Cotton Stalk Management and Cover Crop Use on CLRDV Incidence and Soil Properties

by

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Abstract

Cotton leafroll dwarf virus (CLRDV) was reported in cotton (*Gossypium hirsutum* L.) in Alabama in 2017. CLRDV can now be found as far west as Texas, and as north as Virginia. Due to such wide distribution and potential yield loss, CLRDV has been explored across various disciplines. However, there have been few investigations involving agronomic management. This study recorded CLRDV presence in cotton following various cotton stalk destruction methods with and without a cover crop, as well as the effect on soil properties in 2021-2022. Stalk destruction methods were (1) Destroy, which included two diskings, followed by chisel plowing and a repeat disking for final leveling, (2) mowing (Mow), and (3) mowing followed by pulling (Mow/Pull) with a stalk puller. A mixture of cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.) was used for the cover crop treatment. Two cotton varieties were included, DP 2055 B3XF and PHY 400 W3FE. Trial locations were in the Alabama Agricultural Experiment Station System at the E. V. Smith Research Center (EVS), Shorter, AL; Wiregrass Research and Extension Center (WREC), Headland, AL; and Gulf Coast Research and Extension Center (GCREC), Fairhope, AL. Data collection included soil moisture and soil strength values, cover crop biomass, various cotton growth measurements, pre-bloom aphid presence, CLRDV infection, and cotton lint yield. Soil moisture results show that all values are relatively consistent across stalk management treatments. At all locations in both years, soil moisture values in the 0-6 in depth tended to be higher in cover crop treatments at all locations as expected. Some discrepancies were seen between the two sampling depths but overall no dramatic differences were observed. Area under the curve for cone index ($AUC_{C.I.}$) was used to represent soil strength across all depths and row positions. In 5 of 6 site years, Destroy treatments resulted in the lowest cone index values. In 2022, elevated soil strength values at WREC were seen across all stalk destruction methods, regardless of cover crop. While there were differences among treatments, cotton stands were adequate at all locations. Greater cover crop biomass was obtained across all locations in

2022 (7720 lb/A) as compared to 2021 (5878 lb/A). In regards to locations, cover crop biomass was least at EVS (4102 lb/A) as compared to GCREC (8074 lb/A) and WREC (8216 lb/A). Overall, presence or absence of a cover crop failed to consistently reduce CLRDV incidence or affect yield or fiber quality. Stalk management treatment had no effect on yield in 5 of 6 site years. Fiber quality results showed minimal differences among treatments. CLRDV was confirmed at all locations in both years through PCR testing. August sample results from GCREC in 2021 indicated extremely low virus incidence, and thus, re-sampling for CLRDV and PCR testing was initiated after harvest at all locations in November. From the August to November sampling dates, incidence of CLRDV increased 2 to almost 12-fold, with an average of 309% increase over the 6 site locations. Even though significant main effects and few interactions were observed within the recorded data, results suggest that imposed treatments lacked a consistent effect on CLRDV incidence, cotton yield, or fiber quality. However, it was especially noteworthy that CLRDV sampling dates (August and November), revealed dramatic differences in detectable virus incidence, and the high level of virus present in November indicated prevalence of the virus across the region. More research is needed in order to determine ways to mitigate CLRDV incidence in cotton.

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List of Abbreviations

CBD	Cotton Blue Disease
ACBD	Atypical Cotton Blue Disease
CLRDV	Cotton Leafroll Dwarf Virus
CLRDV-AL	Cotton Leafroll Dwarf Virus – Alabama strain
CLRDV-at	Atypical Cotton Leafroll Dwarf Virus
CLRDV-US	Cotton Leafroll Dwarf Virus – United States strain
RT-PCR	Reverse transcription – polymerase chain reaction
qRT-PCR	Reverse transcription quantitative real-time PCR
N	Nitrogen
C:N	Carbon to Nitrogen ratio
EVS	E. V. Smith Research and Extension Center
GCREC	Gulf Coast Research and Extension Center
WREC	Wiregrass Research and Extension Center
ANOVA	Analysis of variance

DP	Deltapine
PHY	PhytoGen
$AUC_{C.I.}$	Area Under the Curve for Cone Index
mic	Micronaire
UNIF	Uniformity

Literature Review

Cotton Introduction

Cotton (*Gossypium hirsutum* L.) is the most important fiber crop in the world and in addition to providing raw material for the global textile industry, serves as a source of feed, oil and biofuel production (Sunilkumar et al., 2006). As a result of its international importance and widespread use, cotton has spread from its original native habitat in Mesoamerica and is now commercially produced as an agricultural commodity in over forty countries (Smith et al., 1999). Oosterhuis (1990) described the cotton plant as having the most complex structure of any other major field crop and delineated its growth and life cycle into five stages: (1) germination and emergence, (2) seedling establishment, (3) leaf area and canopy development, (4) flowering and boll development, and (5) maturation. Currently, there are four different species of cotton grown as commericial crops; they include *Gossypium arboreum* L., *Gossypium herbaceum* L., *Gossypium barbadense* L., and *Gossypium hirsutum* L. (Coppens d'Eeckenbrugge and Lacape, 2014; Fang and Percy, 2015). *Gossypium hirsutum*, also known as upland cotton, accounts for 90% of the world's cotton production and as much as 97% of that which is grown in the United States (USDA, 2020).

According to "Cotton: From Field to Fabric – Economics of Cotton," annual business revenue stimulated by cotton in the U.S. economy exceeds $120 billion, making cotton America's number one value-added crop. In Alabama, cotton is the most widely planted row crop and in recent years has provided farm gate values of more than $300 million (Nichols, 2018). In 2021, Alabama cotton was harvested across 400,000 acres with an average yield of 826 lb/A for a total of 690,000 total bales (USDA, 2022). The state's planted acreage in 2022 was 438,000 acres with a total production estimated at 840,000 bales or 938 lb/A. Given the economic multiplier effect, cotton annually contributes close to $2 billion to the economy of Alabama.

Problem Statement and Situation

In 1949, unusual cotton plants in Africa were described as showing shortening of internodes and reddening of leaves and petioles. Infected plants also exhibited a distinct blue-green leaf coloration. Combined with the other observed symptoms, the disease was ultimately referred to as cotton blue disease (CBD) (Cauquil & Vaissayre, 1971; Isakeit, 2019). It was determined that cotton aphid (*Aphis gossypii* Glover) was the vector for transmission of CBD and that observed symptomology was considerably more pronounced on cotton plants infected during early cotton growth stages (Corrêa et al., 2005; Cauquil & Vaissayre, 1971). In 1962, similar symptoms were noticed in cotton plants in Brazil and were initially described as vein mosaic "var. Ribeirao Bonito" (Silva et al. 2008). Considering CBD and vein mosaic "var. Ribeirao Bonito," aphid transmission and infection characteristics as well as symptomology strongly suggested that these two diseases had the same pathology (Corrêa et al., 2005). This hypothesis encouraged researchers to believe that CBD could be attributed to another member of the family *Luteoviridae*. Through partial genome sequencing, a new strain was identified and then labeled as cotton leafroll dwarf virus (CLRDV) (genus *Polerovirus*, family *Luteoviridae*) (Corrêa et al., 2005). It was noted to cause yield losses of up to 80 percent in susceptible varieties in South America (Corrêa et al., 2005; Silva et al., 2008). Currently in South America, CBD is still a viral disease that poses a substantial economic threat if control measures are not correctly implemented (Galbieri et al., 2017). According to Cia et al. (2007) and Santos et al. (2004), resistant cultivars are the best method for controlling cotton virus diseases. Other management strategies reported by Miranda et al. (2008) and Cauquil (1977) include planting at earlier dates, manually removing plants exhibiting disease like symptoms from the field during the growing season, completely clearing fields of all plants post-harvest, eliminating weed hosts, and using resistant cultivars. Growers in Brazil have been able to reduce the effects of CLRDV by treating aphid populations, although not without challenges associated with excessive early season rainfall patterns, limited insecticide efficacy, and increased production costs (Galbieri et al., 2017).

In 2017, CLRDV was identified for the first time in the United States in samples collected from Barbour County, Alabama (Connor et al., 2021). Through whole genome sequencing from symptomatic samples collected during 2018, analysis showed that this was a unique strain of CLRDV different from the typical and atypical strains found previously in South America and was subsequently classified as CLRDV-AL (Avelar et al., 2019; Avelar et al., 2020; Connor et al., 2021). In 2017, it was reported that CLRDV-AL incidence ranged anywhere from 3 to 30% in the state, resulting in approximately 500 lb/A loss, and affecting 25% of the cotton crop in Alabama, with a loss of around 50,000 bales valued at $19 million dollars (Avelar et al., 2019; Scherer et al., 2021). CLRDV has now been identified in a number of southern states including Alabama, Texas, Georgia, Mississippi, South Carolina, Louisiana, Florida, North Carolina, and Arkansas (Avelar et al., 2020; Price et al., 2020; Alabi et al., 2020; Tabassum et al., 2019; Wang et al., 2020; Faske et al., 2020; Aboughanem-Sabanadzovic et al., 2019; Iriarte et al., 2020). Given the losses reported from Brazil, even up to 80% (Silva et al. 2008) in extreme cases, the presence of CLRDV in the U.S. prompts significant concern as a potential threat for cotton grown on millions of acres.

CLRDV (Symptoms,Testing, Vector, Green Bridge)

CLRDV is the causal agent of CBD which is regarded as the most economically important disease present in cotton crops in South America (Correa et al. 2005; Agrofoglio et al., 2019). Reports from South America indicate cotton plants can either be infected by the typical strain (CLRDV) or atypical strain (CLRDV-at) (Agrofoglio et al., 2019). Genomes of both strains are closely related; however, the symptoms they produce differ significantly (Agrofoglio et al., 2019). Cotton plants infected with the typical strain exhibit a wide range of symptoms that greatly depend on certain abiotic and biotic factors such as location, variety, planting date, aphid population density, growth stage at which the plant was infected, and other environmental factors such as excessive or extended rainfall patterns (Harrison, 1999; Rochow and Duffus, 1981). Reports of typical symptoms include a stunted phenotype with shortening of internodes, leaf rolling, vein yellowing and intensive green colored foliage (Cauquil & Vaissayre, 1971). In Brazil in 2006, a new disease was identified in fields planted with CBD resistant cotton and was labeled as atypical vein mosaic virus or atypical cotton blue disease (ACBD) (Silva et al. 2008; Galbieri et al. 2010). It was noted that more than 90% of all cotton cultivars planted in Brazil are susceptible to ACBD (Chitarra and Galbieri 2015). Reports of ACBD symptoms include mild typical CBD symptoms along with withered, reddish leaves and accentuated verticality or "whip-top" (Silva et al 2008; da Silva et al. 2015).

Avelar et al. (2020), published a complete genome sequence of a new strain of CLRDV identified in the U.S. in 2017, which documented the first report of the strain in North America (CLRDV-US). The observed symptoms of CLRDV-US include leaf curling, leaf rolling, foliar distortion, bluish-green discoloration, vein-clearing, and shortened internodes, characteristics which can result in reduced boll set, stunted plant growth, as well as swollen and brittle stems (Brown, et al., 2019). Early season symptoms can appear as reddening of leaves and petiole, downward drooping of leaves as an inverted "V", and stunted plants with distorted leaves that can easily be mistaken with other disorders, particularly thrips feeding injury (Bag et al., 2021; Connor et al., 2021). Symptoms become variable later in the season based on age of the plant at infection, nutrient levels, variety, and environmental conditions and can be expressed by leaf crinkling and deformation, leaf rugosity, excess or bushy foliage, reduced boll retention, shorter internodes, flower deformation, and "parrot-shaped" bolls (Bag et al., 2021; Connor et al., 2021). Due to the wide variety of symptoms, molecular diagnosis is needed to positively confirm virus presence. Nucleic acid–based RT-PCR (reverse transcription–polymerase chain reaction) detection assays targeting multiple genes were created and regulated to detect the virus in plant tissues and the qRT-PCR assay has been developed to quantify virus titer for typical (symptomatic) and atypical (asymptomatic) plants (Tabassum et al., 2020; Bag et al., 2021).

Like all other *Polerovirus* species, CLRDV is transmitted by the cotton aphid (*Aphis gossypii*) (Conner et al., 2021 Corrêa et al., 2005; Cauquil & Vaissayre, 1971). According to Michaletto and Busoli (2007), aphids can transmit the virus in as little as 40 seconds of feeding by a single alate (winged) morph for the atypical strain of CLRDV. They also reported that CLRDV can persist in the apterous or wingless morphs for up to 12 days. Up through the 1940's, the cotton aphid was considered a serious pest throughout most cotton-growing regions of the U.S. (Paddock, 1919; Isely, 1946). Damage reports included yield reductions of as much as 250 lb/A seed cotton (Ewing, 1943). Organophosphate insecticides introduced in the 1950s provided sufficient control to minimize losses from aphids (Kerns and Gaylor, 1992; USDA, 1960). High aphid populations typically cause leaves to cup downward and appear crinkled and may reduce photosynthesis, ultimately leading to stunting of younger plants and reduced cotton yields (Chen et al., 2018; Elmer et al., 1975). Currently, growers in the U.S. Mid-South and Southeast are less concerned with controlling aphids due to the presence of *Neozygites fresenii* (Nowakowski) Batko (Entomophthorales: Neozygitaceae), an entomopathogenic fungus that provides natural control of cotton aphid populations without causing harm to plants, beneficial arthropods, or vertebrates (Steinkraus et al., 2002). Reliance on the naturally occurring fungus does not altogether eliminate intervention with insecticides, but it does greatly lessen their use. Recent work shows that aggressive, repeated insecticide applications that target aphids do not completely eliminate the pests, thereby leaving the crop vulnerable to CLRDV infection (Roberts & Bag, 2022).

After cotton harvest, cotton stalks are left in the field and, unless destroyed, can survive mild winters. Infected cotton that successfully overwinters may be a source of virus inoculum to pass to the next cropping season (Sedhain et al., 2021). Various weed species may also be a host for CLRDV. In 2019, substantial surveys were conducted in Georgia to detect the presence of CLRDV on common weeds as well as on overwintered cotton stalks. Results showed that virus presence was detected from 23 weed species belonging to 16 different botanical families. CLRDV was also significantly harbored in overwintering cotton stalks (48%) and regrowth leaves (75%) (Sedhain et al., 2021). Some common weeds that contained the virus included palmer amaranth (*Amaranthus palmeri* S.Wats), carpetweed (*Mollugo verticillata* L.), cutleaf evening primrose (*Oenothera laciniata* L.), henbit deadnettle (*Lamium amplexicaule* L), perennial peanut (*Arachis glabrata* Benth.), and white clover (*Trifolium repens* L.) (Bag et al., 2021). This suggests that chemical weed control and cultural practices, particularly the use of cover crops, could help reduce reservoirs of the virus from both winter weed populations and cotton stalk regrowth which provide a "green bridge" from one season to another (Sedhain et al., 2021). Elimination of this overwintered, "green-bridge" vegetation could reduce the incidence and impact of CLRDV.

Cover Crops

Cover crops can be defined as close-growing crops that provide soil protection and soil improvement between periods of normal crop production, or between trees in orchards and vines in vineyards (SSSA, 1997). Reeves (1994) defined cover crops as crops grown to cover the ground to protect the soil from erosion and loss of plant nutrients through leaching and runoff. Cover crops can either be leguminous or non-leguminous (Fageria et al., 2005). Non-leguminous cover crops such as grasses, are mainly used to reduce NO_3 leaching and erosion (Meisinger et al., 1991) while leguminous cover crops which fix nitrogen (N) through a symbiotic relationship with bacteria (Parker, 2008), have the added benefit of providing N for the cash crop that follows (Smith et al., 1987). Such legume covers offer potential to reduce N fertilizer requirements for the succeeding crop (Singh et al., 2004). A mixture of a legume and a grass cover crop can be used to provide both benefits simultaneously (Ranells and Wagger, 1996). Numerous benefits follow cover crop use including increased nitrogen use efficiency (Hirel et al., 2011; Frye et al., 1988; Bock, 1984), nutrient retention (Isse et al., 1999; Staver and Brinsfield, 1998), soil fertility (Brainard et al., 2017; Mortensen et al., 2021), crop yields (Canqui et al., 2012; Sainju and Singh, 1997), soil moisture conservation (Munawar et al., 1990; Acharya et al., 2019), soil physical properties (Blanco-Canqui et al., 2011; Steele et al. 2012); as well as reduced soil erosion risk potential (Langdale et al., 1991; De Baets et al., 2011), weed populations (Teasdale, 1996; Kruidhof et al., 2009), and diseases and insects (Bowers et al., 2020; Sarrantonio & Gallandt, 2003). Furthermore, cover crop use provided a key role in improving productivity of various row crops by providing advantages related to enhancing soil fertility and structure, water retention, pest management, and reducing soil erosion (Fageria et al., 2005).

Generally, soils in the humid region of the Southeastern U.S. have lower organic matter levels than compared to those in temperate regions because of higher rates of mineralization and severe erosion associated with a long history of intensive cultivation (Langdale et al., 1991; Allmaras et al., 2000; Franzluebbers and Steudemann, 2003; Sainju et al., 2007). Over time, extensive surface tillage without regard for soil protection has created challenges with soil moisture and increased compaction. Reeves (1997) recorded an estimated 38% global degradation of productive soils under conventional tillage practices. However, combined with conservation tillage practices, cover crops improved productivity of degraded soils in the Southeastern U.S. (Sainju et al., 2007; Bruce et al., 1995; Sainju et al., 2002). Soil moisture can become an issue because soils located in the Southeast usually consist of a more coarse-textured top soil, which results in reduced soil moisture content and poor water holding capacity (Johnson et al., 2021). Soil compaction continues to be a common obstacle for many growers in the Southeast and has contributed to reduced yields, poor water availability, and root growth restriction (Blanco-Canqui et al., 2015; Schomberg et al., 2006; Simoes et al., 2009). Concerns about soil compaction led to the development of tools capable of quantifying soil penetration and penetrability (Romig, 1995). Since then, soil penetrometers have been used extensively to measure penetration resistance as a means to classify soil strength properties for various management practices such as tillage and cover crops (Balkcom et al., 2016). Penetrometers range in design from simple to complex, with simple designs consisting of one probe with a penetration resistance gauge used to record data by manually pushing the probe into the ground. More complex designs consist of an electrical or hydraulically-assisted device that slowly pushes multiple probes into the ground and concurrently records data (Balkcom et al., 2016). On a large scale, this can produce massive amounts of data. For these complex, multiple-probed instruments, Balkcom et al. (2016) described a technique that obtains average penetration resistance readings for each specific row position and then calculates the area under the curve for overall cone index values. Research shows that this method can be applied to quantitatively characterize the difference among any treatments examined (Balkcom et al., 2016).

Cotton produces a limited amount of crop residue which leaves cotton fields vulnerable to erosion during late winter and early spring (Keeling et al., 1996). However, planting a small grain cover crop such as cereal rye (*Secale cereale* L.) (Casey, 2012) increases surface residue, reducing soil erosion risk potential (Kessavalou and Walters, 1997), suppressing weed emergence (Blum et al., 1997) and reducing soil compaction (Raper et al., 2000). Cereal rye is a cool season, annual grass that grows 3-6 ft tall with flattened leaf blades and awned flower spikes called heads (Casey, 2012). Planting usually follows after row crop harvest with the most common method involving a conventional grain drill equipped with packer wheels (USDA, 2002). Management is critical as cereal rye plays a vital role in uptake of remaining or unused soil N from the previously-grown cash crop, commonly recovering 25-50 lb N/A, but with uptake as much as 100 lb N/A being measured (Clark, 2007). Acknowledging this characteristic and how microorganisms use N and carbon as a food source to break down surface residues is related to the carbon to N ratio (C:N ratio) and the processes of immobilization or mineralization (Balkcom et al., 2007). Nitrogen immobilization is defined as the transformation of inorganic N compounds (NH_4+, NH_3, $N0_3$-, $N0_2$-) into the organic state, whereas N mineralization is defined as the transformation of N from the organic state into inorganic forms of NH_4 + or NH_3 (Jansson and Persson, 1982).

Nitrogen is required more consistently and in larger amounts than any other nutrient for cotton production and lint yield improvement (Hou et al., 2007; Geng et al., 2015). According to Gerik et al. (1998), bolls (fruiting structures) have a high N requirement, and cotton with sufficient N extends the boll setting periods thus increasing total number of bolls per land area. To aid in N availability, planting a legume cover crop such as crimson clover (*Trifolium incarnatum* L.) (Knight, W.E. (1985)) can increase overall N supply while at the same time reducing the amount of N fertilizer required for the cash crop that follows (Knight, 1985, Meisinger et al., 1991; McCracken et al., 1994; Kuo et al., 1997). According to Kramer and Davis (1949), in the 1940s legumes were considered superior to small grain cover crops because of their N-fixing capabilities. Knight and Hollowell (1959) refer to crimson clover as the most versatile and widely adapted winter annual legume crop of the southern region because of its significant N contributions to the following cash crop as well as provision of soil cover and protection during winter months (Blevins et al., 1990; Holderbaum et al., 1990; Touchton et al., 1984; Stevens et al., 1992). Crimson clover is a winter annual legume with scarlet/crimson flowers that was first introduced into the U.S. in 1818 from Europe where it was known to have been used as a forage crop, as well as a green-manure crop (Kephart, 1920; Knight, 1985). An additional and significant characteristic of crimson clover is that it has the ability to thrive in poor soil quality conditions, including well drained clay and sandy soils (USDA, 2002). Due to the N-fixing capabilities of crimson clover, a *Rhizobium* bacteria inoculant is applied to the seed before planting (Burton and Allen, 1950). The best planting technique involves drilling the seed about 0.25 inches into a firm, weed free seedbed. This factor proves to be highly effective in conservation tillage systems if an adequate weed control program is initiated (USDA, 2002).

Stalk Destruction Methods

Due to the fact that CLRDV can harbor in over-wintered cotton stalks, stalk destruction management techniques could serve as an effective management tool for growers. The destruction of cotton stalks is a long-established control method as it relates to efforts to eradicate the boll weevil (*Anthonomus grandis*, Boheman) (Lange et al., 2009) and pink bollworm (*Pectinophora gossypiella,* Saunders) (Lloyd and Noble, 1969) (King and Phillips, 1993; Smith et al., 1976; Watson, 1980). In some countries, growers can be financially fined for failure to destroy cotton stalks after harvest (Braz et al., 2019). Generally, cotton stalk destruction is achieved through mechanical control measures such as mowing and/or stalk pulling, with chemical control that includes auxin herbicides or a combination of both practices (Braz et al., 2019). Research conducted in 2015 in Brazil by Braz et al. (2019) showed that a single herbicide application was not enough to completely eliminate cotton stalks and that a combination of chemical control and mowing proved to be the best method of stalk destruction. Using a stalk puller attachment is another way to remove cotton stalks after harvest. In 2008, Sarkari and Minaee (2008) evaluated the performance of a stalk puller by testing different tilt angles, rake angles and disk coverings. Set properly, their device delivered 94% stalk removal. While not complete eradication, their methods could have easily been supplemented with herbicide application to achieve near-complete elimination of viable cotton stalks.

The objective of this study was to determine the effects of cotton stalk management practices and the presence of cover crops on the incidence and impact of CLRDV, as well as the influence of soil properties.

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II. Effects of Cotton Stalk Management, Cultivars, and Cover Crops on CLRDV Incidence

Abstract

Cotton leafroll dwarf virus (CLRDV) was reported in cotton (*Gossypium hirsutum* L.) in Alabama in 2017. Infected cotton that successfully overwinters may be a source of virus inoculum to pass to the succeeding crop. As a result, stalk destruction techniques could serve as an effective management tool for growers. This study recorded CLRDV presence in cotton following various cotton stalk destruction methods during 2021-2022. Stalk destruction methods were (1) Destroy, which included two diskings, followed by chisel plowing and a repeat disking for final leveling, (2) mowing (Mow), and (3) mowing followed by pulling (Mow/Pull) with a stalk puller. Cover crops included a mixture of cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.) Two cotton varieties were included, DP 2055 B3XF and PHY 400 W3FE. Trial locations were in the Alabama Agricultural Experiment Station System at the E. V. Smith Research Center (EVS), Shorter, AL; Wiregrass Research and Extension Center (WREC), Headland, AL; and Gulf Coast Research and Extension Center (GCREC), Fairhope, AL. Data collection included cover crop biomass, cotton growth measurements, pre-bloom aphid presence, CLRDV infection, and cotton lint yield. CLRDV was confirmed in early and late season at all locations in both years through PCR testing. Early samples were collected in August and late samples were collected in November. The presence or absence of a cover crop failed to consistently reduce CLRDV incidence or affect yield or fiber quality and similar results were observed across both cotton varieties. Stalk destruction treatment had no effect on yield in 5 of the 6 site years. Fiber quality differences among treatments were minimal. August results from GCREC in 2021 indicated extremely low virus incidence, and thus, re-

sampling for CLRDV and PCR testing was initiated after harvest at all locations in November. From the August to November sampling dates, incidence of CLRDV increased 2 to almost 12-fold, with an average of 309% increase over the 6 site locations. Even though significant main effects and few interactions were observed across the data, results suggest that imposed treatments lacked a consistent effect on CLRDV incidence, cotton yield, or fiber quality. However, the considerable increase in CLRDV incidence at the later sampling date (November) suggests the virus was well established in these areas. More research is needed to determine ways to mitigate the presence of the virus in cotton.

Introduction

Cotton (*Gossypium hirsutum* L.) is the most important fiber crop in the world and in addition to providing raw material for the global textile industry, serves as a source of feed, oil and biofuel production (Sunilkumar et al., 2006). *Gossypium hirsutum*, also known as upland cotton, accounts for 90% of the world's cotton production and as much as 97% of that which is grown in the United States (USDA, 2020). According to, "Cotton: From Field to Fabric – Economics of Cotton", annual business revenue stimulated by cotton in the U.S. economy exceeds $120 billion, making cotton America's number one value-added crop. In Alabama, cotton is the most widely planted row crop and in recent years has provided farm gate values of more than $300 million (Nichols, 2018).

In 1949, unusual cotton plants in Africa were described as showing shortening of internodes, reddening of leaves and petioles, and infected plants exhibited a distinct blue-green leaf coloration. Combined with the other observed symptoms, the disease was ultimately referred to as cotton blue disease (CBD) (Cauquil & Vaissayre, 1971). It was determined that cotton aphid (*Aphis gossypii* Glover) was the vector for transmission of CBD and that observed symptomology was considerably more pronounced on cotton plants infected during early growth stages (Corrêa et al., 2005; Cauquil & Vaissayre, 1971). In 1962, similar symptoms were noticed in cotton plants in Brazil and were initially described as vein mosaic "var. Ribeirao Bonito" (Silva et al. 2008). Similar aphid transmission and infection characteristics as well as symptomology strongly suggested that these two diseases have the same pathology (Corrêa et al., 2005). Partial genome sequencing conducted in South America identified a virus that was named cotton leafroll dwarf virus (CLRDV) (genus *Polerovirus*, family *Luteoviridae*) (Corrêa et al., 2005). It was noted to cause yield losses of up to 80 percent in susceptible varieties in South America (Corrêa et al., 2005; Silva et al., 2008). Management strategies reported by Miranda et al. (2008, Brazil) and Cauquil (1977, Africa) include early planting, manually removing plants exhibiting disease-like symptoms from the field during the growing season, completely clearing fields of all plants post-harvest, eliminating weed hosts, and using resistant cultivars.

In 2017, CLRDV was identified for the first time in the United States in samples collected from Barbour County, Alabama, and, through whole genome sequencing from symptomatic samples collected during 2018, analysis showed that this was a unique strain of CLRDV, different from the typical and atypical strains found previously in South America and classified as CLRDV-AL (Avelar et al., 2019; Avelar et al., 2020; Connor et al., 2021). The observed symptoms of CLRDV-AL include leaf curling, leaf rolling, foliar distortion, bluish-green discoloration, veinal chlorosis, and shortened internodes, characteristics which can result in reduced boll set, stunted plant growth, as well as swollen and brittle stems (Brown, et al., 2019). Due to the wide variety of symptoms, molecular diagnosis is needed to positively confirm virus presence. Nucleic acid–based RT-PCR (reverse transcription–polymerase chain reaction) detection assays targeting multiple genes were created and regulated to detect the virus in plant tissues and an qRT-PCR assay has been constructed to range the virus titer for typical (symptomatic) and atypical (asymptomatic) plants (Tabassum et al., 2020; Bag et al., 2021).

Infected cotton stalks and plant material that successfully overwinters may be a source of virus inoculum to infect the succeeding crop (Sedhain et al., 2021). As a result, stalk destruction techniques could serve as an effective management tool for growers. The destruction of cotton stalks is a long-established control method as it relates to efforts to eradicate the boll weevil (*Anthonomus grandis* Boheman) (Lange et al., 2009) and pink bollworm (*Pectinophora gossypiella* Saunders) (Noble, 1969; King and Phillips, 1993; Smith et al., 1976; Watson, 1980). Generally, cotton stalk destruction is achieved through mechanical control measures such as mowing and/or stalk pulling, with chemical control with auxin herbicides or a combination of both practices (Braz et al., 2019). In 1994-96, studies were carried out in Lower Rio Grande Valley, Texas comparing a moldboard plow with either a rotary mower plus a stalk puller on a flail shredder plus a stalk puller for effectiveness in controlling cotton regrowth, reducing weed populations, as well as boll weevil populations. Results showed that all stalk puller treatments effectively exposed boll weevil infested cotton squares and bolls to higher soil temperatures and lower soil moisture than did the moldboard tillage system (Smart & Bradford, 1997). Research conducted in 2015 in Brazil by Braz et al. (2019) showed that a single herbicide application was not enough to completely eliminate cotton stalks and that a combination of chemical control and mowing proved to be the best method of stalk destruction.

This current research was established to examine the incidence of CLRDV as influenced by cotton stalk destruction methods, the presence of cover crops, and cotton variety.

Materials and Methods

Experimental Design

Field trials were conducted at three locations, E. V. Smith Research and Extension Center (EVS), Shorter, AL; Gulf Coast Research and Extension Center (GCREC), Fairhope, AL; and Wiregrass Research and Extension Center (WREC), Headland, AL. Respective soil types at these research stations were a Marvyn sandy loam at EVS, Dothan sandy loam at WREC and a Malbis fine sandy loam at GCREC. All research stations maintained plots with standard herbicide, insecticide, and fertility practices as recommended by the Alabama Cooperative Extension System. Plots were 4 rows wide and 40 ft long, with 30 ft alleys between replications. All trials were organized in a 2x2 factorial with a split plot design with main plots being cover crop and cotton variety with subplots stalk destruction methods. There were four replications at each site.

Stalk Destruction Methods

All field trials were located in field sites where cotton was previously planted and all cotton stalks were mowed. “Mowed” plots received no further fall treatment. “Destroy” treatments involved significant fall tillage, including two diskings, followed by chisel plowing and a repeat disking for final leveling. “Mow/Pull” treatments were accomplished by using a Stalk Puller to accomplish stalk removal from the soil. Stalk destruction methods initiated in 2020 occurred November 6, 17, and 4, for the three locations EVS, GCREC, and WREC, respectively. In 2021, stalk destruction treatments were accomplished December 1, November 17 and 18, for the three respective locations. All stalk destruction methods were initiated prior to cover crop planting.

Cover Crop Establishment

Cover crop treatments included a fallow (no cover) treatment and a mixture of ‘Wrens Abruzzi’ cereal rye (*Secale cereale* L.) (Casey, 2012) and ‘AU Robin’ crimson clover (*Trifolium incarnatum* L.) (Knight, W.E. (1985)). Seeding rates included 30 lb/ac for cereal rye and 20 lb/a for crimson clover. At EVS and WREC cover crops were drilled with a GP 1206NT (Great Plains Ag, Salina, Kansas) drill. At GCREC, cover crops were drilled with a GP 1560 (Great Plains Ag, Salina, Kansas). In the fall of 2020, cover crops were planted at WREC on November 4, November 9 at EVS, and November 17 at GCREC. In the fall of 2021, cover crops were planted at WREC on November 5, GCREC on November 18, and EVS on December 1. Cover crop biomass samples were obtained at all locations in both years by harvesting two, randomly selected 0.25m areas per plot. All cover crop treatments were chemically terminated two weeks before cotton planting in the spring of 2021 and 2022, followed by rolling using a roller-crimper at all locations.

Cotton

‘Deltapine 2055 B3XF’ and ‘PhytoGen 400 W3FE’ were utilized as the varieties for this experiment. Row spacing at EVS and WREC was 36 in, while GCREC was planted in 38-in rows. Because later planted cotton is more susceptible to CLRDV, planting dates in 2021 were May 18, May 19, and May 21, and June 1, June 2, and May 31 in 2022, for EVS, GCREC, and WREC, respectively. At all locations a JD 1700 MaxEmerge XP planter (John Deere, Moline, Illinois) was used to seed cotton at 2.5 plants per foot. Stand counts were conducted about 3 weeks after planting by counting emerged plants from two different 10 ft sections in each plot. Cotton was harvested from the center two rows in each plot. Harvest dates for the three locations were November 2, 3, and 1, in 2021 and October 18, November 10, and November 1, in 2022 for the three locations, respectively. Seed cotton samples were processed on a table top, 10-saw gin and lint samples were analyzed for fiber quality by the USDA Classing Office in Memphis, TN.

Aphid Presence

In-season aphid presence was determined by visual examination of the 4^{th}-5^{th} most fully expanded leaf and quantifying results on a scale of 0 to 3, where 0 = no aphids, 1 = 1-25 aphids/leaf; 2 = 26-100 aphids/leaf, and 3 = 100+ aphids/leaf. Aphid counts in 2021 were made July 1, June 16, and June 29; and in 2022 on July 25, 27, and 26, for the three locations EVS, GCREC, and WREC, respectively Aphid presence was collected prior to first bloom in 2021 and after bloom in 2022 due to wet conditions.

CLRDV Sampling

At each location in August, 10 leaf and petiole samples from the 4th-5th most fully expanded leaf from the top of the canopy were collected at random from each plot. Late season, follow-up sampling involved post-harvest collection of cotton stalk material from 10 random plants in each plot. Collected plant materials were subjected to nucleic acid–based reverse transcription–polymerase chain reaction (RT-PCR) analysis for virus confirmation as described by Corrêa et al., 2005. Sample collection dates in 2021 were August 12, 13, and 12, and again in November 16, 3, and 16, for the respective locations, EVS, GCREC, and WREC; in 2022, sampling dates were August 18, 17, and 18, and again October 20, November 11 and 2, for the three respective locations. At all locations, ten leaf/petiole samples were randomly collected from each location and were individually sampled for virus presence.

Data Analysis

All data were subjected to analysis of variance (ANOVA) using JMP 14.2.0 with alpha = 0.10 and mean separations using a protected LSD. Models tested included cotton stand counts, cover crop biomass, aphid presence, CLRDV incidence, cotton lint yield, and fiber quality. All models were compared against main effects which included stalk destruction methods, cover crop biomass, year, and location.

Results and Discussion

Cotton Stand Counts

Cotton stand count values were reported by locations and years (Table 2.1). While there were differences among treatments, cotton stand counts were adequate compared to the seeding rate at all locations as indicated by ANOVA (see Appendix Table A.1). Cotton stalk destruction methods did not significantly impact stand count values any location either year.

The presence of a rye/clover cover crop slightly reduced stands compared to where no cover crop was present. In 5 of 6 site years, stand counts with PHY 400 W3FE were greater than those for DP 2055 B3XF.

Cover Crop Biomass

Cover crop biomass was affected by year, location, and a two-way interaction between locations and stalk management as indicated by ANOVA (see Appendix Table A.2). Comparing years, a higher cover crop biomass was obtained across all locations in 2022, and in regards to locations, cover crop biomass was least at EVS as compared to GCREC and WREC (Table 2.2). Regarding stalk management methods, Destroy and Mow/Pull treatments had greater cover crop biomass at EVS, while at GCREC, Mow and Mow/Pull treatments had higher amounts of biomass compared to the Destroy treatment. There were no biomass production differences at WREC.

Aphid Counts

Aphid presence was detected at all locations both years (Table 2.3). There were significant main effects from a three-way interaction between year, location, and treatment as well as significant main effects by year, location, year by location, year by treatment and location by treatment as indicated by ANOVA (see Appendix Table A.3). Data are presented by location, year, cotton stalk management, cover crop, and variety (Table 3). Treatments had minimal effect in aphid counts. For cotton stalk management methods, at EVS in 2021, Mow treatments had slightly higher aphid counts compared to Destroy and Mow/Pull treatments; otherwise, in 5 of 6 site years, aphid counts were similar across the three stalk management treatments. At EVS and WREC in 2021, slightly higher aphid numbers were detected in cotton following the rye/clover cover as compared to cotton planted behind no cover. In the remaining

4 site years, aphid counts were similar for no cover and cover treatments. In 2021 at EVS, aphid numbers were higher in PHY 400 W3FE as compared to DP 2055 B3XF while at the remaining 5 site years, aphid counts were statistically similar for both varieties.

CLRDV Incidence

CLRDV was confirmed at all locations in both years through RT-PCR testing. August sample results from GCREC in 2021 indicated extremely low virus incidence, and thus, re-sampling for CLRDV and PCR testing was initiated after harvest at all locations in November. Overall, there were significant main effects by year and location and significant year by treatment and location by treatment interactions as indicated by ANOVA (see Appendix Table A.4). Data were presented by location and year and sampling date (Table 2.4). There were no significant differences of CLRDV incidence (%) among stalk management treatments in 9 of the 12 site locations for the two sampling dates. For the August sampling date at EVS in 2021 and the November sampling date at WREC in 2022, a significant 3-way interaction (stalk management by cover crop by cotton variety) was observed (Table 2.5). Examination of the multiple-level interaction at these two sample locations/dates suggests a wide variation in data and an almost random effect of treatment. For example, for the August sampling date at EVS, the most aggressive stalk management method, Destroy, which included mowing and multiple tillage, had among the highest and lowest incidences of CLRDV. For the November sampling date, the least aggressive stalk management treatment (Mow) had the widest range of incidence, including for the Mow plus rye/clover mixture, 75% incidence for DP 2055 B3XF and 100% incidence for PHY 400 W3FE. Considering main effects (Table 2.5), treatment separation for CLRDV incidence was detected for main effects of stalk management at EVS, 2021(August sample), and WREC, 2022 (August sample), but treatment order of incidence was inconsistent. For the EVS 2021 August sample date, the Mow/Pull treatment had lower incidence compared to Mow plots, with Destroy intermediate between the two. The incidence order was different for the WREC 2022 August sample date, where the Mow treatment, the least aggressive stalk management method, had the least CLRDV incidence and Mow/Pull had the highest incidence of CLRDV. At EVS in 2021, CLRDV incidence was least in the absence of a cover crop and slightly higher with a rye/clover mixture. For incidence in the two cotton varieties at EVS in 2021, DP 2055 B3XF had higher CLRDV incidence than PHY 400 W3FE, but the opposite occurred at WREC in 2022. Data suggest that imposed treatments lacked a consistent effect on CLRDV incidence.

It is noteworthy the substantial increase in the percentage of infected plants for the two sampling dates (Figure 2.1). From the August to November sampling dates, incidence of CLRDV increased 2 to almost 12-fold, with an average of 309% increase over the 6 site locations.

Yield

Analysis of lint yields indicated significant interactions for location by year by treatment and thus data are presented by location and year (see Appendix Table A.5). Treatment had no effect on yield in five of the six site years (Table 2.6). In 2021, yields were poor at EVS because of extended wet conditions mid to late season (see Appendix Table A.7). At that site, the Mow/pull treatment produced higher yields than other stalk management methods, and PHY 400 W3FE produced around 60% greater yields than DP 2055 B3XF. In 2021 at WREC, the presence of a rye/clover cover crop resulted in higher yields as compared to where no cover was planted. The limited effects of stalk management and cover crop treatments on cotton yield reflect the similarly limited effects observed with CLRDV incidence.

Fiber Quality

For different fiber quality parameters that included micronaire (mic), length, strength, and uniformity (UNIF), there were few multiple level interactions. As a result, data were reported by location and main effects of stalk destruction methods, cover crop presence, variety, and year (see Appendix Table A.6). Fiber quality results showed minimal differences among treatments, and where differences associated with main effects were detected, they were subtle (Table 2.7). Mic was in an acceptable range for all treatments, but slightly higher mic was observed in the Destroy as compared to the Mow/pull stalk management treatment at GCREC; for the no cover treatment at WREC; in 2021 versus 2022 at EVS; for 2022 versus 2021 at WREC; and for DP 2055 B3XF versus PHY 400 W3FE at both GCREC and WREC. Fiber length varied slightly by cover, year, and location, but DP 2055 B3XF had consistently longer fiber than PHY 400 W3FE. Fiber strength was affected by cover crop at GCREC and was greater in 2022 versus 2021 and for PHY 400 W3FE versus DP 2055 B3XF. Uniformity was unaffected by stalk management, cover crop, and cotton variety but was greater in 2022 versus 2021 at all three locations. Few overall meaningful differences in fiber quality were observed.

Conclusion

An important goal of this experiment was to explore possibilities of mitigating CLRDV incidence with agronomic practices, specifically disrupting the overwintering habitat for the virus through cotton stalk destruction, as well as using cover crops. Cotton stalk destruction methods included Destroy, Mow, and Mow/pull; the most aggressive of these, Destroy, included multiple tillage operations and resulted in elimination of the viability of old cotton stalk residue. However, even this aggressive approach did not substantially reduce CLRDV incidence or affect yield or fiber quality. Similarly, the presence or absence of a cover crop failed to consistently reduce CLRDV incidence or affect yield or fiber quality. The choice of cotton variety produced similar outcomes. Even though significant main effects and few interactions were observed within the recorded data, results suggest the imposed treatments lacked a consistent effect on CLRDV incidence, cotton yield, or fiber quality.

CLRDV sampling dates (August and November) revealed dramatic differences in detectable virus incidence. The average incidence for the August sample date was 23% as compared to 71% at the later date. This raises questions about CLRDV titer in infected plants over time, analytical sensitivity, and sampling techniques. Possible reasons for the dramatic increase include: 1) increased aphid feeding over time and subsequent increase in transmission, 2) lack of virus titer at the early sampling dates, 3) lack of sensitivity of PCR detection methods, and 4) variation of virus titer among sampled plant parts – the August samples included petioles and leaves, while the November samples, which were collected after cotton harvest, included only stalk tissue. For a portion throughout the season, aphid colonies continue to build and more confirmed infected plants in November suggest that a higher proportion of plants with aphids increases the risk of CLRDV transmission. Ongoing research is needed to address each of these issues in order to more accurately document the presence of the virus in cotton. The high level of late season CLRDV incidence at the three locations suggests that the virus was well established in the lower regions of Alabama. Despite the high level of measured incidence in November, there were few noticeable symptoms throughout the growing season. The earliest observance of symptoms in 2017 in Alabama, later confirmed by PCR, occurred with dramatic yield losses, but widespread detection of the virus in these trials was not associated with severe, measurable yield effects. The lack of treatment effects suggest that CLRDV transmission dynamics are not playing out at a field-level scale.

Table 2.1 Cotton Stand Counts as Affected by Cotton Stalk Method, Cover Crop, and Cotton Variety at Three Locations in Alabama, 2021-22.						
	EVS		GCREC		WREC	
	2021	2022	2021	2022	2021	2022
Stalk Mgt	Plants/ft					
Destroy	2.12	2.10	1.81	1.84	2.10	2.04
Mow	2.06	1.98	1.90	1.83	2.07	2.28
Mow/Pull	2.09	2.10	1.89	1.75	2.09	2.15
LSD (0.10)	NS	NS	NS	NS	NS	NS
Destroy = mow, disk, chisel plow, disk						
Cover	Plants/ft					
None	2.10	2.14	2.08	2.14	2.16	2.51
Rye/Clover	2.01	1.88	1.65	1.88	2.01	1.81
LSD (0.10)	0.07	0.08	0.11	0.10	0.09	0.18
Variety	Plants/ft					
DP 2055 B3XF	1.99	1.98	1.73	1.59	1.96	2.10
PHY 400 W3FE	2.19	2.14	2.01	2.03	2.21	2.21
LSD (0.10)	0.07	0.08	0.11	0.10	0.09	NS

Table 2.2 Cover Crop Biomass as Affected by Year, Location, and Cotton Stalk Management at Three Locations in Alabama, 2021-22.

Year	lb/A		Location x Stalk mgt	lb/A
2021	5873.1		EVS Destroy	4864.7
2022	7719.9		EVS Mow	3380.3
LSD (0.10)	383.8		EVS Mow/Pull	4062.3
			GCREC Destroy	7325.5
Location	lb/A		GCREC Mow	8456.5
EVS	4102.4		GCREC Mow/Pull	8438.9
GCREC	8073.6		WREC Destroy	8480.6
WREC	8216.4		WREC Mow	8097.4
LSD (0.10)	282.0		WREC Mow/Pull	8062.1
			LSD (0.10)	814.3
			Destroy = mow, disk, chisel plow, disk	

Table 2.3 Aphid Counts as Affected by Cotton Stalk Management, Cover Crop, and Cotton Variety at Three Locations in Alabama in 2021-22.						
	Aphid Counts, Rating Value*					
	EVS		GCREC		WREC	
Stalk Mgt	2021	2022	2021	2022	2021	2022
Destroy	1.63	1.39	1.36	1.66	1.83	1.59
Mow	1.97	1.38	1.38	1.59	1.80	1.49
Mow/Pull	1.65	1.27	1.44	1.67	1.79	1.50
LSD (0.10)	0.19	NS	NS	NS	NS	NS
Destroy = mow, disk, chisel plow, disk						
Cover						
No	1.60	1.41	1.28	1.80	1.68	1.65
Yes	1.90	1.28	1.50	1.48	1.93	1.40
LSD (0.10)	0.15	NS	NS	NS	0.18	NS
Variety						
DP 2055 B3XF	1.49	1.40	1.40	1.65	1.74	1.57
PHY 400 W3FE	2.01	1.29	1.39	1.63	1.87	1.49
LSD (0.10)	0.15	NS	NS	NS	NS	NS
*Rating scale: 0=no aphids; 1=1-25 aphids/leaf; 2=26-100 aphids/leaf; 3=100+ aphids/leaf						

Table 2.4 CLRDV Incidence as Affected by Cotton Stalk Management, Cover Crop, and Cotton Variety for Two Sampling Dates at Three Locations in Alabama in 2021-22.

	CLRDV-Aug, %							CLRDV-Nov, %					
	EVS		GCREC		WREC			EVS		GCREC		WREC	
Stalk Mgt	2021	2022	2021	2022	2021	2022		2021	2022	2021	2022	2021	2022
Destroy	33.8	41.3	1.9	12.5	18.8	25.0		78.1	81.2	32.5	71.3	803	90.0
Mow	37.8	37.5	3.8	17.5	17.5	16.3		66.3	82.5	33.8	76.9	79.4	85.6
Mow/Pull	26.9	46.3	2.5	20.0	20.0	34.4		72.5	84.3	29.4	73.1	67.5	90.6
LSD (0.10)	8.2	NS	NS	NS	NS	10.3		NS	NS	NS	NS	NS	NS
Destroy = mow, disk, chisel plow, disk													
Cover													
No	27.9	44.2	2.5	15.0	22.1	23.3		71.3	83.8	22.5	69.2	77.9	89.6
Yes	37.5	39.2	2.9	18.3	15.4	27.1		73.3	82.9	41.3	78.3	73.8	87.9
LSD (0.10)	6.7	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS
Variety													
DP 2055 B3XF	37.5	45	3.8	16.7	18.8	18.8		73.8	82.5	34.6	68.8	73.3	87.1
PHY 400 W3FE	27.9	38.3	1.7	16.7	18.8	31.7		70.8	84.2	29.2	78.8	78.3	90.4
LSD (0.10)	6.7	NS	NS	NS	NS	8.4		NS	NS	NS	NS	NS	NS

Table 2.5 CLRDV Incidence as Affected by Multiple Factors at Two Locations and Two Sampling Dates in		
	EVS, 2021	WREC, 2022
	Sample date	
Stalk Mgt x Cover x Variety	August	November
Destroy	CLRDV, %	
No Cover		
DP 2055 B3XF	25.0	97.5
PHY 400 W3FE	25.0	95.0
Cover		
DP 2055 B3XF	55.0	75.0
PHY 400 W3FE	30.0	92.5
Mow		
No Cover		
DP 2055 B3XF	40.0	87.5
PHY 400 W3FE	30.0	80.0
Cover		
DP 2055 B3XF	37.5	75.0
PHY 400 W3FE	42.5	100.0
Mow/Pull		
No Cover		
DP 2055 B3XF	25.0	90.0
PHY 400 W3FE	22.5	87.5
Cover		
DP 2055 B3XF	42.5	97.5
PHY 400 W3FE	17.5	87.5
LSD (0.10)	16.4	14.0
Destroy = mow, disk, chisel plow, disk		

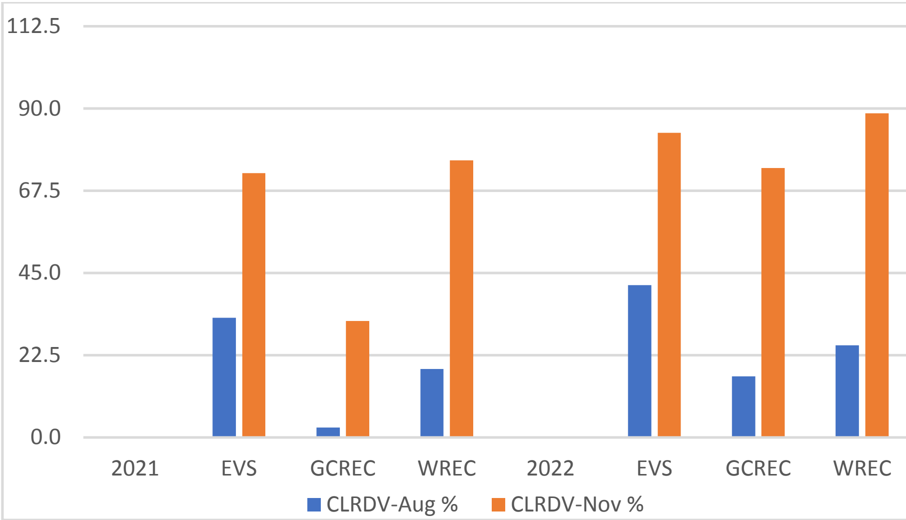
Table 2.6 Lint Yields as Affected by Stalk Management, Cover Crop, and Cotton Variety at Three Locations in Alabama, 2021-22.

	Lint, lb/A					
	EVS		GCREC		WREC	
Stalk Mgt	2021	2022	2021	2022	2021	2022
Destroy	373	961	921	405	1189	1578
Mow	378	810	1089	400	1098	1619
Mow/Pull	506	932	1135	378	1123	1581
LSD (0.10)	86	NS	NS	NS	NS	NS
Destroy = mow, disk, chisel plow, disk						
Cover						
No	391	900	1021	379	1056	1576
Yes	448	902	1076	410	1217	1609
LSD (0.10)	NS	NS	NS	NS	74	NS
Variety						
DP 2055 B3XF	304	888	1071	349	1106	1654
PHY 400 W3FE	498	914	1026	461	1167	1531
LSD (0.10)	71	NS	NS	NS	NS	NS

Table 2.7 Fiber Quality as Affected by Stalk Management, Cover Crop, Year, and Cotton Variety at Three Locations in Alabama, 2021-22.

	EVS	GCREC	WREC	EVS	GCREC	WREC	EVS	GCREC	WREC	EVS	GCREC	WREC
Stalk Mgt		mic			length, in			strength, g/tex			UNIF	
Destroy	4.28	4.51	4.01	1.198	1.199	1.190	32.5	31.6	32.1	83.1	82.1	82.4
Mow	4.26	4.46	4.07	1.194	1.191	1.894	32.0	31.6	32.0	83.2	81.8	82.5
Mow/Pull	4.29	4.42	4.05	1.197	1.184	1.182	32.0	31.9	32.1	82.9	82.0	82.6
LSD (0.10)	NS	0.07	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Destroy = mow, disk, chisel plow, disk												
Cover Crop		mic			length, in			strength, g/tex			UNIF	
No	4.23	4.44	4.09	1.194	1.197	1.186	32.2	32.1	32.1	83	82.0	82.5
Rye/Clover	4.32	4.49	3.99	1.199	1.186	1.188	32.2	31.4	32	83.1	82.0	82.5
LSD (0.10)	NS	NS	0.07	NS	0.009	NS	NS	0.4	NS	NS	NS	NS
Year		mic			length, in			strength, g/tex			UNIF	
2021	4.39	4.43	3.74	1.161	1.206	1.181	31.7	31.2	31.3	82.1	81.4	81.6
2022	4.16	4.49	4.35	1.232	1.177	1.193	32.6	32.3	32.8	84.0	82.6	83.4
LSD (0.10)	0.10	NS	0.07	0.008	0.010	0.009	0.4	0.4	0.3	0.3	0.4	0.3
Variety		mic			length, in			strength, g/tex			UNIF	
DP 2055 B3XF	4.32	4.54	4.15	1.224	1.211	1.223	31.1	31.0	31.7	83.0	82.0	82.6
PHY 400 W3FE	4.23	4.39	3.93	1.169	1.171	1.151	33.2	32.5	32.4	83.1	82.1	82.4
LSD (0.10)	NS	0.05	0.07	0.008	0.009	0.009	0.4	0.4	0.3	NS	NS	NS

Figure 2.1. CLRDV Incidence as Affected by Sampling Date at Three Locations in Alabama, 2021-22.



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III. Evaluation of Soil Moisture and Soil Strength across Stalk Destruction Methods and Cover Crops

Abstract

Due to many years of intense cultivation practices as well as erosion, soils in the Southeast are in poor condition which affects the production of row crops. The utilization of winter cover crops can potentially improve soil health by increasing soil organic matter, improving soil structure, and enhancing nutrient-use efficiency. This study examined the effect of various cotton stalk destruction methods and a cover crop mixture on soil moisture and soil strength properties during 2021-2022. Stalk destruction methods were (1) Destroy, which included two diskings, followed by chisel plowing and a repeat disking for final leveling, (2) Mow, and (3) Mow/Pull mowing/pulling with a stalk puller. A mixture of cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.) was used for the cover crop treatment. Two cotton varieties were included, DP 2055 B3XF and PHY 400 W3FE. Trial locations were in the Alabama Agricultural Experiment Station System at the E. V. Smith Research Center (EVS), Shorter, AL; Wiregrass Research and Extension Center (WREC), Headland, AL; and Gulf Coast Research and Extension Center (GCREC), Fairhope, AL. Data collection included soil moisture and soil strength values, cover crop biomass, cotton stand counts, and cotton lint yield. Soil moisture results show relatively consistent values across stalk management treatments. Soil moisture at 0-6 in tended to be higher in cover crop treatments as compared to where no cover was used. Area under the curve for cone index ($AUC_{C.I.}$) was used to represent soil strength across all depths and row positions. In 5 of 6 site years, Destroy treatments resulted in the lowest cone index values, reflecting reduced soil strength. In 2022, elevated soil strength values at WREC were seen across all stalk destruction methods, regardless of cover crop. While there were differences among treatments, cotton stands were sufficient at all

locations. Greater cover crop biomass was measured across all locations in 2022 (7720 lb/A) as compared to 2021 (5878 lb/A). Cover crop biomass was least at EVS (4102 lb/A) as compared to GCREC (8074 lb/A) and WREC (8216 lb/A). Overall, soil moisture results were consistent at all locations in both years, Destroy treatments had the lowest soil strength characteristics, stalk management treatments had no effect on yield in 5 of the 6 site years, and fiber quality results showed minimal differences among treatments.

Introduction

Generally, soils in the humid region of the Southeastern U.S. have lower organic matter levels compared to those in temperate regions because of higher rates of mineralization and severe erosion associated with a long history of intensive cultivation (Langdale et al., 1991; Allmaras et al., 2000; Franzluebbers and Steudemann, 2003; Sainju et al., 2007). However, combined with conservation tillage practices, cover crops improved the productivity of degraded soils in the Southeastern U.S. (Sainju et al., 2007; Bruce et al., 1995; Sainju et al., 2002). Soil moisture can become limited because soils located in the Southeast usually consist of a coarse-textured top soil, which results in reduced soil moisture content and poor water holding capacity (Johnson et al., 2021). Soil compaction continues to be a common obstacle for many growers in the Southeast and has contributed to reduced yields, poor water availability, and root growth restriction (Blanco-Canqui et al., 2015; Schomberg et al., 2006; Simoes et al., 2009). Concerns about soil compaction led to the development of tools capable of quantifying soil penetration and penetrability (Romig, 1995). Since then, soil penetrometers have been used extensively to measure the resistance of penetration as a means to classify soil strength properties for various management practices such as tillage and cover crops (Balkcom et al., 2016).

The use of cover crops provides a key role in improving the productivity of various row crops by providing advantages related to enhanced soil fertility and structure, water retention, pest management, and reduced soil erosion (Fageria et al., 2005). Reeves (1994) defines cover crops as crops grown to cover the ground to protect the soil from erosion and loss of plant nutrients through leaching and runoff. Cover crops can either be leguminous or non-leguminous (Fageria et al., 2005). Non-leguminous cover crops such as grasses, are mainly used to reduce NO_3 leaching and erosion (Meisinger et al., 1991), while leguminous cover crops which fix nitrogen (N) through a symbiotic relationship with bacteria (Parker, 2008), have the added benefit of providing N for the cash crop that follows (Smith et al., 1987). A mixture of a legume and a grass cover crop can be used with the intention of simultaneously providing both benefits (Ranells and Wagger, 1996). Benefits associated with cover crops include increased N use efficiency (Hirel et al., 2011; Frye et al., 1988; Bock, 1984), nutrient retention (Isse et al., 1999; Staver and Brinsfield, 1998), improved soil fertility (Brainard et al., 2011; Mortensen et al., 2021), increased crop yields (Canqui et al., 2012; Sainju and Singh, 1997), soil moisture conservation (Munawar et al., 1990; Acharya et al., 2019), and improved soil physical properties (Blanco-Canqui et al., 2011; Steele et al. 2012); as well as reduced soil erosion risk potential (Langdale et al., 1991; De Baets et al., 2011), weed populations (Teasdale, 1996; Kruidhof et al., 2009), diseases and insects (Bowers et al., 2020; Sarrantonio & Gallandt, 2003), and global warming potential (Guardia et al., 2019; Gong et al., 2021). Because cotton (*Gossypium hirsutum L.*) produces a limited amount of crop residue, which leaves cotton fields vulnerable to erosion during late winter and early spring (Keeling et al., 1996), planting a small grain cover crop such as cereal rye (*Secale cereale* L.) (Casey, 2012) increases the amount of surface residue, reducing soil erosion risk potential (Kessavalou and Walters, 1997), suppressing weed emergence (Blum et al., 1997) and reducing soil compaction (Raper et al., 2000). Nitrogen is required more consistently and in larger amounts than any other nutrient for cotton production and lint yield improvement (Hou et al., 2007; Geng et al., 2015). To aid in N availability, planting a legume cover crop such as crimson clover (*Trifolium incarnatum* L.) can increase overall N supply while at the same time reducing the amount of N fertilizer required for the cash crop that follows (Knight, 1985, Meisinger et al., 1991; McCracken et al., 1994; Kuo et al., 1997).

Soil strength can be attributed to the amount of resistance the roots push back on the soil. Soil strength could be directly proportional to soil moisture whereas the more moisture from the present cover crop actively pulling it up through the profile, the more potential for compaction is present. These field experiments were established to examine the effect on various cotton stalk destruction methods and a cover crop mixture on properties such as soil moisture and soil compaction.

Materials and Methods

Experimental Design

Field trials were conducted at three locations, E. V. Smith Research and Extension Center (EVS), Shorter, AL; Gulf Coast Research and Extension Center (GCREC), Fairhope, AL; and Wiregrass Research and Extension Center (WREC), Headland, AL. Respective soil types across utilized research stations include a Marvyn sandy, loam at EVREC, Dothan sandy, loam at WREC and a Malbis fine, sandy, loam at GCREC. All research stations maintained plots with standard herbicide, insecticide, and fertility practices as recommended by the Alabama Cooperative Extension System. Plots were 4 rows wide and 40 ft long with 30 ft alleys between replications. Cotton row spacing at EVS and WREC was 36-in, while 38-in rows were planted at GCREC. All trials were organized in a 2x2 factorial with a split plot design with main plots being cover crop and cotton variety and subplots stalk destruction methods. There were four replications at each site. 'Deltapine 2055 B3XF' and 'PhytoGen 400 W3FE' were utilized as the varieties for this experiment and planting dates in 2021 were May 18, May 19, and May 21, and June 1, June 2, and May 31 in 2022, for EVS, GCREC, and WREC, respectively with plots being in different locations each year. Harvest dates for the three locations were November 2, 3, and 1, in 2021 and October 18, November 10, and November 1, in 2022.

Stalk Destruction Methods

All field trials were located in field sites in which cotton was previously planted and all cotton stalks were mowed. “Mow” plots received no further fall treatment. “Destroy” treatments involved fall tillage operations, including two diskings, followed by chisel plowing and a repeat disking for final leveling. “Mow/Pull” treatments were accomplished by using a Stalk Puller to accomplish stalk removal from the soil. Stalk destruction methods initiated in 2020 occurred November 6, 17, and 4, for the three locations EVS, GCREC, and WREC, respectively. In 2021, stalk destruction treatments were initiated December 1, November 17 and 18, for the three respective locations. The three stalk destruction methods were initiated prior to cover crop planting.

Cover Crop Planting and Biomass

Cover crop treatments included a fallow (no cover) treatment and a mixture of ‘Wrens Abruzzi’ cereal rye and ‘AU Robin’ crimson clover. Seeding rates for the rye/clover mixture were 30 lb/A for cereal rye and 20 lb/A for crimson clover. At EVS and WREC cover crops were drill seeded in 7-in spacings with a Great Plains 1206NT drill (Great Plains Ag, Salina, Kansas). At GCREC, cover crops were drill seeded in 7-in spacings with a Great Plains 1560 drill (Great Plains Ag, Salina, Kansas). In both years, cover crops were planted 0-3 days after the stalk destruction treatments were imposed. In the spring, prior to termination (which occurred two weeks before cotton was planted), cover crops were sampled for biomass from two randomly selected 0.25m areas of each plot. Cover crop biomass samples were collected April 19-22 in 2021 and April 21-28 in 2022. Cover crop samples were then oven-dried for at least 48 hr at approximately 140°F. Cover crop samples were weighed to obtain dry cover crop biomass and then ground using a Thomas Model 4 Wiley® and Udy Cyclone Mill grinder. All samples were analyzed for total C and N by a dry combustion process with a CN LECO 2000 analyzer (Leco Corp., St. Joseph, MI). Chemical herbicide treatments were applied 2 weeks prior to planting cotton to terminate the cover crop mixture and eliminate all other vegetation. Following chemical termination but prior to seeding cotton, the cover crop mixture plots were rolled using a roller-crimper.

Soil Moisture and Compaction

After cover crop termination, soil moisture samples were obtained using push probes approximately 3/4" in diameter from four random locations in each plot at two different depths: 0-6 and 6-12 in. Soil samples were weighed, dried for 48 h at 221°F and weighed again to obtain gravimetric water content (θg) (Balkcom et al., 2016). Soil moisture samples were collected May 17, April 27, and May 3, 2021, and May 24, 17, and 20, 2022, at EVS, GCREC, and WREC, respectively.

A hydraulic, five-probe penetrometer tractor attachment was used to collect cone-index values for each plot at multiple depths at the same time soil moisture was taken. The penetrometer has five sampling positions which center over the row, (1) 18-in from the center of the row, (2) 9-in from the center, (3) directly over the row, (4) 9-in from the row to the opposite side, and (5) 18-in from the row continuing away from the row center, covering the entire row profile from row middle to the row to the opposite row middle. Due to the large volume of data generated, Balkcom et al. (2016) described a simpler way to analyze soil strength data by calculating area under the curve for cone index ($AUC_{C.I}$). In doing so, $AUC_{C.I}$ values use average cone index values collected from the penetrometer to analyze soil strength characteristics across all row positions and depths. Area under the curve for cone index was calculated following Equation 1 (Balkcom et al., 2016).). Soil strength was measured May 17, April 27, and May 3, 2021, and May 24, 17, and 20, 2022, at EVS, GCREC, and WREC, and were collected at the same time soil moisture samples were obtained.

Equation 1:

$$AUC_{C.I} = \sum_{i=1}^{k-1} \frac{[CI_{(i+1)} + CI_i]d_i}{2}$$

Data Analysis

Soil moisture and soil compaction data were subjected to log transformation as well as a summary of analysis of variance (ANOVA) using R with alpha = 0.05, with a confidence level of 0.95 used to separate means. Remaining data were subjected to a summary of analysis of variance (ANOVA) using JMP 14.2.0 with alpha = 0.10 with mean separation using a protected LSD. Models tested included cone index values from area under the curve and soil moisture values compared to stalk destruction method, cover crop presence, year and location. Cover crop biomass, stand counts, cotton lint yield, and fiber quality were compared to stalk destruction methods, cover crop presence, year, location, and variety.

Results and Discussion

Soil Moisture

Soil moisture values were assessed at each location across all stalk destruction methods and cover crop treatments in 2021-2022. At EVS in 2021, the boxplot of soil moisture values for the 0-6 in depth and the 6-12 in depth were consistent across stalk management treatments for each depth (Figure 3.1). In the 0-12 in depth, there was more variability in soil moisture values, regardless of cover crop, in the Mow/Pull treatment. As expected, soil moisture was greater for the 6-12 in depth compared to the 0-6 in depth in the no cover and cover crop treatments. At GCREC, the boxplot of soil moisture values for the 0-6 in depth and the 6-12 in depth were consistent across stalk management treatments (Figure 3.3). There is a difference in soil moisture values between the two depths, regardless of stalk management treatment, where no cover was present. In the cover crop treatment, soil moisture values were more consistent between the two depths following the terminated cover crop. At WREC, the boxplot of soil moisture values for the 0-6 in depth and the 6-12 in depth were consistent across stalk management treatments (Figure 3.5). There is was discrepancy in soil moisture values between the two depths, regardless of stalk management treatment, where no cover was present. In the cover crop treatment, soil moisture values were consistent between the two depths following the terminated cover crop, but the lower depth tended to have a higher soil moisture content.

In 2022 at EVS, the boxplot of soil moisture values showed that in the 0-6 in depth, soil moisture was always greater, regardless of stalk destruction method, as compared to the 6-12 in depth (Figure 3.2). Soil moisture in the 0-6 in depth was elevated for the cover crop treatment and destroy method. At GCREC, in the 0-6 in depth, soil moisture was greater for the cover treatment, regardless of stalk destruction method as compared to the no cover treatment across all stalk destruction methods (Figure 3.4). In the 6-12 in depth, soil moisture was less for the cover treatment as compared to the no cover treatment across all stalk destruction methods. At WREC, in the cover treatment, regardless of stalk destruction method, moisture contents in the -6-12 in depth were lower as compared to the other treatment combinations (Figure 3.6). It is likely that the actively growing cover crop extracted a portion of soil moisture upwards from the soil profile before it was terminated. No significant rainfall had occurred at sampling to recharge the soil profile at this deeper depth.

Soil Strength

Soil strength was affected by stalk management method but less so by other factors, (Table 3.1). Area under the curve for cone index ($AUC_{C.I.}$) was used to represent soil strength across all depths and row positions. A higher index value indicates a higher compaction level. In all six site years, the Destroy stalk management treatment had reduced compaction (soil strength) as compared to the other stalk management methods. In 2022 at EVS and WREC, the no cover treatments had lower soil strength than where cover was grown (Figures 3.8 & 2.12). In 2021, a significant cover by stalk management interaction was observed at WREC (Figure

3.11) The Destroy treatments, regardless of cover, had lower soil strength than the other stalk management treatments, which tended to have reduced soil strength for the cover versus where no cover was planted.

At all locations, AUC values indicate, regardless of cover crop treatment, Destroy treatments resulted in the lowest cone index values (Table 3.2). At EVS, there were elevated soil strength values measured across all stalk destruction methods, but the Mow and Mow/Pull treatments were similar, regardless of cover crop treatment (Figure 3.7). At GCREC, values were similar for Destroy treatments with or without a cover crop (Figure 3.9). At all locations, no dramatic differences were observed between the Mow and Mow/Pull treatments in the cover crop or no cover crop treatments. However, at WREC, even though no real separation was observed, differences between the Mow and Mow/Pull treatments were slightly more pronounced in plots that did not contain a cover crop (Figure 3.11).

In 2022, at both EVS and GCREC, regardless of cover crop treatment, Destroy treatments resulted in the lowest AUC values (Table 3.2) (Figures 3.8 and 3.10). Average cone index values measured at WREC, regardless of cover crop treatment and stalk destruction methods, indicated high soil strength values (Figure 3.12). Average cone index values measured where the cover crop was present were greater as compared to where no cover crop was present. The traffic area for the no cover treatment was also elevated compared to the no traffic area, regardless of stalk destruction method.

Cover Crop Biomass

Cover crop biomass was significantly affected by year, location, and a two-way interaction between locations and stalk management as indicated by ANOVA (see Appendix Table A.2). Comparing years, a higher cover crop biomass was obtained across all locations in

2022, and in regards to locations, cover crop biomass was least at EVS as compared to GCREC and WREC (Table 3.3). A higher biomass in 2022 could be attributed to better weather as well as less weed pressure at all locations. Regarding stalk management methods, Destroy and Mow/Pull treatments had greater cover crop biomass than at EVS, while at GCREC, Mow and Mow/Pull treatments had higher amounts of biomass compared to the Destroy treatment. There were no biomass production differences at WREC.

Cotton Stand Counts

Cotton stand count values were reported by locations and years (Table 3.4). While there were differences among treatments as indicated by ANOVA (see Appendix Table A.1), cotton stands were adequate at all locations compared to the seeding rate of 2.5 plants per foot. Cotton stalk destruction methods did not impact stand count values any location either year (Table 3.4). The presence of a rye/clover cover crop reduced stands compared to where no cover crop was present. In 5 of 6 site years, stand counts with PHY 400 W3FE were greater than those for DP 2055 B3XF.

Cotton Yield

Analysis of lint yields indicated significant interactions for location by year by treatment and thus data are present by location and year (Table 3.5). Stalk management treatments had no effect on yield in four of the six site years (see Appendix Table A.5). In 2021, yields were poor at EVS because of extended wet conditions (see Appendix Table A.7) mid to late season. At that site, the Mow/Pull treatment produced superior yields than other stalk management methods, and PHY 400 W3FE produced greater yields than DP 2055 B3XF. In 2021 at WREC, the presence of a rye/clover cover crop resulted in higher yields as compared to where no cover was planted. Overall, treatments had limited, inconsistent effects on cotton yield.

Fiber Quality

Fiber quality parameters such as micronaire (mic), length, strength, and uniformity, provided few multiple level interactions and thus data were reported by location and main effects of stalk destruction methods, cover crop presence, variety, and year (see Appendix Table A.6). Fiber quality results showed minimal differences among treatments, and where differences associated with main effects were detected, they were subtle (Table 3.6). Mic was in an acceptable range for all treatments, but higher mic was observed in the Destroy as compared to the Mow/Pull stalk management treatment at GCREC; for the no cover treatment at WREC; in 2021 versus 2022 at EVS; for 2022 versus 2021 at WREC; and for DP 2055 B3XF versus PHY 400 W3FE at both GCREC and WREC. Fiber length varied by cover, year, and location, but DP 2055 B3XF had longer fiber than PHY 400 W3FE. Fiber strength was affected by cover crop at GCREC and was greater in 2022 versus 2021 and for PHY 400 W3FE versus DP 2055 B3XF. Uniformity was unaffected by stalk management, cover crop, and cotton variety but was greater in 2022 versus 2021 at all three locations.

Few overall meaningful differences in fiber quality were observed.

Conclusion

An important goal of this experiment was to investigate the effects different stalk destruction methods, as well as the use of cover crops on soil moisture and soil compaction. Cotton stalk destruction methods included Destroy, Mow, and Mow/Pull while cover crop treatments included a two-way mix of cereal rye and crimson clover. Different stalk destruction methods and the use of cover crops were expected to affect soil moisture and strength values. Soil moisture values in the 0-6 in depth were higher in cover crop treatments at all locations. Increased soil water is an expected benefit of cover crops (Munawar et al., 1990). However, it is noteworthy that regardless of stalk destruction methods, moisture values from the 6-12 in depth were lower at WREC. This could be attributed to the presence of an actively growing cover crop that was potentially pulling moisture up through the soil profile as well as the amount of biomass and soil type. Area under the curve for cone index ($AUC_{C.I.}$) was used to represent soil strength across all depths and row positions. In 5 of 6 site years, Destroy treatments resulted in the lowest cone index values, which seems appropriate as the Destroy treatment involved multiple tillage operations that included two diskings, followed by chisel plowing and a repeat disking for final leveling. At all locations, no dramatic differences were observed between the Mow and Mow/Pull treatments in the cover crop or no cover crop treatments. Due to the fact that cone index values were obtained before tillage practices were applied, any evidence of the subsoil soil strength should be related to prior tillage, traffic maintenance and soil properties. At both EVS and GCREC, lower soil strength values were noted across the old crop row profile (from row middle to crop row to row middle). However, results at WREC in 2022 showed elevated soil strength across the entire row profile, which is consistent with the tendency of the sandy Coastal Plain soils at that site to naturally form compaction layers. These elevated soil strength values could also be related to the expiration of effects obtained by prior tillage operations and field conditions.

Table 3.1 $AUC_{C.I.}$ Influenced by Cover Crops, Stalk Management Methods, and Two Depths at Three Locations in Alabama, 2021-22.						
	ANOVA, Prob > F					
	EVS		GCREC		WREC	
Variable	2021	2022	2021	2022	2021	2022
Cover	0.6194	0.0031	0.2643	0.7040	0.6864	0.0050
Stalk mgt	<0.0001	<0.0001	<0.0001	<0.0001	0.0015	0.0371
Depth 1	0.3152	0.0587	0.8773	0.5209	0.3142	0.5821
Depth 2	0.4103	0.0711	0.3152	0.0433	0.6155	0.9429
C x Stalk mgt	0.7924	0.3813	0.0491	0.1492	0.7456	0.2380

Table 3.2 $AUC_{C.I.}$ Influenced by Stalk Management and Cover Crop Presence at Three Locations in Alabama, 2021-22.						
	MPa cm-1					
	EVS		GCREC		WREC	
Stalk Mgt	2021	2022	2021	2022	2021	2022
Destroy	134 a	112 a	102 a	136 a	214 a	319 a
Mow	179 b	141 b	134 b	156 b	254 b	353 ab
Mow/Pull	164 b	148 b	130 b	165 b	252 b	371 b
Cover						
Cover	155 a	142 b	117 a	154 a	236 a	415 b
No Cover	161 a	124 a	126 a	150 a	243 a	290 a
Cover x Stalk mgt						
Cover Destroy	129 a	124 b	103 a	143 ab	210 a	397 b
No Cover Destroy	139 ab	102 a	101 ab	130 a	219 a	256 a
Cover Mow	177 bc	151 bc	127 c	154 ab	247 a	400 b
No Cover Mow	181 c	132 bc	141 c	159 b	262 a	312 ab
Cover Mow/Pull	164 abc	154 c	123 bc	166 b	252 a	451 b
No Cover Mow/Pull	165 abc	143 bc	139 c	165 b	252 a	306 ab

Main effect (Stalk Mgt, Cover) and interaction (Cover x Stalk mgt) means followed by the same letter are within the same confidence level grouping (0.95).

Table 3.3 Cover Crop Biomass as Affected by Year, Location, and Cotton Stalk Management at Three Locations in Alabama, 2021-22.

Year	lb/A		Location x Stalk mgt	lb/A
2021	5873.1		EVS Destroy	4864.7
2022	7719.9		EVS Mow	3380.3
LSD (0.10)	383.8		EVS Mow/Pull	4062.3
			GCREC Destroy	7325.5
Location	lb/A		GCREC Mow	8456.5
EVS	4102.4		GCREC Mow/Pull	8438.9
GCREC	8073.6		WREC Destroy	8480.6
WREC	8216.4		WREC Mow	8097.4
LSD (0.10)	282.0		WREC Mow/Pull	8062.1
			LSD (0.10)	814.3
			Destroy = mow, disk, chisel plow, disk	

Table 3.4 Cotton Stand Counts as Affected by Cotton Stalk Method, Cover Crop, and Cotton Variety at Three Locations in Alabama, 2021-22.

	EVS		GCREC		WREC	
	2021	2022	2021	2022	2021	2022
Stalk Mgt	Plants/ft					
Destroy	2.12	2.10	1.81	1.84	2.10	2.04
Mow	2.06	1.98	1.90	1.83	2.07	2.28
Mow/Pull	2.09	2.10	1.89	1.75	2.09	2.15
LSD (0.10)	NS	NS	NS	NS	NS	NS
Destroy = mow, disk, chisel plow, disk						
Cover	Plants/ft					
None	2.10	2.14	2.08	2.14	2.16	2.51
Rye/Clover	2.01	1.88	1.65	1.88	2.01	1.81
LSD (0.10)	0.07	0.08	0.11	0.10	0.09	0.18
Variety	Plants/ft					
DP 2055 B3XF	1.99	1.98	1.73	1.59	1.96	2.10
PHY 400 W3FE	2.19	2.14	2.01	2.03	2.21	2.21
LSD (0.10)	0.07	0.08	0.11	0.10	0.09	NS

Table 3.5 Lint Yields as Affected by Stalk Management, Cover Crop, and Cotton Variety at Three Locations in Alabama, 2021-22.

	Lint, lb/A					
	EVS		GCREC		WREC	
Stalk Mgt	2021	2022	2021	2022	2021	2022
Destroy	373	961	921	405	1189	1578
Mow	378	810	1089	400	1098	1619
Mow/Pull	506	932	1135	378	1123	1581
LSD (0.10)	86	NS	NS	NS	NS	NS
Destroy = mow, disk, chisel plow, disk						
Cover						
No	391	900	1021	379	1056	1576
Yes	448	902	1076	410	1217	1609
LSD (0.10)	NS	NS	NS	NS	74	NS
Variety						
DP 2055 B3XF	304	888	1071	349	1106	1654
PHY 400 W3FE	498	914	1026	461	1167	1531
LSD (0.10)	71	NS	NS	NS	NS	NS

Table 3.6 Fiber Quality as Affected by Stalk Management, Cover Crop, Year, and Cotton Variety at Three Locations in Alabama, 2021-22.

	EVS	GCREC	WREC	EVS	GCREC	WREC	EVS	GCREC	WREC	EVS	GCREC	WREC
Stalk Mgt		mic			length, in			strength, g/tex			UNIF	
Destroy	4.28	4.51	4.01	1.198	1.199	1.190	32.5	31.6	32.1	83.1	82.1	82.4
Mow	4.26	4.46	4.07	1.194	1.191	1.894	32.0	31.6	32.0	83.2	81.8	82.5
Mow/Pull	4.29	4.42	4.05	1.197	1.184	1.182	32.0	31.9	32.1	82.9	82.0	82.6
LSD (0.10)	NS	0.07	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Destroy = mow, disk, chisel plow, disk												
Cover Crop		mic			length, in			strength, g/tex			UNIF	
No	4.23	4.44	4.09	1.194	1.197	1.186	32.2	32.1	32.1	83	82.0	82.5
Rye/Clover	4.32	4.49	3.99	1.199	1.186	1.188	32.2	31.4	32	83.1	82.0	82.5
LSD (0.10)	NS	NS	0.07	NS	0.009	NS	NS	0.4	NS	NS	NS	NS
Year		mic			length, in			strength, g/tex			UNIF	
2021	4.39	4.43	3.74	1.161	1.206	1.181	31.7	31.2	31.3	82.1	81.4	81.6
2022	4.16	4.49	4.35	1.232	1.177	1.193	32.6	32.3	32.8	84.0	82.6	83.4
LSD (0.10)	0.10	NS	0.07	0.008	0.010	0.009	0.4	0.4	0.3	0.3	0.4	0.3
Variety		mic			length, in			strength, g/tex			UNIF	
DP 2055 B3XF	4.32	4.54	4.15	1.224	1.211	1.223	31.1	31.0	31.7	83.0	82.0	82.6
PHY 400 W3FE	4.23	4.39	3.93	1.169	1.171	1.151	33.2	32.5	32.4	83.1	82.1	82.4
LSD (0.10)	NS	0.05	0.07	0.008	0.009	0.009	0.4	0.4	0.3	NS	NS	NS

Figure 3.1. Boxplot depicting soil mositure values across stalk destruction methods and cover crop presence at EVS in 2021.

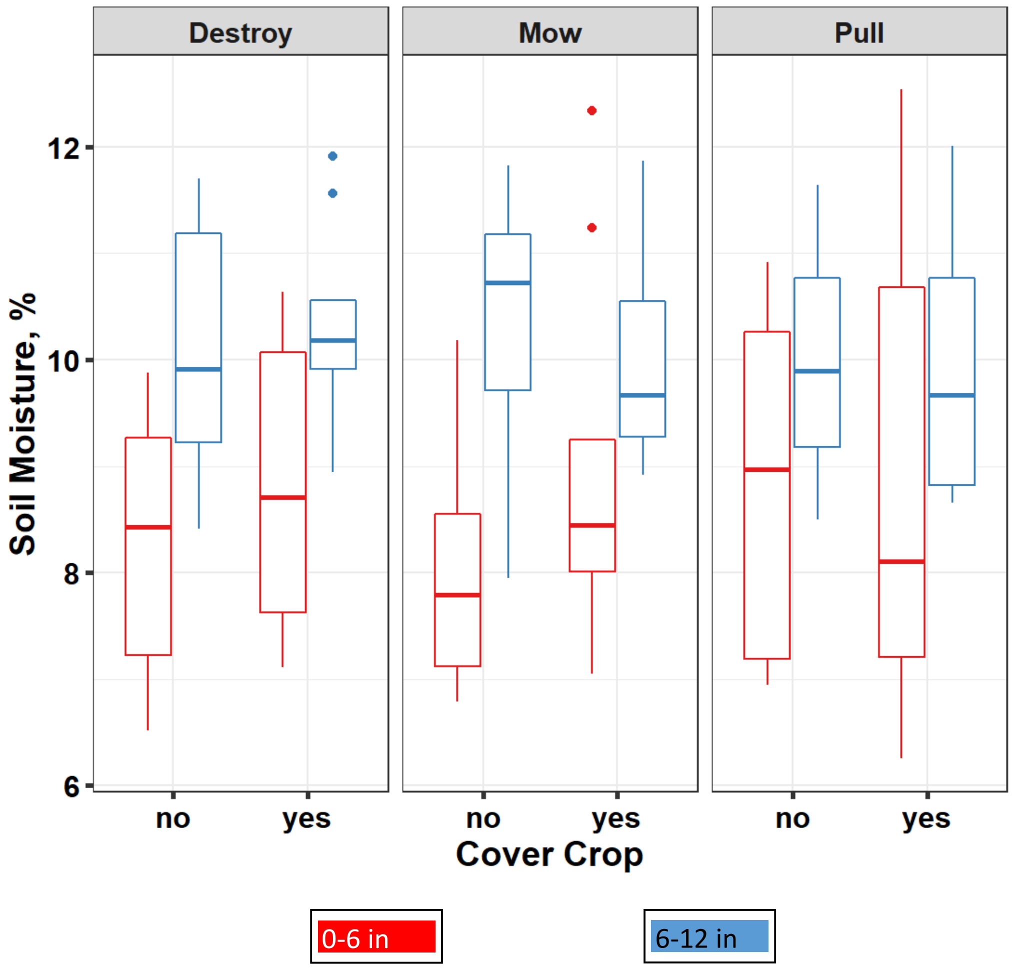


Figure 3.2. Boxplot depicting soil moisture values across stalk destruction methods and cover crop presence at EVS in 2022.

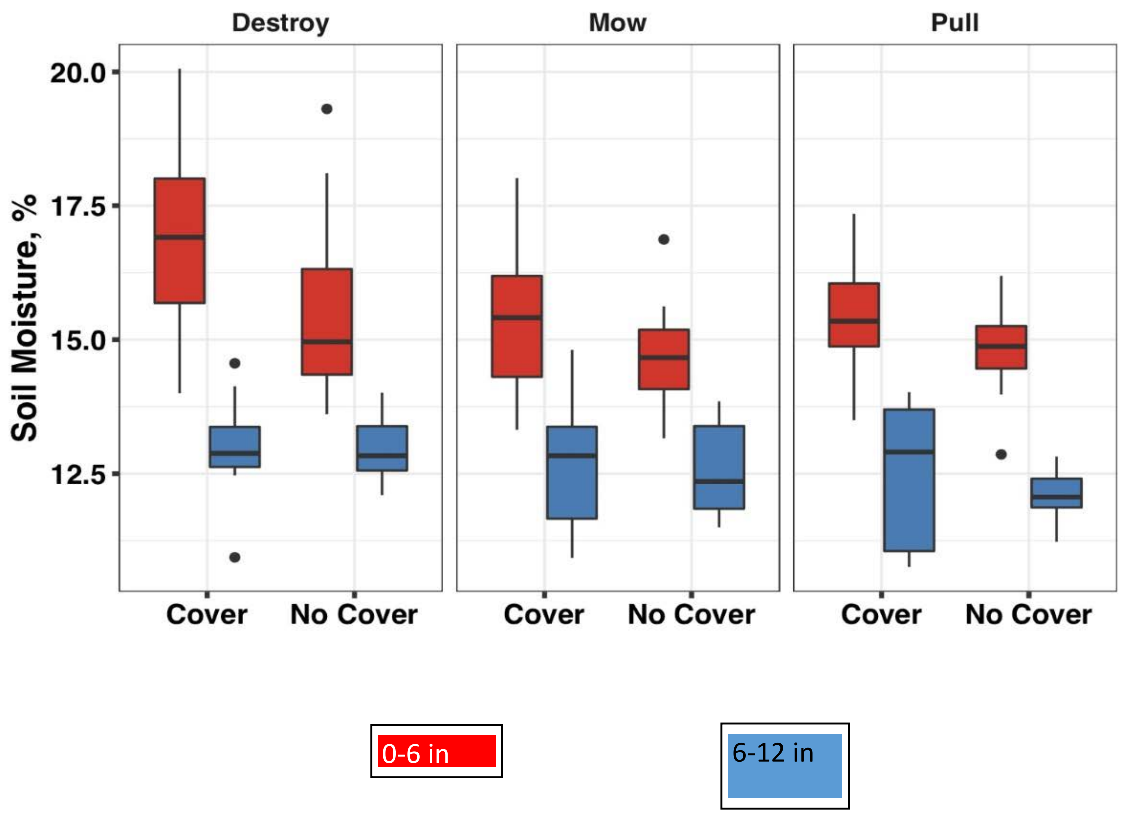


Figure 3.3. Boxplot depicting soil moisture values across stalk destruction methods and cover crop presence at GCREC in 2021.

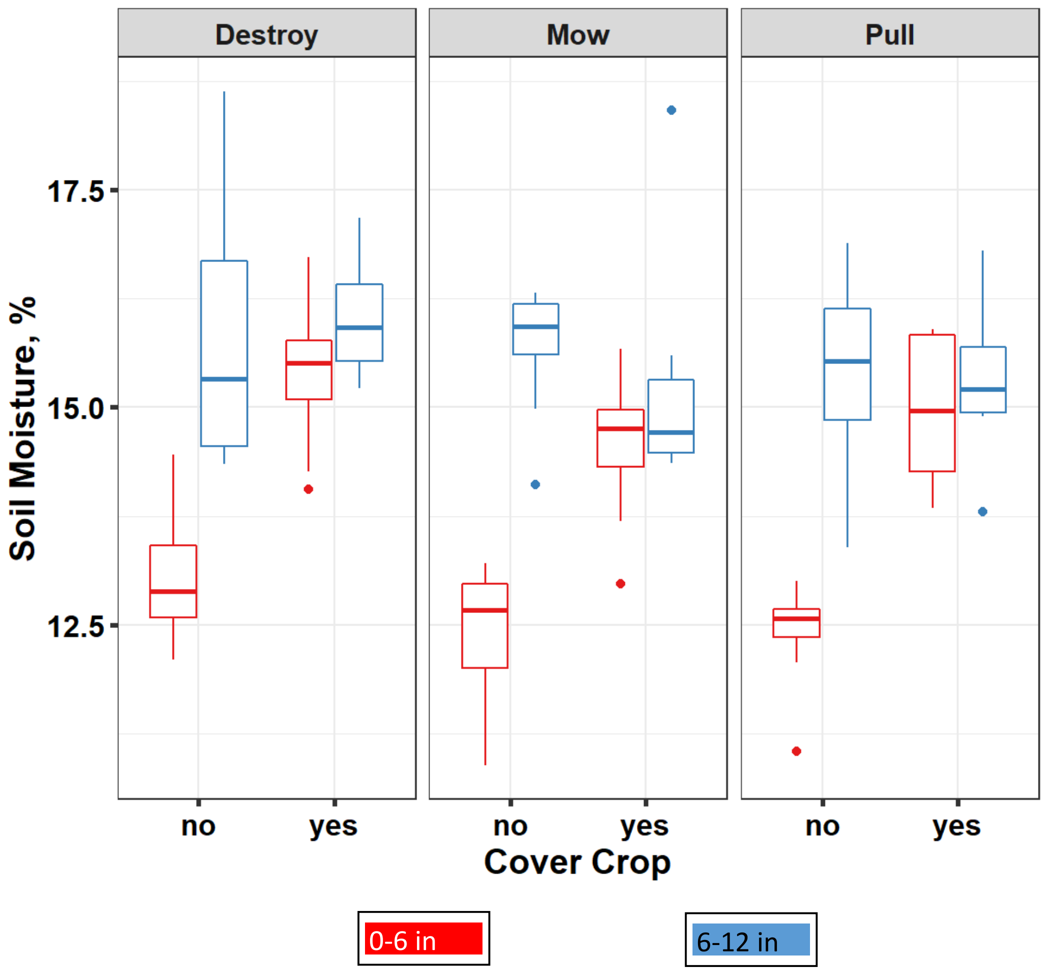


Figure 3.4. Boxplot depicting soil mositure values across stalk destruction methods and cover crop presence at GCREC in 2022.

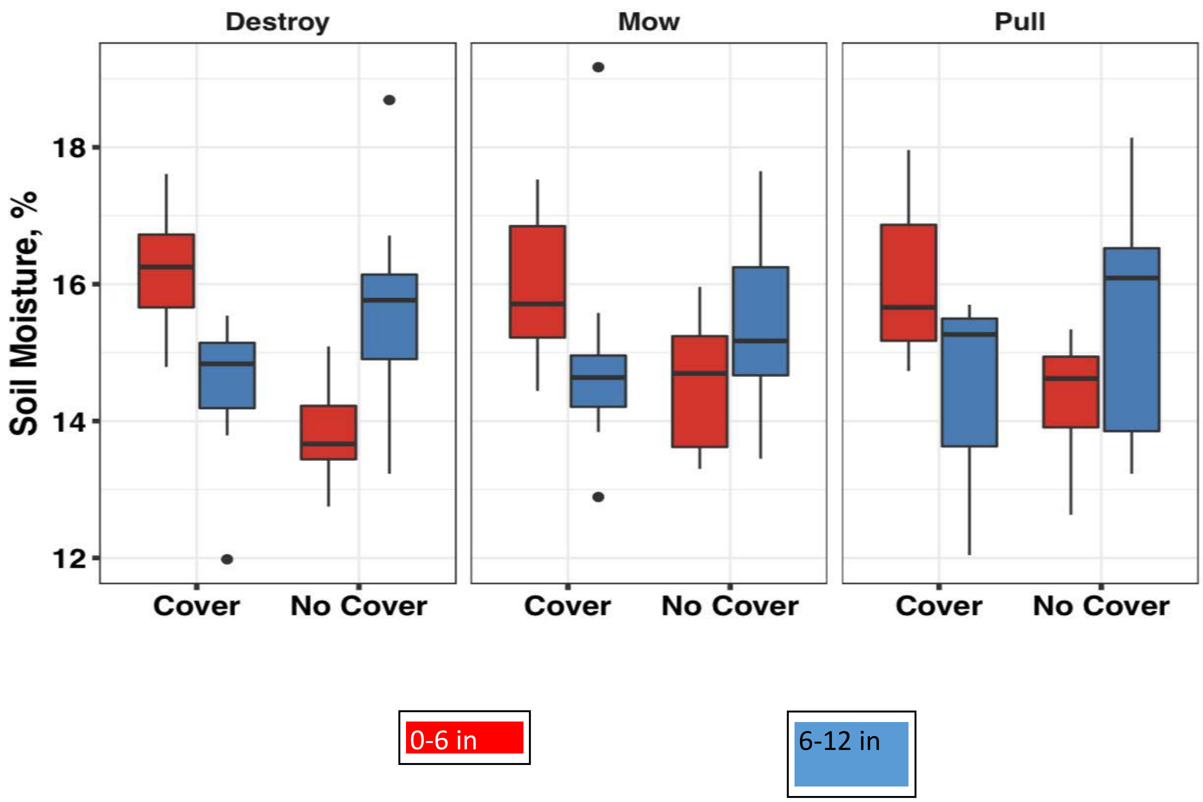


Figure 3.5. Boxplot depicting soil mositure values across stalk destruction methods and cover crop presence at WREC in 2021.

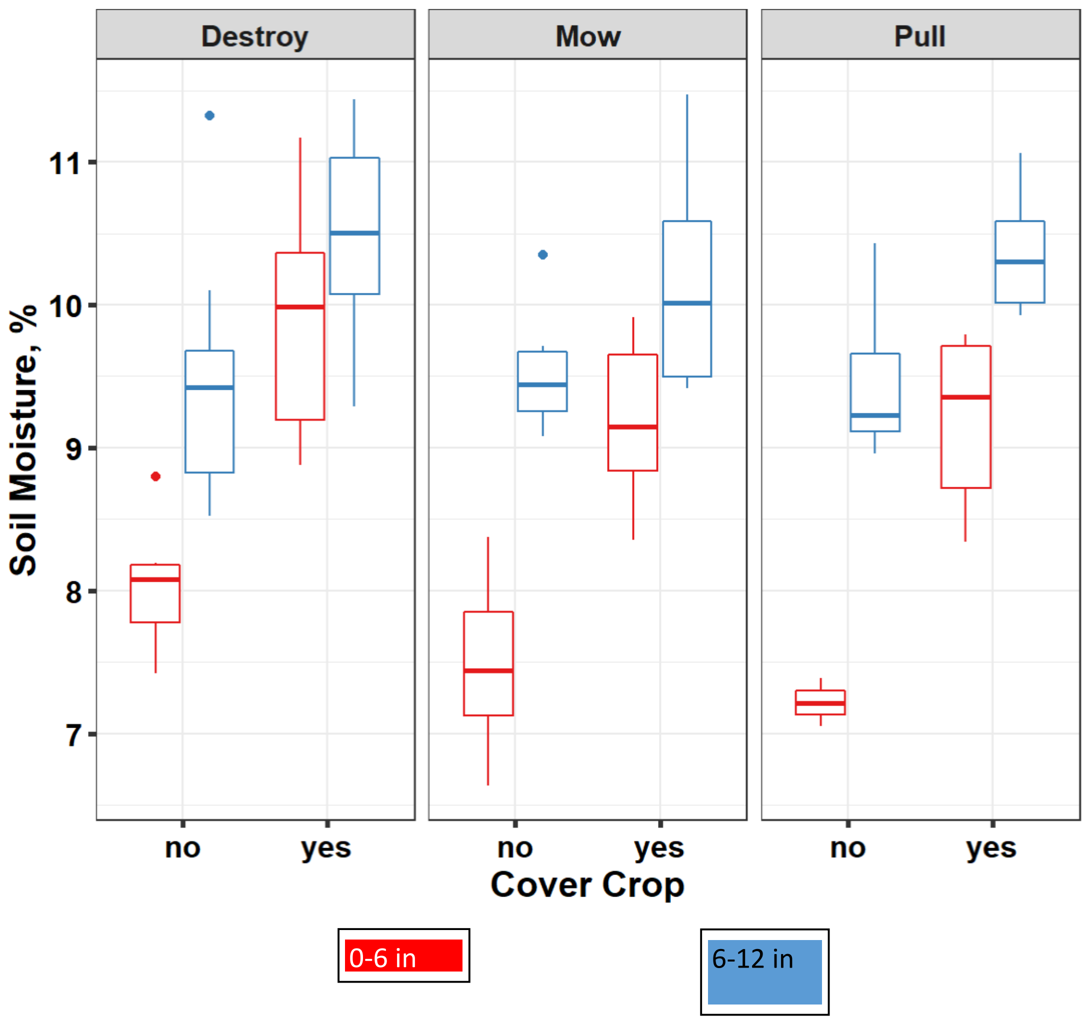


Figure 3.6. Boxplot depicting soil mositure values across stalk destruction methods and cover crop presence at WREC in 2022.

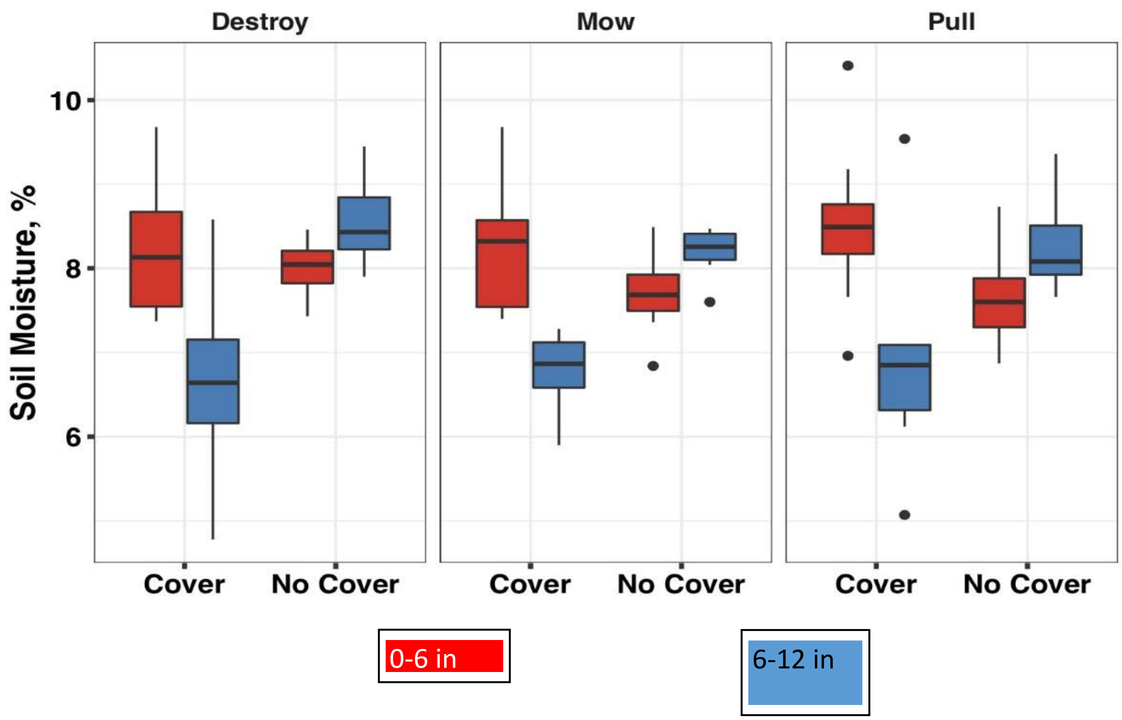


Figure 3.7. Contour Plot Depicting Soil Strength Values from Cone Index Values at EVS in 2021

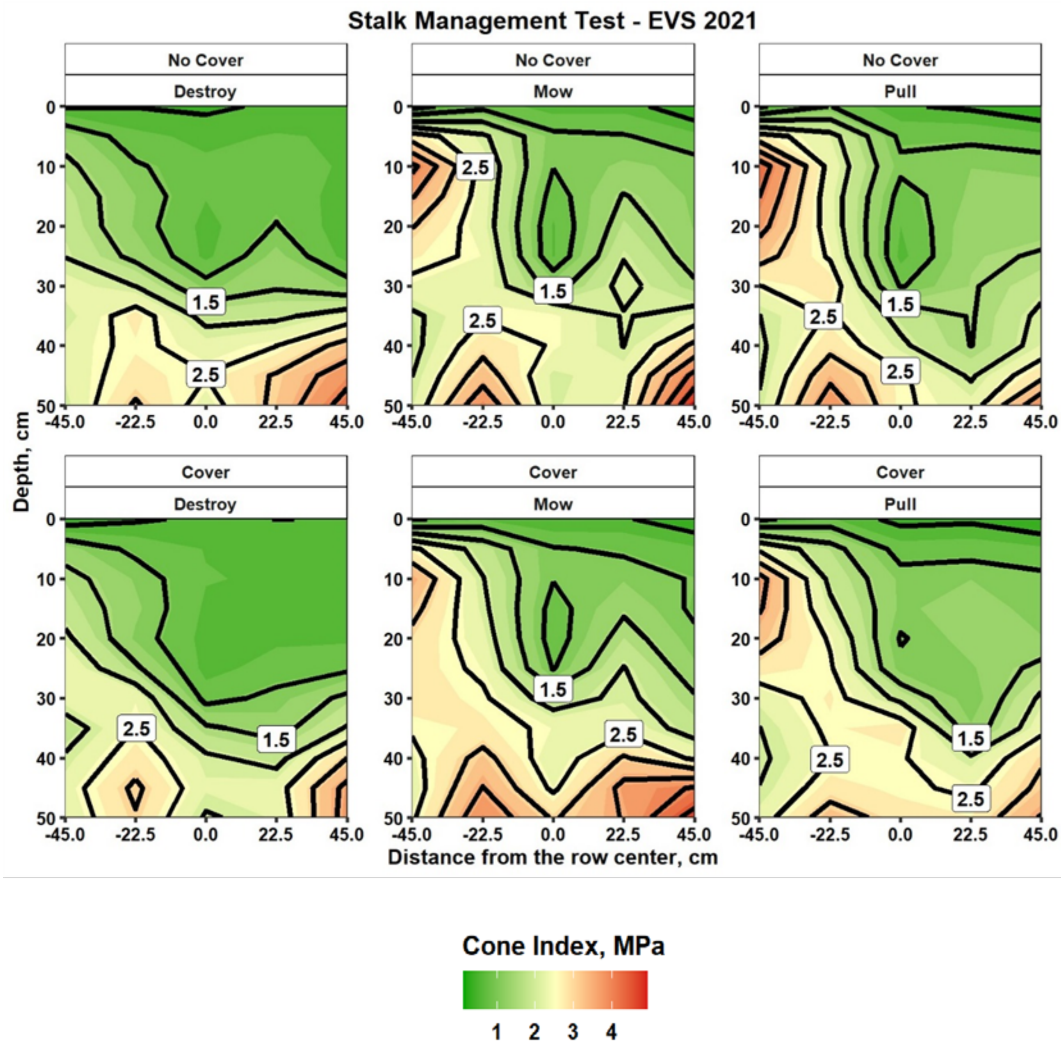


Figure 3.8. Contour Plot Depicting Soil Strength Values from Cone Index Values at EVS in 2022

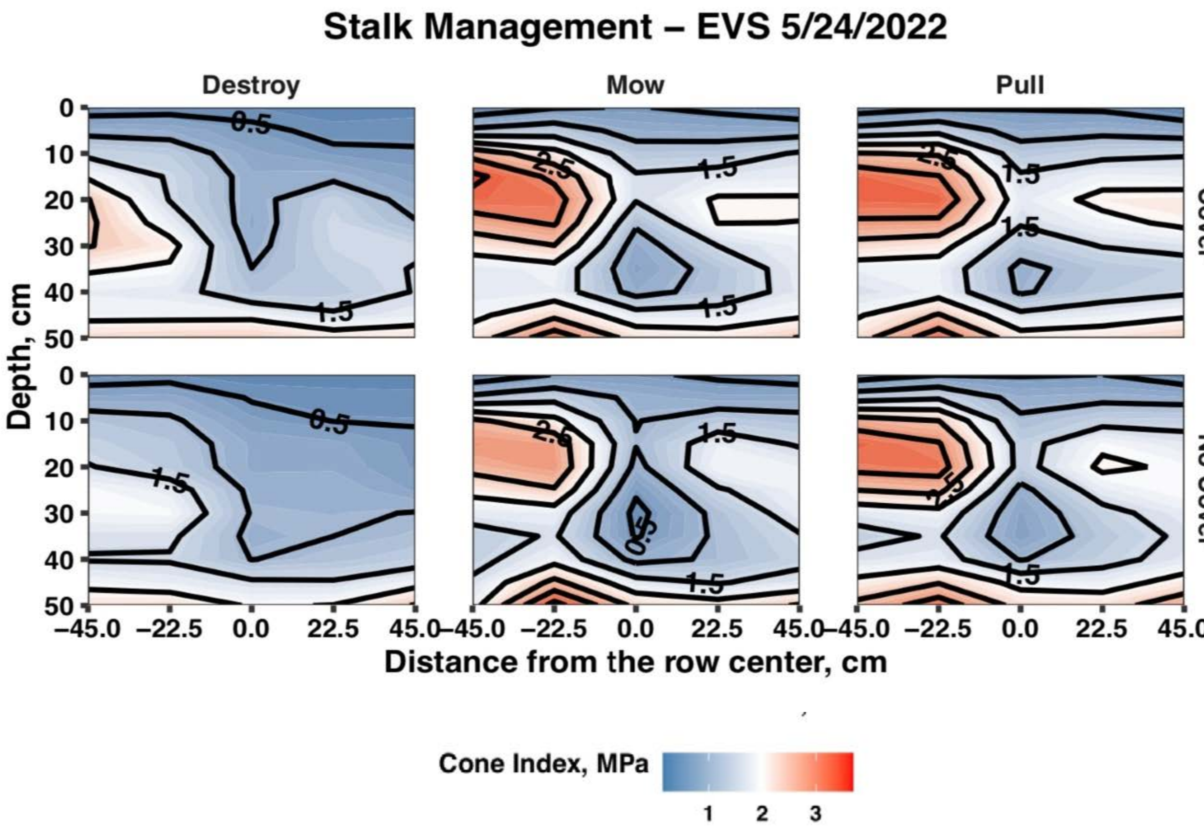


Figure 3.9 Contour Plot Depicting Soil Strength Values from Cone Index Values at GCREC in 2021

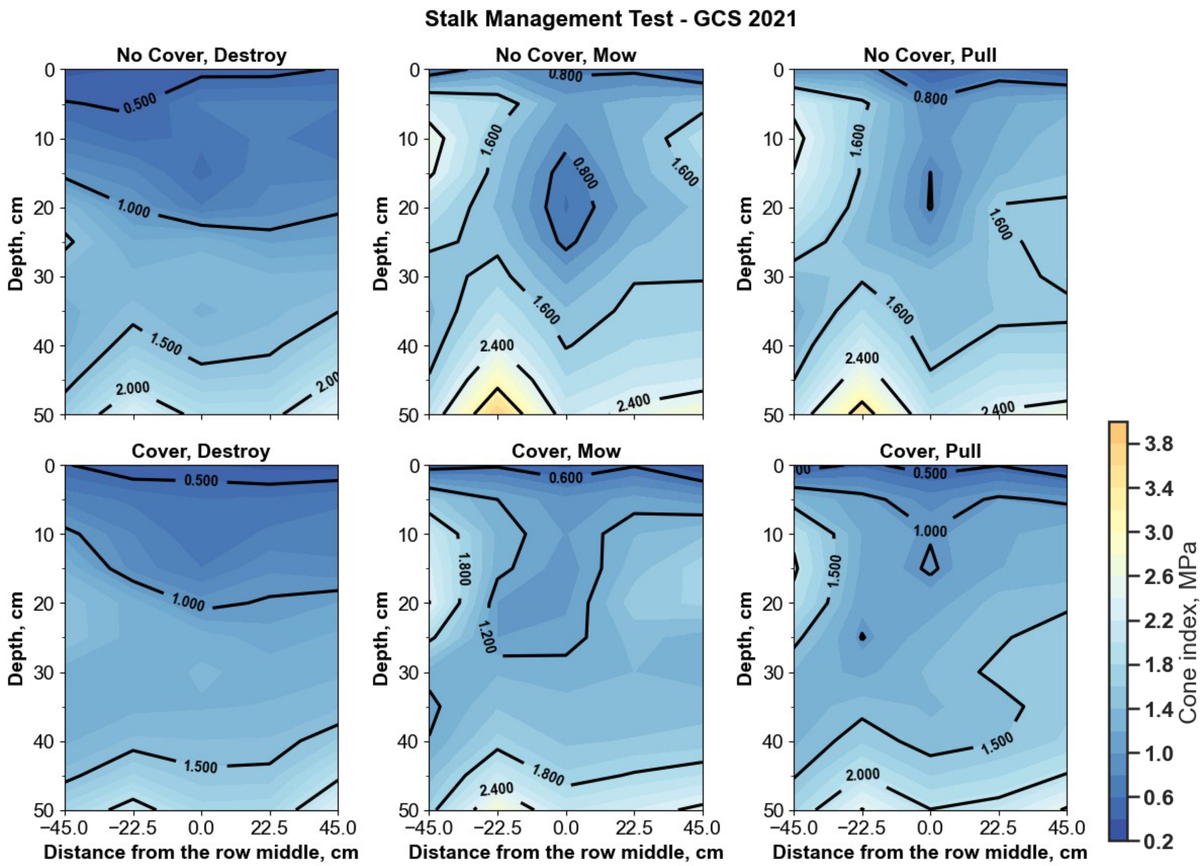


Figure 3.10 Contour Plot Depicting Soil Strength Values from Cone Index Values at GCREC in 2022

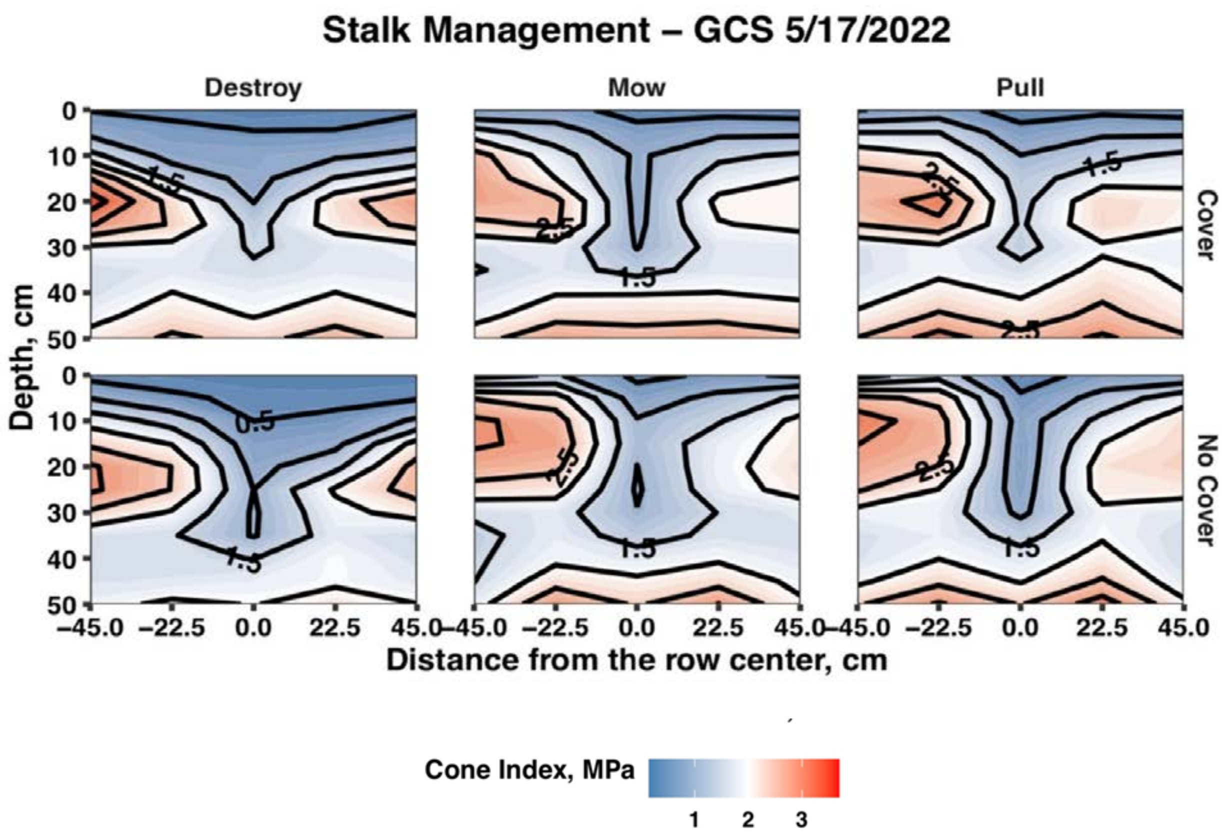


Figure 3.11 Contour Plot Depicting Soil Strength Values from Cone Index Values in MPa at WREC in 2021

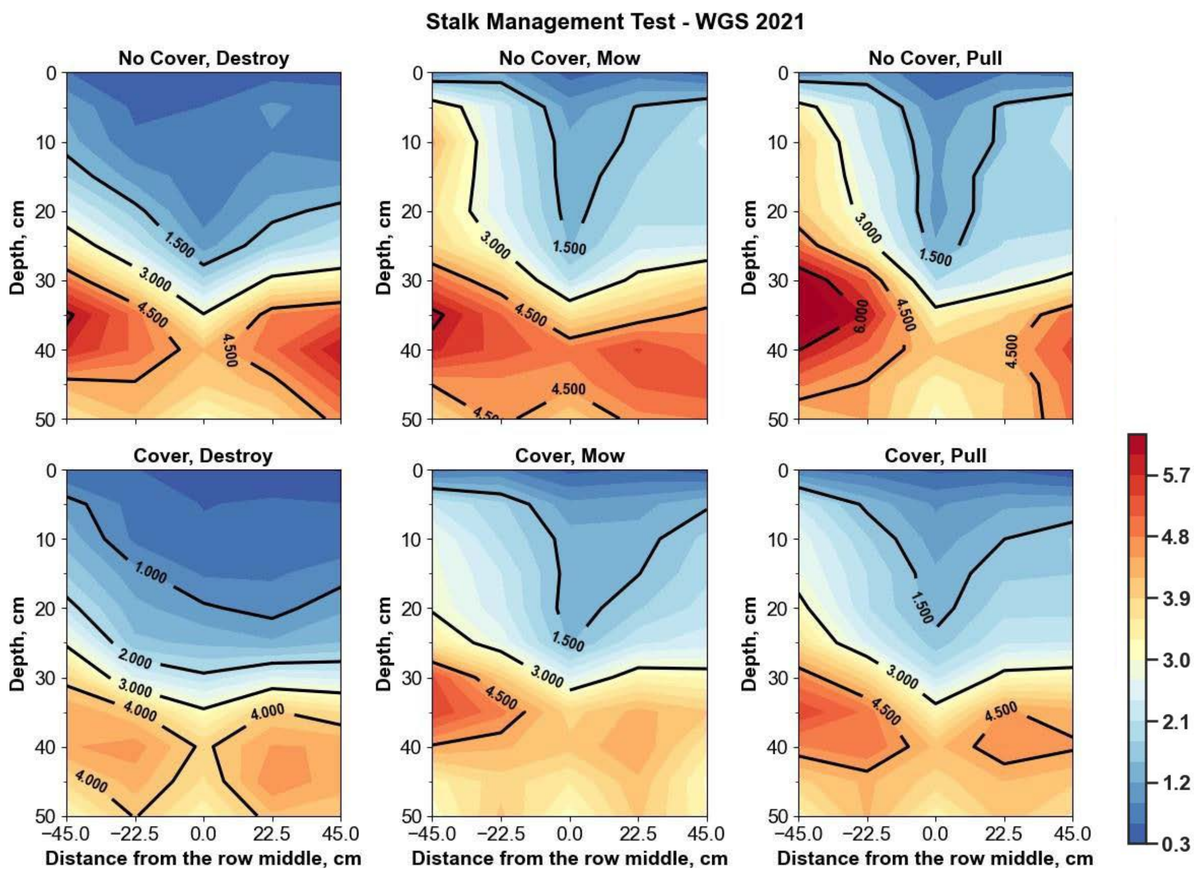
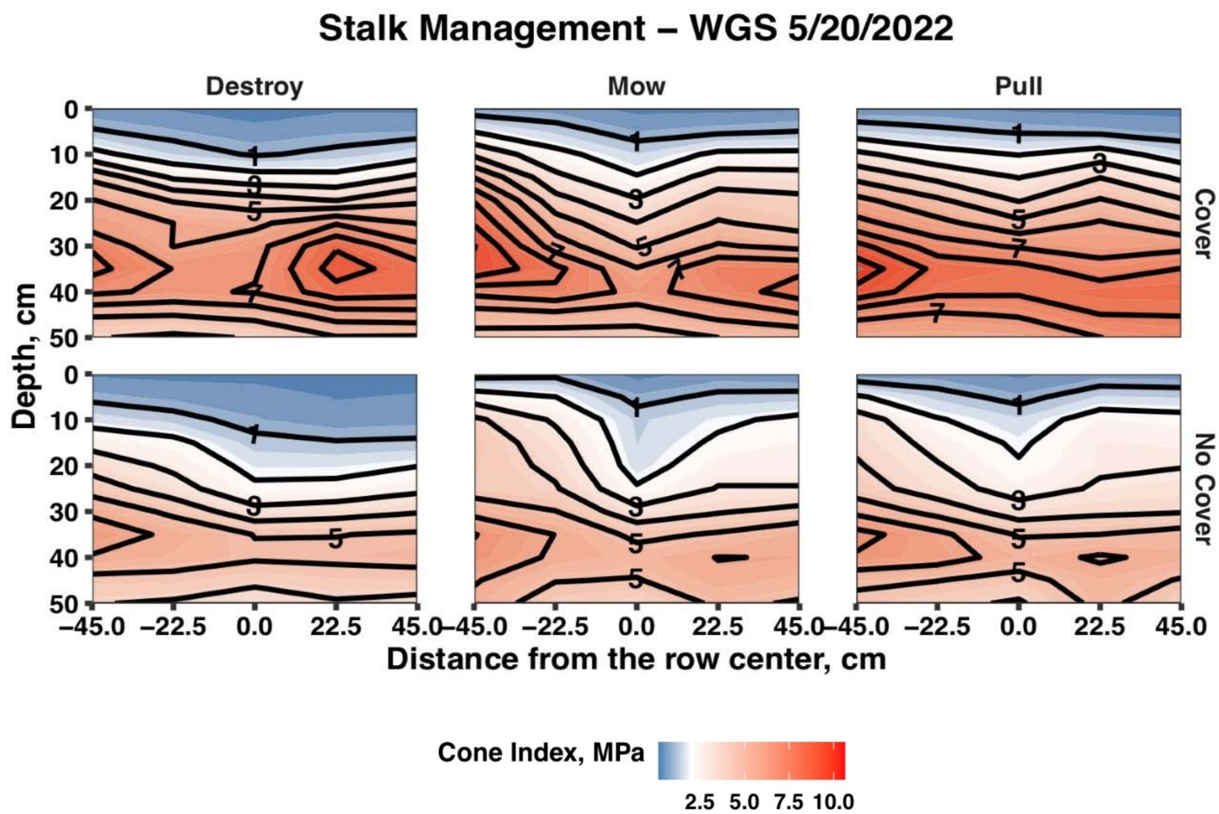


Figure 3.12 Contour Plot Depicting Soil Strength Values from Cone Index Values at WREC in 2022



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Appendix

AP 1. Summary of Analysis of Variance (ANOVA) for Cotton Stand Counts as Affected by Cotton Stalk Method, Cover Crop, and Cotton Variety at Three Locations in Alabama, 2021-22.

	Cotton Stand Counts ANOVA, Prob > F					
	EVS		GCREC		WREC	
Variable	2021	2022	2021	2022	2021	2022
Overall model	0.0008	0.0061	< 0.0001	< 0.0001	0.0046	0.0002
Variety	< 0.0001	0.0031	0.0001	< 0.0001	< 0.0001	0.3089
Cover	0.0171	0.0697	< 0.0001	0.0023	0.0084	< 0.0001
Var x Cov	0.3532	0.9656	0.7192	0.222	0.6577	0.9372
Stalk mg	0.4322	0.1006	0.4063	0.4004	0.9277	0.1725
Var x Stlk	0.1159	0.1691	0.7904	0.7442	0.7690	0.8802
Cov x Stlk	0.1646	0.0302	0.0624	0.1237	0.1581	0.5335
V x C x S	0.2041	0.2214	0.8945	0.003	0.5109	0.5851

AP 2. Analysis of Variance (ANOVA) for Cover Crop Biomass as Affected by Year, Location, and Cotton Stalk Management at Three Locations in Alabama, 2021-22

Cover biomass, lb/A	
Variable	Prob > F
Overall model	< 0.0001
Year	< 0.0001
Location	< 0.0001
YR x Loc	0.9289
Stalk mgt	0.6469
YR x Stalk mgt	0.1351
Loc x Stalk mgt	0.0041
YR x Loc x Stlk	0.2756

AP 3. Summary of Analysis of Variance (ANOVA) for Aphid Counts as Affected by Cotton Stalk Management, Cover Crop, and Cotton Variety at Three Locations in Alabama in 2021-22.

	Aphid Counts					
	Prob > F					
	EVS		GCREC		WREC	
Variable	2021	2022	2021	2022	2021	2022
Overall model	< 0.0001	0.2689	0.3964	0.1089	0.0561	0.2649
Variety	< 0.0001	0.1156	0.9124	0.8770	0.2552	0.2333
Cover	0.0016	0.0710	0.0581	0.0002	0.0266	0.0021
Var x Cov	0.8543	0.2717	0.0496	0.5711	0.0986	0.9129
Stalk mgt	0.0061	0.2800	0.8093	0.6577	0.9593	0.5070
Var x Stlk	0.8525	0.9086	0.8093	0.8176	0.0617	0.8242
Cov x Stlk	0.2725	0.1570	0.3176	0.8488	0.6113	0.9643
V x C x S	0.6248	0.9226	0.6743	0.9501	0.0773	0.9879

AP 4. Summary of Analysis of Variance (ANOVA) for CLRDV Incidence as Affected by Cotton Stalk Management, Cover Crop, and Cotton Variety for Two Sampling Dates at Three Locations in Alabama in 2021-22.

	CLRDV-Aug						CLRDV-Nov					
	Prob > F						Prob > F					
	EVS		GCREC		WREC		EVS		GCREC		WREC	
Variable	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Overall model	0.0189	0.6018	0.9024	0.1058	0.8904	0.0376	0.8393	0.6213	0.2840	0.5524	0.7132	0.0465
Variety	0.0207	0.3132	0.2146	1.000	1.0000	0.0139	0.6678	0.0001	0.0001	0.0712	0.3607	0.3313
Cover	0.0207	0.4480	0.8020	0.3690	0.1670	0.4576	0.7590	< 0.0001	< 0.0001	0.0970	0.4454	0.6255
Var x Cov	0.1799	0.3132	0.8020	0.1809	0.8610	0.1217	0.1310	0.6625	0.7192	0.3588	0.8782	0.0331
Stalk mgt	0.0989	0.5516	0.6432	0.2483	0.9112	0.0196	0.3653	0.8175	0.4063	0.6879	0.1052	0.4302
Var x Stlk	0.4536	0.1402	0.3092	0.8568	0.3093	0.4391	0.8300	0.6691	0.7904	0.8511	0.5050	0.1481
Cov x Stlk	0.3752	0.7117	0.9383	0.0815	0.8055	0.3158	0.6624	0.8948	0.0624	0.5840	0.9592	0.0913
V x C x S	0.0831	0.7713	0.9383	0.0298	0.8055	0.4756	0.8491	0.1089	0.8945	0.7926	0.9257	0.0600

AP 5. Summary of Analysis of Variance (ANOVA) for Lint Yields as Affected by Stalk Management, Cover Crop, and Cotton Variety at Three Locations in Alabama, 2021-22.

	Lint, lb/A Prob > F					
	EVS		GCREC		WREC	
Variable	2021	2022	2021	2022	2021	2022
Overall model	0.0229	0.4006	0.1962	0.6493	0.0443	0.7755
Variety	0.0006	0.6460	0.4115	0.0225	0.1719	0.0408
Cover	0.1840	0.9824	0.3240	0.2748	0.0008	0.5776
Var x Cov	0.9079	0.2725	0.8451	0.5777	0.1407	0.9680
Stalk mgt	0.0220	0.0795	0.0070	0.9860	0.2265	0.8197
Var x Stlk	0.8953	0.5045	0.7298	0.8174	0.9290	0.7863
Cov x Stlk	0.5954	0.7687	0.4229	0.6918	0.6405	0.5249
V x C x S	0.8648	0.2255	0.8508	0.8756	0.4896	0.9432

AP 6. Summary of Analysis of Variance (ANOVA) for Fiber Quality as Affected by Stalk Management, Cover Crop, Year, and Cotton Variety at Three Locations in Alabama, 2021-22.

Fiber Quality	Prob > F				Prob > F				Prob > F				Prob > F		
Variable	EVS	GCREC	WREC		EVS	GCREC	WREC		EVS	GCREC	WREC		EVS	GCREC	WREC
Overall model	0.0547	0.0029	< 0.0001		< 0.0001	< 0.0001	< 0.0001		< 0.0001	< 0.0001	< 0.0001		< 0.0001	0.0008	< 0.0001
Year	0.0003	0.1095	< 0.0001		< 0.0001	< 0.0001	0.0173		0.002	< 0.0001	< 0.0001		< 0.0001	< 0.0001	< 0.0001
Variety	0.1131	< 0.0001	< 0.0001		< 0.0001	< 0.0001	< 0.0001		< 0.0001	< 0.0001	0.0010		0.5403	0.5990	0.3065
Cover	0.1474	0.1532	0.0226		0.2880	0.0677	0.7470		0.9723	0.0097	0.7747		0.4559	0.7818	0.8020
Var x Cov	0.4459	0.3529	0.7625		0.7013	0.1499	0.8718		0.3409	0.9008	0.2499		0.4167	0.4072	0.4947
Stalk mg	0.9288	0.0634	0.4959		0.8166	0.1066	0.3182		0.1544	0.5425	0.8304		0.3032	0.4187	0.7880
Var x Stlk	0.5686	0.5673	0.1619		0.2184	0.8836	0.6730		0.3556	0.7788	0.7945		0.0829	0.5064	0.8878
Cov x Stlk	0.8555	0.5210	0.3164		0.3169	0.6540	0.2892		0.7461	0.0764	0.5339		0.5573	0.0471	0.8130
V x C x S	0.5236	0.8945	0.6189		0.4402	0.4378	0.8451		0.1139	0.3061	0.9156		0.2859	0.8101	0.9676

A.P.7 Monthly Mean Precipitation for Three Locations in Alabama during 2021-22

Central/East, AL	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
(LaFayette, AL)	2021	0.11	0.17	0.17	0.17	0.18	0.25	0.27	0.25	0.15	0.29	0.04	0.23	0.19
	2022	0.14	0.14	0.23	0.14	0.06	0.1	0.17	0.15	0.12	0.08	0.24	0.13	0.14
	Mean	0.13	0.15	0.2	0.16	0.12	0.17	0.22	0.2	0.13	0.18	0.14	0.18	0.17
		0.14	0.17	0.23	0.17	0.18	0.25	0.27	0.25	0.15	0.29	0.24	0.23	
	Max	2022	2021	2022	2021	2021	2021	2021	2021	2021	2021	2022	2021	0.19
		0.11	0.14	0.17	0.14	0.06	0.1	0.17	0.15	0.12	0.08	0.04	0.13	
	Min	2021	2022	2021	2022	2022	2022	2022	2022	2022	2022	2021	2022	0.14
Southwest, AL	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
(Fairhope, AL)	2021	0.09	0.19	0.15	0.38	0.19	0.31	0.25	0.4	0.26	0.22	0.03	0.07	0.21
	2022	0.08	0.07	0.14	0.13	0.24	0.07	0.46	0.47	0.04	0.16	0.22	0.17	0.19
	Mean	0.08	0.13	0.14	0.26	0.22	0.19	0.35	0.44	0.15	0.19	0.13	0.12	0.2
		0.09	0.19	0.15	0.38	0.24	0.31	0.46	0.47	0.26	0.22	0.22	0.17	
	Max	2021	2021	2021	2021	2022	2021	2022	2022	2021	2021	2022	2022	0.21
		0.08	0.07	0.14	0.13	0.19	0.07	0.25	0.4	0.04	0.16	0.03	0.07	
	Min	2022	2022	2022	2022	2021	2022	2021	2021	2022	2022	2021	2021	0.19
Southeast, AL,	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
(Dothan, AL)	2021	0.16	0.19	0.22	0.18	0.14	0.21	0.25	0.28	0.08	0.14	0.02	0.13	0.17
	2022	0.11	0.06	0.23	0.11	0.17	0.27	0.15	0.14	0.04	0.06	0.09	0.11	0.13
	Mean	0.14	0.13	0.23	0.14	0.15	0.24	0.2	0.21	0.06	0.1	0.05	0.12	0.15
		0.16	0.19	0.23	0.18	0.17	0.27	0.25	0.28	0.08	0.14	0.09	0.13	
	Max	2021	2021	2022	2021	2022	2022	2021	2021	2021	2021	2022	2021	0.17
		0.11	0.06	0.22	0.11	0.14	0.21	0.15	0.14	0.04	0.06	0.02	0.11	
	Min	2022	2022	2021	2022	2021	2021	2022	2022	2022	2022	2021	2022	0.13