of both Georganic and Tifguard peanut cultivars in an organic management scenario. In this experiment, cultivated treatments significantly reduced densities of annual grasses and Florida pusley. They did not, however, effectively control yellow nutsedge or smallflower morningglory. These weed control regimes also resulted in significant final plant stand and yield improvements. Yields in cultivated treatments were 55-280% greater than those in the non-cultivated controls. There was also evidence that initial weed species composition played a significant role in the effectiveness of cultivation on peanut stand and pod yield. Annual grasses are very competitive with peanut. However, the combination of timely tine weeding, sweep cultivation, and supplemental hand-weeding controlled annual grasses and maximized pod yields. Tifguard appeared to be a strong cultivar option in an organic system, having resulted in lower hand-weeding times and producing greater plant densities, yields, and net revenues than Georganic. With the high price premiums available today for certified organic peanut, there is significant potential for the profitability of utilizing tine cultivation regimes for weed control in organic peanut. All cultivation regimes resulted in greater net revenues than the control. However, in this experiment, the varying frequencies and durations of cultivation did not differ significantly in how they affected weed control, pod yield, or net revenue. It appears that the minimum cultivation treatment (1x – 3 wk) was acceptable to provide both sufficient weed control and maximized yield and revenue. However, additional cultivations up to 5 wk provided a 10% increase in net revenue. From our observations, it was also apparent that supplemental hand-weeding is an unavoidable necessity in any organic weed management program and represents one of the costliest inputs to any organic cropping system. A limitation of this data is that we did not have the ability to include a cultivated control that did not have hand-weeding to quantify differences of cultivation vs. hand-weeding. Additional research is needed to address such differences.

Table 5.1. Effect of cultivation frequency and duration on annual grasses, Florida pusley, and smallflower morningglory populations, final plant stand, and pod yield of peanut under organic management in Tifton, GA in 2008-2009.

Cultivation Regime[a]	Annual Grasses[b]	Florida Pusley		Smallfl. Morningglory		Final Plant Stand		Pod Yield	
	2008	2008	2009	2008	2009	2008	2009	2008	2009
	------------------------------plants m^{-2}----------------------------					------plants m^{-1}------		--------kg ha^{-1}-------	
Control	12.3 a	0.7 a	12.0 a	0.6 a	1.5 a	3.9 b	7.9 b	1140 c	2220 b
1x – 3 wk[c]	4.0 b	0.8 a	2.5 b	0.1 ab	1.0 a	11.7 a	9.4 ab	3770 ab	3700 a
2x – 3 wk	1.9 b	0.8 a	2.0 b	0 b	0.5 a	12.1 a	9.5 ab	3620 ab	3550 a
1x – 4 wk	2.4 b	1.2 a	3.7 b	0 b	0.5 a	13.2 a	10.6 a	3520 b	3670 a
2x – 4 wk	2.1 b	0.3 a	5.2 b	0.2 ab	1.5 a	12.6 a	10.9 a	4150 ab	3520 a
1x – 5 wk	2.8 b	0.1 a	5.0 b	0.1 ab	0.5 a	12.3 a	9.8 ab	4340 a	3490 a
2x – 5 wk	1.4 b	0.6 a	2.7 b	0.5 ab	0.5 a	12.5 a	9.2 ab	4240 ab	3420 a
MSD[d]	3.5	1.2	5.6	0.6	1.4	2.6	2.5	810	400

Means within a column followed by the same lowercase letter are not significantly different according to Tukey's Honestly Significant Difference test at P = 0.05.

[a] Data pooled over cultivar.

[b] "Annual grasses" were a composite of crowfootgrass (65%), southern crabgrass (25%), and goosegrass (10%).

[c] "1x" and "2x" indicate weekly and twice weekly cultivations, respectively; "wk" indicates total number of weeks of cultivation

[d] Minimum significant difference.

Table 5.2. Hand-weeding times as influenced by cultivation regime, in peanut under organic management in Tifton, GA in 2008-2009.

Cultivation Regime[a,b]	Hand-Weeding Time
	man hours ha^{-1}
1x – 3 wk[c]	69 ab
2x – 3 wk	64 ab
1x – 4 wk	58 b
2x – 4 wk	74 ab
1x – 5 wk	74 ab
2x – 5 wk	89 a
MSD[d]	27

Means within a column followed by the same lowercase letter are not significantly different according to Tukey's Honestly Significant Difference test at P = 0.05.

[a] Data pooled over cultivar and year.

[b] Non-cultivated treatments were not hand-weeded due to heavy weed infestations and were thus excluded from analysis

[c] "1x" and "2x" indicate weekly and twice weekly cultivations, respectively; "wk" indicates total number of weeks of cultivation

[d] Minimum significant difference.

Table 5.3. Final plant stand, hand-weeding times, and pod yield as influenced by peanut cultivar under organic management in Tifton, GA in 2008-2009.

Cultivar[a]	Final Plant Stand	Hand-Weeding Time	Pod Yield[b] 2008	2009
	plants m^{-1}	man hours ha^{-1}	-----------kg ha^{-1}---------	
Georganic[c]	10.1 b	78 a	2820 b	2700 b
Tifguard[d]	11.0 a	64 b	4260 a	3700 a
MSD[e]	0.6	11	270	130

Means within a column followed by the same lowercase letter are not significantly different according to Tukey's Honestly Significant Difference test at P = 0.05.

[a] Data pooled over cultivation treatment and year.

[b] Data pooled over cultivation treatment only.

[c] Reaches maturity at approximately 150 days after planting (DAP).

[d] Reaches maturity at approximately 135 DAP.

[e] Minimum significant difference.

CHAPTER 6

SUMMARY AND CONCLUSIONS

There are clear differences among cover crop species in decomposition and nutrient release, however these can vary based on tillage system. Wheat displayed the greatest rate of biomass decline in conventional-tillage, but was not different from rye in strip-tillage both years. The lower C:N ratio of wheat in 2009 accounted for some of this effect, however the lignin:N ratios of the residues could have also been a factor, since crimson clover typically has a higher lignin:N ratio than wheat and rye. Conventional-tillage resulted in more rapid residue decomposition than strip-tillage, as a result of greater contact with soil and soil microorganisms in the former. Despite the sharper decline of wheat residues, crimson clover residues in conventional-tillage released the greatest amounts of N, P, K, Ca, Mg, B, and Zn in 2009. Cover crops had very little impact on soil nutrients, although a slight increase was apparent for some nutrients during the first 60-90 DAB. Additionally, cover crops had only minimal effects on nutrient uptake by peanut. Strip-tillage resulted in greater N, K, Mg, S, Mn, and Zn in pods under the near-drought conditions observed in 2010, likely as a result of subsoiling and greater root growth and nutrient uptake by peanut in response to drought. These nutrient effects, however, had almost no effect on peanut yield and grade. More research is needed to evaluate the potential for cover crops and strip-tillage to improve peanut nutrition and production in a long-term scenario, where nutrient benefits could potentially become more pronounced in strip-tillage over time.

The results of this research also indicate that a number of peanut cultivars are available for viable use in organic production in the southeastern U.S. It is ideal to consider stand establishment, disease resistance, and yield and grade potential when selecting a cultivar for organic production. CRSP 983 and Georganic both displayed excellent resistance to early and late leaf spot diseases, but produced either poor stands or meager yields. Tifguard, however, exhibited the most ideal combination of stand establishment, leaf spot resistance, and yield and would be an excellent candidate for commercial organic production. It also has near-immunity to the peanut root-knot nematode, which gives it added potential for production in areas of heavy nematode pressure. Florida-07 and Georgia-06G are also excellent options, with widespread commercial-availability for growers interested in organic production. Additionally, the organic fungicides evaluated in these experiments all showed potential for improving peanut yield under heavy leaf spot pressure, but effects were minimized when pressure was light. Combined with high-yielding, disease-resistant cultivars, these fungicides could help peanut growers effectively combat the harmful effects of leaf spot diseases that limit organic production in the southeastern U.S.

Cultivation is a viable option for effective, economical weed control in organic peanut. Utilizing tine cultivation at least once weekly for three weeks, combined with one flat-sweep cultivation and one hand-weeding, appears to be sufficient for controlling annual grasses and broadleaf weeds, while maximizing yields and subsequent net revenues. There does not appear to be a significant benefit from performing additional tine cultivations, although another two weekly cultivations resulted in a \$300 ha^{-1} revenue boost. These results indicate that this combination of cultivation and hand-weeding can be a viable and affordable for organic peanut, without a single herbicide application.

These production strategies all have the potential to reduce grower dependency on agrichemicals for significant, profitable production. By improving nutrient management through cover cropping, growers could potentially reduce costly fertilizer inputs and/or improve the efficient use of those inputs. Additionally, by utilizing disease-resistant cultivars and cultivation, conventional peanut growers could reduce fungicide and herbicide inputs, or eliminate them altogether for certified organic production. Over time, reduced dependency on synthetic agrichemicals could significantly improve both the stability and sustainability of peanut production for the long-term.

SOURCES OF MATERIALS

[1] AGCO Corporation, Duluth, GA 30096

[2] Roundup WeatherMax®, Monsanto Company, St. Louis, MO 63167

[3] Lime Plaster Corporation, Ty Ty, GA 31795

[4] Kelley Manufacturing Company, Tifton, GA 31793

[5] Phifer, Inc., Tuscaloosa, AL 35401

[6] Monosem, Inc., Edwardsville, KS 66111

[7] Amvac Chemical Corporation, Los Angeles, CA 90023

[8] Dynasty®, Syngenta Crop Protection, Inc., Greensboro, NC 27409

[9] Headline®, BASF Corp., Research Triangle Park, NC 27709

[10] Provost®, Bayer CropScience LP, Research Triangle Park, NC 27709

[11] Abound®, Syngenta Crop Protection, Inc., Greensboro, NC 27409

[12] Bravo®, Syngenta Crop Protection, Inc., Greensboro, NC 27409

[13] Solubor®, U.S. Borax, Inc., Boron, CA 93516

[14] CEM Corporation, Matthews, NC 28104

[15] Thermo Jarrell-Ash Corporation, Franklin, MA 02038

[16] LECO Corporation, St. Joseph, MI 49085

[17] LabFit, Perth, Australia

[18] Spectrum Technologies, Inc., Plainfield, IL 60585

[19] SAS Institute, Cary, NC 27513

[20] Triangle® 99% Copper Sulfate, Phelps Dodge, El Paso, TX 79915

[21] Serenade®, Agraquest Inc., Davis, CA 95618

[22] Aerostar®, Einböck GmbH & CoKG, Austria

REFERENCES

Baldwin, J.A. and J. Hook. 1998. Reduced tillage systems for peanut production in Georgia. Proc. Am. Peanut Res. Educ. Soc. 30:48.

Baldwin, K.R. 2006. Conservation tillage on organic farms. E06-45788. North Carolina State Univ. Coop. Ext. Serv., NCSU, Raleigh, NC.

Ball, D.F. 1964. Loss-on-ignition as an estimate of organic matter and organic carbon in non-calcareous soils. Euro. J. Soil Sci. 15:84-92.

Banerjee, S., S.W. Martin, R.K. Roberts, J.A. Larson, R. Hogan, Jr., J.L. Johnson, K.W. Paxton, and J.M. Reeves. 2007. Adoption of conservation-tillage practices in cotton production. Southern Agric. Econ. Assoc. Annual Meeting, 4-7 Feb. 2007, Mobile, AL.

Bàrberi, P. 2002. Weed management in organic agriculture: Are we addressing the right issues? Weed Res. 42:177-193.

Bauer, P.J., J.R. Frederick, J.M. Novak, and P.G. Hunt. 2004. Soil respiration rates after 25 years of no-tillage. p. 118-125. *In* Proc. 26th Southern Conserv. Tillage Conf. for Sustainable Agric., 8-9 June 2004, Raleigh, NC.

Beasley, J.P., Jr., J.A. Baldwin, S.L. Brown, S.M. Brown, B. Padgett, M.J. Bader, and D. Shurley. 1997. Georgia peanut production guide. Univ. of Georgia Coop Ext. Serv. Guid Agron. 95-001, Athens, GA.

Böhrnsen, A. 1993. Several years' results about mechanical weeding in cereals. *In* Communications 4th International Conference IFOAM, Non-chemical Weed Control, Dijon, France, p. 95-101.

Bond, W. and A.C. Grundy. 2001. Non-chemical weed management in organic farming systems. Weed Res. 41:383-405.

Boudreau, M.A., R. Walker, W.C. Johnson, R. Hicks, N. Smith, and E. Cantonwine. 2008. Preliminary report: On-farm validation of an integrated weed management system in certified organic peanut production in Georgia [Abstract]. p. 50-51. *In* Proc. 2008 Southeast Regional Fruit and Vegetable Growers Association Conf., 10-13 Jan. 2008, Savannah, GA.

Bowman, G. 1997. Steel in the Field: a Farmer's Guide to Weed Management Tools. Burlington, VT: Sustainable Agriculture Publications. Univ. of Vermont, Burlington, VT.

Brady, N.C. and R.R. Weil. 2002. The nature and properties of soils. 13th Ed. Pearson Educ., Inc., Upper Saddle River, NJ.

Branch, W.D. 2004. Registration of ‘Georgia-03L’ peanut. Crop Sci. 44:1485-1486.

Branch, W.D. 2007. Registration of ‘Georgia-06G’ peanut. J. Plant Reg. 1:120.

Branch, W.D. 2009. Registration of ‘Georgia-08V’ peanut. J. Plant Reg. 3:143-145.

Branch, W.D., and A.K. Culbreath. 2008. Disease and insect assessment of candidate cultivars for potential use in organic production. Peanut Sci. 35:61-66.

Brandi-Dohrn, F.M., R.P. Dick, M. Hess, S.M. Kauffman, and D.D. Hemphill, Jr., and J.S. Selker. 1997. Nitrate leaching under a cereal rye cover crop. J. Environ. Qual. 26:181-188.

Brecke, B.J. and and D.O. Stephenson, IV. 2006. Weed management in single- vs. twin-row peanut (*Arachis hypogaea*). Weed Tech. 20:368-376.

Brown, S., J. Todd, A. Culbreath, J. Beasley, R. Kemerait, E. Prostko, T. Brenneman, N. Smith, D. Gorbet, B. Tillman, R. Weeks, A. Hagan, W. Faircloth, D. Rowland, and R. Pittman. 2007. TSWV of peanut: minimizing spotted wilt of peanut including the 2007 version of the Tomato Spotted Wilt Risk Index [Online]. Available at http://www.tomatospottedwiltinfo.org/peanut/risk.html#population (verified 28 Apr. 2011).

Caamal-Maldonado, J.A., J.J. Jiménez-Osornio, A. Torres-Barragán, and A.L. Anaya. 2001. The use of allelopathic legume cover and mulch species for weed control in cropping systems. Agron. J. 93:27-36.

Cantonwine, E.G., A.K. Culbreath, B.B. Shew, and M.A. Boudreau. 2008. Efficacy of organically acceptable fungicides for management of early and late leaf spot diseases on partially resistant peanut cultivars. Online. Plant Health Progress doi:10.1094/PHP-2008-0317-03-RS.

Cantonwine, E.G., A.K. Culbreath, and K.L. Stevenson. 2007. Effects of cover crop residue and preplant herbicide on early leaf spot of peanut. Plant Dis. 91:822-827.

Collins, G., J. Whitaker, S. Culpepper, G. Harris, R. Kemerait, P. Roberts, D. Shurley, and A. Smith. 2011. 2011 Georgia cotton production guide. Tifton, GA: University of Georgia Cooperative Extension Service Publ. CSS-11-01.

Collins, H.P., L.F. Elliot, R.W. Rickman, D.F. Bezdicek, and R.I. Papendick. 1990. Decomposition and interactions among wheat residue components. Soil Sci. Soc. Am. J. 54:780-785.

Colvin, D.L, B.J. Brecke, and E.B. Whitty. 1988. Tillage variables for peanut production. Peanut Sci. 15:94-97.

Coppens, F., P. Garnier, S. De Gryze, R. Merckx, and S. Recous. 2006. Soil moisture, carbon, and nitrogen dynamics following incorporation and surface application of labeled crop residues in soil columns. Euro. J. Soil Sci. 57:894-905.

Cox, F.R., F. Adams, and B.B. Tucker. 1982. Liming, fertilization, and mineral nutrition. p. 139-163. *In* H.E. Pattee and C.T. Young (eds.) Peanut science and technology. Am. Peanut Res. Educ. Soc., Inc., Yoakum, TX.

Crusciol, C.A.C. and R.P. Soratto. 2009. Nitrogen supply for cover crops and effects on peanut grown in succession under a no-till system. Agron. J. 101:41-46.

[CTIC] Conservation Technology Information Center. 2004. Conservation tillage and other tillage types in the U.S. – 1990-2004 [Online]. Available at http://ctic.org/media/pdf/Core4/1990-2004data.pdf (verified 28 Apr. 2011). CTIC, West Lafayette, IN.

[CTIC] Conservation Technology Information Center. 2011. Tillage type definitions [Online]. Available at http://ctic.org/resourcedisplay/322/ (verified 28 Apr. 2011). CTIC, West Lafayette, IN.

Culbreath, A., J. Beasley, R. Kemerait, E. Prostko, T. Brenneman, N. Smith, S. Tubbs, R. Olatinwo, R. Srinivasan, B. Tillman, and A. Hagan. 2010. Peanut Rx: Minimizing diseases of peanut in the southeastern United States, the 2010 version of the peanut disease risk index. p. 81-96. *In* J.P. Beasley (ed.) 2010 Peanut Update. Spec. Publ. CSS-10-0125. Univ. of Georgia Coop. Ext., Athens, GA.

Dabney, S.M., J.A. Delgado, and D.W. Reeves. 2001. Using winter cover crops to improve soil and water quality. Commun. Soil Sci. Plant Anal. 32:1221-1250.

Derpsch, R. 2003. Conservation tillage, no tillage, and related technologies. p. 181-190. *In* L. Garcia-Torres et al. (eds.) Conservation agriculture. Kluwer Academic Publishers, The Netherlands.

Dick, R.P. 1992. A review: long-term effects of agricultural systems on soil biochemical and microbial parameters. Agric., Ecosystems, and Env. 40:25-36.

Dimitri, C., and C. Greene. 2002. Recent growth patterns in the U.S. organic foods market [Online]. USDA-Econ. Res. Ser. Agric. Info. Bull. No. 777. Available at http:// www.ers.usda.gov/publications/aib777/aib777c.pdf (verified 28 Apr. 2011).

Doran, J.W. and M.S. Smith. 1991. Role of cover crops in nitrogen cycling. p. 85-90. *In* W.L. Hargrove (ed.) Cover crops for clean water. Soil and Water Conserv. Soc., Ankeny, IA.

Douglas, C.L, Jr. and R.W. Rickman. 1992. Estimating crop residue decomposition from air temperature, initial nitrogen content, and residue placement. Soil Sci. Am. J. 56:272-278.

Durham, S. 2003. Drought survival with conservation tillage. Agric. Res. 51:22.

Ebelhar, S.A., W.W. Frye, and R.L. Blevins. 1984. Nitrogen from legume cover crops for no-tillage corn1. Agron. J. 76:51-55.

Everman, W.J., S.B. Clewis, W.E. Thomas, I.C. Burke, and J.W. Wilcut. 2008. Critical period of weed interference in peanut. Weed Tech. 22(1):63-67.

[FAO] Food and Agricultural Organization of the United Nations. 2009. FAO Statistical yearbook [Online]. Available at http://www.fao.org/economic/the-statistics-division-ess/publications-studies/statistical-yearbook/fao-statistical-yearbook-2009/en/ (verified 28 Apr. 2011). FAO, Rome, Italy.

[FAO] Food and Agricultural Organization of the United Nations. 2008. What is conservation agriculture? [Online]. Available at http://www.fao.org/ag/ca/1a.html (verified 28 Apr. 2011). FAO, Rome, Italy.

Ferrell, J.A., G.E. MacDonald, and B.J. Brecke. 2009. Weed management in peanuts. Spec. 3 Ser. SS-AGR-03. Florida Coop. Ext. Serv., IFAS, Univ. of Florida, Gainesville.

Gallaher, R.N. (ed.). 1980. Proc. 3rd Annu. No-Tillage Systems Conf.: Energy Relationships in Minimum Tillage Systems. Univ. of Florida, IFAS, Gainesville, FL.

Gallaher, R.N. and L. Hawf. 1997. Role of conservation tillage in production of a wholesome food supply. p. 23-27. *In* R.N. Gallaher and R. McSorley (eds.) Proc. Southern Conserv. Tillage Conf. for Sustainable Agric., 20th, Gainseville, FL. 24-26 June 1997. Spec. Ser. SS-AGR-60. Florida Coop. Ext. Serv., IFAS, Univ. of Florida, Gainesville.

Gaskell, M., B. Fouche, S. Koike, T. Lanini, J. Mitchell, and R. Smith. 2000. Organic vegetable production in California—science and practice. Hort. Tech. 10:699-713.

Gebhardt, M.R., T.C. Daniel, E.E. Schweizer, and R.R. Allmaras. 1985. Conservation tillage. Science 230:625-630.

Gopinath, K.A., N. Kumar, B.L. Mina, A.K. Srivastva, and H.S. Gupta. 2009. Evaluation of mulching, stale seedbed, hand weeding, and hoeing for weed control in organic garden pea (*Pisum sativum* sub sp. Hortens L.). Arch. Agron. Soil Sci. 55:115-123.

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

Grey, T.L., W.K. Vencill, N. Mantripagada, and A.S. Culpepper. 2007. Residual herbicide dissipation from soil covered with low-density polyethylene mulch or left bare. Weed Sci. 55:638–643.

Grichar, W.J. 2006. Peanut response to conservation tillage systems. Online. Crop Management doi:10.1094/CM-2006-0228-01-RS.

Guerena, M. and K. Adam. 2008. Peanuts: Organic production [Online]. Available at http://attra.ncat.org/attra-pub/PDF/peanuts.pdf (verified 28 Apr. 2011). ATTRA – National Sustainable Agriculture Information Service, Fayetteville, AR.

Hallock, D.L., D.C. Martens, and M.W. Alexander. 1971. Distribution of P, K, Ca, Mg, B, Cu, Mn, and Zn in peanut lines near maturity. Agron J 63:251-256.

Hauser, E.W., S.R. Cecil, and C.C. Dowler. 1973. Systems of weed control for peanut. Weed Sci. 21(3):176-180.

Havlin, J.L., J.D. Beaton, S.L. Tisdale, and W.L. Nelson. 2005. Soil fertility and fertilizers: an introduction to nutrient management. 7th Ed. Pearson Educ., Inc., Upper Saddle River, NJ.

Henning, R.J., A.H. Allison, and L.D. Tripp. 1982. Cultural practices. p. 123-138. *In* H.E. Pattee and C.T. Young (eds.) Peanut science and technology. Am. Peanut Res. Educ. Soc., Inc., Yoakum, TX.

Hively, W.D. and W.J. Cox. 2001. Interseeding cover crops into soybean and subsequent corn yields. Agron. J. 93:308-313.

Holbrook, C.C., and A.K. Culbreath. 2008. Registration of ‘Georganic’ peanut. J. Plant Reg. 2:17.

Holbrook, C.C., P. Timper, A.K. Culbreath, and C.K. Kvien. 2008a. Registration of ‘Tifguard’ peanut. J. Plant Reg. 2:92-94.

Holbrook, C.C., P. Timper, W. Dong, C.K. Kvien, and A.K. Culbreath. 2008b. Development of near-isogenic lines with and without resistance to the peanut root-knot nematode. Crop Sci. 48:194–198.

Ibewiro, B., N. Sanginga, B. Vanlauwe, and R. Merckx. 2000. Nitrogen contributions from decomposing cover crop residues to maize in a tropical derived savanna. Nutr. Cycl. in Agroecosystems. 57:131-140.

Johnson, W.C. 2006. Progress report: weed management in organic peanut production [Abstract]. *In* Proc. Am. Peanut Res. Educ. Soc. Annual Meeting. 11-14 July 2006, Savannah, GA. 38:90.

Johnson, W.C., III, and B.G. Mullinix, Jr. 2005. Texas panicum (*Panicum texanum*) interference in peanut (*Arachis hypogaea*) and implications for treatment decisions. Peanut Sci. 32:68-72.

Johnson, W.C., III, and B.G. Mullinix, Jr. 2008. Potential weed management systems for organic peanut production. Peanut Sci. 35:67-72.

Johnson, W.C., III, B.G. Mullinix, Jr., and M.A. Boudreau. 2008. Peanut response to naturally derived herbicides used in organic crop production. Peanut Sci. 35:73-75.

Johnson, W.C., E. Prostko, and B. Mullinix, Jr. 2002. Texas panicum (*Panicum texanum*) control in strip-tillage peanut (*Arachis hypogaea*) production. Peanut Sci. 29:141-145.

Johnson, W.C., T.B. Brenneman, S.H. Baker, A.W. Johnson, D.R. Sumner, and B.G. Mullinix, Jr. 2001. Tillage and pest management considerations in a peanut–cotton rotation in the southeastern Coastal Plain. Agron. J. 93:570–576.

Jordan, D.L., J.S. Barnes, C.R. Bogle, G.C. Naderman, G.T. Roberson, and P.D. Johnson. 2001. Peanut response to tillage and fertilization. Agron. J. 93:1125-1130.

Jordan, D.L., J.S. Barnes, C.R. Bogle, R.L. Brandenburg, J.E. Bailey, P.D. Johnson, and A.S. Culpepper. 2003. Peanut response to cultivar selection, digging date, and tillage intensity. Agron. J. 95:380-385.

Jordan, D.L., J.S. Barnes, T. Corbett, C.R. Bogle, P.D. Johnson, B.B. Shew, S.R. Koenning, W. Ye, and R.L. Brandenburg. 2008. Crop response to rotation and tillage in peanut-based cropping systems. Agron. J. 100:1580-1586.

Kemerait, R. C., Brenneman, T. B., and Culbreath, A. K. 2009. Peanut disease control. p. 157-159, in: 2009 Georgia Pest Management Handbook, Commercial Edn. P. Guillebeau, ed. Coop. Ext. Ser., Univ. of Georgia, Athens.

[Keystone] Keystone Alliance for Sustainable Agriculture. 2009. Field to market. 90th Annual Meeting Am. Farm Bureau Fed., 11-14 Jan. 2009, San Antonio, TX. Available online at http://keystone.org/files/file/FINAL%20Field_to_Market_Background_June_2010.ppt (verified 28 Apr. 2011).

Koike, S.T., M. Gaskell, C. Fouche, R. Smith, and J. Mitchell. 2000. Plant disease management for organic crops. Davis: University of California. ANR Publication 7252.

Kuepper, G. and L. Gegner. 2004. Organic crop production overview [Online]. Available at http://attra.ncat.org/attra-pub/PDF/organiccrop.pdf (verified 28 Apr. 2011). ATTRA – National Sustainable Agriculture Information Service, Fayetteville, AR.

Kuo, S., U.M. Sainju, and E.J. Jellum. 1997. Winter cover crop effects on soil organic carbon and carbohydrate in soil. Soil Sci. Soc. Am. J. 61:145-152.

Lamb, M.C., E. Cantonwine, R.B. Sorensen, R.C. Nuti, G. Tillman, and N.B. Smith. 2007. Economics of organic versus conventional peanut and cotton. Proc. Am. Peanut Res. Educ. Soc. 39:73.

Logan, T.J. 1990. Sustainable agriculture and water quality. p. 584-585. *In* C.A. Edwards, R. Lal, P. Madden, R.H. Miller, and G. House (eds.) Sustainable Agricultural Systems. Soil and Water Conserv. Soc., Ankeny, IA.

Marois, J.J. and D.L. Wright. 2003. Effect of tillage system, phorate, and cultivar on tomato spotted wilt of peanut. Agron. J. 95:386-389.

Mehlich, A. 1953. Determination of P, K, Ca, Mg, Na, and NH_4. Soil Test Div. Mimeo, N.C. Dept. of Agri., Raleigh. Available online at http://www.ncagr.com/agronomi/pdffiles/ mehlich53.pdf (verified 28 Apr. 2011).

Melillo, J.M., J.D. Aber, and J.F. Muratore. 1982. Nitrogen and lignin control of hardwood leaf litter decomposition dynamics. Ecology 63:621-626.

Morey, D.D. 1970. Registration of ‘Wrens Abruzzi’ rye1 (reg. no. 3). Crop Sci. 10:209-210.

Munawar, A., R.L. Blevins, W.W. Frye, and M.R. Saul. 1990. Tillage and cover crop management for soil water conservation. Agron. J. 82:773-777.

[NASS] USDA National Agricultural Statistics Service. 2007. 2008 Organic Survey [Online]. http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Organics/ organics_1_01.pdf (verified 28 Apr. 2011). USDA-NASS, Washington, D.C.

[NASS] National Agricultural Statistics Service. 2008. Organic field crops harvested from certified and exempt organic farms: 2008 [Online]. NASS, Agricultural Statistics Board, U.S. Dept. of Agriculture, Washington, D.C. Available at http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Organics/ organics_1_07.pdf (verified 28 Apr. 2011).

[NASS-GA] National Agricultural Statistics Service in cooperation with the Georgia Department of Agriculture. 2010. Farm labor news release: hired workers down 1 percent, wage rates up 2 percent from a year ago. NASS, U.S. Dept. of Agriculture, Georgia Field Office, Athens, GA.

Pandey, R.K., W.A.T. Herrera, A.N. Villegas, and J.W. Pendleton. 1984. Drought response of grain legumes under irrigation gradient: III. Plant Growth1. Agron. J. 76:557-560.

Phatak, S.C. 1998. Managing pests with cover crops. p. 25-33. *In* C. Shirley, G. Bowman, and C. Cramer (eds.) Managing Cover Crops Profitably. Sustainable Agriculture Network, Burlington, VT.

Pimentel, D., P. Hepperly, J. Hanson, D. Douds, and R. Seidel. 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioSci. 55(7):573-582.

Price, A.J., D.W. Reeves, M.G. Patterson, K.S. Balkcom, F.J. Arriaga, and D. Monks. 2007. Weed control in peanut (*Arachis hypogaea* L.) grown in a high-residue conservation-tillage system. Peanut Sci. 34:59-64.

Puppala, N. 2007. Effects of biofungicides and botanical extracts on yield and quality of Valencia peanut. Proc. Am. Peanut Res. Educ. Soc. 38:90-91.

Quemada, M. and M.L. Cabrera. 1995. Carbon and nitrogen mineralized from leaves and stems of four cover crops. Soil Sci. Soc. Am. J. 59:471-477.

Ranells, N.N. and M.G. Wagger. 1992. Nitrogen release from crimson clover in relation to plant growth stage and plant growth stage and composition. Agron. J. 84:424-430.

Reddiex, S.J., S.D. Wratten, G.D. Hill, G.W. Bourdôt, and C.M. Frampton. 2001. Evaluation of mechanical weed management techniques on weed and crop populations. New Zealand Plant Prot. 54:174-178.

Rowland, D.L., W.H. Faircloth, and K. Gray. 2006. Conservation tillage and water management I: Quantifying crop water use in conservation tillage systems [Abstract]. *In* R.C. Schwartz, R.L. Baumhardt, and J.M. Bell (eds.) Proc. 28th Southern Conserv. Tillage Systems Conf., Amarillo, Texas. June 26-28, 2006. USDA–ARS Conserv. and Prod. Res. Lab, Report No. 06-1, Bushland, TX.

Ruark, S.J. and B.B. Shew. 2008. Evaluation of biological and other novel seed treatments for use in organic peanut production. Proc. Am. Peanut Res. Educ. Soc. 40:20-21.

Sainju, U.M., B.P. Singh, and W.F. Whitehead. 1997. Cover crop root distribution and its effects on soil nitrogen cycling. Agron J. 90:511-518.

Sainju, U.M., B.P. Singh, and W.F. Whitehead. 2002. Long-term effects of tillage, cover crops, and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. Soil Tillage Res. 63:167-179.

[SAN] Sustainable Agriculture Network. 2007. Benefits of cover crops. p. 9-11. *In* A. Clark (ed.) Managing cover crops profitably. SAN, Beltsville, MD.

Sarrantonio, M. 2007. Building soil fertility and tilth with cover crops. p. 16-24. *In* A. Clark (ed.) Managing cover crops profitably. Sustainable Agriculture Network, Beltsville, MD.

Schomberg, H.H., P.B. Ford, and W.L. Hargrove. 1994. Influence of crop residues on nutrient cycling and soil chemical properties. p. 99-121. *In* P.L. Unger (ed.) Managing agricultural residues. CRC Press, Inc., Boca Raton, FL.

Schomberg, H.H., R.G. McDaniel, E. Mallard, D.M. Endale, D.S. Fisher, and M.L. Cabrera. 2006. Conservation tillage and cover crop influences on cotton production on a southeastern U.S. coastal plain soil. Agron. J. 98:1247-1256.

Shew, B.B., E.G. Cantonwine, A.K. Culbreath, and M.A. Boudreau. 2006. Disease control for organic peanuts. Proc. Am. Peanut Res. Educ. Soc. 38:90-91.

Sholar, J.R., Mozingo, R.W., and Beasley, J.P., Jr. 1995. Peanut cultural practices. p. 354-382. *In* H.E. Pattee and H.T. Stalker (eds.) Advances in Peanut Science, Amer. Peanut Res. Educ. Soc., Stillwater, OK.

Simoes, R.P., R.L. Raper, F.J. Arriaga, K.S. Balkcom, and J.N. Shaw. 2009. Using conservation systems to alleviate soil compaction in a southeastern United States ultisol. Online abstract. doi:10.1016/j.still.2009.01.004. Elsevier, St. Louis, MO.

Siri-Prieto, G., D.W. Reeves, and R.L. Raper. 2007. Tillage systems for a cotton-peanut rotation with winter-annual grazing: Impacts on soil carbon, nitrogen, and physical properties. Soil Till. Res. 96:260-268.

Smith, D.H. 1984. Foliar diseases: early and late leaf spots. p. 5-7. *In* D.M. Porter, D.H. Smith, and R. Rodríguez-Kábana (ed.) Compendium of peanut diseases. Am. Phytopath. Soc., St. Paul, MN.

Smith, N.B., and A.R. Smith. 2009. Peanuts, irrigated – estimated costs and returns [Online]. Univ. of Georgia Coop. Ext. Serv., Ext. Agric. and Applied Economics, Athens, GA. Available at http://www.ces.uga.edu/Agriculture/agecon/budgets/printed/2010PeanutIrrigated.pdf (verified 28 Apr. 2011).

Smith, R., W.T. Lanini, M. Gaskell, J. Mitchell, S.T. Koike, and C. Fouche. 2000. Weed management for organic crops. Davis: University of California. ANR Publication 7250.

Somda, Z.C., P.B. Ford, and W.L. Hargrove. 1991. Decomposition and nitrogen recycling of cover crops and residues. p. 103-105. *In* W.L. Hargrove (ed.) Cover crops for clean water. Soil and Water Conserv. Soc., Ankeny, IA.

Sorensen, R.B., T.B. Brenneman, and M.C. Lamb. 2010. Peanut yield response to conservation tillage, winter cover crop, peanut cultivar, and fungicide applications. Peanut Sci. 37:44-51.

Tabatabai, M.A., and J.M. Bremner. 1991. Automated instruments for determination of total carbon, nitrogen, and sulfur in soils by combustion techniques. p. 229-259. *In* K.A. Smith (ed.) Soil analysis: modern instrumental techniques. 2nd ed. Marcel Dekker, New York.

Teare, I.D. (ed.). 1989. Proc. 1989 Southern Conserv. Tillage Conf. 12-13 July 1989, Tallahassee, FL. Univ. of Florida, IFAS, Spec. Bull. 89-1. NFREC Quincy, FL.

Tillman, B., D. Gorbet, M. Gomillion, J. McKinney, G. Person, and B. Thomas. 2008. Peanut variety performance, 2004-2007. Spec. Ser. SS-AGR-311. Florida Coop. Ext. Serv., IFAS, Univ. of Florida, Gainesville. Available online at http://edis.ifas.ufl.edu/pdffiles/AG/AG31700.pdf (verified 28 Apr. 2011).

Truman, C.C. and R.G. Williams. 2001. Effects of peanut cropping practices and canopy cover conditions on runoff and sediment yield. J. Soil and Water Conserv. 56:152-159.

Tubbs, R.S. 2003. Management of legumes and windows of opportunity in multiple-cropping and conservation tillage systems. Ph.D. dissertation. Univ. of Florida, Gainesville.

Tubbs, R.S. and R.N. Gallaher. 2005. Conservation tillage and herbicide management for two peanut cultivars. Agron. J. 97:500-504.

[USDA] United States Department of Agriculture. 2005. Organic foods production act of 1990 [Online]. Title XXI of the Food, Agric., Conservation, and Trade Act of 1990 (Public Law 101-624). USDA, Washington, D.C. Available at http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5060370&acct=nopgeninfo (verified 28 Apr. 2011).

[USDA-ERS] United States Department of Agriculture Economic Research Service. 2008. Organic agriculture [Online]. Available at http://www.ers.usda.gov/Briefing/Organic/ (verified 28 Apr. 2011). USDA-ERS, Washington, D.C.

Van Bruggen, A.H.C. and A.J. Termorshuizen. 2003. Integrated approaches to root disease management in organic farming systems. Australasian Plant Path. 32(2):141-156.

Van Santen, Edzard, J.F. Pedersen, and J.T. Touchton. 1992. Registration of ‘AU Robin’ crimson clover. Crop Sci. 32:1071-1072.

Wagger, M.G., M.L. Cabrera, and N.N. Ranells. 1998. Nitrogen and carbon cycling in relation to cover crop residue quality. J. Soil and Water Conserv. 53:214-218.

Wang, K.H., R. McSorley, A.J. Marshall, and R.N. Gallaher. 2004. Nematode community changes associated with decomposition of *Crotalaria juncea* amendment in litterbags. J. App. Soil Eco. 27:31-45.

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, and T.V. Hicks. 1990. Evaluation of herbicide systems in minimum- and conservation-tillage peanuts (*Arachis hypogaea*). Weed Sci. 38:243-248.

Williams, E.J., and J.S. Drexler. 1981. A non-destructive method for determining peanut pod maturity. Peanut Sci. 8:134-141.

Williams, S.M. and R.R. Weil. 2004. Cover crop root channels may alleviate soil compaction effects on soybean crop. Agron. J. 68:1403-1409.

Wright, D.L., B.L. Tillman, J.J. Marois, J.R. Rich, R.K. Sprenkel, and J.A. Ferrell. 2009. Conservation tillage peanut production. SS-AGR-185. Florida Coop. Ext. Serv., Univ. of Florida, IFAS, Gainsville, FL. Available online at http://edis.ifas.ufl.edu/ pdffiles/AG/AG18700.pdf (verified 28 Apr. 2011).

Wright, D.L., J.J. Marois, P.J. Wiatrak, and B. Kidd. 2000. Tillage and thimet effects on three peanut cultivars: Tomato spotted wilt virus control. p. 130-134. *In* Proc. Southern Conservation Tillage Conf. for Sustainable Agric., 23rd, Monroe, LA. 19-21 June 2000. Louisiana State Univ. Agric. Cent., Baton Rouge.

Wynne, J.C., M.K. Beute, and S.N. Nigam. 1991. Breeding for disease resistance in peanut (*Arachis hypogaea* L.). Annu. Rev. Phytopathol. 29:279-303.