COVER CROPS IN FIELD-GROWN NURSERIES: IMPACTS ON TREE GROWTH, PEST, AND BENEFICIAL ARTHROPODS

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June 2021

Axel Gonzalez

To the Graduate School:

We are submitting a thesis by Axel Gonzalez titled "Cover Crops in Field-Grown Nurseries: Impacts on Tree Growth, Pest, and Beneficial Arthropods". We recommend that it be accepted in partial fulfillment of the requirements for the degree, Master of Science in Agricultural Sciences with concentration in Plant Science.

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DEDICATION

This thesis is dedicated to my family and friends, especially to my beloved wife Susan and my daughter Maya, for always be there to me in the good and bad times.

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COVER CROPS IN FIELD-GROWN NURSERIES: IMPACTS ON TREE GROWTH, PEST, AND BENEFICIAL ARTHROPODS

ABSTRACT

AXEL GONZALEZ. Cover Crops in Field-Grown Nurseries: Impacts on Tree Growth, Pest, and Beneficial Arthropods (Under the direction of DR. KARLA ADDESSO).

The purpose of this thesis was to evaluate the performance of cover cropping in ornamental nursery production systems. The first experiment evaluated the growth of red maple trees at two different transplant timings into a crimson clover, Fall Transplant and Spring Transplant. The trees in the Spring Transplanted treatment grew more compared to the Fall Transplanted treatment.

In the second experiment, the establishment of two winter cover crops, crimson clover and triticale, was evaluated using Broadcast or Drill planting methods. The triticale established better with Drill method while crimson clover established equally well when Drilled or Broadcast. No significant differences were observed in soil microbial biomass carbon and nitrogen, or arthropod community composition indices between the treatments.

The third experiment consisted of the final two years of a four-year study on red maple trees grown with or without cover crop during the first two years post-transplant. The initial two-year study established the success of the cover crop in protecting trees against flatheaded borer damage, but with negative impact on tree growth. The total number of damaged trees during years 3 and 4 confirms that trees are more susceptible

during first two years after transplant. A total of 24 attacks on Herbicided trees, 2 attacks on Herbicide + insecticide trees, 6 attacks on Cover Crop trees and 0 attacks on Cover Crop + Insecticide trees were recorded. Trees in Herbicide rows remained one season ahead in growth compared to the trees under Cover Crop rows.

A fourth experiment was conducted as a follow-up to the original cover crop study. Four treatments were evaluated: Cover Crop, Early Kill Cover Crop, Herbicide and Mulch Mat. The Early Kill treatment was evaluated to minimize competition between the cover crop and trees while still providing protection against borers. Unfortunately, the Early Kill treatment did not prevent borer attacks. Over the two-year evaluation period, the Early Kill treatment had more attacks than the Herbicide treatment (16 vs. 11 attacks). The Cover Crop and Mulch Mat treatments had 6 attacked trees each.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
INTRODUCTION

Overview

The nursery crop industry is one of the most important operations in the United States. Nursery stock sales were the largest horticultural category valued at $4.5 billion, which represent the 33% of all horticultural sales, and an increase of up to 7% between 2014 and 2019 [National Agricultural Statistics Service (NASS), 2019]. In Tennessee, the nursery industry directly contributes nearly $965 million in economic activity to the state's economy (Jensen et al., 2020). The red maple (*Acer rubrum* L.) is a popular ornamental deciduous tree that is widely grown in eastern and central North America and is characterized by fast-growth rate, high seed production and ability to grow on a wide range of soil types in both moist and dry biomass (Li et al., 2019). Wood boring beetles are a serious problem in red maples and nursery ornamental production. The flatheaded appletree borer (*Chrysobothris femorata* [Olivier]) (Coleoptera: Buprestidae) is a common and destructive pest of many species of deciduous shade, fruit and nut trees, especially those that are newly transplanted or otherwise under stress (Potter et al., 1988a). Flatheaded appletree borer (FAB) attacks are more common on newly planted trees. The female beetle oviposits usually at the base of the trees. The larvae enter the tree by chewing through the egg and bark and their tunneling and feeding activity in young trees disrupt the vascular tissues, interrupting the translocation of nutrients from the root system and often killing the tree (Addesso et al., 2020). Cover crops provide a great opportunity to improve soil quality in different agricultural systems. In woody ornamental production, the usage of cover crops has not been studied profoundly. However, winter cover crops planted at the base of red maple trees was demonstrated to be an effective management method for controlling flatheaded borers (Dawadi et al., 2019).

The selection of the winter cover crop species will vary depending on the desired short- or long-term results. Cover crops can be a source of food for pollinators, can help in mitigating weed competition, and in long term can be an important management strategy to increase soil biotic activity by improving both soil physical and chemical properties and productivity (Cates et al., 2019a). Crimson clover (*Trifolium incarnatum* L.) is a legume that is commonly used as winter cover crop, and it is important as a source of crop-available nitrogen (N) in field crop rotations (Yang et al., 2020). Winter cereal grains such as triticale (× *Triticosecale* W.) can prevent soil erosion during periods of high rainfall, and it is a great weed suppressor (Gibson et al., 2007). Establishment of cover crop is important for achieving optimal benefits in crops, and the selection of the planting method is a factor in successful establishment of cover cropping systems. Broadcast interseeding of cover crops into cash crops earlier in the growing season has been a common and recommended practice since the 1940's (Curran et al., 2018). However, some cover crop species will grow better and exhibit greater biomass consistency when drilled into the ground due to better soil-seed contact, particularly under intermittent soil moisture conditions (Curran et al., 2018).

Another potential benefits of incorporating cover crops is the increase of predatory arthropods that can affect pest management during the cash growing season (Rivers et al., 2018). Cover crop studies in orchards demonstrated enhanced biological control by increasing the densities and diversities of generalist predators (Horton et al., 2009). Farming practices that preserve beneficial arthropods may be a practical alternative to insecticides to manage pests in agricultural systems (Carmona & Landis, 1999). In agriculture the use of pesticides is a common practice worldwide, but the indiscriminate use of insecticides can result in environmental contamination and impacts on arthropod natural enemies. Generally, 4.6 million t of pesticides are released into the environment annually (Ansari et al., 2014). Environmental contamination can occur in multiple ways; by accumulation in soil and subterranean water, movement to new sites in water runoff or by volatilization, and direct intake by non-target plants (Ricupero et al., 2020).

Objectives

Objective 1. Evaluation of winter cover crop stand recovery and tree health following fall or spring planting of tree liners.

- Assess the effect of cover crops on tree growth after transplant.
- Determine if fall tree transplanting improves cover crop establishment.
- Assess the effect of cover crops on soil temperature and moisture.
- Assess the effect of cover crop on arthropod community indices.
- Evaluate the germination rate and biomass of a winter cover crop.

Objective 2. Evaluation of two planting methods for winter cover crops in established trees fields.

- Asses cover crop performance using seed broadcast or drill planting methods.
- Assess the effect of two winter cover crops on soil temperature and moisture.
- Assess the effect of two winter cover crops on arthropod community indices.
- Assess the effect of two winter cover crops on soil microbial content.
- Evaluate the germination rate and biomass of two winter cover crops.

Objective 3. Long term recovery of tree growth in trees established with cover crops for management of flatheaded borers.

- Assess the total number of damaged trees by flatheaded borers after four-year production.
- Evaluate the growth recovery capability of trees after two years of cover crop competition.

Objective 4. Early kill cover crop management for protection against flatheaded borers.

- Assess the effect of winter cover crops on tree growth.
- Assess the effect of winter cover crops on tree protection against flatheaded borers.
- Assess the effect of winter cover crops in soil temperature and moisture.
- Assess the effect of winter cover crops on arthropod community indices.
- Evaluate the effect of early cover crop termination on reduction of competition with the tree crop.

CHAPTER II

LITERATURE REVIEW

Nursery Industry

The ornamental industry in the United States represents a significant portion of the agricultural economy, with annual production estimated at $ 4.5 billion [National Agricultural Statistics Service (NASS), 2019]. In the southeastern United States, the industry is worth an estimated $1.5 billion. In Tennessee, nursery crops account for a significant portion of agricultural production with approximately $130 million in sales annually, the majority of which is field-grown woody ornamentals. Tennessee has more than 700 nurseries, 300 greenhouses, 2,500 plant dealers, and 400 landscapers certified across the state (Lockman, 2012). The state is the world's larger supplier of dogwood and peach tree liners. McMinnville is known as the Nursery capital of the world and boasts the largest nursery producers for many species of perennials, annuals, ground cover, shrubs, and shade, fruit, and flowering trees. It is not surprising that nursery growers are constantly looking for ways to improve their production and profitability across the state, especially in a market that becomes increasingly demanding in terms of the quality of its products.

Sustainable agriculture practices have been implemented in many other areas of crop production, which opens a market window to customers that recognize the aggregated value of products produced with environment friendly practices.

Tennessee State University'sOtis L. Floyd Nursery Research Center (TSU-NRC) has a strong history of conducting and promoting the results for different advances and alternatives for the nursery growers that will improve the local economy. The work proposed here will add value to those recommendations

Red Maple Production

Red maple (*Acer rubrum* L.) (Sapindaceae) is one of the most important species produced by the woody ornamental nursery industry. The wide adaptability to diverse growing conditions is one of the characteristics that make red maple a poplar and lucrative tree crop. Examples of red maples growing sites include dry ridges and southwest slopes to peat bogs and swamps. Red maple commonly grows under the most extreme soil-moisture conditions from very wet to dry (*Russell* 1990). As an ornamental, it has many positive characteristics including the ease of establishment, rapid growth, brightly colored flowers and fruits, and fall leaf colors, ranging from clear yellow to orange to vivid red displays during different seasons of the year (USDA NRCS National Plant Data Center).

In the lumber industry, red maple wood is called a soft wood. Its wood has been widely used for furniture, cabinets, and veneer. In addition to these applications, red maple also has been used for the manufacture of soaps, and the sap of red maple is sometimes used for producing maple syrup (Russell, S. 1990 *Silvics of North America*) Red maple is one of the most abundant species in the temperate forests of eastern North America and has a wide north to south distribution. Given this extensive distribution, red maple species haves many growing forms and varieties. Because of the abundance and distribution of red maple, its early-produced pollen may be important to the biology of bees and others pollen dependent insects (USDA NRCS National Plant Data Center). The attractiveness of red maple as an ornamental comes from the ability to display different features throughout the year, such as buds in winter, flowers in spring and in the fall with the brilliant leaf colors.

Pest Problems in Red Maple

Despite red maples high adaptability and beauty as an ornamental, the tree also has a wide variety of pests. Key pests of concern, include the flatheaded appletree borer (FAB) (*Chrysobothris femorata* [Olivier]) (Coleoptera : Buprestidae), ambrosia beetles (e.g., *Xylosandrus crassiusculus* [Motschulsky]) (Coleoptera: Curculionidae), maple and two-spotted spider mites (*Oligonychus aceris* [Shimer] and *Tetranychus urticae* Koch) (Trombidiformes: Tetranychidae), maple shoot borer (*Proteoteras aesculana* Riley) (Lepidoptera: Tortricidae), maple leaftier (*Episimus tyrius* Heinrich) (Lepidoptera: Tortricidae), potato leafhopper and various species of armored and soft scales (Hemiptera).(Dawadi et al. 2019).

Another important pest for the red maple is the Asian longhorned beetle (ALB) (*Anoplophora glabripennis* [Motschulsky]) (Coleoptera: Cerambycidae). The ALB is an invasive polyphagous wood-boring insect that could potentially destroy 30 % of the urban trees in the United States at an economic loss of US$669 billion (Meng et al. 2015). Wood borers are among the most significant problem pests and represent a serious challenge for red maple production. Borers attacks occur most often when trees are stressed due to the importance of stress in borer attacks, prevention is the most important step in managing borers. Healthy trees tend to be less attractive to a wide variety of wood borer species; and therefore, have less attacks. Usually, borers focus on stressed trees that release volatile chemicals signaling that the plant has some levels of stress. For example, ambrosia beetles are attracted to stressed plants that produce high levels of ethanol. However, the mechanism of attraction for borers like the flatheaded appletree borer are still unclear.

Flatheaded Appletree Borer

The FAB, is a common and destructive pest of many species of deciduous shade, fruit and nut trees, especially those that are newly transplanted or otherwise under stress (Potter et al. 1988). Bupestrid larvae are commonly called flatheaded borers because the first segment of the prothorax is enlarged behind the reduced head, which gives the appearance of a flattened head (Oliver et al., 2010). Adult *C. femorata* are bullet-shaped and 7.6-15.2 mm long, and their elytra have irregularly shaped grayish-brassy spots on the dorsal surface. Beneath the elytra, the dorsal abdomen is metallic purple and the ventral abdominal surface is metallic bronze (Frank et al. 2013). *Chrysobothris femorata* is mostly univoltine, but some larvae under stress or in the northern parts of the range may require 2 yr to reach maturity (Brooks 1919). Adult beetles emerge from trees in late spring and early summer (Frank et al., 2013). Trees under stress (e.g, digging and transplanting process) are more likely to be attacked by the FAB (Potter et al. 1988). Larval feeding damage beneath the bark interferes with the transport of water and nutrients in the vascular systems, which weakens or kills the tree. Damage caused by FAB attacks are a concern not just because of tree death, but also because trees that survive *C. femorata* attacks usually have trunk scars that ruin their aesthetic marketability. Early application of systemic insecticide drenches containing imidacloprid (or other neocotinoids) is currently the most effective treatment for nursery growers (Oliver et al. 2010). In the case of trunk spray insecticide treatments, the best control of flatheaded borer larvae will likely occur if the trunk contact sprays are applied shortly before oviposition, so that the newly hatched borers are exposed to a lethal dosage while chewing through the bark at the point of egg attachment (Potter et al. 1988). Use of insecticides can have direct effects on non-target arthropod pests and their natural enemies (Dawadi et al. 2019) Alternatives to minimize the use of insecticides are needed to aid nursery growers. Better economic thresholds for *C. femorata* damage also are needed to facilitate insecticide applications in accordance with the principles of integrated pest management. Research conducted at the TSU-NRC has shown that the incorporation of winter cover crops can significantly reduce the number of trees attacked by FAB.

Cover Crops

Cover crops are well recognized for all of the benefits they provide, including slowing erosion, improving soil and suppressing weeds, enhancing nutrient and moisture availability and aiding in pest control (Bukovsky-Reyes et al., 2019). One crucial aspect in agriculture production is soil health and the interactions among micro-organisms and minerals to provide the maximum nutrient access to plants. Cover crops can improve soil health by stimulating the microbial community composition, abundance, and activities. The root exudates of cover crops can prime decomposition of native soil organic carbon by providing easily decomposable carbon to the rhizosphere microbial community (Cates et al., 2019). The main crop will benefit from the microbial processes by gaining nutrients like nitrogen or phosphorus via decomposition. For instance, cover crops directly create food chain cycle by feeding bacteria and fungi, these will be a source of food for earthworms and arthropods, helping nutrient turnover thus benefiting nutrient acquisition by main crops (Rob Myers., 2017). Cover crops represent an important management strategy to increase soil biotic activity, therefore improving both soil physicochemical properties and productivity (Cates et al., 2019). Increasing food sources for soil organisms may have a direct impact on the nematode community as well. For instance, use of winter cover crops has been shown to alter the number of entomopathogenic nematodes (EPN) in the soil (Jaffuel et al., 2017).

In agriculture, water quality and quantity are crucial factors to successful crop production. There are several parameters that affect water availability, including plant cover, root density, porosity, infiltration, water storage and soil penetration resistance. Evidence is mounting that the incorporation of cover crops can increase the water storage and microporosity of soils, making more water available for the main crop (Sastre et al., 2018). Water quality refers to the chemical and physical composition of subterranean and above ground soil sources. The cover crop will retain soil and water availability above ground and beneath. In addition, the interaction with the cover crop and microorganisms influence soil physical properties, such as water relationships, aggregation, infiltration capacities, bulk density, temperature, and hydraulic conductivity. By the mulch effect the cover crop can reduce the evaporation of water and provide a barrier to water vapor movement (Sainju et al., 1997). A cover crop also can reduce soil erosion through diminished raindrop impact and surface runoff and increase water infiltration and transpiration. Overall, research estimated that a cover crop can reduce erosion by an average of 62% (SAINJU, 1997).

The loss of soil as a result of erosion can lead to a decline in organic matter and nutrient contents, the breakdown of soil structure and a reduction in water-holding capacity (Robačer et al., 2016).

Cover crops are not usually grown for harvesting, but only to provide agroecological services at field, farm and landscape levels, as well as contributing to the management of weeds and pests in the field (Robačer et al., 2016). Cover crops are widely used for weed suppression (den Hollander et al., 2007). Cover crops residues remaining on the soil surface can physically modify seed germination by altering the seed environment through changes in, light availability, soil temperature, soil moisture, and other types of interferences like, allelopathy (Creamer et al., 1996). Reducing the soil weed seed bank by using cover crops is translated into a decrease in the weed infestation in subsequent crop production cycles (Uchino et al., 2012). Except for herbicides, weed control in agriculture is usually conducted by multiple rounds of tillage and hand weeding, but these activities are labor, time and resource intensive. An alternative option could be the use of cover crops (Uchino et al., 2012). Surface coverage is important because cover crops block the light stimulus required for germination of many small-seeded weed species (Bottenberg et al., 1997). The weed suppression benefit is important to consider since weeds in optimal conditions are often more competitive than the cover crop in relation to the cash crops (Amossé et al., 2013). Weed density, biomass or ground cover are generally higher than in conventional production systems (Amossé et al., 2013).

Cover crops also have been evaluated for their usage in pest management. Increasing crop diversity through intercropping is a simple and effective practice that offers advantages in reducing disease and pest population densities and severity (He et al., 2019). The use of a cover crop can increase the populations of beneficial ground predators like carabids, staphylinids and spiders (Robačer et al., 2016). Cover crops conserve beneficial insects, and populations of soil and litter dwelling predators such as ground beetles (Carabidae) are favored by reducing tillage (Bottenberg et al., 1997). Cover crop diversity can also help by reducing pest dispersal, reproduction, and visual orientation needed to colonize the main crop (Bottenberg et al., 1997). Crop diversity has been widely adopted in many regions because of the reduction in disease severity due to foliar pathogens. One major mechanism believed to be responsible for such decreased disease severity is the reduction of disease inoculum when the distance between plants of the same genotype is increased (He et al., 2019). There are many positive benefits for the use of cover crops. However, there are negative aspects that are important to mention. The competition generated by the cover crops used as a weed suppression method can also potentially affect the growth of main crop. In some cases, the cover crop can suppress the main crop by starting a direct competition for light, nutrients and water (Uchino et al., 2009). Therefore, more information is needed about adopting cover crops for weed suppression and soil management to ensure any negative impacts are outweighed by the benefits.

Another potential negative aspect of cover crop is the possibility of increasing insect pest populations. Adding cover crops increases the quantity of primary resources for herbivorous insects. One risk of adding cover plants is that this new resource may be consumed by herbivores that also favor the main crop and may thus increase the pest population (Duyck et al., 2011). Therefore, it is important, to assess the impact of cover crops on main crop beneficial and pest populations before making recommendations.

Types of Cover Crops

The characteristics of cover crop plant species are important to obtain the best usage as a cover crop. The crop should be able to tolerate adverse environmental conditions, have a fast seed germination and emergence period, be competitive with weeds, easy to kill and have a low cost of establishment (Scholberg et al., 2010). Two types of cover crops include the legumes, which contribute to nitrogen fixation, and the grasses, which help suppress weeds with allelopathic chemicals. Commonly used cover crop species include winter wheat, a winter annual grass which is tall, fast growing and has an abundance of dry matter that produces a good mulch (Gao et al., 2017). Winter wheat is a cool-season crop and can be grown successfully in all counties of Tennessee (Robačer et al., 2016). Another common cover crop is crimson clover which is an annual winter legume that is a good nitrogen producer that can reduce fertilization application requirements over time, additionally crimson clover may be beneficial to pollinators, as well as providing nectar and pollen sources for other beneficial insects

(Yang et al., 2020). Annual ryegrass is another prevalent cover crop grass that is used for its quick establishment, vigorous growth, and competitive and strong allelopathic mechanisms for weed suppression.

Cover Crops in Nursery Production

Unlike agronomic crops, there is minimal information about the impacts of incorporating cover cropping in nurseries. However, the usage of winter cover crops such as ryegrass or crimson clover can be easily incorporated into current nursery production systems and potentially reduce soil erosion, improve weed suppression and pest management (Cripps and Bates, 1993).

In an experiment conducted by Dawadi et al. (2019), cover crops reduced oviposition by FAB in maple plantings. Although cover cropping may be an ideal solution for FAB management, it is unclear how these crops may affect other non-target arthropod pests of red maple trees or beneficial insect population in the field (Dawadi et al., 2019). Additionally, cover crops can affect plant growth performance by competition, (Dawadi et al., 2019). Another study reported trunk growth sensitivity to cover crop competition (Hànninen, 1998) Therefore, more information is needed to understand the impact of cover crops on tree growth, as well as beneficial and pest organisms.

CHAPTER III

MATERIALS AND METHODS

Objective 1: Evaluation of Winter Cover Crop Stand Recovery and Tree Health Following Fall or Spring Planting of Tree Liners

Field Experimental Design and Layout

The experiment was conducted in a field at the Tennessee State University Otis L. Floyd Nursery Research Center (TSU-NRC) (35.7102174°N, 85.7904774°W) in McMinnville, TN, between August 2018 and June 2019. The experiment was established in a plot measuring 27 × 30 m. Two field management treatments included the legume crimson clover (*Trifolium incarnatum* L) as the 'Cover Crop' treatment and a plot with no cover crop application as control treatment 'Weeds'. Plots were established in 14.8 × 2.4 m blocks in a randomized complete block design with four replicate blocks per treatment. The cultivar used for this experiment was red maple 'Brandywine' rooted cutting. The cuttings were transplanted into plastic nursery containers (number 3 size) using Barky Beaver Nursery Mix (pine bark fines, peat moss, sand perlite, starter fertilizer charge) (Cookeville, TN, USA) as a medium on 21 June 2018. Containers were fertilized with a complete slow-release fertilizer with micronutrients at transplant on 5 July 2018 (Nutricote Total, 13-11-11, FLORIKAN E.S.A LLC., Sarasota, FL, USA., 40g/plant). Two planting treatment timings were evaluated. On 5 December 2018, the 'Fall Transplant' treatment of maple trees were transplanted into the plot row using a nursery tree planter attached to a John Deere 770 tractor (Moline, IL, USA). The 'Spring Transplant' treatments were transplanted on 21 March 2019. Spring transplanted trees were overwintered in a plastic shade house. Each plot had a total of 16 maples, 8 trees per season with trees spaced using 1.8 m within the row and 1.4 m between trees in the rows. A second plot assigned as trial 2 was established next to the trial 1 plot from August 2019 to June 2020 with the same treatments ('Cover Crop' and 'Weed').

Cover Crop Establishment

Crimson clover (*T. incarnatum*) was established as a cover crop on 26 September 2018. The soil was first prepared with a disk harrow. Seeds were sown by using an Earthway EV-N-SPRED 2150 Commercial Broadcast Spreader (Earthway Products, Bristol, IN, USA) at a rate of 16.78 kg/hectare. A second cover crop application was performed on 10 October 2018 to maximize cover crop establishment. After trees were transplanted into the experimental plots, tree rows were maintained with pre-and post-emergent herbicide using Finale (Glufosinate-ammonium;flumioxazin, 16 ml/L) and Round up (Glyphosate, 1.1 % and 1.30 g/L) to avoid weed competition. The second plot or trial 2 was established similarly with crimson clover as cover crop on 27 September and second application on 12 October 2019.

Soil Moisture and Temperature Measurements

Soil moisture and temperature was collected for each plot from December 2018 to June 2019 for trial 1 and from December 2019 to June 2020 trial 2. Readings were made within tree rows and middles between 10:00 AM to 11:00 AM once a month. Four locations in the row and middle were chosen randomly, two sites for temperature using a probe (Digital Soil Temp Tester, Spectrum Technologies, Inc., East Plainfield, IL, USA; 11.4 cm probe) and two for soil moisture (percentage of volumetric water content [VWC %]) using a FieldScout time-domain reflectometer (TDR) soil moisture sensor with pro check handheld reader (TDR 100, Soil Moisture Meter, Spectrum Technologies, Inc., East Plainfield, IL, USA; 7.6 cm probe).

Cover Crop Evaluation

After cover crop establishment, evaluation for cover crop density was performed by germination rate. In November 2018, a 30 × 30 cm PVC square frame was tossed randomly within rows and between rows and the number of plants germinated were counted. Another evaluation was performed in April 2019 using the same methodology to rate the percentage of the cover crop within rows and row middles, as well as cover crop height in four random locations per treatment plot. The cover crop evaluation for trial 2 was performed using the same methodology and by counting the number of germinated plants in December 2019 and a second counting in May 2020.

Weed Assessment

Percentage of ground area covered by cover crop or weeds was visually assessed on 25 April 2019 for trial 1 and on 11 May 2020 for trial 2, using the same PVC square at four random locations each within rows and within middles for each plot. Cover crop samples were harvested within the squares at each site for biomass analyzes. Samples were collected and put in a dryer for 24 hours at 50° C in paper bags (DURO, Bag MFG, Co, Florence, KY, USA) and after drying weight data for all treatments was collected.

Tree Growth

Tree height and trunk diameter (15.2 cm [6 in] above the soil line) was taken for all test maple trees at transplant and repeated in October 2018 and 2019. Trunk diameter data was taken at 15 cm above ground level using a digital caliper (Mitutoyo Corporation, Kanagawa, Japan). Trunks were marked with a white paint marker to facilitate consistency of future measurements, and tree height was taken using a digital measuring pole (Sokkia, Senshin Industry, Co., LTD. Japan) from the base of the trees to the highest point on the same dates. The same method was used to collect tree growth data from trial 2 in the fall of 2019 and 2020.

Pest and Beneficial Insect Assessments

Maple tree plots were evaluated for major arthropod pests and beneficial insects monthly from May to July 2019 during peak cover crop coverage. Sticky and pitfall traps were used to collect flying and ground dwelling arthropods, pitfall traps were set in the ground at ~8 cm deep (pitfall traps cups: 8 cm tall × 7 cm diameter). Pitfall traps were filled with an antifreeze solution to preserve arthropods (RV & Marine antifreeze, SPLASH Products, Inc., MN, USA). Also, a plastic cover (7.5 × 7.5 cm) was used on the top of the trap to prevent overflow during rain events, but with enough space in between the trap and cover for collecting specimens. Yellow sticky traps (7×12 cm) were placed at cover crop height (between 30 to 40 cm). Two pitfall and two sticky traps were placed in each plot and collected 7 d later. Arthropod specimens were filtered out of the antifreeze using a (TRIMACO, Morrisville, NC, USA) fine mesh paint filter, and filters were stored in Ziploc bags at -4°C. Sticky trap cards were wrapped in wax paper and stored in a -

20°C freezer. Arthropods samples were identified to family to investigate differences between arthropod population diversity and evenness in the different treatments. Insect identification was completed using keys in books and webpages (Photographic Atlas of Entomology and Guide to Insect Identification, American Beetles Vol. 2, An Introduction to The Study of Insects Sixth Edition, and www.bugguide.net).

Objective 2: Evaluation of Two Planting Methods for Winter Cover Crops in Established Trees Fields

Field Experimental Design and Layout

Two locations were selected for this experiment, one at Flower City Nursery (35.637783°N, 85.838652°W) in Smartt, TN, USA. and Pleasant Cove Nursery (35.741835°N, 85.656947°W) in Rock Island, TN, USA. Both experimental locations had the same treatment and layout. The goal for this test was to identify cover crop species and seeding methods that are compatible with established nursery fields. In Flower City a plot with eastern redbud (*Cercis canadensis* L.) was selected, and a plot with red maple (*Acer rubrum* L.) at Pleasant Cove. A brush cutter was used to mow the row middles before cover crop application. Cover crop treatments were arranged in a Randomized Complete Block Design (RCBD), with four replicates per cover crop and seeding treatment. Each plot was 10 m in length with one replicate per tree row. Cover crop replicates were blocked by tree row. Two cover crop species were used, crimson clover (*T. incarnatum* L.) and triticale (× *Triticosecale* W.) with two seeding methods, one using a Herd GT77 Spreader (Herd Seeder Co., GA, USA) and a second, drill method using a Kubota tractor (Kubota L3301Dt, Tennessee Valley, Tractor & Equipment, McMinnville TN, USA) with a seeder with drilling roller implement (Land Pride APS1548, Salina, Kansas, USA) operated at 1300 RPM. Seeds applications were done in September 2018 at both locations and plots consisted of five treatments, (1) Crimson Clover Drill, (2) Crimson Clover Broadcast, (3) Triticale Drill, (4) Triticale Broadcast and 5) an untreated plot as control (Weed). Applications of pre-emergent herbicide SureGuard (Flumioxazin 51%, Valent U.S.A Corp., Walnut Creek, CA, USA) was performed in both locations with a rate of 708.8 g/ha to the tree rows to prevent weed or cover crop competition at the base of the trees during the experiment plot.

Soil Moisture and Temperature Measurement

Soil moisture and temperature data were collected monthly from October 2018 to June 2019, and readings were performed by using the method described above in 3.1.3.

Soil Microbial Carbon Content

Research literature suggests that cover crops can modify soil condition over time. However, changes to soil quality are difficult to assess in the short-term. Soil samples were collected for assessment of soil microbial carbon, since microbial carbon is more sensitive to changes in soil quality than organic matter or total carbon assessments. To assess soil microbial carbon content, soil samples from plots were collected on 24 June 2019. To compare the impact of different cover crop species, 50 g soil/plot was collected from Crimson Clover Drill, Triticale Drill and Weed treatments. After mixing the freshly collected soil sample, 5.0 g were used to estimate biomass carbon (MBC) and microbial biomass nitrogen (MBN) in each core by chloroform fumigation-K_2SO_4 extraction and potassium persulfate digestion methods (Brookes et al., 1985; Vance et al., 1987). Briefly, 0.5 M K_2SO_4 was used to extract soil dissolved organic carbon and nitrogen from fumigated and unfumigated soil samples. Soil extracts were digested with 0.5 M K_2SO_4 in an oven at 85 °C for 20 h. The K_2SO_4-extractable C and N in fumigated and unfumigated samples were determined with a Shimadzu TOC-L & TNM-L (Shimadzu Corporation, Kyoto, Japan). MBC or MBN was calculated as the difference in K_2SO_4-extractable C or N concentration between fumigated and unfumigated soils, divided by 0.45 for C and 0.54 for N, respectively (Brookes et al., 1985; Wu et al., 1990).

Cover Crop Plot Evaluation

Cover crop evaluations for density and coverage were done using the method previously described in 3.1.4.

Weeds Assessment

Weed pressure was evaluated by using the method previously described in 3.1.5.

Pest and Beneficial Insect Assessments

Arthropod data collection was conducted as previously described in 3.1.7.

Objective 3: Long-Term Recovery of Tree Growth in Trees Established with Cover Crops for Management of Flatheaded Borers

Field Experimental Design and Layout

In 2016, a cover crop experiment was initiated at Moore Nursery in Irving College, TN, USA (35.583889∘N, 85.713056∘W) (Warren Co.) with the main objective of testing the efficacy of cover crops as an alternative strategy for controlling flatheaded appletree borer (FAB). During the first two years, four treatments were assigned in a 2 × 2 factorial design. The treatments were 1) Cover Crop + Non-Insecticide, 2) Cover crop + Insecticide, 3) Herbicide + Non-Insecticide (Bare row) and 4) Herbicide + Insecticide (Bare row), with four replicate blocks per treatment having a total of 400 plants (25 trees per block) with a distance between each tree of 1.8 m and between rows of 2.1 m. The total size of the plot was 97.5 × 24.4 m. Each treatment block was 11 × 11 m with 25 trees assigned per block.

Red maple 'Franksred' was used as the cultivar and liners were initially propagated at the Otis L. Floyd Nursery Research Center, McMinnville, TN. All trees were grown in #3 containers in June 2014 and later transplanted into the field on 13 November 2015. Initial height and caliper were recorded to evaluate the effects of cover crops on maple growth. During the first two years, cover crops provided effective protection against borer attacks, however, the presence of cover crop at the base of the trees resulted in a significant reduction in tree growth compared to trees in rows that were kept clean with pre-emergent herbicides (Dawadi et al. 2019). For the continuation of this study (years 3 & 4), all tree rows were maintained with standard management using herbicides to reduce competition in the tree row, and row middles were mowed periodically. Tree growth was evaluated for year 3 and 4 to see if smaller trees in the original cover crop plots would catch up in size to trees in the bare row plots after being in competition with cover crops during their first two years of establishment. Trunk diameter and height data were collected twice a year, first in the spring and once in the fall for each year as previously described in section 3.1.6. Additional flatheaded borer attacks also were recorded when observed.

Objective 4: Early Kill Cover Crop Management for Protection Against Flatheaded Borers

Experimental Design

FAB attacks are usually focused on the base of the tree trunks (0-40 cm). In another follow up experiment to Dawadi et al. (2019), we explored whether killing the cover crop early could reduce competition with the trees, while still providing FAB protection. In this experiment, management methods were evaluated to maximize growth of trees while minimizing the threat of FAB attacks. At the same location (Moore's Nursery) a new plot was established in November 2018 with 400 'Franksred' red maples and trees propagated in # 3 containers at the TSU-NRC as described previously. Unlike the experiment in 3.3.1, treatments were assigned to individual trees, not to blocks of trees. The four treatments were randomly assigned to each replicate, with 100 trees per treatment. The four treatments were as follows; 1) cover crop was allowed to senescence naturally (Cover Crop), 2) a post-emergent herbicide (Round up, glyphosate 1.1%) was used to kill the cover crop within the tree rows when it reached 60 cm in height to reduce cover crop competition (Early Kill), 3) a pre-emergent herbicide SureGuard (Flumioxazin 51%) was used to maintain a clean 30 cm (1ft) radius around the tree trunk (Bare) and 4) a mulch mat ring (30 cm radius) around the base of the tree was used to suppress weeds without herbicide (Mulch Mat). The Mulch Mat treatment was added to assess whether herbicide treatments were contributing to FAB attacks, a question that had been brought up by previous investigators. In this test, tree growth and FAB attacks were evaluated for 2 yr post-transplant (2019-2020). In 2020, trunks of attacked trees were harvested to rear adult beetles for species identification and to identify any parasitoids present in the system.

Cover Crop Application

Crimson clover (T. *incarnatum* L.) and triticale (× *Triticosecale* W.) were broadcast in September 2018 using the same broadcast spreader previously described and lightly disked into the soil. Cover crop was evaluated for coverage and density in December 2018 and May 2019. For the second year, crimson clover and annual ryegrass was broadcast in September 2019 and coverage and density were measured in December 2019.

Pest and Beneficial Insect Assessments

Arthropod diversity in the plots was evaluated in Summer 2019 by using pitfall and sticky traps, each trap was randomly assigned and set 15 cm from the tree trunk base of selected trees. A total of 40 pitfall traps and 40 sticky traps were deployed near four trees for the four treatments. Trapping locations were randomly assigned on each sampling date and repeated for 3 months from April to June 2019. Traps were collected after 7 d and arthropod evaluations were made for diversity and richness.

Flatheaded Appletree Borer Evaluations

Trees that showed FAB attacks were counted and monitored in Fall 2019, but since damage for FAB is not easy to identify in its early stages, a second evaluation was performed in April 2020. Trees with clear symptoms were harvested and moved to the

TSU-NRC and kept in plastic containers with enough airflow to reduce chances of molding. Adults started emerging by the end of May 2020 and borers and parasitoids were identified to species.

Statistical Analysis

For objective 1: Plant height and caliper data as well as the cover crop coverage, and biomass data were analyzed using a general linear model procedure fitted to a normal distribution (PROC GLM; Transplant Cover Transplant * Cover) and post-hoc pair-wise with SAS statistical software 2016 (SAS Institute Inc., Cary, NC, USA) and means were separated by LSmeans adjusted Tukey's analysis ($P< 0.05$).

Arthropod community diversity indices were calculated by using Simpson's index. Diversity was calculated by using the formula: $D = \frac{1}{\sum_{i=1}^{s}}(p_i^2)$ and evenness by using the formula: $ED = D/D_{max} = \frac{1}{\sum_{i=1}^{s}}(p_i^2) \times 1/S$. The variables were: D = Diversity index, S = total number of species (families) in the community (richness), p_i = proportion of S made up of the ith family, and ED = equitability (evenness).

Community statistics were compared between treatments using a general linear model fitted to a normal distribution (PROC GLM; CoverType) and post-hoc pair wise, with SAS statistical software 2016 (SAS Institute Inc., Cary, NC, USA) and means were separated by LSmeans adjusted Tukey's analysis ($P< 0.05$).

For objective 2: Cover crop data for coverage, cover crop biomass, soil temperature and soil moisture from both locations were analyzed using a general linear model procedure

(PROC GLM) with SAS statistical software 2016 (SAS Institute Inc., Cary, NC, USA) and means were separated by LSmeans adjusted Tukey's analysis ($P< 0.05$). Arthropods samples for the diversity indices were analyzed and compared as previously described.

For objective 3: All plant height and trunk diameter data were analyzed using a general linear model procedure (PROC GLM) with SAS statistical software 2016 (SAS Institute Inc., Cary, NC, USA) and means were separated by LSmeans adjusted Tukey's analysis ($P< 0.05$). Tree FAB damage counts were analyzed by a generalized linear model fitted to a binomial distribution (dist=bin for 1/0 data) (Proc Genmod). Arthropods samples for the diversity indices were analyzed and compared as previously described.

CHAPTER IV

RESULTS

Objective 1: Evaluation of Winter Cover Crop Stand Recovery and Tree Health Following Fall or Spring Planting of Tree Lines

Plant Growth Measurement

In Trial 1, there was a significant difference in trunk diameter growth, with Cover Crop Spring Transplant adding an average of 17.3 ± 0.6 mm (average ± SE) after 1-yr post- transplant and 14.8 ± 0.5 mm (average ± SE) for Cover Crop Fall Transplant. Additionally, the Weed Spring Transplanted trees were larger with an average trunk diameter of 16.3 ± 0.5 mm and 15.9 ± 0.5 mm (average ± SE) for the Weed Fall Transplanted trees. The same trend was observed for plant height with taller trees occurring in the Cover Crop Spring Transplanted trees (average of 95.8 ± 3.4 cm) Cover Crop Transplanted trees (average 72.3 ± 2.4 cm). Trees in the Weed Spring Transplant plots were also taller than trees in the Fall Transplant plots; 83.2 ± 4.3 cm and 68.3 ± 2.2 cm, respectively (Table 1).

The results for Trial 2 at the end of year one season were unlike Trial 1. No difference was found in the trunk diameter growth for Cover Crop or Weed Spring or Fall Transplant.

Cover Crop Spring and Fall Transplanted trees averaged 139.6 ± 3.0 cm and 136.7 ± 3.0 cm tall, respectively. However, there was a significant difference between Weed Spring

Transplanted trees, with Spring Transplants growing taller than Fall Transplants (138.9 ± 2.5 cm and 131.6 ± 3.0 cm respectively) (Table 2).

Cover Crop Coverage and Density

In trial 1, there was no difference detected in the percentage area covered for Cover Crop Spring Transplant and Cover Crop Fall Transplant (F = 2.20, df = 1, P = 0.1979) treatments, but there was a significant difference with cover crop height (F = 9.02, df = 1, P = 0.030). Crimson clover in the Cover Crop Spring Transplanted plots had an average height of 38.3 ± 3.2 cm compared to 29.8 ± 0.8 cm in the Cover Crop Fall Transplanted plots. (Table 3). There was no difference detected in the average dry weight of Cover Crop Fall Transplant and Cover Crop Spring Transplant (43.6 ± 5.7 g and 34.9 ± 3.5 g, respectively), though the trend was for higher biomass in the Fall Transplant plots (Table 4). In trial 2, there was no difference detected in the percentage area covered for Cover Crop Spring Transplant and Cover Crop Fall Transplant (F = 0.49, df = 1, P = 0.51), as well as for cover crop height (F = 0.35, df = 1, P = 0.578) (Table 5).

Soil Moisture and Temperature Measurements

In trial 1, there was no significant difference detected for soil moisture and soil temperature between Cover Crop and Weed plots. The volumetric water content in the Cover Crop plots averaged 21.7 ± 1.2 % and 20.3 ± 1.2 % for Weeds (Fig. 1). For the soil temperature, Cover Crop and Weed plots averaged 18.6 ± 1.1 °C and 18.6 ± 1.1 °C, respectively (Fig. 2). Data were collected and analyzed for 7 mo, and February 2019 was the month with the lowest soil temperature for both treatments (average 6.5 ± 0.1 C°). The highest average soil temperature recorded was in June 2019 at 31.2 ± 0.2 C°. January

2019 was the month with the highest average volumetric water content (VWC) of 32.8 ± 2.1 %, and the lowest average (VWC) was May at 7.9 ± 0.9 % (Figs. 5, 6).

In trial 2, there was a similar trend with no significant difference detected for soil moisture and soil temperature between Cover crop and Weed plots. The volumetric water content in the Cover Crop and Weed plots averaged 22.94 ± 0.61% and 22.63 ± 1.03%, respectively (Fig. 3). For the soil temperature, Cover Crop and Weed plots averaged 13.7± 1.1 °C and 13.7 ± 1.12 °C respectively (Fig. 4). The month with the lowest average soil temperature was February at 3.9 ± 0.07 C°. The month with the highest average soil temperature was May at 27.23 ± 0.14 C°. February was the month with the highest average VWC at 24.7 ± 0.8%, and the lowest average VWC was January at 19.23 ± 0.7% (Figs. 7, 8).

Pest and Beneficial Insect Assessments

Key families of beneficial insects found in the plots included Staphylinidae, Carabidae Chalcidoidae, Platygastridae, Ichneumonidae, Anthocoridae, and Braconidae. Key families of pest species include Curculionidae, Thripidae, Aphididae, Cercopidae, Cicadellidae, and Cydnidae. There were no significant differences in family diversity indices between Cover Crop and Weeds plots in the pitfall traps, with a diversity index value for the Cover Crop and Weed plots of 5.1 ± 0.7 D and 4.4 ± 1.1 D, respectively (Table 6). Treatments were compared for equitability (evenness) with no statistical difference for average equitability of Cover Crop or Weed plots at 0.3 ± 0.02 ED and 0.3 ± 0.07 ED, respectively. A similar tendency was detected for the family richness with 15.0 ± 2.1 S and 14.0 ± 0.9 S for Cover Crop and Weed plots, respectively.

After analyzing the sticky traps collected during the summer in 2019, there was likewise no significant differences detected for diversity index (Table 7), equitability, and family richness between the Cover Crop and Weed plots.

Objective 2: Evaluation of Two Planting Methods for Winter Cover Crops in Established Trees Fields

Cover Crop Coverage and Density in Pleasant Cove

Triticale established at a higher rate in the Drilled treatment at 4.6 ± 0.8 plants/ft² compared to the Broadcast treatment with 1.1 ± 0.5 plants/ft². In the case of the Crimson Clover treatments, the Clover performed better in the Broadcast planting method, but those differences were not significant. Crimson Clover Broadcast had 6.4 ± 1.1 plants/ ft² and the Crimson Clover Drilled treatment had 4.3 ± 0.5 plants/ ft² (Fig. 9). There was no significant difference between for the dry weight for Triticale Drilled treatment (63.5 ± 3.3 g) and Triticale Broadcasted treatment (50.0 ± 6.3 g), but the trend was for greater mass when drilled. No difference in dry weight was observed between Crimson Clover Drilled treatment (58.6 ± 5.7 g) and Crimson Clover Broadcast treatment (57.1 ± 5.8 g) (Table 11).

Cover Crop Coverage and Density in Flower City

The cover crop plants established at the second Flower City Nursery location again showed improved establishment in Triticale Drilled treatment with 10.0 ± 0.8 plants/ ft² compared to 3.8 ± 0.9 plants/ ft² for Triticale Broadcasted treatment. For the

Crimson Clover treatments, there was no statistical difference between Broadcasted and Drilled establishment (15.3 ± 3.9 plants/ ft^2 and 7.4 ± 0.5 plants/ ft^2, respectively); however, the trend was for more plants in the Broadcast plots (Fig. 10). There was no difference detected in the dry weight for Triticale Drill (25.6 ± 1.2 g) and Broadcast (19.7 ± 2.0 g) treatments, and no difference was found between weight of Crimson Clover Drilled (27.6 ± 3.3 g) and Broadcast (32.1 ± 2.4 g) treatments. However, there was a difference between Crimson Clover Broadcast (32.08 ± 2.38 g) and Triticale Broadcast (19.66 ± 2.02 g), with more cover crop biomass produced in the Crimson Clover Broadcast plots (Table 12).

Soil Moisture and Temperature Measurements in Pleasant Cove

There was no difference detected in soil moisture between Crimson Clover Drill, (30.6 ± 1.9% VWC) and Broadcast (31.0 ± 2.0% VWC) treatments. The tendency was the same with no difference for the Triticale Drill and Broadcast treatments (33.7 ± 1.8%VWC and 35.4 ± 2.1%VWC, respectively). The control plot with Weeds had similar moisture levels (32.1 ± 1.8 %VWC) (Table 13). Data collected from October 2018 to June 2019 showed that January 2019 was the month with the highest average VWC (38.4 ± 0.7%), and May 2019 was the month with the lowest average VWC (9.7 ± 0.5%; Fig. 11).

There was no significant difference in soil temperature between Crimson Clover Drill and Crimson Clover Broadcast plots (15.0 ± 1.2°C and 15.1 ± 1.2°C, respectively). No difference was detected between Triticale Drill and Triticale Broadcast plots (15.3 ± 1.2°C and 14.9 ± 1.2°C, respectively) (Table 13). The month with the highest soil temperature from October 2018 to June 2019 was May at 27.0 ± 0.3°C and the lowest temperature recorded was in December 2018 at 7.6 ± 0.1°C (Fig. 12).

Soil Moisture and Temperature Measurements in Flower City

There was no significant difference detected for soil moisture for Crimson Clover Drill and Crimson Clover Broadcast (26.7 ± 1.5% VWC and 26.8 ± 1.5% VWC). In the Triticale treatments, no significant difference was found between Triticale Drill and Triticale Broadcast (26.1 ± 1.7% VWC and 26.8 ± 1.5% VWC) (Table 14). The month with the highest average VWC was January 2019 at 38.4 ± 0.7% and the lowest average VWC was May 2019 at 9.7 ± 0.5% (Fig. 13).

From data collected for soil temperature, there was no difference between Crimson Clover Drill and Crimson Clover Broadcast (14.8 ± 1.4°C and 14.6 ± 1.4°C). There was no difference between Triticale Drill and Triticale Broadcast for soil temperature (15.2 ± 1.5°C and 15.2 ± 1.5°C) (Table 14). The month with the highest average soil temperature was May 2019 at 30.99 ± 0.47°C, and the month with the lowest average soil temperature was November 2018 at 5.03 ± 0.15°C (Fig. 14).

Pest and Beneficial Insect Assessments in Pleasant Cove

Key families of beneficial insects included, Anthocoridae, Carabidae, Charipidae, Cryptophagidae, Diapriidae, Ichneumonidae, and Platygastridae. Key families of pest species include Aphididae, Curculionidae, Cicadellidae, Drosophilidae, Mordellidae, and Thripidae. There was no significant difference in the diversity index between Broadcasted and Drilled Crimson Clover (3.7 ± 0.7 *D* and 6.0 ± 0.8 *D,* respectively). A similar trend was found when comparing Broadcasted and Drilled Triticale (6.8 ± 2.0 *D* and 5.7 ± 1.4 *D*). Arthropod equitability (evenness) was similar for Broadcasted and Drilled Crimson Clover (0.2 ± 0.05 *ED* and 0.3 ± 0.06 *ED*). No difference was detected between Broadcasted and Drilled Triticale (0.3 ± 0.07 *ED* and 0.3 ± 0.05 *ED*). A similar trend was repeated when comparing the family richness for Broadcast Crimson Clover (18.0 ± 1.3 *S*) and Drilled Crimson Clover (21.5 ± 2.3 *S*). Both triticale plots performed similarly with 23.5 ± 2.3 *S* for Broadcast Triticale and 19.7 ± 1.1 *S* for Drilled Triticale (Table 15).

The sticky traps collection had, no significance difference detected for any treatment when comparing the diversity index, evenness, and richness (Table 16).

Pest and Beneficial Insect Assessments in Flower City

Key families of beneficial insects included, Anthocoridae, Charipidae, Carabidae, Cryptophagidae, Diapriidae, Ichneumonidae, and Platygastridae. Key families of pest species include Aphididae, Curculionidae, Cicadellidae, Drosophilidae, Mordellidae, and Thripidae. There was no difference in the diversity index for Broadcast and Drilled Crimson Clover (5.9 ± 0.6 *D* and 6.3 ± 1.2 *D*). Triticale plots performed similarly with no difference for diversity index for Broadcast Triticale (6.9 ± 1.2 *D*) or drilled Triticale (3.7 ± 0.7 *D*).

No difference was detected for arthropod equitability with 0.3 ± 0.07 *ED* for Broadcasted Crimson Clover and 0.2 ± 0.05 *ED* for Drilled Crimson Clover. Triticale plots were similar between, Broadcast Triticale (0.3 ± 0.04 *ED*) and Drilled (0.2 ± 0.05

ED). Again, no difference was found when comparing for arthropod richness with 24.2 ± 5.5 *S* Broadcast, and 25.0 ± 0.7 *S* for Drilled Crimson Clover. With the triticale plots, no difference was detected with 22.7 ± 1.4 *S* for Broadcast and 23.5 ± 1.7 *S* for Drilled Triticale (Table 17). Likewise, there was no significant difference after analyzing the sticky traps for any treatment when comparing the diversity index, evenness, and richness (Table 18).

Soil Microbial Biomass Content

There was no difference in microbial carbon at Pleasant Cove between Triticale Drilled treatment (1.4 ± 0.04 MBC), Weeds (0.97 ± 0.25 MBC) and Crimson Clover Drill (1.1 ± 0.09 MBC) (Table 39). A similar trend was detected when comparing the average microbial nitrogen content with no difference for Triticale Drill, Crimson Clover Drill, or Weeds at 0.04 ± 0.01 MBN, 0.03 ± 0.01 MBN, 0.04 ± 0.01 MBN, respectively.

The results obtained at the second location; Flower City indicated that no statistical difference was detected for any of the treatments evaluated either for the microbial biomass carbon or nitrogen content (Table 40).

Objective 3: Long-Term Recovery of Tree Growth in Tress Established with Cover Crops for Management of Flatheaded Borers

Red Maple Plants Growth After Four-Year Transplant Using Winter Cover Crops.

When comparing the Cover Crop with the Herbicide treatments, Cover Crop trees had a smaller final average trunk diameter at 51.9 ± 0.6 mm compared to 65.2 ± 0.6 mm for the Herbicide treated trees after 4 yr of growth. The same trend was detected for height when comparing the Cover Crop and the Herbicide treatments, with the Cover Crop trees being shorter than the Herbicide treated trees (389.96 ± 4.5 cm and 441.7 ± 3.2 cm, respectively) (Table 41). At the end of the fourth year, the total number of trees damaged by flatheaded borer in the Herbicide treatment was 24 damaged trees, 6 in the Cover Crop treatment, 2 in the Herbicide + Insecticide and 0 damaged trees in the Cover Crop + Insecticide (Chi-Square = 34.40, df = 3, $P = 0.0001$) (Fig. 15).

Objective 4: Early Kill Cover Crop Management for Protection Against Flatheaded Borers

Plant Caliper and Height

At the beginning of the experiment, red maple plants initial trunk diameter and height was an average of 11.72 ± 0.11 mm for trunk diameter and 191.65 ± 1.50 cm for initial plant height (Table 42). After 1 yr, Herbicide trees had larger diameters and height compared to the rest of the treatments with an average of 28.1 ± 0.52 mm for trunk diameter and 249.04 ± 3.52 cm for height. No growth differences were detected between the Early Kill Cover Crop treatment and the Cover Crop trees. However, the Cover Crop treatment had the lowest means for diameter and plant height with 22.6 ± 0.4 mm for trunk diameter and 226.4 ± 3.1 cm for plant height (Table 43).

Cover Crop Density

In the Cover Crop plots, triticale had an average of 3.22 ± 0.39 plant/ft² and crimson clover with 2.52 ± 0.59 plant/ft² for the first year. In the second-year, triticale had an average of 3.75 ± 0.40 plant/ft² and crimson clover averaged 3.01 ± 0.46 plant/ft².

Pest and Beneficial Insect Assessments

Key families of beneficial insects include, Carabidae, Histeridae, Ichneumonidae, Phalacridae, Platygastridae, Scelionidae, and Reduviidae. Key families of pest species include Aphididae, Coreidae, Curculionidae, Delpharidae, Mordellidae, Thripidae, and Ulidiidae. There was no difference detected in the diversity index, equitability, and family richness of insect populations collected at the base of the trees after comparing the four treatments (Tables 44, 45).

Flatheaded Appletree Borer Evaluations

In April 2020, 31 red maple trees were harvested for rearing adult FAB. Only 13 adults of FAB emerged at the end of May 2020, however damage counts were too low to detect statistical differences between the four treatments. The average mean for each treatment suggests that the Cover Crop treatment had the lowest mean with 3.0 ± 0.2 damaged trees. The Early Kill Cover Crop and Herbicide treatments had the highest average number of damaged trees at 12.0 ± 0.3 and 10.0 ± 0.3 respectively, while the Mulch Mat treatment averaged 6.0 ± 0.2 damaged trees. From the 3 Cover Crop damaged trees only 2 FAB adults emerged from the 12 damaged trees from the Early Kill Cover Crop treatment only 5 FAB adults emerged from the 10 damaged trees from the Herbicide treatment only 3 FAB adults emerged and finally from the 6 damaged trees from the Mulch Mat treatment only 3 FAB adults emerged (Fig. 22). At the end of the second-year damaged tree count, total new FAB damaged trees included six in Cover Crop, six in Mulch Mat, 11 in Herbicide, and 16 in Early Kill Cover Crop, respectively (Fig. 23).

The red maples harvested from the year one already had evidence of some parasitoid wasps associated with FAB larvae. The number of parasitoids in rearing cages were count and included, 13 (*Eusandalum spp*, Eupelmidae) in Early Kill Cover Crop from one of the damaged trees previously identified from the harvested trees from the year one, a second tree from the same Early Kill treatment had 17 similar parasitoids (*Eusandalum spp*, Eupelmidae). one adult of (*Labena grallator*, Ichneumonidae), was reared from one of the Mulch Mat trees previously harvested and one (*Phasgonophora sulcata*, Chalcididae) in one of the trees from the Herbicide treatment (Fig. 24).

CHAPTER V

CUNCLUSION

Impacts of Cover Crops in Plant Growth with Fall or Spring Transplants

Cover crops provide a great opportunity to improve soil quality in different agricultural systems. From the point of view of the grower, the use of cover crops presents both advantages and disadvantages (Dabney et al. 2001). Plant growth is one of the aspects to consider when using cover crops, especially for new transplanted trees. The results obtained from these experiments suggest that the red maple trees transplanted either with or without cover crops during the spring may grow taller than the trees transplanted during the fall. The greater growth in the Spring transplanted trees was unexpected. We hypothesized that the Fall transplanted trees would grow more since they were less likely to experience transplant shock. However, the trees that were transplanted in the spring were kept in a covered hoop house to overwinter. A possible explanation for the greater growth is that the trees transplanted in the fall experienced a deeper extended dormancy period compared to the spring trees, which overwintered in a hoop house. Harris and Fanelli (1999) suggest that the potential for root growth after fall leaf drop is low, and establishment of fall-transplanted tress may be more successful than trees planted in the spring. However, the opposite occurred in this study with spring transplants growing better. It is also possible that competition between the Fall Transplant trees, and cover crop/weeds may have been stronger than in the spring transplant plots since the nursery row soil for the fall transplants was more recently disturbed by the planting equipment. Every effort was made to maintain weed-free status of tree rows with herbicides, but the overall competitive pressure of the surrounding vegetation may have been compromised by the spring transplanting process. While the results were not significant, there was a trend for more cover crop biomass in the Fall Transplant plots, which suggest there may have been greater competition for resources in these plots (Sánchez et al. 2007).

In the experiments, ground area covered by crimson clover and weeds was similar. However, crimson clover plants in Spring Transplant treatment were taller than plants in the fall plots. Crimson clover used as a winter cover crop had better establishment with fall seeding before winter, and it resumed the vegetative growth in early spring (den Hollander et al. 2007b). A taller cover crop can help to reduce weed competition in the main crop (De Haan et al. 1994). The clover growth in the Spring Transplant plots was disrupted by the tree planting process. The spring cover crop disruption appears to have resulted in taller plants, but slightly lower biomass, although the differences were not statistically significant. Consequently, disruption was not a major factor affecting the crimson clover cover crop. Growers my find some advantage to transplanting trees in the spring if those trees were overwintered.

The crimson clover cover crop had minimal impact on soil temperature and moisture. However, other benefits can be provided by using cover crop instead of weed cover. Cover crops can increase the soil moisture in the top 30 cm of soil from 3.3% to 5.3% due to the water conductivity through the root channels reducing the soil compaction and surface water runoff (Acharya et al., 2019). Cover crops from both Fall and Spring Transplant treatments resulted in greater biomass to recycle into the soil compared to the weedy plots. Soils grown with cover crops can help alleviate soil compaction, and improve water availability (Williams & Weil, 2004).

Impacts of Cover Crops in Pest and Beneficial Communities

Arthropod communities can be altered by the presence of cover crops, Management of such habitat in agriculture fields can provide stable environments that aid the proliferation of natural enemy communities that can reduce pest populations (Bowers et al. 2020). In this experiment, the overall community diversity at the family level was not noticeably different between cover crop and weeds plots, but there was a trend for slightly higher indices in the cover crop plots. Insect families with beneficial species include the Staphylinidae, Carabidae, Chalcidoidae and Platygastridae, which were found in almost all the samples from the cover crop plots. Rove beetles in the family Staphylinidae play an important role in terrestrial ecosystems, and they have a great potential as bioindicators of change in the agroecosystems, as well as their importance as biocontrol agents against pest populations (Klimaszewski et al., 2018). Parasitoids from the families Platygastridae and Chalcidoidea are important in woody ornamental production because of their potential as biological control over aphids. There are around 85 aphidiine species and 269 parasitoid aphid associations in the agriculture (Kavallieratos et al., 2013). Overall cover crops can contribute to the health of agroecosystems by providing a habitat and food resources for arthropod predators or pollinators. One thing to keep in mind is that the effects of using cover crop are not easy the see in one production season or over the small spatial scale assessed in these plots. Our goal in making these assessments was to determine whether changes to insect fauna could be detected in small-scale studies. Additional analysis of the data at the species and genus level may provide further insights.

Cover Crop Performance with Two Planting Methods in Established Trees Fields

There are important aspects to consider when planning to incorporate cover crops. In agriculture, the decision is determined by the seed size, seeding rate, date of emergence and planting method. Establishment of cover crop by selecting the right planting method is crucial to assure good germination. In this study, a comparison on the planting method for two cover crops was made including Drill or Broadcast. The results from this study suggest that the establishment of crimson clover as cover crop can be successfully achieved either by using the Drill or the Broadcast method. However, after analyzing the data collected on both sites the Broadcast Crimson Clover showed better results, even though there was no statistical difference detected. The broadcasted evaluated area had higher numbers of plants. But, broadcasting cover crops on the soil surface can minimize seed contact with the soil and can leave the seed expose to desiccation under dry conditions; thus, potentially reducing the cover crop establishment rate (Wallace et al., 2021). Triticale established better with the Drill treatment method with significant differences at one site (Pleasant Cove), but not the other (Flower City). The Flower City site did have a higher mean triticale plant establishment. It is recommended that winter triticale should be no more than 2.45 cm deep, since deep planting increases the time to emergence and some winter triticale varieties take longer to develop their maximum cold tolerance (Mergoum & Gómez Macpherson, 2004). Dry matter from both nursery locations indicated that Drill treatment achieved a good amount of biomass for both cover crops species. While the Broadcast method can be less expensive than the use of Drill, it is considered a riskier method for crop establishment, which can also result in inconsistent cover crop yields (Fisher et al., 2011).

The usage of cover crops can reduce the soil temperature and increase the soil moisture (Vann et al., 2018). Soil moisture and soil temperature from both locations were not statistically different, regardless of the planting method or cover crop species. For this experiment, cover crops were terminated in July 2019, but rolling the cover crop and using it as a mulch can reduce soil temperature and soil water evaporation, which can be beneficial for moisture conservation (Daniel et al., 1999).

An important finding was that Ichnneuminidae and the Ceraphronidae parasitoid families were found only in the Drill Crimson Clover treatment and not in the Weeds or Triticale. Unfortunately, there was not enough specimens to infer that crimson clover will provide a suitable host for parasitoids, but Braconidae and Ichnneuminidae are usually present in cover crops in apple orchards (Altierr & Schmidt, n.d.).

Cover Crop Effect on Soil Microbial Biomass Content

The impact in soil microbial biomass content is determined by the species utilized as a cover crop. In the past, legumes were well known in agriculture for their capability of N fixation and also helping to enrich surface soil organic C (Liang, 2014). The effect of legumes in altering N levels is more negligible when the legumes decompose and incorporate to soil. In our experiment, soil samples from the Drill Crimson Clover and Triticale were analyzed for the microbial content for both N and C, and the decision to collect soil samples only from the Drill treatments was based on the hypothesis that the cover crop species would establish better on this planting method. The results obtained from our experiment showed no detectable difference in the microbial content between Drill Crimson Clover and Triticale, with similar results for Weeds. However, Drill Triticale was slightly higher in C and N than Drill Crimson Clover at Pleasant Cove, but slightly lower at Flower City. In overall establishment, clover performed better using the Broadcast method. It is possible the results would be different if the soil microbial biomass content samples were from the Drill Clover treatment.

Cover Crop Impact on Tree Growth in Trees Established After Fourth Years

Findings in a 2 yr evaluation from Dawadi et al. (2017), indicated cover crops planted at the base of the trunk of red maple trees were an effective method for controlling flatheaded appletree borers (FAB), but the cover crops also had a significantly negative impact on the tree growth. The same experimental plot was evaluated in years three and four after transplant to determinate if trees exposed to cover crop treatments recovered from the direct competition during years one and two. Trees increased in trunk diameter more in the Herbicide treated trees in year 1 (2015-2016). However, by year 3 (2017-2018), Cover Crop trees began to recover and by the end of year 4 Cover Crop trees were adding more diameter (44-46%) than Herbicide trees (26-31%). The same tendency was observed for the plant height where Herbicide trees grew more during year 1 with good growth recovery rate (32-35%) after year 3 than Herbicide trees (25-28%).

Even though trees can recover from early competition with cover crops, trees in the cover crop plots remained about one season behind in trunk diameter and height than trees in the clean herbicide treated tree plots.

Trees were examined for FAB attacks in years 3 and 4 to test the hypothesis that trees are more susceptible to FAB damage primarily during the first two years after transplanting. The number of trees damaged by FAB was less, compared to the first two years, the Herbicide + Non Insecticide was the control treatment with the higher number of FAB attacks at the end of the four years test with a total of 24 damaged trees, however 23 were during the first two years and one in 2019. Only four damaged trees by FAB were identified for years 3 and 4, which confirms the assumption that trees are more vulnerable during the first two years after transplant.

Early Kill Cover Crop Management for Protection Against Flatheaded Borers

From this study there is enough evidence to confirm the efficacy of winter cover crops for controlling flatheaded borers. However, tree growth is highly affected by the presence of cover crops. The experiment from 2018 to 2020 at Moore's Nursery proposed the hypothesis that removing the cover crop earlier could potentially reduce the competition with trees, balancing tree protection against FAB damage and tree growth. The results showed statistical difference between the Herbicide treatment and the Early Kill Cover Crop, with the herbicide trees growing more. In addition to better tree growth in the Herbicide treatment, the number of damaged trees by the flatheaded borer were higher in the Early Kill Cover Crop treatment. A possible explanation for more flatheaded borer attacks in the Early Kill Cover Crop treatment was a mis-match between cover crop removal time and the timing of FAB adults flight activity. The killing of the cover crop may have suddenly exposed the base of the trees, making it easier for female to find the right spot for the oviposition. Reports by (Johnson & Fenton, 1939) indicated that adults of *C. femorata* emerged from logs between May to early August with some variations among years. Termination of the Early Kill Cover Crop treatment was performed in mid-May, which is exactly the time when adults start emerging from infested trees. Based on the emergence information, we can assume that red maples trees did not have protection against FAB at the moment of the highest number of flying adults.

A possible solution to extent the benefits of the cover crop in the field as a FAB controlling alternative is to establish the cover crop in the late fall to reduce competition and terminate in July rather than mid-May. A July termination of cover crop may provide a better tree protection window during the active period of FAB adult flight.

An additional important finding related to the numbers of parasitoids species found in the trees. The majority of parasitoids were from the Early Kill Cover Crop treatment which, had 30 *Eusandalum spp.* (Eupelmidae) from two logs and one *Labena grallator* (Ichneumonidae) from another log in the same treatment. Only one parasitoid wasp *Phasgonophora sulcate*, (Chalcididae) was found in the Herbicide treatment. Based on parasitoid number differences between study treatments, it is possible the cover crop may improve the habitat and flatheaded borer host availability for some of the natural enemies. However, the data collected from the pitfall and sticky traps did not provide enough evidence to confirm this assumption. The formula used to estimate the diversity indices among treatments are well used in many ecology studies. This formula provide an idea of the distribution of individuals in a specific population, but in this case the information does not specify the unique arthropod groups found in the different treatments such as the case of these parasitoid species found in the Early Kill Cover Crop treatment. Even with no statistical difference detected, the Early Kill Cover Crop was slightly higher in the Diversity index and equitability.

Recommendations

Tree Transplant Timing: Our study indicated that red maples transplanted with a winter cover crop that has been established in the field can grow more during the first year when transplanted during the spring instead of being transplanted in the fall. However, that is not always the case, as the results from this experiment are different from previous studies that indicated transplanting during the fall will benefit the trees for better growth since they experience less transplant shock. The benefits of spring transplant may depend on the way the transplants are overwintered. If trees are stored under plastic cover, as ours were, they may be able to emerge from dormancy more quickly than fall-planted trees which may have taken longer to break dormancy in the spring.

The final biomass from the Cover Crop Fall Transplant was slightly greater than the Cover Crop Spring Transplant plot, suggesting that disrupting the cover crop in the spring by transplanting, had a greater negative effect on the cover crop than early disturbance. A recommendation for this experiment will be to monitor spring dormancy break timing of fall and spring-transplanted trees more closely to confirm if overwintering in a hoop house was the reason for the growth discrepancies.

Cover Crop Establishment Methods: From this experiment the establishment of crimson clover as a winter cover crop can be achieved by using both broadcast and drill planting methods, while triticale had better result using the drilling method. We expected triticale to perform better in the drill treatment, since planting recommendations for this crop include planting depth of 1.3 to 3.8 cm. Crimson clover can germinate on contact with the ground, so it was expected to perform equally well in the broadcast treatment. Crimson clover and triticale can both provide good benefits to improve soil health and, maintain soil temperature and moisture. The selection of specific cover crops depends on the preference and grower necessities. Getting the maximum benefits from cover cropping system is the main goal for nursery growers, and a blend of these two-cover crops can potentially increase these benefits. From the results for this experiment, using the drilling method will provide the best establishment of triticale and will not impede the establishment of clover. Therefore, if a grower wishes to plant both crops simultaneously, the drill method is recommended for the blend. At the end of this experiment microbial content for carbon and nitrogen was similar for both cover crop species. The microbial analysis was conducted because it is more sensitive to changes in soil quality than total organic carbon or nitrogen analysis, and we wanted to measure changes in a single season of cover cropping. It appears that one season of cover cropping is not sufficient to drastically alter soil health. In the future, this analysis may help inform soil health changes in multi-year cover cropping studies.

Cover Crops and Arthropod Diversity: In our studies of arthropod diversity, community indices were similar between the cover crop and weed sampled sites, but the tendency on each sample indicated slightly higher indices from the cover crop. In these studies, the plot sizes were relatively small and movement of insects between and through different plots might have increased variability. In the future, it would be useful to include the study of arthropod diversity over time in more than one production season and in larger scale test sites. A deeper look at changes in species composition may be more informative than the family level. Samples have been preserved from these studies and more information on cover crop impacts on arthropod diversity may be gleaned from genus or species level identification and analysis.

Management of Flatheaded Borer with Cover Crops: The results from the 4-yr study confirms that the presence of cover crops at the base of red maple trees is an effective alternative for controlling FAB damage. At the same time there is enough evidence to indicate that the major disadvantage of using cover crop is the direct competition with recently transplanted trees. The two-year study from 2018 to 2020 again showed that cover crops compete aggressively with red maples. The Early Kill treatment did not protect the trees from flatheaded borers, so removing the cover crop earlier is not an appropriate solution to improving tree growth. In the future, we recommend adding irrigation to trees during their first year in the field to reduce competition and allowing the cover crop to senesce naturally to extend the protection against FAB. In this study, the Mulch Mat and Cover Crop treatment ended with the same numbers of damage trees from FAB presence. There are two possible explanations why this tow treatment ended with the same number of damaged trees. First, we did note that weeds tended to grow around the Mulch Mat, so they may not have provided the weed reduction necessary to allow borers unimpeded access to the tree trunks. Alternatively, the usage of herbicides may have increased the stress levels of trees and increased FAB damage. This possibility must be considered since the Early Kill treatment had more FAB attacked trees than the herbicide treatment. Future studies can include the evaluation of FAB damage on stressed trees by treating trunks intentionally with different herbicides.

REFERENCES

Acharya, B. S., Dodla, S., Gaston, Lewis. A., Darapuneni, M., Wang, J. J., Sepat, S., & Bohara, H. (2019). Winter cover crops effect on soil moisture and soybean growth and yield under different tillage systems. *Soil and Tillage Research*, *195*, 104430. https://doi.org/10.1016/j.still.2019.104430

Addesso, K. M., Oliver, J. B., Youssef, N. N., & Fare, D. C. (2020). Evaluation of Systemic Imidacloprid and Herbicide Treatments on Flatheaded Borer (Coleoptera: Buprestidae) Management in Field Nursery Production. *Journal of Economic Entomology*, *113*(6), 2808–2819. https://doi.org/10.1093/jee/toaa228

Altierr, M. A., & Schmidt, L. L. (n.d.). *Cover crops affect insect and spider populations in apple orchards*. 3.

Amossé, C., Jeuffroy, M.-H., Celette, F., & David, C. (2013). Relay-intercropped forage legumes help to control weeds in organic grain production. *European Journal of Agronomy*, *49*, 158–167. https://doi.org/10.1016/j.eja.2013.04.002

Ansari, M. S., Moraiet, M. A., & Ahmad, S. (2014). Insecticides: Impact on the Environment and Human Health. In A. Malik, E. Grohmann, & R. Akhtar (Eds.), *Environmental Deterioration and Human Health* (pp. 99–123). Springer Netherlands. https://doi.org/10.1007/978-94-007-7890-0_6

Bottenberg, H., Masiunas, J., Eastman, C., & Eastburn, D. M. (1997). The Impact of Rye Cover Crops on Weeds, Insects, and Diseases in Snap Bean Cropping Systems.

Journal of Sustainable Agriculture, *9*(2–3), 131–155. https://doi.org/10.1300/J064v09n02_09

Bowers, C., Toews, M., Liu, Y., & Schmidt, J. M. (2020). Cover crops improve early season natural enemy recruitment and pest management in cotton production. *Biological Control*, *141*, 104149. https://doi.org/10.1016/j.biocontrol.2019.104149

Bukovsky-Reyes, S., Isaac, M. E., & Blesh, J. (2019). Effects of intercropping and soil properties on root functional traits of cover crops. *Agriculture, Ecosystems & Environment*, *285*, 106614. https://doi.org/10.1016/j.agee.2019.106614

Carmona, D. M., & Landis, D. A. (1999). Influence of Refuge Habitats and Cover Crops on Seasonal Activity-Density of Ground Beetles (Coleoptera: Carabidae) in Field Crops. *Environmental Entomology*, *28*(6), 1145–1153. https://doi.org/10.1093/ee/28.6.1145

Cates, A. M., Ruark, M. D., Grandy, A. S., & Jackson, R. D. (2019a). Small soil C cycle responses to three years of cover crops in maize cropping systems. *Agriculture, Ecosystems & Environment*, *286*, 106649. https://doi.org/10.1016/j.agee.2019.106649

Cates, A. M., Ruark, M. D., Grandy, A. S., & Jackson, R. D. (2019b). Small soil C cycle responses to three years of cover crops in maize cropping systems. *Agriculture, Ecosystems & Environment*, *286*, 106649. https://doi.org/10.1016/j.agee.2019.106649

Creamer, N. G., Bennett, M. A., Stinner, B. R., Cardina, J., & Regnier, E. E. (1996). Mechanisms of Weed Suppression in Cover Crop-based Production Systems. *HortScience*, *31*(3), 410–413. https://doi.org/10.21273/HORTSCI.31.3.410

Cripps, R. W., & Bates, H. K. (1993). *Effect of Cover Crops on Soil Erosion in Nursery Aisles*. 5.

Curran, W. S., Hoover, R. J., Mirsky, S. B., Roth, G. W., Ryan, M. R., Ackroyd, V. J., Wallace, J. M., Dempsey, M. A., & Pelzer, C. J. (2018). Evaluation of Cover Crops Drill Interseeded into Corn Across the Mid-Atlantic Region. *Agronomy Journal*, *110*(2), 435–443. https://doi.org/10.2134/agronj2017.07.0395

Dabney, S. M., Delgado, J. A., & Reeves, D. W. (2001). USING WINTER COVER CROPS TO IMPROVE SOIL AND WATER QUALITY. *Communications in Soil Science and Plant Analysis*, *32*(7–8), 1221–1250. https://doi.org/10.1081/CSS-100104110

Daniel, J. B., Abaye, A. O., Alley, M. M., Adcock, C. W., & Maitland, J. C. (1999). *Winter Annual Cover Crops in a Virginia No-till Cotton Production System: I. Biomass Production, Ground Cover, and Nitrogen Assimilation*. *3*(3), 10.

Dawadi, S., Oliver, J. B., O’Neal, P., & Addesso, K. M. (2019). Management of flatheaded appletree borer (Chrysobothris femorata Olivier) in woody ornamental nursery production with a winter cover crop. *Pest Management Science*, *75*(7), 1971–1978. https://doi.org/10.1002/ps.5310

De Haan, R. L., Wyse, D. L., Ehlke, N. J., Maxwell, B. D., & Putnam, D. H. (1994). Simulation of Spring-Seeded Smother Plants for Weed Control in Corn (*Zea mays*). *Weed Science*, *42*(1), 35–43. https://doi.org/10.1017/S0043174500084125

den Hollander, N. G., Bastiaans, L., & Kropff, M. J. (2007a). Clover as a cover crop for weed suppression in an intercropping design. *European Journal of Agronomy*, *26*(2), 104–112. https://doi.org/10.1016/j.eja.2006.08.005

den Hollander, N. G., Bastiaans, L., & Kropff, M. J. (2007b). Clover as a cover crop for weed suppression in an intercropping design. *European Journal of Agronomy*, *26*(2), 104–112. https://doi.org/10.1016/j.eja.2006.08.005

Duyck, P.-F., Lavigne, A., Vinatier, F., Achard, R., Okolle, J. N., & Tixier, P. (2011). Addition of a new resource in agroecosystems: Do cover crops alter the trophic positions of generalist predators? *Basic and Applied Ecology*, *12*(1), 47–55. https://doi.org/10.1016/j.baae.2010.11.009

Fisher, K. A., Momen, B., & Kratochvil, R. J. (2011). Is Broadcasting Seed an Effective Winter Cover Crop Planting Method? *Agronomy Journal*, *103*(2), 472–478. https://doi.org/10.2134/agronj2010.0318

Frank, S. D., Klingeman, W. E., White, S. A., & Fulcher, A. (2013). Biology, Injury, and Management of Maple Tree Pests in Nurseries and Urban Landscapes. *Journal of Integrated Pest Management*, *4*(1), 1–14. https://doi.org/10.1603/IPM12007

Gao, D., Zhou, X., Duan, Y., Fu, X., & Wu, F. (2017). Wheat cover crop promoted cucumber seedling growth through regulating soil nutrient resources or soil microbial communities? *Plant and Soil*, *418*(1–2), 459–475. https://doi.org/10.1007/s11104-017-3307-9

Gibson, L. R., Nance, C. D., & Karlen, D. L. (2007). Winter Triticale Response to Nitrogen Fertilization when Grown after Corn or Soybean. *Agronomy Journal*, *99*(1), 49–58. https://doi.org/10.2134/agronj2006.0195

Harris, J. R., & Fanelli, J. (1999). Root and Shoot Growth Periodicity of Pot-in-Pot Red and Sugar Maple. *Journal of Environmental Horticulture*, *17*(2), 80–83. https://doi.org/10.24266/0738-2898-17.2.80

He, H., Liu, L., Munir, S., Bashir, N. H., Wang, Y., Yang, J., & Li, C. (2019). Crop diversity and pest management in sustainable agriculture. *Journal of Integrative Agriculture*, *18*(9), 1945–1952. https://doi.org/10.1016/S2095-3119(19)62689-4

Horton, D. R., Jones, V. P., & Unruh, T. R. (2009). Use of a New Immunomarking Method to Assess Movement by Generalist Predators Between a Cover Crop and Tree Canopy in a Pear Orchard. *American Entomologist*, *55*(1), 49–56. https://doi.org/10.1093/ae/55.1.49

Jaffuel, G., Blanco-Pérez, R., Büchi, L., Mäder, P., Fließbach, A., Charles, R., Degen, T., Turlings, T. C. J., & Campos-Herrera, R. (2017). Effects of cover crops on the overwintering success of entomopathogenic nematodes and their antagonists. *Applied Soil Ecology*, *114*, 62–73. https://doi.org/10.1016/j.apsoil.2017.02.006

Jensen, K. L., English, B. C., Menard, J., Schexnayder, S., Bruhin, J., & Fulcher, A. (2020, November 13). *Estimated Economic Contributions From the*

Nursery/Greenhouse Industry in Tennessee (No. 1767-2020–1351). AgEcon Search. https://doi.org/10.22004/ag.econ.307650

Johnson, G. V., & Fenton, F. A. (1939). Control of the Flatheaded Apple Tree Borer in Oklahoma. *Journal of Economic Entomology*, *32*(1), 134–142. https://doi.org/10.1093/jee/32.1.134

Kavallieratos, N. G., Tomanović, Ž., Petrović, A., Janković, M., Starý, P., Yovkova, M., & Athanassiou, C. G. (2013). Review and Key for the Identification of Parasitoids (Hymenoptera: Braconidae: Aphidiinae) of Aphids Infesting Herbaceous and Shrubby Ornamental Plants in Southeastern Europe. *Annals of the Entomological Society of America*, *106*(3), 294–309. https://doi.org/10.1603/AN12090

Klimaszewski, J., Brunke, A. J., Work, T. T., & Venier, L. (2018). Rove Beetles (Coleoptera, Staphylinidae) as Bioindicators of Change in Boreal Forests and Their Biological Control Services in Agroecosystems: Canadian Case Studies. In O. Betz, U. Irmler, & J. Klimaszewski (Eds.), *Biology of Rove Beetles (Staphylinidae)* (pp. 161–181). Springer International Publishing. https://doi.org/10.1007/978-3-319-70257-5_9

Li, L., Manning, W., & Wang, X. (2019). Elevated CO2 Increases Root Mass and Leaf Nitrogen Resorption in Red Maple (Acer rubrum L.). *Forests*, *10*(5), 420. https://doi.org/10.3390/f10050420

Liang, S. (2014). Soil microbial responses to winter legume cover crop management during organic transition. *European Journal of Soil Biology*, 8.

Lockman, C. (2012, March 1). Nursery Industry Blooms in Middle Tennessee. *Farm Flavor*. https://www.farmflavor.com/tennessee/tennessee-ag-products/horticulture-and-nursery-industry-blooms-in-middle-tennessee/

Meng, P. S., Hoover, K., & Keena, M. A. (2015). Asian Longhorned Beetle (Coleoptera: Cerambycidae), an Introduced Pest of Maple and Other Hardwood Trees in North America and Europe. *Journal of Integrated Pest Management*, *6*(1). https://doi.org/10.1093/jipm/pmv003

Mergoum, M., & Gómez Macpherson, H. (Eds.). (2004). *Triticale improvement and production*. Food and Agriculture Organization of the United Nations.

Oliver, J. B., Fare, D. C., Youssef, N., Scholl, S. S., Reding, M. E., Ranger, C. M., Moyseenko, J. J., & Halcomb, M. A. (2010). Evaluation of a Single Application of Neonicotinoid and Multi-Application Contact Insecticides for Flatheaded Borer Management in Field Grown Red Maple Cultivars. . . *September*, 15.

Potter, D. A., Timmons, G. M., & Gordon, F. C. (1988a). *Flatheaded Apple Tree Borer (Coleoptera: Suprestidae) in Nursery-Grown Red Maples: Phenology of Emergence, Treatment Timing, and Response to Stressed Trees1*. 6.

Potter, D. A., Timmons, G. M., & Gordon, F. C. (1988b). *Flatheaded Apple Tree Borer (Coleoptera: Suprestidae) in Nursery-Grown Red Maples: Phenology of Emergence, Treatment Timing, and Response to Stressed Trees1*. 6.

Ricupero, M., Desneux, N., Zappalà, L., & Biondi, A. (2020). Target and non-target impact of systemic insecticides on a polyphagous aphid pest and its parasitoid. *Chemosphere*, *247*, 125728. https://doi.org/10.1016/j.chemosphere.2019.125728

Rivers, A. N., Mullen, C. A., & Barbercheck, M. E. (2018). Cover Crop Species and Management Influence Predatory Arthropods and Predation in an Organically Managed, Reduced-Tillage Cropping System. *Environmental Entomology*, *47*(2), 340–355. https://doi.org/10.1093/ee/nvx149

Robačer, M., Canali, S., Kristensen, H. L., Bavec, F., Mlakar, S. G., Jakop, M., & Bavec, M. (2016). Cover crops in organic field vegetable production. *Scientia Horticulturae*, *208*, 104–110. https://doi.org/10.1016/j.scienta.2015.12.029

SAINJU, U. M. (1997). Winter cover crops for sustainable agriculture systems: Influence on soil properties, water quality and crop yields. *HortScience*, *32*, 21–28.

Sánchez, E. E., Giayetto, A., Cichón, L., Fernández, D., Aruani, M. C., & Curetti, M. (2007). Cover crops influence soil properties and tree performance in an organic apple (Malus domestica Borkh) orchard in northern Patagonia. *Plant and Soil*, *292*(1–2), 193–203. https://doi.org/10.1007/s11104-007-9215-7

Sastre, B., Marques, M. J., García-Díaz, A., & Bienes, R. (2018). Three years of management with cover crops protecting sloping olive groves soils, carbon and water effects on gypsiferous soil. *CATENA*, *171*, 115–124. https://doi.org/10.1016/j.catena.2018.07.003

Scholberg, J. M. S., Dogliotti, S., Zotarelli, L., Cherr, C. M., Leoni, C., & Rossing, W. A. H. (2010). Cover Crops in Agrosystems: Innovations and Applications. In E. Lichtfouse (Ed.), *Genetic Engineering, Biofertilisation, Soil Quality and Organic Farming* (pp. 59–97). Springer Netherlands. https://doi.org/10.1007/978-90-481-8741-6_3

Silvics of North America. (1990). U.S. Government Printing Office.

Social Indicators. (1990). Department of Commerce, Bureau of the Census, Center for Demographic Studies.

Sujan Dawadi, Jason B. Oliver, Paul A. O'Neal, & Karla M. Addesso. (2019). Impact of Cover Cropping on Non-Target Arthropod Pests of Red Maple Trees in Nursery Production. *Florida Entomologist*, *102*(1), 187–193.

Uchino, H., Iwama, K., Jitsuyama, Y., Ichiyama, K., Sugiura, E., Yudate, T., Nakamura, S., & Gopal, J. (2012). Effect of interseeding cover crops and fertilization on weed suppression under an organic and rotational cropping system. *Field Crops Research*, *127*, 9–16. https://doi.org/10.1016/j.fcr.2011.10.007

Uchino, H., Iwama, K., Jitsuyama, Y., Yudate, T., & Nakamura, S. (2009). Yield losses of soybean and maize by competition with interseeded cover crops and weeds in organic-based cropping systems. *Field Crops Research*, *113*(3), 342–351. https://doi.org/10.1016/j.fcr.2009.06.013

Vann, R. A., Reberg-Horton, S. C., Edmisten, K. L., & York, A. C. (2018). Implications of Cereal Rye/Crimson Clover Management for Conventional and Organic Cotton Producers. *Agronomy Journal*, *110*(2), 621–631. https://doi.org/10.2134/agronj2017.06.0246

Wallace, J. M., Isbell, S., Hoover, R., Barbercheck, M., Kaye, J., & Curran, W. S. (2021). Drill and broadcast establishment methods influence interseeded cover crop performance in organic corn. *Renewable Agriculture and Food Systems*, *36*(1), 77–85. https://doi.org/10.1017/S174217052000006X

Williams, S. M., & Weil, R. R. (2004). Crop Cover Root Channels May Alleviate Soil Compaction Effects on Soybean Crop. *Soil Science Society of America Journal*, *68*(4), 1403–1409. https://doi.org/10.2136/sssaj2004.1403

Yang, X. M., Drury, C. F., Reynolds, W. D., & Phillips, L. A. (2020). Nitrogen release from shoots and roots of crimson clover, hairy vetch, and red clover. *Canadian Journal of Soil Science*. https://doi.org/10.1139/cjss-2019-0164

APPENDICES

Table 1. Final trunk diameter and height for Trial 1, in 2019 after one year season grown in crimson clover or weedy plots.

Treatments	Tree Height (cm)	Tree Caliper (mm)
Cover Crop Fall Transplant	72.25 ± 2.44 c[z]	14.80 ± 0.51 b
Cover Crop Spring Transplant	95.75 ± 3.75 a	17.35 ± 0.58 a
Weeds Fall Transplant	68.31 ± 2.19 c	15.88 ± 0.45 ab
Weeds Spring Transplant	83.21 ± 4.30 b	16.27 ± 0.48 ab
F value	22.75	5.95
df	6	6
P value	0.0001	0.0001

[z] Treatment means within columns with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$). Treatments: 1) Cover Crop Spring Transplant, 2) Weed Spring Transplant, 3) Weed Fall Transplant and 4) Cover Crop Fall Transplant. Cover crop used was crimson clover.

Table 2. Final caliper and height for Trial 2, in 2020 after one year season grown in crimson clover or weedy plots.

Treatments	**Height (cm)**	**Caliper (mm)**
Cover Crop Fall Transplant	136.66 ± 3.01 ab[z]	16.06 ± 0.44 a
Cover Crop Spring Transplant	139.41 ± 2.97 a	16.45 ± 0.44 a
Weeds Fall Transplant	131.56 ± 2.98 b	15.46 ± 0.39 a
Weeds Spring Transplant	138.91 ± 2.47 a	16.47 ± 0.55 a
F value	33.06	8.27
df	6	6
P value	0.0001	0.0001

[z] Treatment means within columns with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$). Treatments: 1) Cover Crop Spring Transplant, 2) Weed Spring Transplant, 3) Weed Fall Transplant and 4) Cover Crop Fall Transplant. Cover crop used was crimson clover.

Table 3. Cover crop height and percentage coverage, Trial 1 in April 2019.

Treatments	**Cover Crop Height (cm)**	**% Coverage**	**Biomass**
Cover Crop Fall Transplant	29.8 ± 0.8 b	9.7 ± 2.1 a	43.6 ± 5.7 a
Cover Crop Spring Transplant	38.2 ± 3.2 a	18.3 ± 6.3 a	35.0 ± 3.5 ab
F value	9.02	2.2	3.09
df	1	1	6
P value	0.03	0.1979	0.0109

[z] Treatment means within columns with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$). Treatments: 1) Cover Crop Spring Transplant, 2) Cover Crop Fall Transplant. Cover crop used was crimson clover.

Table 4. Dry weight of middle biomass from experimental field plots (mean ± SEM) in trial 1 in 2019.

Treatments	**Average Dry Weight (g)**
Cover Crop Fall Transplant	43.6 ± 5.7 a[z]
Cover Crop Spring Transplant	35.0 ± 3.5 ab
Weeds Fall Transplant	35.9 ± 4.7 ab
Weeds Spring Transplant	29.3 ± 2.5 b
F value	3.09
df	6
P value	0.0109

[z] Treatment means within columns with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$).

Table 5. Average (± SE) height and percentage coverage of crimson clover crop after one year for Trial 2 (2020).

Treatments	**Cover Crop Height (cm)**	**% Coverage**
Cover Crop Fall Transplant	33.20 ± 4.25 a	40.43 ± 1.54 a
Cover Crop Spring Transplant	38.43 ± 7.86 a	42.87 ± 3.12 a
F value	0.35	0.49
df	1	1
P value	0.578	0.51

[z] Treatment means within columns with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$). Treatments: 1) Cover Crop Spring Transplant, 2) Cover Crop Fall Transplant. Cover crop used was crimson clover.

Table 6. Results of the diversity indices for the arthropod samples from the pitfall traps collected from May 2019 to July 2019 at the NRC Trial 1 plot.

Treatment	Diversity index	Equitability	Family richness
Cover Crop	5.06 ± 0.69 a[z]	0.34 ± 0.02 a	15.00 ± 2.12 a
Weeds	4.41 ± 1.13 a	0.31 ± 0.07 a	14.00 ± 0.91 a
F value	0.24	0.18	0.19
df	1	1	1
P value	0.6408	0.6882	0.68

[z]Treatment means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis (P< 0.05). Cover crop used was crimson clover.

Table 7. Results of the diversity indices for the arthropod samples from the sticky traps collected from May 2019 to July 2019 at the NRC Trial 1 plot.

Treatment	Diversity index	Equitability	Family richness
Cover Crop	6.0 ± 0.9 a[z]	0.16 ± 0.03 a	37.8 ± 0.8 a
Weeds	5.9 ± 1.5 a	0.14 ± 0.03 a	42.7 ± 2.17 a
F value	0	0.39	4.58
df	1	1	1
P value	0.9699	0.5569	0.0761

[z] Treatment means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis (P< 0.05). Cover crop used was crimson clover.

Table 8. List of total number of arthropod families in samples from the pitfall traps, collected from May 2019 to July 2019 at the NRC Trial 1 plot. List sorted by largest to smallest count. Cover crop used was crimson clover.

Treatment	Order	Family	#
Cover Crop	Hymenoptera	Formicidae	90
	Unknown	Unknown	55
	Collembola	Entomobryidae	45
	Coleoptera	Carabidae	15
	Coleoptera	Staphylinidae	11
	Orthoptera	Gryllidae	10
	Hemiptera	Aphididae	6
	Coleoptera	Elateridae	4
	Coleoptera	Curculionidae	3
	Collembola	Poduromorpha	3
	Araneae	Lycosidae	2
	Diptera	Phoridae	2
	Hemiptera	Alydidae	1
	Araneae	Dictynidae	1
	Diptera	Ephydridae	1
	Dermaptera	Forficulidae	1
	Coleoptera	Histeridae	1
	Coleoptera	Latridiidae	1
	Hemiptera	Miridae	1
	Sarcoptiformes	Oribatellidae	1
	Hymenoptera	Platygastridae	1
	Coleoptera	Silphidae	1
	Collembola	Symphypleon	1
Total			257

Treatment	Order	Family	#
Weeds	Unknown	Unknown	118
	Hymenoptera	Formicidae	104
	Collembola	Entomobryidae	33
	Orthoptera	Gryllidae	30
	Collembola	Symphypleon	21
	Hemiptera	Aphididae	16
	Coleoptera	Carabidae	15
	Coleoptera	Elateridae	10
	Coleoptera	Staphylinidae	6
	Araenae	Lycosidae	5
	Hymenoptera	Platygastridae	3
	Diptera	Phoridae	2
	Hemiptera	Reduviidae	2
	Thysanoptera	Thripidae	2
	Hymenoptera	Chalcidoidae	1
	Coleoptera	Dermestidae	1
	Diptera	Drosophila	1
	Coleoptera	Mordellidae	1
	Diptera	Muscidae	1
	Hemiptera	Nabidae	1
	Coleoptera	Nitidulidae	1
	Coleoptera	Passalidae	1
	Hemiptera	Phylinae	1
Total			376

Table 9. List of total number of arthropod families in samples from the sticky traps from the Cover Crop treatment, collected from May 2019 to July 2019 at the NRC Trial 1 plot. List sorted by largest to smallest count. Cover crop used was crimson clover.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Cover Crop	Unknow	Unknow	502	Hemiptera	Aleyrodidae	11	Hymenoptera	Cynipoidea	2
	Hemiptera	Cicadellidae	116	Diptera	Ceratopogonidae	10	Coleoptera	Elateridae	2
	Diptera	acalypterate muscoid (unknown)	95	Coleoptera	Curculionidae	7	Hymenoptera	Eucoilidae	2
	Diptera	Sacrophogidae	46	Diptera	Phoridae	7	Hymenoptera	Eupelmidae	2
	Hymenoptera	Platygastridae	41	Hemiptera	Anthocoridae	6	Hymenoptera	Ichneumonidae	2
	Hemiptera	Miridae	36	Hymenoptera	Formicidae	6	Hemiptera	Reduviidae	2
	Diptera	Asilidae	35	Diptera	Sciaridae	6	Diptera	Syrphidae	2
	Hymenoptera	Chalcidoidea	35	Diptera	Ulidiidae	6	Diptera	Chloropidae	1
	Coleoptera	Chrysomelidae	31	Hemiptera	Membracidae	5	Hymenoptera	Diapriidae	1
	Hymenoptera	Apoidea	30	Hymenoptera	Mymaridae	5	Diptera	Empididae	1
	Hemiptera	Aphididae	25	Diptera	Dolichopodidae	4	Hemiptera	Geocoridae	1
	Hemiptera	Cercopidae	23	Hymenoptera	Eucharitidae	4	Coleoptera	Latridiidae	1
	Diptera	Rhinophoridae	23	Hemiptera	Phylloxeridae	4	Diptera	Lauxaniidae	1
	Coleoptera	Coccinellidae	19	Diptera	Tephritidae	4	Coleoptera	Mordellidae	1
	Collembola	Poduromorpha	18	Diptera	Conopidae	3	Hemiptera	Pentatomidae	1
	Coleoptera	Lampyridae	15	Hemiptera	Cydnidae	3	Coleoptera	Phalacridae	1
	Diptera	Cecidomyidae	14	Hymenoptera	Braconidae	2	Orthoptera	Tettigoniidae	1
	Hymenoptera	Trichogrammatidae	13	Coleoptera	Cantharidae	2	Hymenoptera	Tiphiidae	1
	Diptera	Sarcophagidae	12	Hymenoptera	Ceraphronidae	2	Total		1251

Table 10. List of total number of arthropod families in samples from the sticky traps from the Weed treatment, collected from May 2019 to July 2019 at the NRC Trial 1 plot. Listed sort by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Weed	Unknow	Unknow	576	Hemiptera	Anthocoridae	9	Coleoptera	Mordellidae	2
	Hemiptera	Cicadellidae	112	Coleoptera	Lampyridae	9	Diptera	Muscidae	2
	Diptera	acalypterate muscoid (unknown)	98	Hymenoptera	Mymaridae	9	Hemiptera	Reduviidae	2
	Hymenoptera	Platygastridae	53	Hemiptera	Phylloxeridae	8	Coleoptera	Staphylinidae	2
	Diptera	Sacrophagidae	40	Orthoptera	Tettigoniidae	8	Diptera	Tephritidae	2
	Hymenoptera	Chalcidoidea	36	Diptera	Ceratopogonidae	7	Orthoptera	Acrididae	1
	Hymenoptera	Apoidea	34	Diptera	Dolichopodidae	7	Hymenoptera	Braconidae	1
	Diptera	Asilidae	32	Coleoptera	Lampyridae	7	Hemiptera	Rhyparochromidae	1
	Coleoptera	Chrysomelidae	26	Diptera	Phoridae	7	Diptera	Calliphoridae	1
	Hemiptera	Miridae	26	Diptera	Cecidomyidae	5	Hymenoptera	Diapriidia	1
	Hemiptera	Cercopidae	22	Hymenoptera	Formicidae	5	Diptera	Empididae	1
	Hemiptera	Aphididae	19	Coleoptera	Cantharidae	4	Hymenoptera	Euchalitidae	1
	Diptera	Sarcophagidae	17	Coleoptera	Ripiphoridae	4	Coleoptera	Latridiidae	1
	Hemiptera	Membracidae	13	Hymenoptera	Ceraphronidae	3	Oribatida	Oribateridae	1
	Coleoptera	Curculionidae	12	Diptera	Chironomidae	3	Hemiptera	Pentatomidae	1
	Coleoptera	Coccinellidae	11	Diptera	Conopidae	3	Hemiptera	Rhyparochromidae	1
	Hymenoptera	Trichogrammatidae	11	Hymenoptera	Cynipoidea	3	Diptera	Tachinidae	1
	Hemiptera	Aleyrodidae	10	Hemiptera	Geocoridae	3	Araneae	Thomisidae	1
	Collembola	Poduromorpha	10	Diptera	Syrphidae	3	Hemiptera	Thyreocoridae	1
	Diptera	Sciaridae	10	Hemiptera	Cydnidae	2	Hymenoptera	Tiphiidea	1
	Diptera	Ulidiidae	10	Hymenoptera	Eucoilidae	2	Total		1314

Table 11. Average dry weight from samples collected at Pleasant Cove in 2019 in cover crop and weed treatments.

Treatment	**Average dry weight**
Triticale Drill	63.50 ± 3.30
Triticale Broadcast	50.97 ± 6.26
Crimson clover Drill	58.62 ± 5.74
Crimson clover broadcast	57.14 ± 5.77
Weeds	43.34 ± 4.39
F value	2.23
df	4
P value	0.0737

Treatments: 1) Triticale Drill, 2) Triticale Broadcast, 3) Crimson Clover Drill, 4) Crimson Clover Broadcast, 5) Weeds as control.

Table 12. Average dry weight from samples collected at Flower City in 2019 in cover crop and weed treatments.

Treatment	**Average dry weight**
Triticale Drill	25.59 ± 1.19 bc[z]
Triticale Broadcast	19.66 ± 1.19 c
Crimson clover Drill	27.55 ± 3.27 ab
Crimson clover broadcast	32.08 ± 2.38 a
Weeds	25.04 ± 1.90 bc
F value	3.95
df	4
P value	0.0058

[z]Treatment means that do not share the same letter are significantly different (α=0.05). Treatments; 1) Triticale Drill, 2) Triticale Broadcast, 3) Crimson Clover Drill, 4) Crimson Clover Broadcast, 5) Weeds as control.

Table 13. Average soil moisture and soil temperature at Pleasant Cove in 2019.

Treatment	**Soil Moisture**	**Soil Temperature**
Triticale Drill	33.7 ± 1.8	15.3 ± 1.2
Triticale Broadcast	35.4 ± 2.0	14.9 ± 1.2
Crimson clover Drill	30.6 ± 1.9	15.0 ± 1.2
Crimson clover broadcast	31.0 ± 2.0	15.1 ± 1.2
Weeds	32.1 ± 1.8	14.7 ± 1.1
F value	1.1	0.04
df	4	4
P value	0.3573	0.9975

Treatments; 1) Triticale Drill, 2) Triticale Broadcast, 3) Crimson Clover Drill, 4) Crimson Clover Broadcast, 5) Weeds as control.

Table 14. Average soil moisture and soil temperature at Flower City in 2019.

Treatment	Soil Moisture	Soil Temperature
Triticale Drill	26.1 ± 1.7	15.2 ± 1.5
Triticale Broadcast	26.8 ± 1.5	15.2 ± 1.5
Crimson clover Drill	26.7 ± 1.5	14.8 ± 1.4
Crimson clover broadcast	26.8 ± 1.5	14.6 ± 1.4
Weeds	26.1 ± 1.6	15.0 ± 1.5
F value	0.05	0.03
df	4	4
P value	0.9944	0.9984

Treatments; 1) Triticale Drill, 2) Triticale Broadcast, 3) Crimson Clover Drill, 4) Crimson Clover Broadcast, 5) Weeds as control.

Table 15. Mean arthropod diversity index, equitability, and family richness at the Pleasant Cove plots from the pitfall traps collected from May 2019 to July 2019.

Treatment	**Diversity index**	**Equitability**	**Family richness**
Crimson Clover Broadcast	3.75 ± 0.71	0.22 ± 0.05	18.00 ± 1.35
Crimson Clover Drill	6.03 ± 0.79	0.30 ± 0.06	21.50 ± 1.94
Triticale Broadcast	6.76 ± 2.02	0.28 ± 0.07	23.50 ± 2.33
Triticale Drill	5.68 ± 1.37	0.28 ± 0.05	19.75 ± 1.11
Weeds	5.04 ± 0.60	0.22 ± 0.02	22.50 ± 1.66
F value	0.87	0.47	1.61
df	4	4	4
P value	0.5039	0.7573	0.2231

Treatments; 1) Triticale Drill, 2) Triticale Broadcast, 3) Crimson Clover Drill, 4) Crimson Clover Broadcast, 5) Weeds as control.

Table 16. Mean arthropod diversity index, equitability, and family richness at the Pleasant Cove plots from the sticky traps collected from May 2019 to July 2019.

Treatment	**Diversity index**	**Equitability**	**Family richness**
Crimson Clover Broadcast	6.22 ± 0.81 a[z]	0.23 ± 0.02 a	27.75 ± 3.20 a
Crimson Clover Drill	5.65 ± 0.23 a	0.19 ± 1.78 a	30.00 ± 1.78 a
Triticale Broadcast	7.49 ± 1.41 a	0.28 ± 0.06 a	27.50 ± 1.32 a
Triticale Drill	8.10 ± 0.59 a	0.30 ± 0.02 a	27.00 ± 1.08 a
Weeds	6.10 ± 1.30 a	0.20 ± 0.03 a	29.25 ± 1.65 a
F value	1.13	2.14	0.42
df	4	4	4
P value	0.3779	0.1259	0.7905

[z] Treatments means within columns followed by different letters were significantly different (P < 0.05). With treatments; 1) Triticale Drill, 2) Triticale Broadcast, 3) Crimson Clover Drill, 4) Crimson Clover Broadcast, 5) Weeds as control.

Table 17. Mean arthropod diversity index, equitability, and family richness at the Flower City plots from the pitfall traps collected from May 2019 to July 2019.

Treatment	**Diversity index**	**Equitability**	**Family richness**
Crimson Clover Broadcast	5.93 ± 0.65 a[z]	0.29 ± 0.07 a	24.25 ± 5.48 a
Crimson Clover Drill	6.26 ± 1.17 a	0.25 ± 0.05 a	25.00 ± 0.71 a
Triticale Broadcast	6.89 ± 1.25 a	0.30 ± 0.04 a	22.75 ± 1.38 a
Triticale Drill	3.67 ± 0.70 a	0.17 ± 0.05 a	23.50 ± 1.71 a
Weeds	4.87 ± 0.55 a	0.26 ± 0.02 a	22.75 ± 1.84 a
F value	1.96	1.23	0.12
df	4	4	4
P value	0.1534	0.3389	0.9719

[z] Treatments means within columns followed by different letters were significantly different ($P < 0.05$). With treatments; 1) Triticale Drill, 2) Triticale Broadcast, 3) Crimson Clover Drill, 4) Crimson Clover Broadcast, 5) Weeds as control.

Table 18. Mean arthropod diversity index, equitability, and family richness at the Flower City plots from the sticky traps collected from May 2019 to July 2019.

Treatment	**Diversity index**	**Equitability**	**Family richness**
Crimson Clover Broadcast	9.08 ± 1.86 a[z]	0.49 ± 0.09 a	18.75 ± 1.60 a
Crimson Clover Drill	8.04 ± 1.52 a	0.59 ± 0.11 a	15.00 ± 3.72 a
Triticale Broadcast	8.78 ± 0.99 a	0.41 ± 0.05 a	21.25 ± 0.75 a
Triticale Drill	7.60 ± 0.93 a	0.58 ± 0.03 a	13.00 ± 1.35 a
Weeds	8.12 ± 2.02 a	0.52 ± 0.09 a	15.50 ± 2.63 a
F value	0.15	0.83	2.09
df	4	4	4
P value	0.959	0.5283	0.1333

[z] Treatments means within columns followed by different letters were significantly different ($P < 0.05$). With treatments; 1) Triticale Drill, 2) Triticale Broadcast, 3) Crimson Clover Drill, 4) Crimson Clover Broadcast, 5) Weeds as control.

Table 19. List of total number of arthropod families in samples from the pitfall traps from the Crimson Clover Broadcast treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Clover Broadcast	Oribatida	Oribatellidae	448	Araenae	Araenae unknown	3
	Collembola	Entomobryomorpha	197	Araenae	Spider unknown	3
	Collembola	Symphypleona	70	Diptera	Cecidomyiidae	2
	acari	Mite unknown	56	Coleoptera	Curculionidae	2
	Hymenoptera	Formicidae	55	Araenae	Linyphiidae	2
	Coleoptera	Carabidae	19	Coleoptera	Silphidae	2
	Coleoptera	Coleoptera unknown	12	Thysanoptera	Thripidae	2
	Coleoptera	Latrididae	7	Hymenoptera	Ceraphronoidea	1
	Coleoptera	Scarabaeidae	7	Hymenoptera	Chalcidoidea	1
	Coleoptera	Silvanidae	7	Hemiptera	Cicadoidea	1
	Coleoptera	Staphylinidae	7	Diptera	Drosophilidae	1
	Thysanoptera	Thysanoptera unknown	7	Coleoptera	Lampyridae	1
	Diptera	Diptera unknown	6	Lepidoptera	Lepidoptera unknown	1
	Hemiptera	Hemiptera unknown	6	Hemiptera	Lygaeidae	1
	Coleoptera	Nitidulidae	6	Diptera	Phoridae	1
	Hymenoptera	Scelionidae	6	Hymenoptera	Platygastridae	1
	Orthoptera	Gryllidae	5	Diptera	Syrphidae	1
	Hemiptera	Aphididae	3	Total		950

Table 20. List of total number of arthropod families in samples from the pitfall traps from the Crimson Clover Drill treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Clover Drill	Collembola	Entomobryomorpha	175	Thysanoptera	Thripidae	3
	Acari	Mite unknown	82	Thysanoptera	Thysanoptera unknown	3
	Collembola	Symphypleona	80	Hemiptera	Aphididae	2
	Oribatida	Oribatellidae	38	Hymenoptera	Chalcidoidea	2
	Diptera	Diptera unknown	22	Neuroptera	Chrysopidae	2
	Hymenoptera	Formicidae	22	Coleoptera	Curculionidae	2
	Coleoptera	Carabidae	15	Lepidoptera	Lepidoptera unknown	2
	Coleoptera	Nitidulidae	8	Hymenoptera	Platygastridae	2
	Diptera	Cecidomyiidae	7	Araenae	Spider unknown	2
	Coleoptera	Coleoptera unknown	7	Orthoptera	Acrididae	1
	Coleoptera	Latrididae	7	Araenae	Agelenidae	1
	Coleoptera	Staphylinidae	7	Hemiptera	Cicadellidae	1
	Orthoptera	Gryllidae	6	Coleoptera	Coccinellidae	1
	Hemiptera	Hemiptera unknown	5	Collembola	Collembola unknown	1
	Collembola	Poduromorpha	5	Hymenoptera	Ichneumonidae	1
	Hymenoptera	Scelionidae	5	Araenae	Linyphiidae	1
	Hemiptera	Alydidae	4	Hemiptera	Lygaeidae	1
	Hymenoptera	Hymenoptera unknown	4	Hemiptera	Nabidae	1
	Coleoptera	Scarabaeidae	4	Diptera	Phoridae	1
	Coleoptera	Cantharidae	3	Diptera	Syrphidae	1
	Araenae	Lycosidae	3	Araenae	Thomisidae	1
					Total	540

Table 21. List of total number of arthropod families in samples from the pitfall traps from the Triticale Broadcast treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Triticale Broadcast	Acari	Mite unknown	305	Hemiptera	Cydnidae	4
	Collembola	Entomobryomorpha	253	Orthoptera	Gryllidae	4
	Oribatida	Oribatellidae	224	Lepidoptera	Lepidoptera unknown	4
	Collembola	Symphypleona	217	Mesostigmata	Blattisociidae	3
	Coleoptera	Coleoptera unknown	34	Araenae	Linyphiidae	3
	Hymenoptera	Formicidae	33	Araenae	Spider unknown	3
	Hymenoptera	Scelionidae	32	Thysanoptera	Thripidae	3
	Hemiptera	Pentatomidae	28	Coleoptera	Chrysomelidae	2
	Oribatida	Ceratozetoidea	22	Hemiptera	Cicadellidae	2
	Diptera	Diptera unknown	21	Coleoptera	Curculionidae	2
	Coleoptera	Carabidae	19	Hymenoptera	Diapriidae	2
	Hemiptera	Hemiptera unknown	18	Hymenoptera	Hymenoptera unknown	2
	Thysanoptera	Thysanoptera unknown	16	Collembola	Poduromorpha	2
	Coleoptera	Silvanidae	13	Diptera	Cecidomyiidae	1
	Collembola	Collembola unknown	10	Coleoptera	Cryptophagidae	1
	Coleoptera	Latrididae	10	Araenae	Lycosidae	1
	Coleoptera	Staphylinidae	8	Hemiptera	Miridae	1
	Coleoptera	Scarabaeidae	7	Hymenoptera	Mymaridae	1
	Hemiptera	Aphididae	6	Coleoptera	Phalacridae	1
	Mesostigmata	Parasitidae	6	Diptera	Phoridae	1
	Coleoptera	Nitidulidae	5	Coleoptera	Ptilodactylidae	1
	Diptera	Ceraphoridae	4	Araenae	Salticidae	1
					Total	1336

Table 22. List of total number of arthropod families in samples from the pitfall traps from the Triticale Drill treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Triticale Drill	Oribatida	Oribatellidae	222	Diptera	Cecidomyiidae	3
	Collembola	Entomobryomorpha	169	Hemiptera	Alydidae	2
	Acari	Mite unknown	100	Diptera	Ephydridae	2
	Hymenoptera	Formicidae	69	Araenae	Lycosidae	2
	Coleoptera	Coleoptera unknown	61	Diptera	Phoridae	2
	Collembola	Symphypleona	34	Hymenoptera	Platygastridae	2
	Coleoptera	Nitidulidae	18	Araenae	Spider unknown	2
	Diptera	Diptera unknown	17	Thysanoptera	Thysanoptera unknown	2
	Coleoptera	Carabidae	14	Hemiptera	Aphididae	1
	Collembola	Collembola unknown	13	Diptera	Ceraphoridae	1
	Coleoptera	Staphylinidae	10	Hemiptera	Cercopidae	1
	Coleoptera	Latrididae	8	Coleoptera	Chrysomelidae	1
	Coleoptera	Scarabaeidae	8	Coleoptera	Coccinellidae	1
	Orthoptera	Gryllidae	7	Coleoptera	Cryptophagidae	1
	Hemiptera	Hemiptera unknown	6	Coleoptera	Curculionidae	1
	Hymenoptera	Scelionidae	5	Diptera	Drosophilidae	1
	Hemiptera	Cydnidae	4	Lepidoptera	Hesperiidae	1
	Hymenoptera	Hymenoptera unknown	4	Coleoptera	Leiodidae	1
	Hemiptera	Pentatomidae	4	Diptera	Ulidiidae	1
	Coleoptera	Silvanidae	4	Total		805

Table 23. List of total number of arthropod families in samples from the pitfall traps from the Weed treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Weed	Oribatida	Oribatellidae	221	Thysanoptera	Thripidae	3
	Acari	Mite unknown	191	Hymenoptera	Chalcidoidea	2
	Collembola	Entomobryomorpha	177	Coleoptera	Coccinellidae	2
	Hymenoptera	Formicidae	58	Coleoptera	Curculionidae	2
	Diptera	Diptera unknown	26	Hemiptera	Cydnidae	2
	Coleoptera	Carabidae	25	Araenae	Lycosidae	2
	Thysanoptera	Thysanoptera unknown	25	Araenae	Lygaeidae	2
	Coleoptera	Coleoptera unknown	23	unknown	unknown	2
	Hemiptera	Hemiptera unknown	15	Hymenoptera	Braconidae	1
	Collembola	Symphypleona	13	Coleoptera	Cantharidae	1
	Coleoptera	Staphylinidae	12	Coleoptera	Chrysomelidae	1
	Coleoptera	Latrididae	11	Hemiptera	Cicadellidae	1
	Hymenoptera	Scelionidae	11	Hemiptera	Geocoridae	1
	Hymenoptera	Hymenoptera unknown	10	Hemiptera	Miridae	1
	Hemiptera	Aphididae	4	Hymenoptera	Platygastridae	1
	Coleoptera	Dermestidae	4	Collembola	Poduromorpha	1
	Orthoptera	Gryllidae	4	Coleoptera	Scarabaeidae	1
	Coleoptera	Nitidulidae	4	Diptera	Sciaridae	1
	Hemiptera	Pentatomidae	4	Diptera	Simuliidae	1
	Lepidoptera	Cosmopterigidae	3	Diptera	Syrphidae	1
	Lepidoptera	Lepidoptera unknown	3	Diptera	Thaumaleidae	1
	Araenae	Spider unknown	3	Total		877

Table 24. List of total number of arthropod families in samples from the sticky traps from the Crimson Clover Broadcast treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Clover Broadcast	Oribatida	Oribatellidae	448	Araenae	Araenae unknown	3
	Collembola	Entomobryomorpha	197	Araenae	Spider unknown	3
	Collembola	Symphypleona	70	Diptera	Cecidomyiidae	2
	Acari	Mite unknown	56	Coleoptera	Curculionidae	2
	Hymenoptera	Formicidae	55	Araenae	Linyphiidae	2
	Coleoptera	Carabidae	19	Coleoptera	Siliphidae	2
	Coleoptera	Coleoptera unknown	12	Thysanoptera	Thripidae	2
	Coleoptera	Latrididae	7	Hymenoptera	Ceraphoridae	1
	Coleoptera	Scarabaeidae	7	Hymenoptera	Chalcidoidea	1
	Coleoptera	Silvanidae	7	Hemiptera	Cicadoidea	1
	Coleoptera	Staphylinidae	7	Diptera	Drosophilidae	1
	Thysanoptera	Thysanoptera unknown	7	Coleoptera	Lampyridae	1
	Diptera	Diptera unknown	6	Lepidoptera	Lepidoptera unknown	1
	Hemiptera	Hemiptera unknown	6	Hemiptera	Lygaeidae	1
	Coleoptera	Nitidulidae	6	Diptera	Phoridae	1
	Hymenoptera	Scelionidae	6	Hymenoptera	Platygastridae	1
	Orthoptera	Gryllidae	5	Diptera	Syrphidae	1
	Hemiptera	Aphididae	3	Total		950

Table 25. List of total number of arthropod families in samples from the Sticky traps from the Crimson Clover Drill treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Clover Drill	Collembola	Entomobryomorpha	175	Thysanoptera	Thripidae	3
	Acari	Mite unknown	82	Thysanoptera	Thysanoptera unknown	3
	Collembola	Symphypleona	80	Hemiptera	Aphididae	2
	Acari	Oribatellidae	38	Hymenoptera	Chalcidoidea	2
	Diptera	Diptera unknown	22	Neuroptera	Chrysopidae	2
	Hymenoptera	Formicidae	22	Coleoptera	Curculionidae	2
	Coleoptera	Carabidae	15	Lepidoptera	Lepidoptera unknown	2
	Coleoptera	Nitidulidae	8	Hymenoptera	Platygastridae	2
	Diptera	Cecidomyiidae	7	Araenae	Spider unknown	2
	Coleoptera	Coleoptera unknown	7	Orthoptera	Acridiae	1
	Coleoptera	Latrididae	7	Araenae	Agelenidae	1
	Coleoptera	Staphylinidae	7	Hemiptera	Cicadellidae	1
	Orthoptera	Gryllidae	6	Coleoptera	Coccinellidae	1
	Hemiptera	Hemiptera unknown	5	Collembola	Collembola unknown	1
	Collembola	Poduromorpha	5	Hymenoptera	Ichneumonidae	1
	Hymenoptera	Scelionidae	5	Araenae	Linyphiidae	1
	Hemiptera	Alydidae	4	Hemiptera	Lygaeidae	1
	Hymenoptera	Hymenoptera unknown	4	Hemiptera	Nabidae	1
	Coleoptera	Scarabaeidae	4	Diptera	Phoridae	1
	Coleoptera	Cantheridae	3	Diptera	Syrphidae	1
	Araenae	Lycosidae	3	Araenae	Thomiasidae	1
					Total	541

Table 26. List of total number of arthropod families in samples from the sticky traps from the Triticale Broadcast treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Triticale Broadcast	Acari	Mite unknown	349	Hemiptera	Cydnidae	4
	Collembola	Entomobryomorpha	270	Lepidoptera	Lepidoptera unknown	4
	Acari	Oribatellidae	224	Acari	Blattisociidae	3
	Collembola	Symphypleona	217	Coleoptera	Chrysomelidae	3
	Coleoptera	Coleoptera unknown	52	Araenae	Linyphiidae	3
	Hymenoptera	Formicidae	47	Araenae	Spider unknown	3
	Hymenoptera	Scelionidae	32	Thysanoptera	Thripidae	3
	Hemiptera	Pentatomidae	28	Hemiptera	Cicadellidae	2
	Coleoptera	Carabidae	22	Coleoptera	Curculionidae	2
	Acari	Ceratozetoidea	22	Hymenoptera	Diapriidae	2
	Diptera	Diptera unknown	21	Hymenoptera	Hymenoptera unknown	2
	Hemiptera	Hemiptera unknown	19	Araenae	Lycosidae	2
	Thysanoptera	Thysanoptera unknown	18	Diptera	Phoridae	2
	Coleoptera	Silvanidae	16	Collembola	Poduromorpha	2
	Coleoptera	Latrididae	14	Diptera	Cecidomyiidae	1
	Coleoptera	Staphylinidae	11	Coleoptera	Coccinellidae	1
	Collembola	Collembola unknown	10	Coleoptera	cryptophagidae	1
	Coleoptera	Nitidulidae	9	Hemiptera	Miridae	1
	Hemiptera	Aphididae	7	Hymenoptera	Mymaridae	1
	Coleoptera	Scarabaeidae	7	Coleoptera	Phalacridae	1
	Acari	Parasitidae	6	Coleoptera	Ptilodactylidae	1
	Orthoptera	Gryllidae	5	Araenae	Salticidae	1
	Hymenoptera	Ceraphoridae	4	Diptera	Ulidiidae	1
					Total	1456

Table 27. List of total number of arthropod families in samples from the sticky traps from the Triticale Drill treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Triticale Drill	Acari	Oribatellidae	222	Coleoptera	Latrididae	4
	Collembola	Entomobryomorpha	152	Hemiptera	Pentatomidae	4
	Hymenoptera	Formicidae	55	Diptera	Cecidomyiidae	3
	Acari	Mite unknown	50	Hemiptera	Alydidae	2
	Coleoptera	Coleoptera unknown	43	Diptera	Ephydridae	2
	Collembola	Symphypleona	34	Hymenoptera	Platygastridae	2
	Diptera	Diptera unknown	17	Araenae	Spider unknown	2
	Coleoptera	Nitidulidae	14	Hymenoptera	Ceraphoridae	1
	Collembola	Collembola unknown	13	Hemiptera	Cercopidae	1
	Coleoptera	Carabidae	11	Coleoptera	cryptophagidae	1
	Coleoptera	Scarabaeidae	8	Coleoptera	Curculionidae	1
	Coleoptera	Staphylinidae	7	Diptera	Drosophilidae	1
	Acari	Mite unknown	6	Lepidoptera	Hesperidae	1
	Orthoptera	Gryllidae	6	Coleoptera	Leiodidae	1
	Hemiptera	Hemiptera unknown	5	Araenae	Lycosidae	1
	Hymenoptera	Scelionidae	5	Diptera	Phoridae	1
	Hemiptera	Cydnidae	4	Coleoptera	Silvanidae	1
	Hymenoptera	Hymenoptera unknown	4	Total		685

Table 28. List of total number of arthropod families in samples from the sticky traps from the Weed treatment, collected from May 2019 to July 2019 at Pleasant Cove. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Weed	Oribatida	Oribatellidae	221	Hymenoptera	Chalcidoidea	2
	Acari	Mite unknown	191	Coleoptera	Coccinellidae	2
	Collembola	Entomobryomorpha	177	Collembola	Collembola unknown	2
	Hymenoptera	Formicidae	58	Coleoptera	Curculionidae	2
	Diptera	Diptera unknown	26	Araenae	Lycosidae	2
	Coleoptera	Carabidae	25	Hemiptera	Lygaeidae	2
	Thysanoptera	Thysanoptera unknown	25	Hymenoptera	Braconidae	1
	Coleoptera	Coleoptera unknown	23	Coleoptera	Cantheridae	1
	Hemiptera	Hemiptera unknown	15	Coleoptera	Chrysomelidae	1
	Collembola	Symphypleona	13	Hemiptera	Cicadellidae	1
	Coleoptera	Staphylinidae	12	Hemiptera	Cydnidae	1
	Coleoptera	Latrididae	11	Hemiptera	Cynidae	1
	Hymenoptera	Scelionidae	11	Hemiptera	Geocoridae	1
	Hymenoptera	Hymenoptera unknown	10	Hemiptera	Miridae	1
	Hemiptera	Aphididae	4	Hymenoptera	Platygastridae	1
	Coleoptera	Dermestidae	4	Collembola	Poduromorpha	1
	Orthoptera	Gryllidae	4	Coleoptera	Scarabaeidae	1
	Coleoptera	Nitidulidae	4	Diptera	Sciaridae	1
	Hemiptera	Pentatomidae	4	Diptera	Simuliidae	1
	Lepidoptera	Cosmopterigidae	3	Araenae	Spider unknown	1
	Lepidoptera	Lepidoptera unknown	3	Diptera	Syrphidae	1
	Thysanoptera	Thripidae	3	Diptera	Thaumalcidae	1
	Araenae	Spider unknown	2		Total	877

Table 29. List of total number of arthropod families in samples from the pitfall traps from the Crimson Clover Broadcast treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Clover Broadcast	Collembola	Entomobryomorpha	337	Hymenoptera	Ceraphronidae	3
	Hymenoptera	Formicidae	117	Coleoptera	Nitidulidae	3
	Collembola	Symphypleona	94	Orthoptera	Orthoptera unknown	3
	Collembola	Poduromorpha	79	Araenae	Spider unknown	3
	Collembola	Collembola unknown	73	Hemiptera	Anthocoridae	2
	Coleoptera	Staphylinidae	54	Blattaria	Blattaria unknown	2
	Oribatida	Oribatellidae	48	Hymenoptera	Braconidae	2
	Acari	Mite unknown	47	Diptera	Diapriidae	2
	Coleoptera	Carabidae	37	Lepidoptera	Lepidoptera unknown	2
	Hymenoptera	Platygastridae	24	Hemiptera	Reduviidae	2
	Orthoptera	Gryllidae	15	Hemiptera	Rhyparachromidae	2
	Coleoptera	Coleoptera unknown	11	Coleoptera	Scarabaeidae	2
	Thysanoptera	Thripidae	11	Hemiptera	Cicadellidae	1
	Araenae	Linyphiidae	10	Hemiptera	Cydnidae	1
	Araenae	Lycosidae	10	Coleoptera	Elateridae	1
	Hemiptera	Hemiptera unknown	9	Diptera	Ephydridae	1
	Diptera	Phoridae	8	Hymenoptera	Hymenoptera unknown	1
	Hymenoptera	Scelionidae	7	Hymenoptera	Ichneumonidae	1
	Hemiptera	Aphididae	6	Hemiptera	Lygaeidae	1
	Hymenoptera	Chalcidoidea	6	Hemiptera	Nabidae	1
	Diptera	Diptera unknown	5	Opiliones	Opiliones unknown	1
	Thysanoptera	Thysanoptera unknown	5	Hymenoptera	Pemphredoninae	1
	Coleoptera	Lampyridae	4	Orthoptera	Tetrigidae	1
	Trombidiformes	Trombidiidae	4		Total	1060

Table 30. List of total number of arthropod families in samples from the pitfall traps from the Crimson Clover Drill treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Clover Drill	Collembola	Entomobryomorpha	366	Coleoptera	Coleoptera unknown	5
	Collembola	Symphypleona	131	Coleoptera	Elateridae	4
	Collembola	Poduromorpha	128	Hemiptera	Miridae	4
	Hymenoptera	Formicidae	106	Hemiptera	Lygaeidae	3
	Acari	Mite unknown	74	Coleoptera	Scarabaeidae	3
	Oribatida	Oribatellidae	51	Diptera	Sciaridae	3
	Coleoptera	Staphylinidae	48	Hymenoptera	Ceraphronidae	2
	Araenae	Lycosidae	24	Hymenoptera	Chalcidoidea	2
	Hymenoptera	Scelionidae	24	Coleoptera	Lampyridae	2
	Coleoptera	Carabidae	21	Hymenoptera	Mymaridae	2
	Orthoptera	Gryllidae	19	Hemiptera	Nabidae	2
	Collembola	collembola unknown	15	Thysanoptera	Thripidae	2
	Hymenoptera	Hymenoptera unknown	12	Araenae	Agelenidae	1
	Hymenoptera	Platygastridae	11	Diptera	Cecidomyiidae	1
	Hemiptera	Aphididae	9	Hymenoptera	Charipidae	1
	Diptera	Diptera unknown	8	Coleoptera	Cryptophagidae	1
	Hymenoptera	Braconidae	7	Coleoptera	Erotylidae	1
	Hemiptera	Hemiptera unknown	7	Coleoptera	Mordellidae	1
	Coleoptera	Latrididae	7	Araenae	Salticidae	1
	Araenae	Linyphiidae	7	Araenae	Spider unknown	1
	Diptera	Phoridae	6	Diptera	Therevidae	1
	Thysanoptera	Thysanoptera unknown	6	Isopoda	Trachelipodidae	1
				Total		1131

Table 31. List of total number of arthropod families in samples from the pitfall traps from the Triticale Broadcast treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Triticale Broadcast	Collembola	Entomobryomorpha	243	Araenae	Linyphiidae	7
	Hymenoptera	Formicidae	95	Coleoptera	Scarabaeidae	6
	Collembola	Poduromorpha	76	Hemiptera	Hemiptera unknown	5
	Acari	Mite unknown	62	Hemiptera	Cydnidae	4
	Collembola	Collembola unknown	56	Hymenoptera	Hymenoptera unknown	3
	Coleoptera	Staphylinidae	48	Araenae	Spider unknown	3
	Collembola	Symphypleona	41	Hymenoptera	Ceraphronidae	2
	Coleoptera	Carabidae	30	Hymenoptera	Chalcidoidea	2
	Hymenoptera	Scelionidae	26	Hemiptera	Nabidae	2
	Orthoptera	Gryllidae	17	Hymenoptera	Charipidae	1
	Araenae	Lycosidae	17	Hemiptera	Cicadellidae	1
	Hymenoptera	Braconidae	16	Coleoptera	Curculionidae	1
	Diptera	Diptera unknown	14	Hymenoptera	Ichneumonidae	1
	Acari	Oribatellidae	14	Lepidoptera	Lepidoptera unknown	1
	Hemiptera	Aphididae	13	Coleoptera	Nitidulidae	1
	Hymenoptera	Platygastridae	12	Hemiptera	Pentatomidae	1
	Hemiptera	Lygaeidae	10	Phasmatodea	Phasmatidae	1
	Coleoptera	Coleoptera unknown	7	Diptera	Phoridae	1
				Total		840

Table 32. List of total number of arthropod families in samples from the pitfall traps from the Triticale Drill treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Triticale Drill	Collembola	Entomobryomorpha	715	Thysanoptera	Thysanoptera unknown	4
	Hymenoptera	Formicidae	111	Hemiptera	Cicadoidea	3
	Acari	Mite unknown	82	Hemiptera	Cydnidae	3
	Collembola	Symphypleona	77	Araenae	Lycosidae	3
	Collembola	Poduromorpha	67	Hemiptera	Lygaeidae	3
	Coleoptera	Carabidae	38	Araenae	Amaurobiidae	2
	Coleoptera	Staphylinidae	38	Hymenoptera	Ceraphronidae	2
	Acari	Oribatellidae	20	Coleoptera	Chrysomelidae	2
	Hymenoptera	Braconidae	17	Coleoptera	Melyridae	2
	Orthoptera	Gryllidae	16	Diptera	Muscidae	2
	Diptera	Diptera unknown	13	Diptera	Phoridae	2
	Coleoptera	Coleoptera unknown	10	Blattaria	Blattaria unknown	1
	Hymenoptera	Scelionidae	9	Hemiptera	Cicadellidae	1
	Hemiptera	Aphididae	7	Coleoptera	Curculionidae	1
	Hemiptera	Hemiptera unknown	6	Coleoptera	Elateridae	1
	Hymenoptera	Chalcidoidea	5	Coleoptera	Latrididae	1
	Coleoptera	Scarabaeidae	5	Hymenoptera	Mutilidae	1
	Diptera	Sciaridae	5	Hymenoptera	Mymaridae	1
	Araenae	Spider unknown	5	Hymenoptera	Platygastridae	1
	Thysanoptera	Thripidae	5	Hemiptera	Rhyparachromidae	1
	Araenae	Linyphiidae	4	Coleoptera	Silphidae	1
					Total	1293

Table 33. List of total number of arthropod families in samples from the Pitfall traps from the Weed treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Weed	Collembola	Entomobryomorpha	399	Hemiptera	Lygaeidae	6
	Collembola	Poduromorpha	150	Coleoptera	Scarabaeidae	6
	Collembola	Symphypleona	113	Coleoptera	Entognatha	4
	Hymenoptera	Formicidae	87	Hemiptera	Cicadellidae	3
	Acari	Mite unknown	54	Lepidoptera	Lepidoptera unknown	3
	Coleoptera	Carabidae	37	Orthoptera	Acrididae	2
	Coleoptera	Staphylinidae	32	Hymenoptera	Ceraphronidae	2
	Hymenoptera	Scelionidae	28	Hemiptera	Cydnidae	1
	Orthoptera	Gryllidae	27	Coleoptera	Elateridae	1
	Acari	Oribatellidae	19	Hymenoptera	Hymenoptera unknown	1
	Hemiptera	Hemiptera unknown	18	Coleoptera	Lampyridae	1
	Coleoptera	Coleoptera unknown	17	Araenae	Linyphiidae	1
	Araenae	Lycosidae	14	Araenae	Liocranidae	1
	Hemiptera	Aphididae	12	Hemiptera	Miridae	1
	Collembola	collembola unknown	12	Coleoptera	Nitidulidae	1
	Hymenoptera	Platygastridae	10	Hymenoptera	Pteromalidae	1
	Araenae	Spider unknown	8	Hemiptera	Rhyparachromidae	1
	Hymenoptera	Braconidae	7	Coleoptera	Silphidae	1
	Diptera	Phoridae	7	Thysanoptera	Thripidae	1
	Diptera	Diptera unknown	6	Thysanoptera	Thysanoptera unknown	1
				Total		1093

Table 34. List of total number of arthropod families in samples from the sticky traps from the Crimson Clover Broadcast treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Clover Broadcast	Unknown	Unknown	59	Hemiptera	Miridae	2
	Hemiptera	Cicadellidae	24	Hemiptera	Psylloidea	2
	Diptera	Acalypterate muscoid unknown	17	Diptera	Sphaerocredidae	2
	Hymenoptera	Platygastridae	15	Diptera	Tipulidae	2
	Hemiptera	Aphididae	13	Coleoptera	Corylophidae	1
	Diptera	Chironomidae	13	Coleoptera	Curculionidae	1
	Thysanoptera	Thripidae	9	Hymenoptera	Cynipoidea	1
	Hymenoptera	Chalcidoidea	8	Coleoptera	Dermestidae	1
	Hymenoptera	Mymaridae	8	Hymenoptera	Diapriidae	1
	Hemiptera	Cercopidae	5	Hymenoptera	Eucoilidae	1
	Diptera	Sciaridae	5	Hymenoptera	Ichneumonoidea	1
	Hymenoptera	Trichogrammatidae	4	Coleoptera	Lampyridae	1
	Hymenoptera	Ceraphronidae	3	Coleoptera	Lathridiidae	1
	Hemiptera	Phylloxeridae	3	Hemiptera	Lygaeoidea	1
	Hymenoptera	Braconidae	2	Hemiptera	Membracidae	1
	Coleoptera	Buprestidae	2	Araneae	Miturgidae	1
	Diptera	Chloropidae	2	Acari	Oribatidae	1
	Coleoptera	Chrysomelidae	2	Hemiptera	Psyllidae	1
	Coleoptera	Coccinellidae	2	Diptera	Scathaphagidae	1
	Diptera	Dolichopididae	2	Diptera	Stratiomyidae	1
	Hymenoptera	Megaspilidae	2	Hemiptera	Tingidae	1
					Total	225

Table 35. List of total number of arthropod families in samples from the Sticky traps from the Crimson Clover Drill treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Clover Drill	Hemiptera	Cicadellidae	36	Diptera	Chironomidae	2
	Unknown	Unknown	28	Hemiptera	Delphacidae	2
	Hymenoptera	Platygastridae	18	Hymenoptera	Diapriidae	2
	Coleoptera	Chrysomelidae	17	Hemiptera	Psyllidae	2
	Diptera	Chloropidae	12	Diptera	Sciaridae	2
	Coleoptera	Coccinellidae	11	Diptera	Ulididae	2
	Hymenoptera	Chalcidoidea	9	Hymenoptera	Braconidae	1
	Hemiptera	Miridae	7	Coleoptera	Corylophidae	1
	Coleoptera	Dermestidae	6	Hymenoptera	Eucoilidae	1
	Thysanoptera	Thripidae	5	Hymenoptera	Figitidae	1
	Hymenoptera	Mymaridae	4	Hymenoptera	Ichneumonoidea	1
	Diptera	Sarcophagidae	3	Hymenoptera	Megaspilidae	1
	Hemiptera	Aphididae	2	Coleoptera	Nitidulidae	1
	Coleoptera	Buprestidae	2	Coleoptera	Phalacridae	1
	Hemiptera	Cercopidae	2	Diptera	Stratiomyidae	1
					Total	183

Table 36. List of total number of arthropod families in samples from the sticky traps from the Triticale Broadcast treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Triticale Broadcast	Unknown	Unknown	54	Diptera	Tephritidae	2
	Hemiptera	Cicadellidae	45	Hymenoptera	Trichogrammatidae	2
	Diptera	Chironomidae	15	Hemiptera	Adelgidae	1
	Hymenoptera	Mymaridae	14	Coleoptera	Carabidae	1
	Diptera	Chloropidae	11	Diptera	Cecidomyiidae	1
	Hymenoptera	Chalcidoidea	9	Hymenoptera	Ceraphronidae	1
	Coleoptera	Chrysomelidae	8	Hymenoptera	Crabronidae	1
	Hymenoptera	Platygastridae	8	Hymenoptera	Cynipoidea	1
	Hemiptera	Aphididae	5	Coleoptera	Dermestidae	1
	Hymenoptera	Braconidae	5	Diptera	Dolichopididae	1
	Coleoptera	Buprestidae	4	Diptera	Dolichopodidae	1
	Coleoptera	Coccinellidae	4	Blattodea	Epifamily Termitoidae	1
	Hemiptera	Miridae	4	Coleoptera	Erotylidae	1
	Hemiptera	Cercopidae	3	Hymenoptera	Eupelmidae	1
	Diptera	Muscidae	3	Coleoptera	Lampyridae	1
	Diptera	Sciaridae	3	Hymenoptera	Megaspilidae	1
	Diptera	Ulididae	3	Diptera	Sarcophagidae	1
	Hemiptera	Membracidae	2	Diptera	Syrphidae	1
	Hemiptera	Phylloxeridae	2	Orthoptera	Tettigoniidae	1
				Total		223

Table 37. List of total number of arthropod families in samples from the sticky traps from the Triticale Drill treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	**Order**	**Family**	**#**	**Order**	**Family**	**#**
Triticale Drill	Unknown	Unknown	24	Hemiptera	Membracidae	2
	Hemiptera	Cicadellidae	16	Diptera	Muscidae	2
	Hymenoptera	Mymaridae	12	Hymenoptera	Platygastridae	2
	Diptera	Chloropidae	10	Diptera	Sciaridae	2
	Hymenoptera	Chalcidoidea	9	Hemiptera	Aleyrodidae	1
	Coleoptera	Buprestidae	8	Diptera	Anthomyzidae	1
	Diptera	Chironomidae	7	Hemiptera	Cercopidae	1
	Coleoptera	Coccinellidae	7	Diptera	Dolichopodidae	1
	Diptera	Cecidomyiidae	6	Hymenoptera	Megaspilidae	1
	Thysanoptera	Thripidae	5	Diptera	Sarcophagidae	1
	Hymenoptera	Formicidae	3	Diptera	Scathophagidae	1
	Hemiptera	Aphididae	2	Coleoptera	Staphylinidae	1
	Coleoptera	Chrysomelidae	2	Diptera	Ulididae	1
				Total		128

Table 38. List of total number of arthropod families in samples from the sticky traps from the Weed treatment, collected from May 2019 to July 2019 at Flower City. List sorted by largest to smallest count.

Treatment	Order	Family	#	Order	Family	#
Weed	Hemiptera	Cicadellidae	42	Hymenoptera	Platygastridae	2
	Unknown	Unknown	23	Thysanoptera	Thripidae	2
	Coleoptera	Coccinellidae	12	Hymenoptera	Trichogrammatidae	2
	Diptera	Chironomidae	10	Hemiptera	Aleyrodidae	1
	Coleoptera	Chrysomelidae	9	Hymenoptera	Ceraphronidae	1
	Hemiptera	Aphididae	8	Hymenoptera	Cynipoidea	1
	Diptera	Chloropidae	8	Diptera	Drosphilidae	1
	Hemiptera	Miridae	7	Hymenoptera	Formicidae	1
	Hemiptera	Cercopidae	6	Hymenoptera	Halticidae	1
	Hemiptera	Phylloxeridae	6	Coleoptera	Lampyridae	1
	Diptera	Ulididae	6	Hymenoptera	Megaspilidae	1
	Hymenoptera	Chalcidoidea	4	Coleoptera	Phalacridae	1
	Hemiptera	Membracidae	3	Diptera	Sciaridae	1
	Diptera	Muscidae	3	Diptera	Stratiomyidae	1
	Coleoptera	Curculionidae	2	Total		166

Table 39. Microbial biomass carbon and nitrogen content at Pleasant Cove in 2019.

Treatments	**Microbial Biomass Carbon**	**Microbial Biomass Nitrogen**
Triticale Drill	1.39 ± 0.04 a[z]	0.04 ± 0.01 a
Crimson Clover Drill	1.08 ± 0.09 a	0.03 ± 0.01 a
Weeds	0.97 ± 0.25 a	0.04 ± 0.01 a
F value	1.99	0.55
df	2	2
P value	0.1926	0.5934

[z] Treatments means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis (P< 0.05). With treatments; 1) Triticale Drill, 2) Crimson Clover Drill, and Weeds as control.

Table 40. Microbial biomass carbon and nitrogen content at Pleasant Cove in 2019.

Treatments	Microbial Biomass Carbon	Microbial Biomass Nitrogen
Triticale Drill	0.72 ± 0.05 a[z]	0.02 ± 0.01 a
Crimson Clover Drill	0.75 ± 0.12 a	0.04 ± 0.01 a
Weeds	0.66 ± 0.04 a	0.03 ± 0.01 a
F value	0.32	2.14
df	2	2
P value	0.7319	0.1741

[z] Treatments means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis (P< 0.05). With treatments; 1) Triticale Drill, 2) Crimson Clover Drill, and Weeds as control.

Table 41. Final tree trunk diameter and height after four years of cover crop evaluation at Moore's nursery.

Treatments	Final Diameter (mm)	Final Height (cm)
Herbicide + Ins	66.79 ± 0.62 a[z]	472.30 ± 4.26 a
Herbicide	65.25 ± 0.64 a	441.72 ± 3.25 a
Cover C + Ins	51.84 ± 0.70 b	380.52 ± 4.41 b
Cover C	51.86 ± 0.62 b	389.96 ± 4.49 b
F value	88.68	60.85
df	6	6
P value	0.0001	0.0001

[z] Treatments means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$). Treatments; 1) Herbicide + Insecticide, 2) Herbicide, 3) Cover Crop + Insecticide and 4) Cover Crop.

Table 42. Initial trunk diameter and tree height at the time of transplanting for the Early Kill Cover Crop experiment.

Treatments	Initial Diameter	Initial Height
Cover Crop	11.88 ± 0.23 a[z]	193.71 ± 3.05 a
Early Kill Cover Crop	11.57 ± 0.21 a	191.91 ± 2.74 a
Herbicide	11.66 ± 0.21 a	189.98 ± 3.33 a
Mulch Mat	11.84 ± 0.22 a	191.00 ± 2.86 a
F value	0.48	0.28
df	3	3
P value	0.699	0.8408

[z]Treatments means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis (P< 0.05). Treatments: 1) Cover Crop, 2) Early Kill Cover Crop, 3) Herbicide and 4) Mulch Mat. Experiment located at Moore's Nursery, TN.

Table 43. Final trunk diameter and tree height one year after transplanting for the Early Kill Cover Crop experiment.

	Final Diameter	Final Height
Cover Crop	22.65 ± 0.41 b[z]	226.39 ± 3.12 b
Early Kill Cover Crop	23.50 ± 0.51 b	229.26 ± 3.15 b
Herbicide	28.14 ± 0.52 a	249.04 ± 3.52 a
Mulch Mat	24.04 ± 0.46 b	229.76 ± 3.25 b
F value	26.11	10.12
df	3	3
P value	0.0001	0.0001

[z]Treatments means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$). Treatments: 1) Cover Crop, 2) Early Kill Cover Crop, 3) Herbicide and 4) Mulch Mat. Experiment located at Moore's Nursery, TN.

Table 44. Community statistics for arthropod samples from the pitfall traps collected at Moore's nursery from May 2019 to July 2019.

Treatment	**Diversity index**	**Equitability**	**Family richness**
Cover Crop	5.48 ± 0.83 a[z]	0.37 ± 0.05 a	14.80 ± 1.30 a
Early Kill Cover Crop	5.06 ± 0.46 a	0.33 ± 0.02 a	15.40 ± 1.21 a
Herbicide	6.28 ± 0.71 a	0.42 ± 0.05 a	16.10 ± 1.72 a
Mulch Mat	5.19 ± 0.55 a	0.46 ± 0.04 a	12.10 ± 1.64 a
F value	0.7	1.76	1.39
df	3	3	3
P value	0.556	0.1713	0.2622

[z]Treatments means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis (P< 0.05). Treatments: 1) Cover Crop, 2) Early Kill Cover Crop, 3) Herbicide and 4) Mulch Mat. Experiment located at Moore's Nursery, TN.

Table 45. Community statistics for arthropods samples from the sticky traps collected at Moore's nursery from May 2019 to July 2019.

Treatment	Diversity index	Equitability	Family richness
Cover Crop	7.33 ± 0.62 a[z]	0.23 ± 0.02 a	32.00 ± 1.02 a
Early Kill Cover Crop	8.34 ± 0.58 a	0.27 ± 0.02 a	30.60 ± 1.07 a
Herbicide	6.82 ± 0.57 a	0.23 ± 0.02 a	30.30 ± 1.33 a
Mulch Mat	7.33 ± 0.92 a	0.24 ± 0.03 a	30.70 ± 0.62 a
F value	0.85	0.97	0.52
df	3	3	3
P value	0.4754	0.4166	0.6679

[z]Treatments means within columns with different letters are statistically different by General Linear Model with means separated by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis (P< 0.05). Treatments: 1) Cover Crop, 2) Early Kill Cover Crop, 3) Herbicide and 4) Mulch Mat. Experiment located at Moore's Nursery, TN.

Table 46. Total number of arthropods samples from the pitfall traps collected at Moore's nursery from May 2019 to July 2019 for the Cover Crop treatment.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Cover Crop	Collembola	Entomobryomorpha	207	Diptera	Sciaridae	6	Hemiptera	Miridae	2
	Hemiptera	Hemiptera unknow	100	Coleoptera	Silphidae	5	Thysanoptera	Thripidae	2
	Hymenoptera	Formicidae	67	Diptera	diptera unknown	4	Coleoptera	Anthicidae	1
	Hymenoptera	Platygastridae	42	Orthoptera	Gryllidae	4	Araneae	Cybaeidae	1
	Coleoptera	Staphylinidae	40	Araneae	Linyphiidae	4	Hemiptera	Cydnidae	1
	Acari	unknown mite	30	Diptera	Phoridae	4	Diplopoda	Diplopoda unknow	1
	Coleoptera	Coleoptera unknown	23	Araneae	Salticidae	4	Diptera	Drosophilidae	1
	Coleoptera	Carabidae	16	Thysanoptera	Thysanoptera unknow	4	Coleoptera	Elateridae	1
	Araneae	Lycosidae	15	Diptera	Cecidomyiidae	3	Coleoptera	Histeridae	1
	Hemiptera	Lygaeidae	15	Diptera	Ceratopogonidae	3	Coleoptera	Lampyridae	1
	Collembola	Symphypleona	15	Coleoptera	Chrysomelidae	3	Diptera	Muscidae	1
	Coleoptera	Nitidulidae	12	Mesostigmata	Mesostigmata unknown	3	Hemiptera	Nabidae	1
	Hymenoptera	Scelionidae	12	Araneae	Araneae unknow	2	Collembola	Poduromorpha	1
	Oribatida	Oribatidae	11	Hemiptera	Cercopidae	2	Coleoptera	Scarabaeidae	1
	Hymenoptera	Braconidae	9	Hemiptera	Cicadellidae	2	Coleoptera	Scarabidae	1
	Hemiptera	Aphidoidea	8	Hymenoptera	Diapriidae	2	Trombidiformes	Tetranychidae	1
	Total								695

Table 47. Total number of arthropods samples from the pitfall traps collected at Moore's nursery from May 2019 to July 2019 for the Cover Crop Early Kill treatment.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Cover Early Kill	Collembola	Entomobryomorpha	243	Thysanoptera	Thysanoptera unknow	6	Coleoptera	Curculionidae	1
	Hymenoptera	Formicidae	117	Diptera	Diptera unknown	5	Hemiptera	Cydnidae	1
	Hymenoptera	Platygastridae	64	Araneae	Araneae unknow	4	Hymenoptera	Diapriidae	1
	Araneae	Lycosidae	35	Hymenoptera	Scelionidae	4	Hymenoptera	Hymenoptera unknow	1
	Collembola	Symphypleona	32	Araneae	Linyphiidae	3	Coleoptera	Latridiidae	1
	Coleoptera	Coleoptera unknown	25	Diptera	Ceraphronidae	2	Lepidoptera	Lepidoptera unknow	1
	Acari	unknown mite	23	Hemiptera	Cicadellidae	2	Mesostigmata	Mesostigmata unknown	1
	Coleoptera	Staphylinidae	21	Diptera	Phoridae	2	Hymenoptera	Mymaridae	1
	Oribatida	Oribatidae	20	Diptera	Sciaridae	2	Mesostigmata	Platyseiinae	1
	Collembola	Collembola unknow	15	Orthoptera	Acridoidea	1	Araneae	Salticidae	1
	Coleoptera	Carabidae	14	Araneae	Agelenidae	1	Coleoptera	Scarabaeidae	1
	Coleoptera	Nitidulidae	14	Hemiptera	Alydidae	1	Coleoptera	Silphidae	1
	Hemiptera	Hemiptera unknow	9	Coleoptera	Anthicidae	1	Orthoptera	Tetrigidae	1
	Hemiptera	Lygaeidae	8	Diptera	Cecidomyiidae	1	Araneae	Theridiidae	1
	Hemiptera	Aphidoidea	7	Hemiptera	Cercopidae	1	Thysanoptera	Thripidae	1
	Orthoptera	Gryllidae	6	Coleoptera	Chrysomelidae	1	Total		705

Table 48. Total number of arthropods samples from the pitfall traps collected at Moore's nursery from May 2019 to July 2019 for the Herbicide treatment.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Herbicide	Hymenoptera	Formicidae	216	Coleoptera	Nitidulidae	7	Hymenoptera	Mymaridae	2
	Collembola	Entomobryomorpha	152	Orthoptera	Gryllidae	6	Diptera	Sciaridae	2
	Hymenoptera	Platygastridae	57	Diptera	Phoridae	5	Hemiptera	Anthocoridae	1
	Collembola	Symphypleona	42	Hemiptera	Aphidoidea	4	Araneae	Araneae unknow	1
	Oribatida	Oribatidae	32	Coleoptera	Chrysomelidae	4	Diptera	Asilidae	1
	Acari	unknown mite	23	Hemiptera	Dipsocoridae	4	Hymenoptera	Braconidae	1
	Coleoptera	Carabidae	22	Collembola	Poduromorpha	4	Hymenoptera	Chalcidoidae	1
	Coleoptera	Staphylinidae	21	Hemiptera	Cercopidae	3	Diptera	Chloropidae	1
	Coleoptera	Coleoptera unknown	16	Hymenoptera	Diapriidae	3	Hemiptera	Cicadellidae	1
	Araneae	Lycosidae	14	Coleoptera	Latridiidae	3	Araneae	Dictynidae	1
	Diptera	Cecidomyiidae	13	Mesostigmata	Mesostigmata unknown	3	Hymenoptera	Hymenoptera unknow	1
	Hemiptera	Hemiptera unknow	13	Diptera	Mycetophylidae	3	Hymenoptera	Mutillidae	1
	Hemiptera	Aphididae	10	Araneae	Agelenidae	2	Neuroptera	Neuroptera unknown	1
	Hymenoptera	Scelionidae	10	Hemiptera	Alydidae	2	Diptera	Platystomatidae	1
	Thysanoptera	Thysanoptera unknown	8	Hemiptera	Coreidae	2	Coleoptera	Scarabaeidae	1
	Diptera	diptera unknown	7	Coleoptera	Lampyridae	2	Coleoptera	Silphidae	1
	Araneae	Linyphiidae	7	Lepidoptera	Lepidoptera unknow	2	Total		749
	Hemiptera	Lygaeidae	7	Hemiptera	Miridae	2			

Table 49. Total number of arthropods samples from the pitfall traps collected at Moore's nursery from May 2019 to July 2019 for the Mulch Mat treatment.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Mulch Mat	Collembola	Entomobryomorpha	168	Coleoptera	Lampyridae	4	Collembola	Collembola unknow	1
	Hymenoptera	Formicidae	65	Coleoptera	Nitidulidae	4	Hemiptera	Delpharidae	1
	Oribatida	Oribatidae	49	Araneae	Araneae unknow	3	Araneae	Dictynidae	1
	Hymenoptera	Platygastridae	46	Diptera	diptera unknown	3	Hemiptera	Hemiptera unknow	1
	Acari	unknown mite	29	Araneae	Linyphiidae	3	Coleoptera	Histeridae	1
	Coleoptera	Coleoptera unknown	27	Diptera	Cecidomyiidae	2	Mesostigmata	Mesostigmata unknown	1
	Araneae	Lycosidae	23	Hemiptera	Cydnidae	2	Diptera	Muscidae	1
	Coleoptera	Staphylinidae	18	Diptera	Drosophilidae	2	Collembola	Poduromorpha	1
	Coleoptera	Carabidae	10	Coleoptera	Latridiidae	2	Hemiptera	Reduviidae	1
	Collembola	Symphypleona	10	Hemiptera	Lygaeidae	2	Diptera	Sciaridae	1
	Diptera	Phoridae	8	Araneae	Agelenidae	1	Orthoptera	Tetrigidae	1
	Hemiptera	Aphididae	5	Diptera	Chironomidae	1	Thysanoptera	Thysanoptera unknow	1
	Orthoptera	Gryllidae	5	Coleoptera	Chrysomelidae	1	Total		510
	Hymenoptera	Braconidae	4	Hemiptera	Cicadellidae	1			

Table 50. Total number of arthropods samples from the sticky traps collected at Moore's nursery from May 2019 to July 2019 for the Cover Crop treatment.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Cover Crop	Unknown	Unknown	510	Hemiptera	Cercopidae	10	Hemiptera	Reduviidae	2
	Hemiptera	Cicadellidae	171	Hemiptera	Membracidae	10	Diptera	Stratiomyidae	2
	Diptera	Diptera unknown	138	Diptera	Sciardae	10	Diptera	Syrphidae	2
	Hemiptera	Miridae	83	Diptera	Sciaridae	10	Diptera	Tephritidae	2
	Hymenoptera	Platygastridae	72	Hymenoptera	Ceraphronidae	9	Hemiptera	Berytidae	1
	Coleoptera	Lampyridae	54	Coleoptera	Curculionidae	9	Hymenoptera	Bethylidae	1
	Coleoptera	Chrysomelidae	47	Coleoptera	Ptilodactylidae	8	Coleoptera	Carabidae	1
	Diptera	Sarcophagidae	34	Hymenoptera	Ichneumonidae	7	Coleoptera	Cerambycidae	1
	Hymenoptera	Chalcidoidea	28	Hymenoptera	Braconidae	6	Coleoptera	Corylophidae	1
	Hemiptera	Aphididae	23	Hymenoptera	Chrysidoidea	6	Coleoptera	Elateridae	1
	Diptera	Phoridae	19	Diptera	Dolichopodidae	6	Hemiptera	Enicocephalidae	1
	Diptera	Ulidiidae	18	Coleoptera	Cantharidae	5	Hemiptera	Geocoridae	1
	Diptera	Asilidae	17	Coleoptera	Latridiidae	5	Coleoptera	Melyridae	1
	Hemiptera	Cydnidae	15	Hymenoptera	Apoidea	4	Coleoptera	Mordellidae	1
	Hymenoptera	Mymaridae	15	Hymenoptera	Diapriidae	4	Coleoptera	Nitidulidae	1
	Hymenoptera	Trichogrammatidae	15	Coleoptera	Phalacridae	4	Mecoptera	Panorpidae	1
	Diptera	Cecidomyiidae	13	Hymenoptera	Formicidae	3	Hemiptera	Plataspidae	1
	Diptera	Chironomidae	13	Coleoptera	Staphylinidae	3	Hemiptera	Rhyparochromidae	1
	Hemiptera	Aleyrodidae	12	Orthoptera	Tettigoniidae	3	Araneae	Salticidae	1
	Diptera	Ceratopogonidae	12	Hemiptera	Anthocoridae	2	Collembola	Symphypleona	1
	Coleoptera	Coccinellidae	12	Hemiptera	Derbidae	2	Diptera	Tachinidae	1
	Hymenoptera	Cynipoidea	11	Diptera	Muscidae	2	Total		1485

Table 51. Total number of arthropods samples from the sticky traps collected at Moore's nursery from May 2019 to July 2019 for the Cover Crop Early Kill treatment.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Cover Early Kill	Unknown	Unknown	406	Diptera	Syrphidae	9	Coleoptera	Mordellidae	2
	Diptera	Diptera unknown	187	Hymenoptera	Trichogrammatidae	9	Hemiptera	Psyllidae	2
	Hemiptera	Cicadellidae	144	Hemiptera	Aleyrodidae	8	Coleoptera	Staphylinidae	2
	Coleoptera	Chrysomelidae	83	Hemiptera	Cercopidae	7	Hymenoptera	Braconidae	1
	Hemiptera	Miridae	81	Coleoptera	Chysomelidae	7	Coleoptera	Carabidae	1
	Coleoptera	Lampyridae	56	Coleoptera	Cantharidae	6	Coleoptera	Cleridae	1
	Hymenoptera	Platygastridae	43	Hemiptera	Derbidae	6	Diptera	Conopidae	1
	Hemiptera	Aphididae	30	Hymenoptera	Ichneumonoidea	6	Hemiptera	Coreidae	1
	Hymenoptera	Chalcidoidea	29	Hymenoptera	Ceraphronidae	5	Coleoptera	Elateridae	1
	Diptera	Sarcophagidae	29	Coleoptera	Corylophidae	5	Hymenoptera	Encyrtidae	1
	Diptera	Sciardae	28	Diptera	Dolichopodidae	5	Hymenoptera	Formicidae	1
	Diptera	Cecidomyiidae	18	Coleoptera	Phalacridae	5	Hemiptera	Lygaeoidea	1
	Coleoptera	Coccinellidae	16	Diptera	Ulidiidae	5	Hemiptera	Reduviidae	1
	Hemiptera	Cydnidae	15	Hemiptera	Anthocoridae	4	Araneae	Salticidae	1
	Hymenoptera	Mymaridae	15	Hemiptera	Geocoridae	4	Hemiptera	scale	1
	Diptera	Chironomidae	13	Coleoptera	Ptilodactylidae	4	Coleoptera	Silvanidae	1
	Coleoptera	Curculionidae	13	Hymenoptera	Diapriidae	3	Diptera	Tachinidae	1
	Diptera	Phoridae	13	Coleoptera	Latridiidae	3	Diptera	Tephritidae	1
	Hymenoptera	Cynipoidea	11	Diptera	Muscidae	3	Orthoptera	Tettigoniidae	1
	Diptera	Asilidae	10	Hemiptera	Thyreocoridae	3	Diptera	Tipulidae	1
	Diptera	Ceratopogonidae	9	Hymenoptera	Apoidea	2	Total		1392
	Hemiptera	Membracidae	9	Coleoptera	Erotylidae	2			

Table 52. Total number of arthropods samples from the sticky traps collected at Moore's nursery from May 2019 to July 2019 for the Herbicide treatment.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Herbicide	Unknown	Unknown	538	Hymenoptera	Trichogrammatidae	10	Coleoptera	Latridiidae	2
	Diptera	Diptera unknown	190	Hemiptera	Aleyrodidae	9	Diptera	Muscidae	2
	Hemiptera	Cicadellidae	151	Hymenoptera	Ichneumonoidea	9	Hemiptera	Reduviidae	2
	Coleoptera	Chrysomelidae	107	Diptera	Ulidiidae	9	Hymenoptera	Agridae	1
	Hemiptera	Miridae	67	Coleoptera	Cantharidae	7	Hemiptera	Alydidae	1
	Hymenoptera	Chalcidoidea	59	Hymenoptera	Ceraphronidae	7	Hymenoptera	Braconidae	1
	Hymenoptera	Platygastridae	54	Diptera	Ceratopogonidae	7	Coleoptera	Cerylonidae	1
	Coleoptera	Rhipiphoridae	42	Diptera	Dolichopodidae	7	Hymenoptera	Chrysididae	1
	Diptera	Sarcophagidae	38	Diptera	Asilidae	5	Hemiptera	Coreidae	1
	Hemiptera	Aphididae	30	Hymenoptera	Chrysidoidea	5	Coleoptera	Elateridae	1
	Hymenoptera	Mymaridae	23	Hymenoptera	Formicidae	5	Coleoptera	Erotylidae	1
	Coleoptera	Lampyridae	21	Coleoptera	Phalacridae	5	Diptera	Hybotidae	1
	Hemiptera	Cydnidae	20	Coleoptera	Staphylinidae	5	Coleoptera	Mycetophagidae	1
	Hymenoptera	Cynipoidea	18	Diptera	Syrphidae	5	Hemiptera	Nabidae	1
	Diptera	Sciaridae	17	Hymenoptera	Apoidea	4	Coleoptera	Nitidulidae	1
	Coleoptera	Coccinellidae	15	Hemiptera	Anthocoridae	3	Hemiptera	Pentatomidae	1
	Diptera	Chironomidae	13	Coleoptera	Corylophidae	3	Hemiptera	Plataspidae	1
	Diptera	Phoridae	11	Hymenoptera	Diapriidae	3	Hemiptera	Psyllidae	1
	Diptera	Cecidomyiidae	10	Hemiptera	Phylloxeridae	3	Collembola	Symphypleona	1
	Hemiptera	Cercopidae	10	Araneae	Salticidae	3	Diptera	Tachinidae	1
	Coleoptera	Curculionidae	10	Diptera	Stratiomyidae	3	Hemiptera	Thyreocoridae	1
	Hemiptera	Membracidae	10	Diptera	Conopidae	2	Total		1609
	Coleoptera	Ptilodactylidae	10	Hemiptera	Geocoridae	2			

Table 53. Total number of arthropods samples from the sticky traps collected at Moore's nursery from May 2019 to July 2019 for the Mulch Mat treatment.

Treatment	Order	Family	#	Order	Family	#	Order	Family	#
Mulch Mat	Unknown	Unknown	527	Diptera	Sciaridae	12	Orthoptera	Tettigoniidae	3
	Diptera	Diptera unknown	177	Diptera	Ulidiidae	12	Diptera	Bibionidae	2
	Hemiptera	Cicadellidae	165	Diptera	Cecidomyiidae	11	Diptera	Muscidae	2
	Hemiptera	Miridae	83	Hymenoptera	Trichogrammatidae	10	Mecoptera	Panorpidae	2
	Coleoptera	Chrysomelidae	69	Hemiptera	Aleyrodidae	9	Araneae	Salticidae	2
	Hymenoptera	Platygastridae	63	Diptera	Dolichopodidae	9	Coleoptera	Staphylinidae	2
	Hymenoptera	Chalcidoidea	56	Hymenoptera	Apoidea	8	Diptera	Syrphidae	2
	Diptera	Sarcophagidae	44	Hymenoptera	Ichneumonoidea	8	Hemiptera	Anthocoridae	1
	Coleoptera	Lampyridae	39	Coleoptera	Ptilodactylidae	7	Hymenoptera	Argidae	1
	Hemiptera	Cydnidae	23	Hymenoptera	Ceraphronidae	5	Hemiptera	Bethylidae	1
	Diptera	Phoridae	19	Diptera	Ceratopogonidae	5	Coleoptera	Buprestidae	1
	Hemiptera	Aphididae	18	Hemiptera	Phylloxeridae	5	Coleoptera	Carabidae	1
	Coleoptera	Rhipiphoridae	18	Coleoptera	Cantharidae	4	Hymenoptera	Chyrsidoidea	1
	Hemiptera	Membracidae	16	Coleoptera	Latridiidae	4	Coleoptera	Erotylidae	1
	Hemiptera	Cercopidae	15	Hymenoptera	Braconidae	3	Hymenoptera	Formicidae	1
	Diptera	Asilidae	13	Coleoptera	Corylophidae	3	Hemiptera	Lygaeoidea	1
	Coleoptera	Curculionidae	13	Hemiptera	Derbidae	3	Hymenoptera	Megaspilidae	1
	Diptera	Chironomidae	12	Coleoptera	Elateridae	3	Diptera	Psychodidae	1
	Coleoptera	Coccinellidae	12	Collembola	Entomobryomorpha	3	Hemiptera	Rhyparochromidae	1
	Hymenoptera	Cynipoidea	12	Coleoptera	Phalacridae	3	Hemiptera	scale	1
	Hymenoptera	Mymaridae	12	Diptera	Stratiomyidae	3	Diptera	Tephritidae	1
	Total								1565

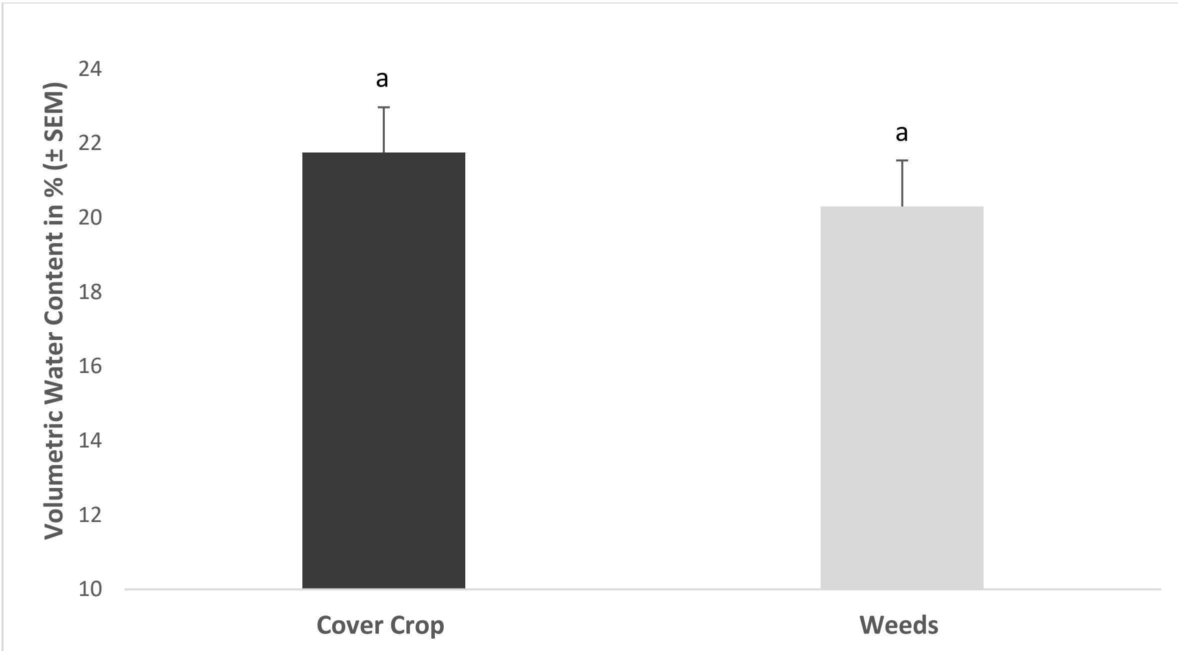

Figure 1. Cover crop and weeds volumetric water content (± SEM) from 7 mo, Trial 1 2019 with crimson clover as a winter cover crop. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 0.69$, df = 1, $P = 0.4082$).

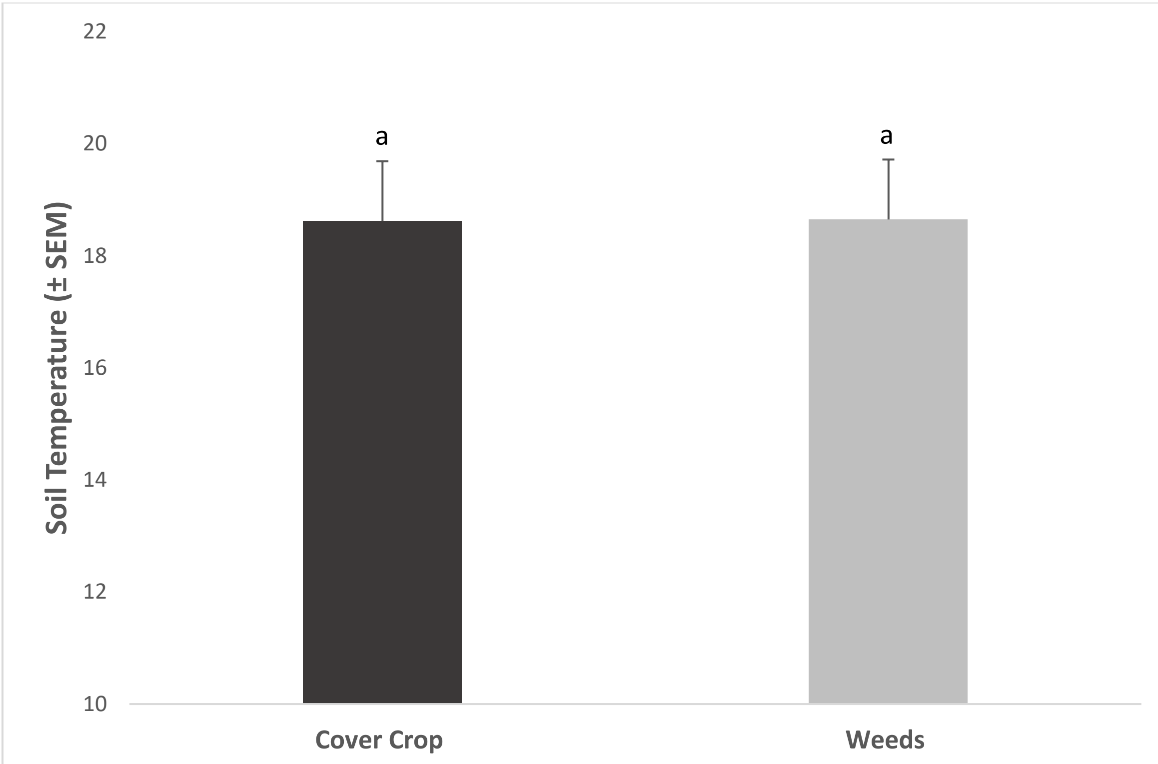

Figure 2. Cover crop and weeds soil temperature (± SEM) from 7 mo, Trial 1 2019 with crimson clover as a winter cover crop. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 0.0$, df = 1, $P = 0.9817$)

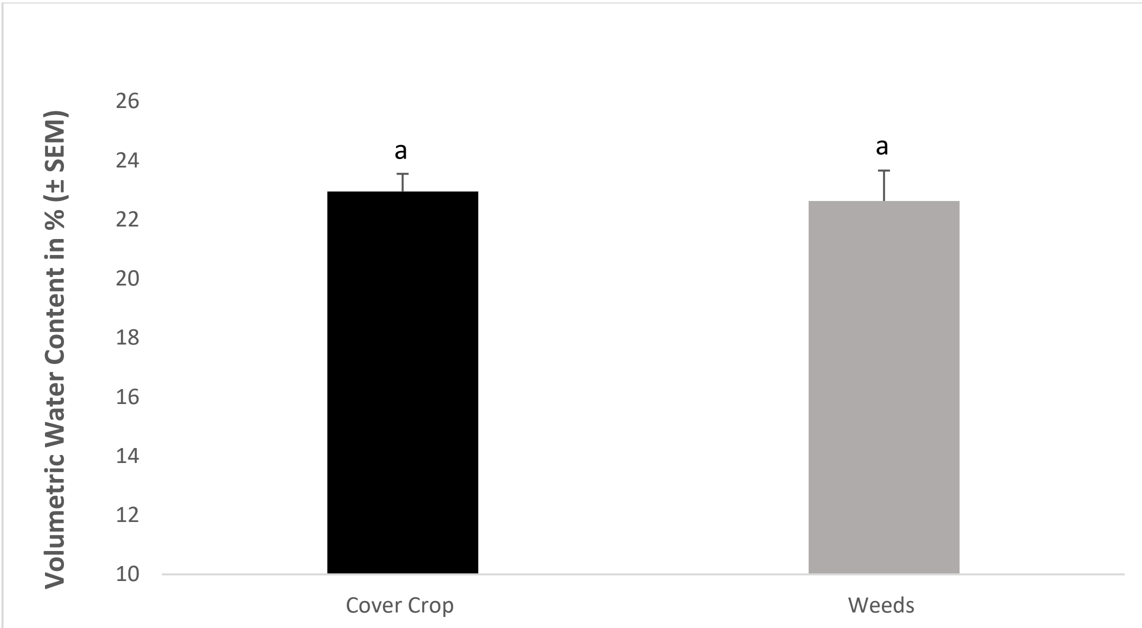

Figure 3. Cover crop and weeds volumetric water content (± SEM) from 7 mo, Trial 2 2020 with crimson clover as a winter cover crop. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 0.36$, df = 1, $P = 0.551$).

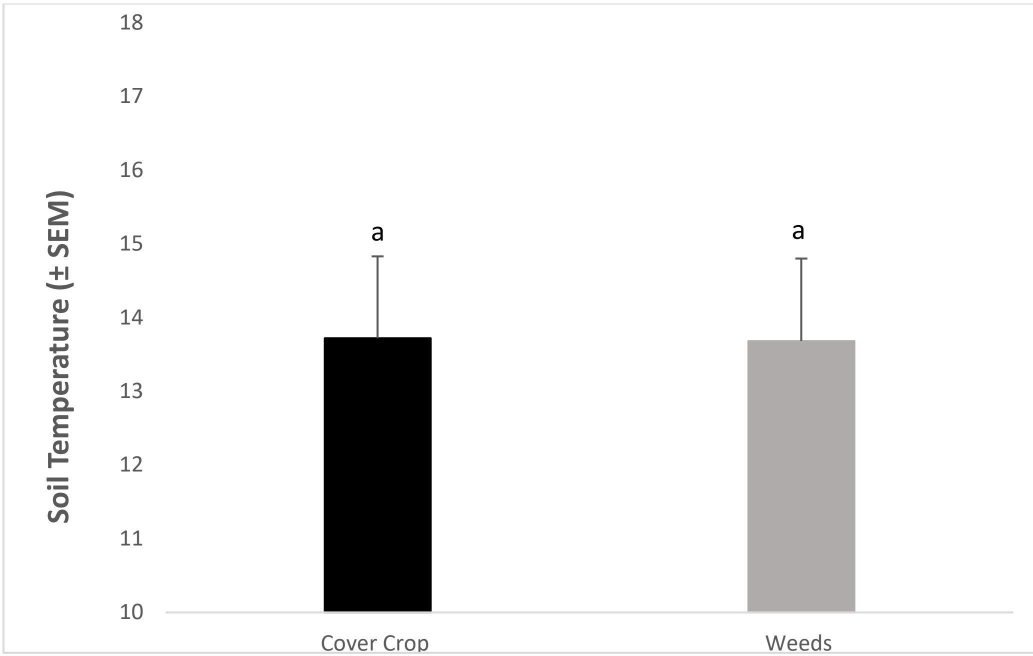

Figure 4. Cover crop and weeds soil temperature (± SEM) from 7 mo, Trial 2 2020 with crimson clover as a winter cover crop. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 0.0$, df = 1, $P = 0.9499$).

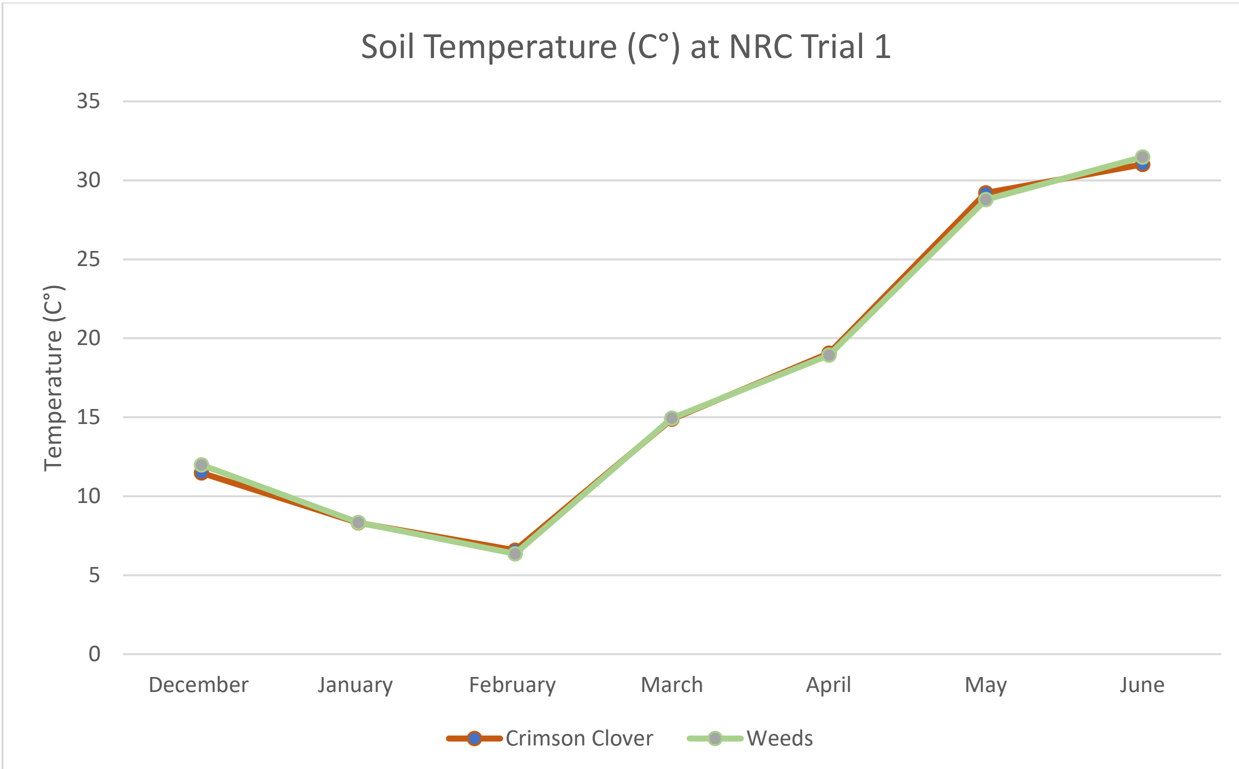

Figure 5. Soil temperatures at NRC plot Trial 1 from Dec. 2018 to Jun. 2019. Using crimson clover as cover crop and weeds as control.

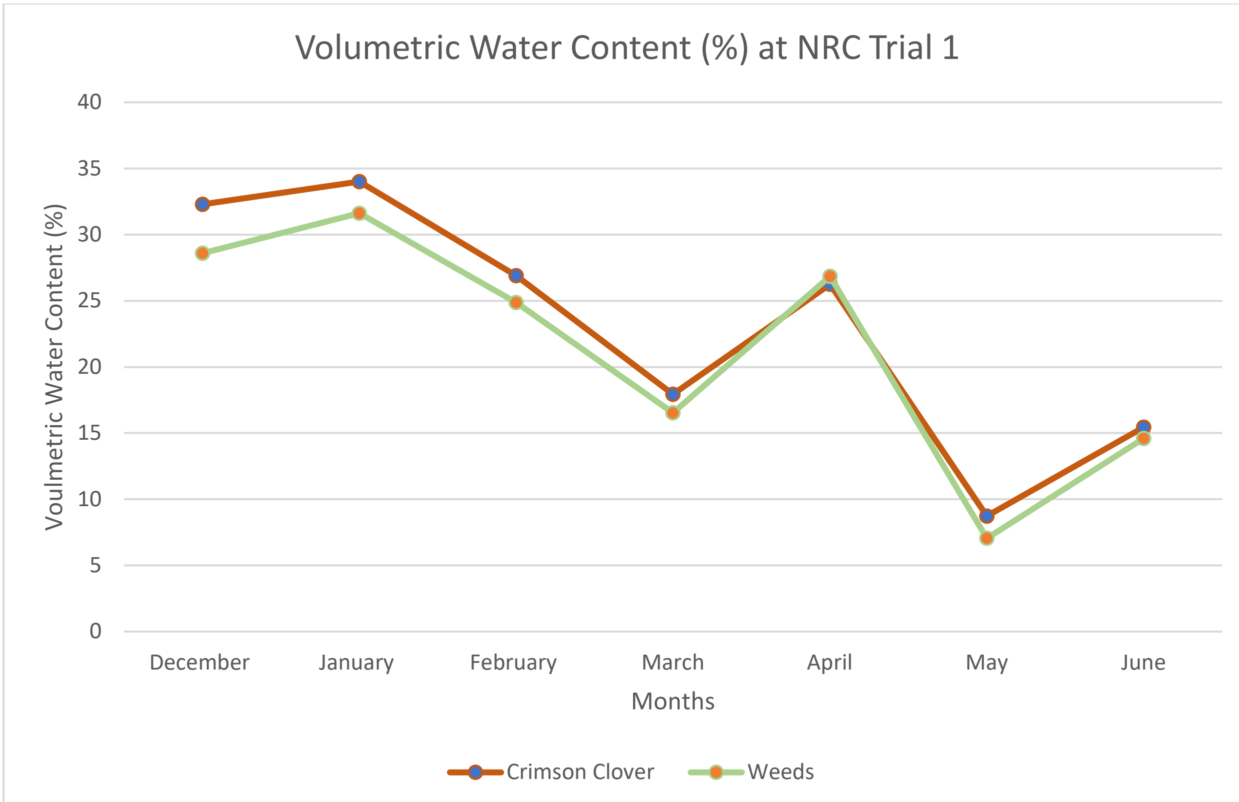

Figure 6. Volumetric water content at NRC plot Trial 1 from Dec. 2018 to Jun. 2019.

Using crimson clover as cover crop and weeds as control.

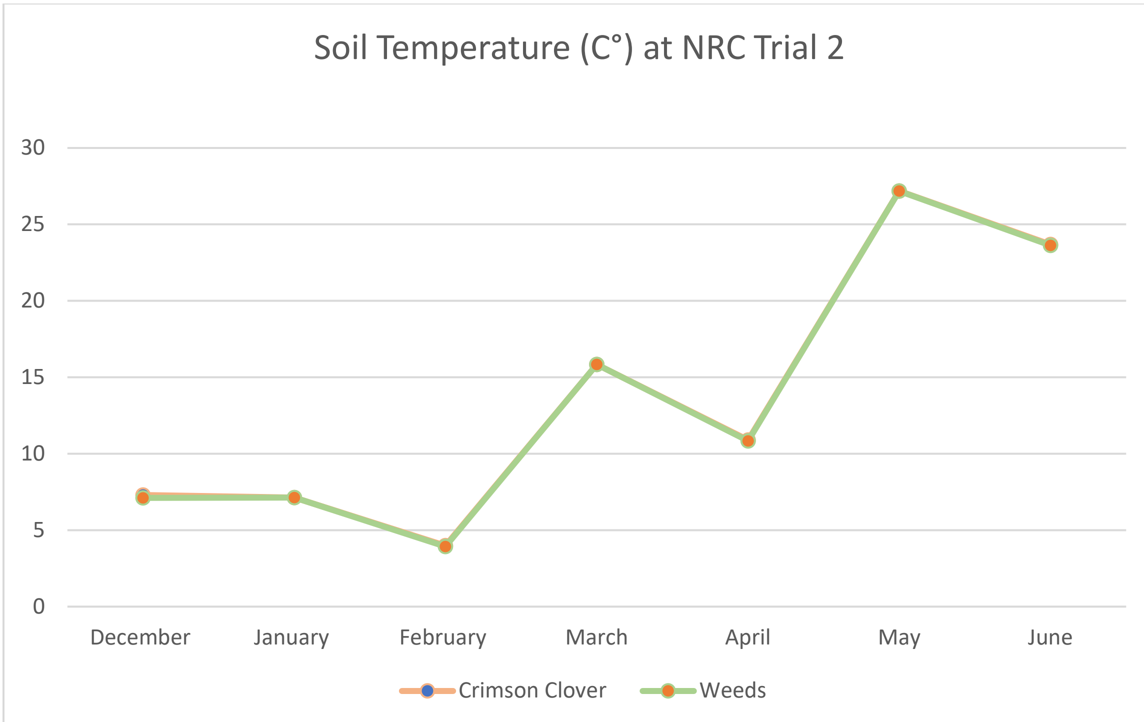

Figure 7. Soil temperatures at NRC plot Trial 2 from Dec. 2019 to Jun. 2020. Using crimson clover as cover crop and weeds as control.

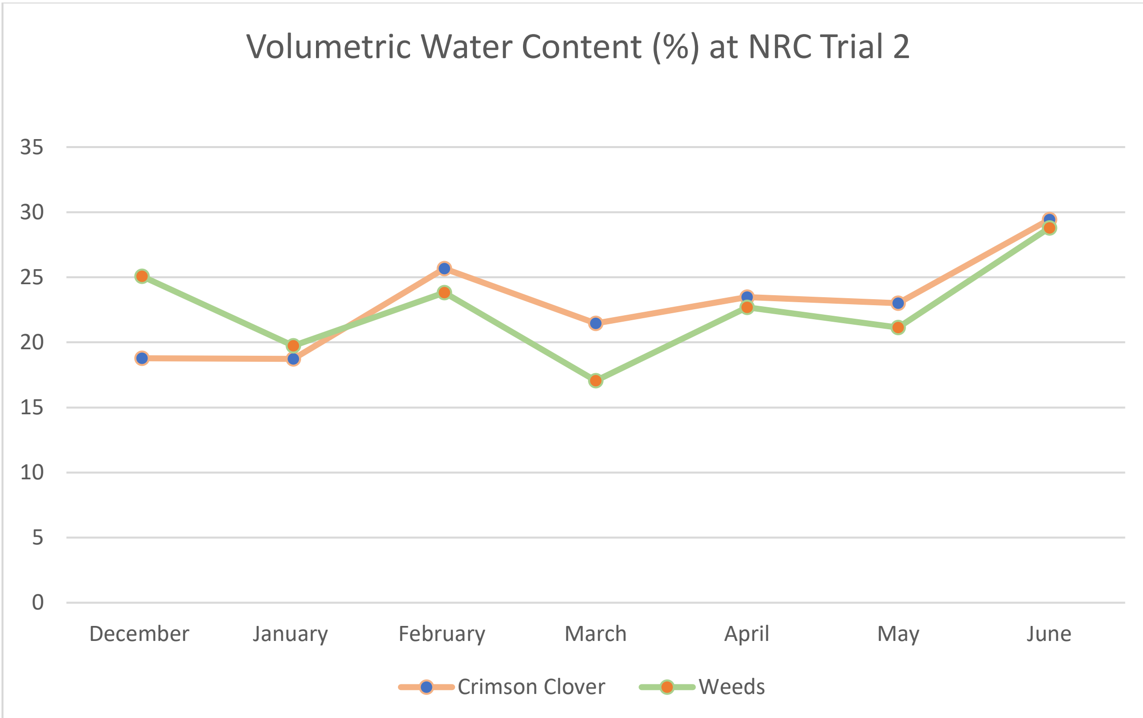

Figure 8. Volumetric water content at NRC plot Trial 2 from Dec. 2019 to Jun. 2020. Using crimson clover as cover crop and weeds as control.

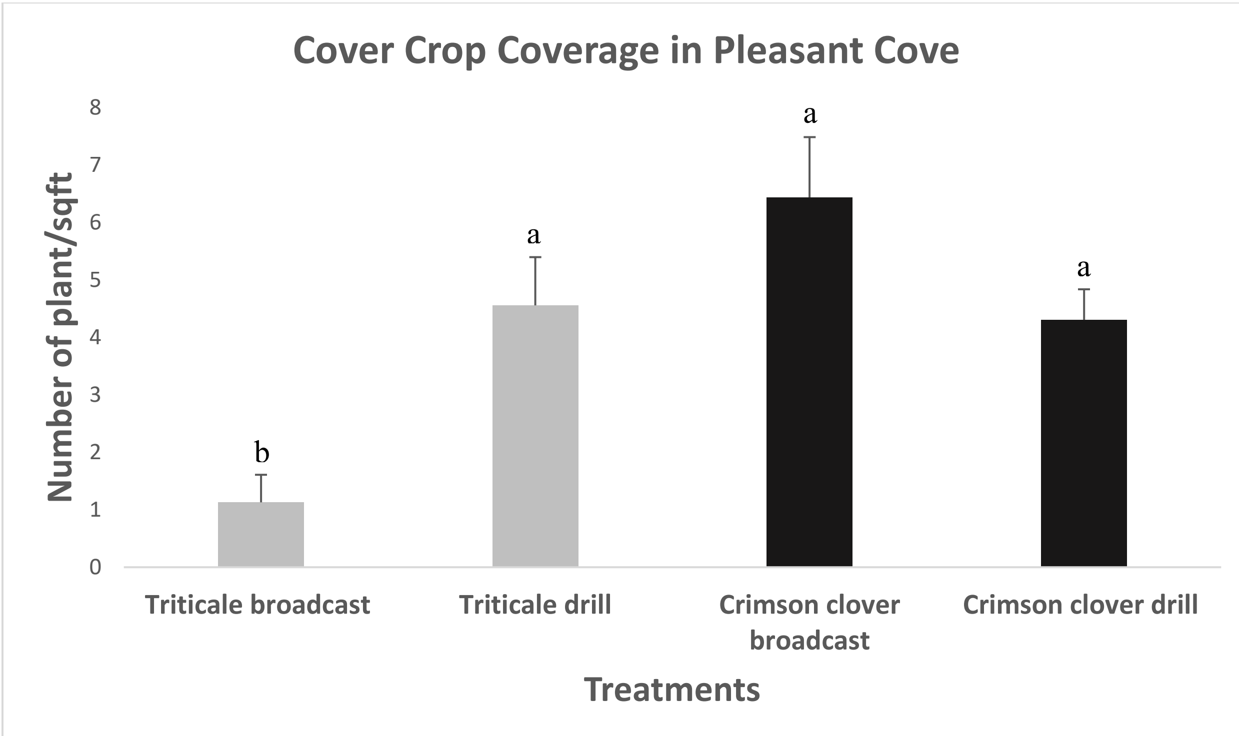

Figure 9. Average cover crop ground area coverage at Pleasant Cove, using triticale and crimson clover as winter cover crops with two planting methods; Drill and Broadcast. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 8.38$, df = 3, $P = 0.0028$).

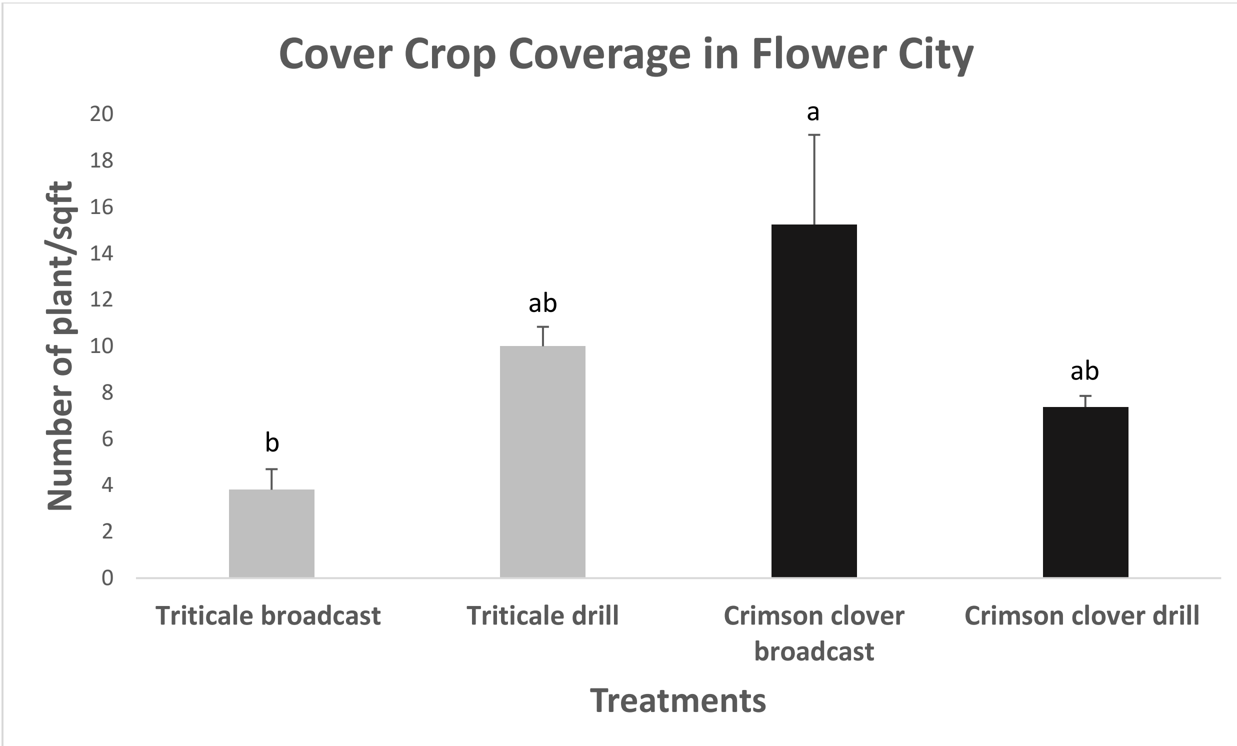

Figure 10. Average cover crop ground area coverage at Flower City, using triticale and crimson clover as winter cover crops with two planting methods; Drill and Broadcast. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 5.57$, df = 3, $P = 0.0125$).

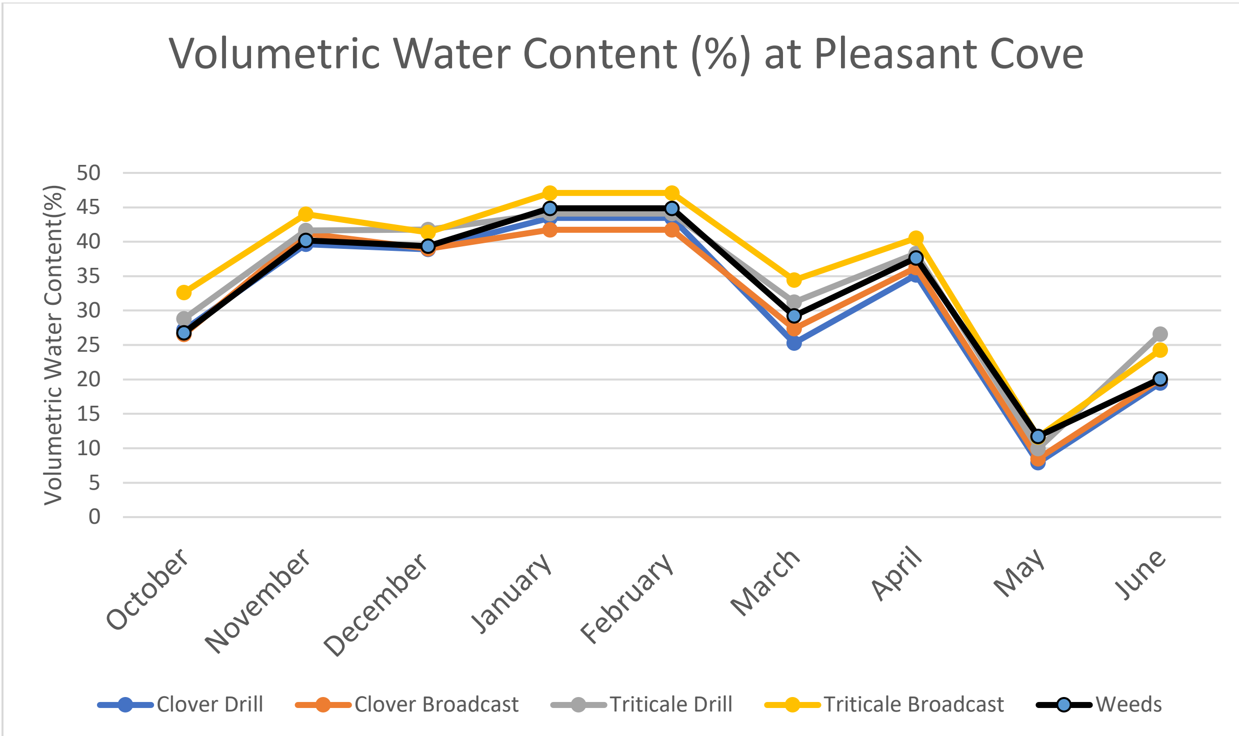

Figure 11. Volumetric water content in percentage at Pleasant Cove. Data collected from October 2018 to June 2019. Using triticale and crimson clover as winter cover crops with two planting methods, drill, and broadcast.

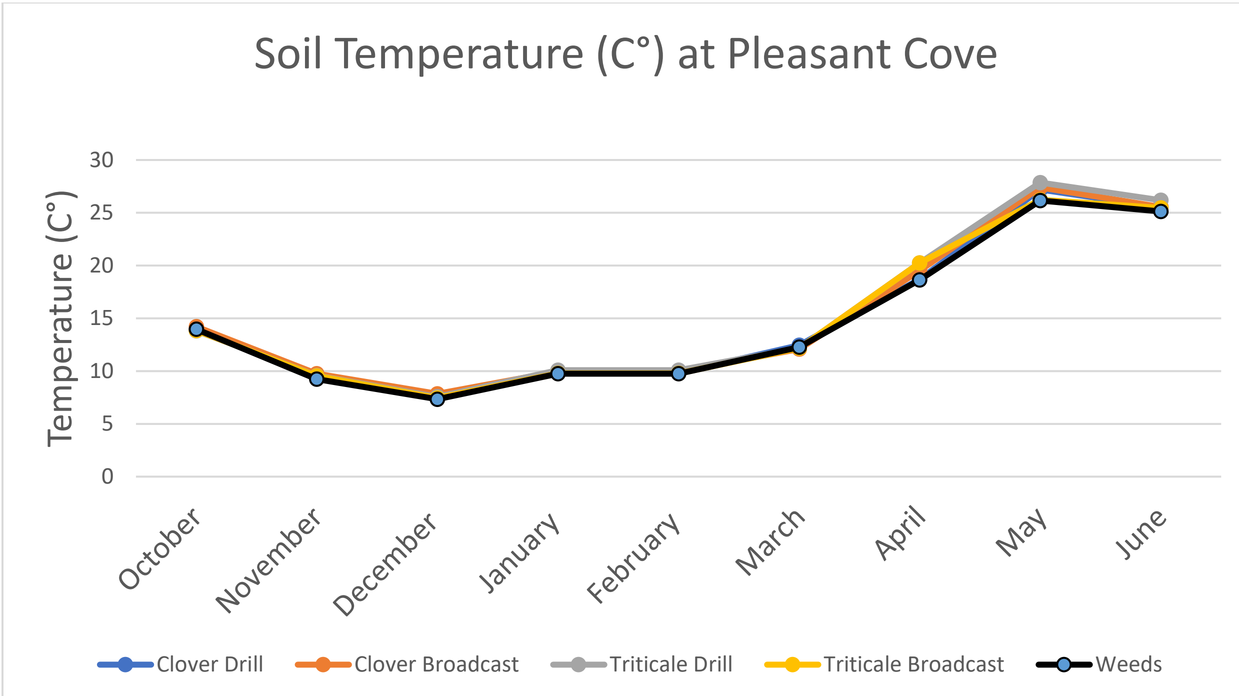

Figure 12. Average soil temperature (C°) by month at Pleasant Cove. Data collected from October 2018 to June 2019. Using triticale and crimson clover as winter cover crops with two planting methods, drill, and broadcast.

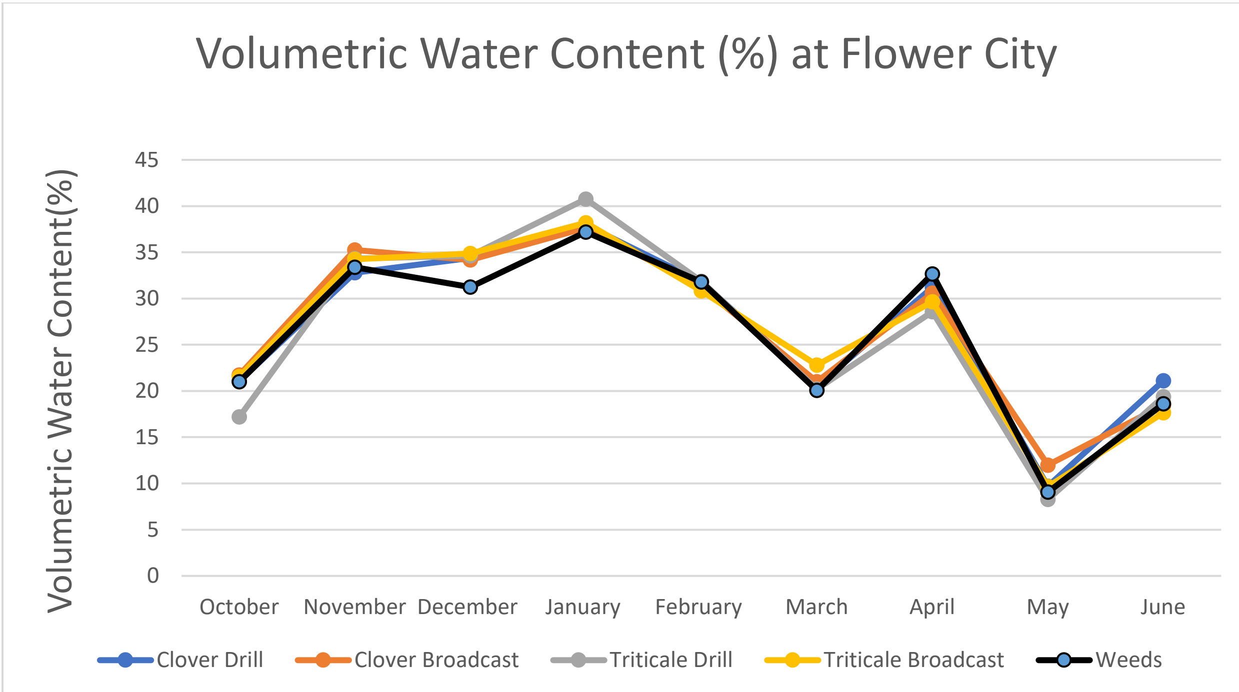

Figure 13. Volumetric water content in percentage at Flower City. Data collected from October 2018 to June 2019. Using triticale and crimson clover as winter cover crops with two planting methods, drill, and broadcast.

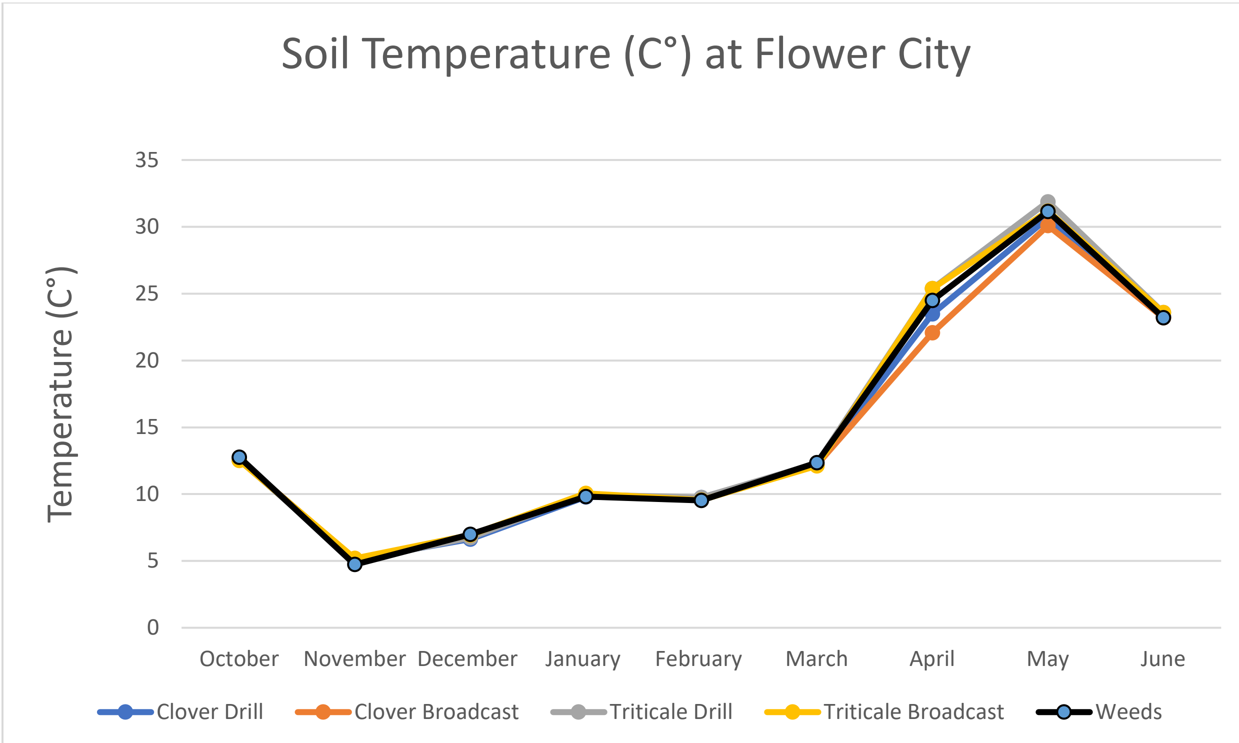

Figure 14. Average soil temperature (C°) by month at Flower City. Data collected from October 2018 to June 2019. Using triticale and crimson clover as winter cover crops with two planting methods, drill, and broadcast.

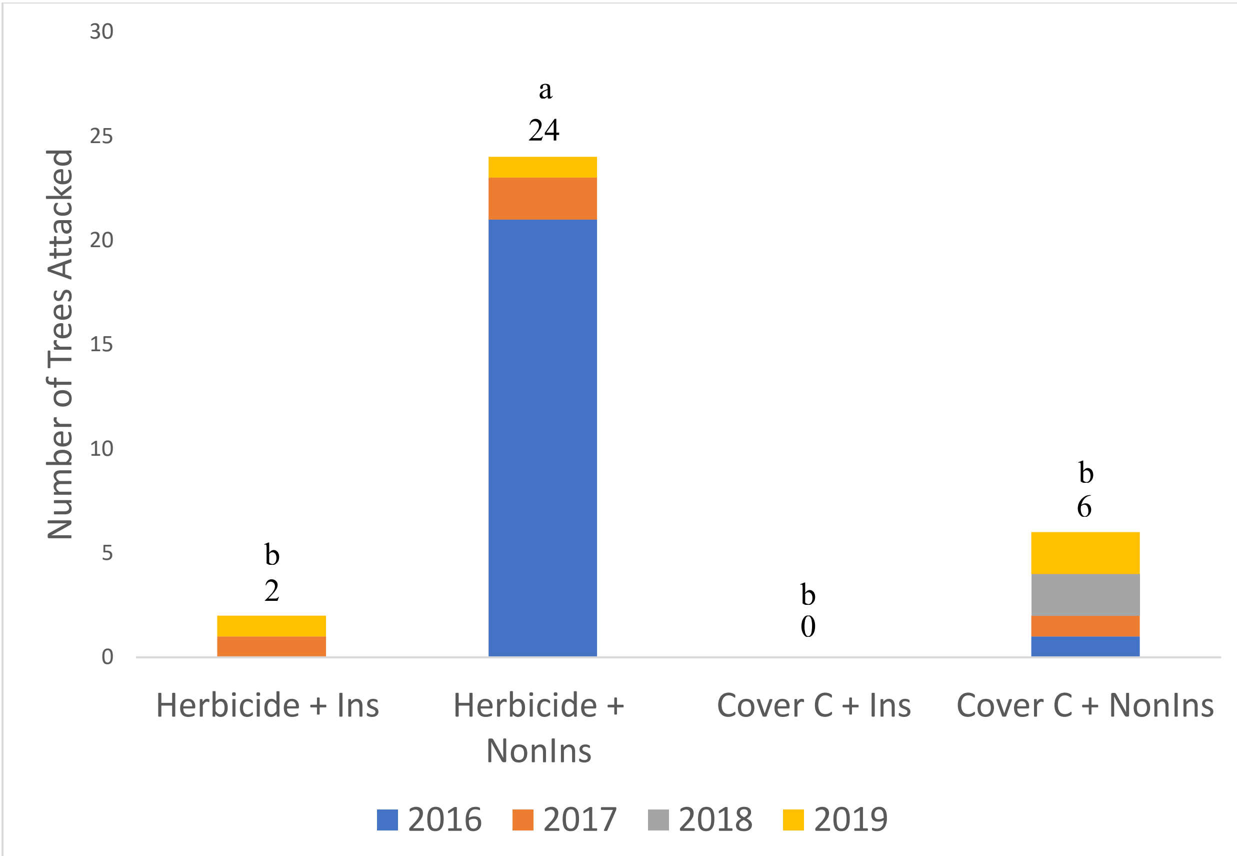

Figure 15. Total number of trees damaged by flatheaded borers in treatments after 4 yr. Tree damage was analyzed by using a General Linear Model fitted to a negative binomial distribution (Proc Genmod) (Chi-Square = 34.40, df = 3, P = 0.0001). Treatments: 1) Herbicide + Insecticide, 2) Herbicide + Non-Insecticide, 3) Cover Crop + Insecticide and 4) Cover Crop + non-insecticide. Cover crops used were winter wheat, crimson clover, and annual rye grass.

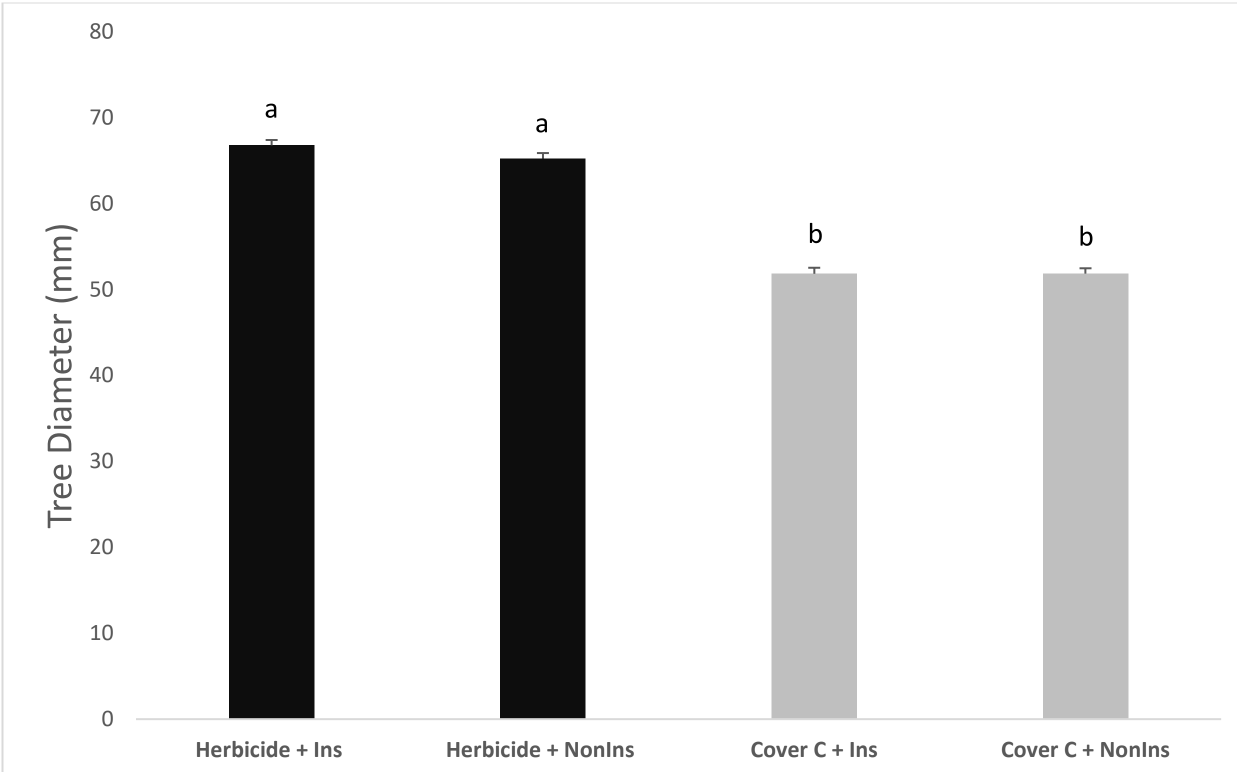

Figure 16. Final tree diameter after 4-yr production. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 88.68$, df = 6, $P = 0.0001$). Treatments: 1) Herbicide + Insecticide, 2) Herbicide + Non-Insecticide, 3) Cover Crop + Insecticide and 4) Cover Crop + non-insecticide. Cover crops used were winter wheat, crimson clover, and annual rye grass.

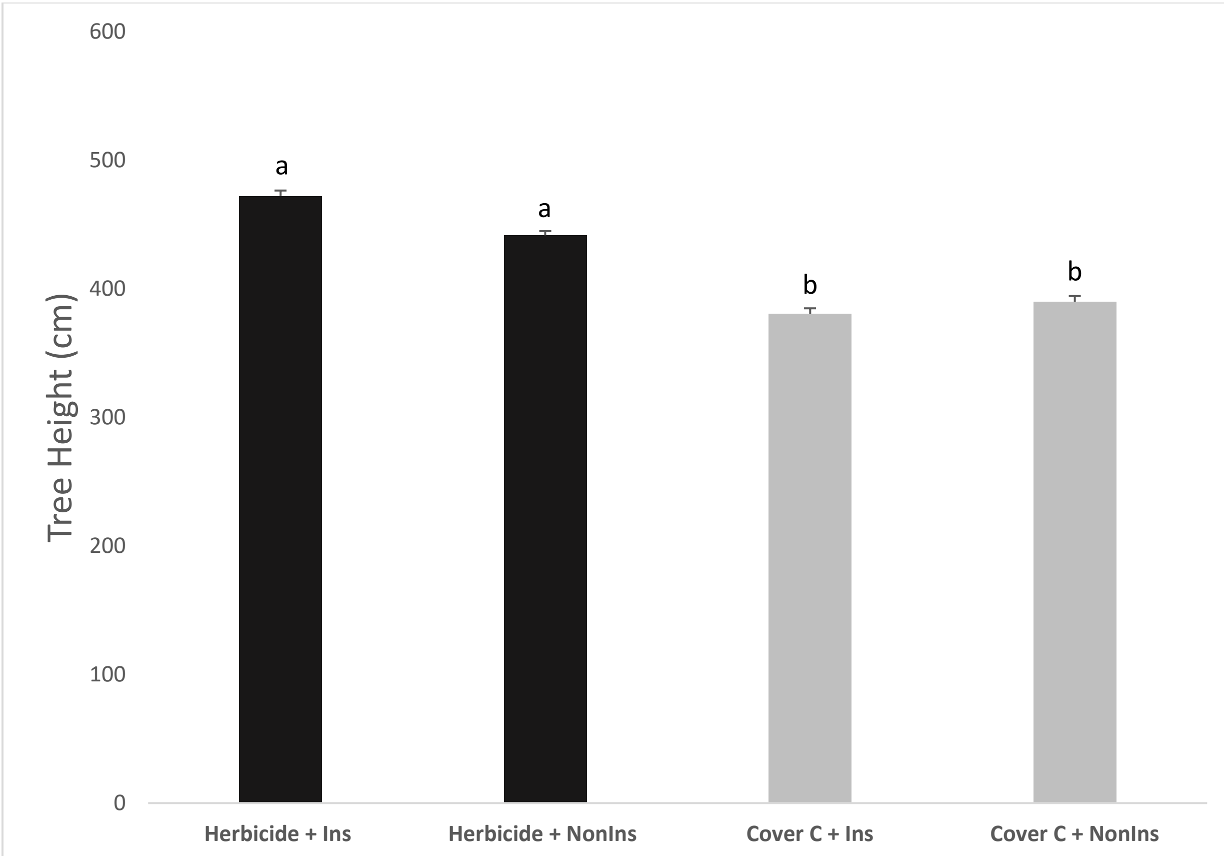

Figure 17. Final tree height after 4-yr production. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 60.85$, df = 6, $P = 0.0001$). Treatments: 1) Herbicide + Insecticide, 2) Herbicide + Non-Insecticide, 3) Cover Crop + Insecticide and 4) Cover Crop + non-insecticide. Cover crops used were winter wheat, crimson clover, and annual rye grass.

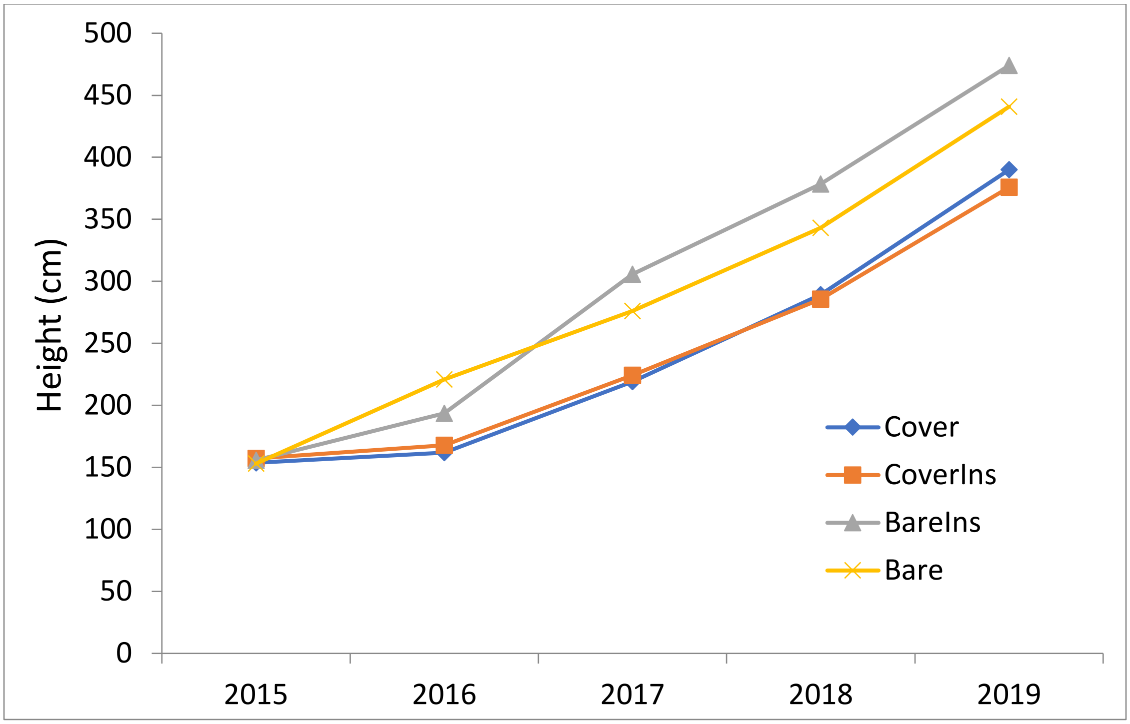

Figure 18. Tree height growth over time after 4-yr production. Treatments: 1) Herbicide + Insecticide (BareIns), 2) Herbicide (Bare), 3) Cover Crop + Insecticide (CoverIns) and 4) Cover Crop + non-insecticide (Cover). Cover crops used were winter wheat, crimson clover, and annual rye grass.

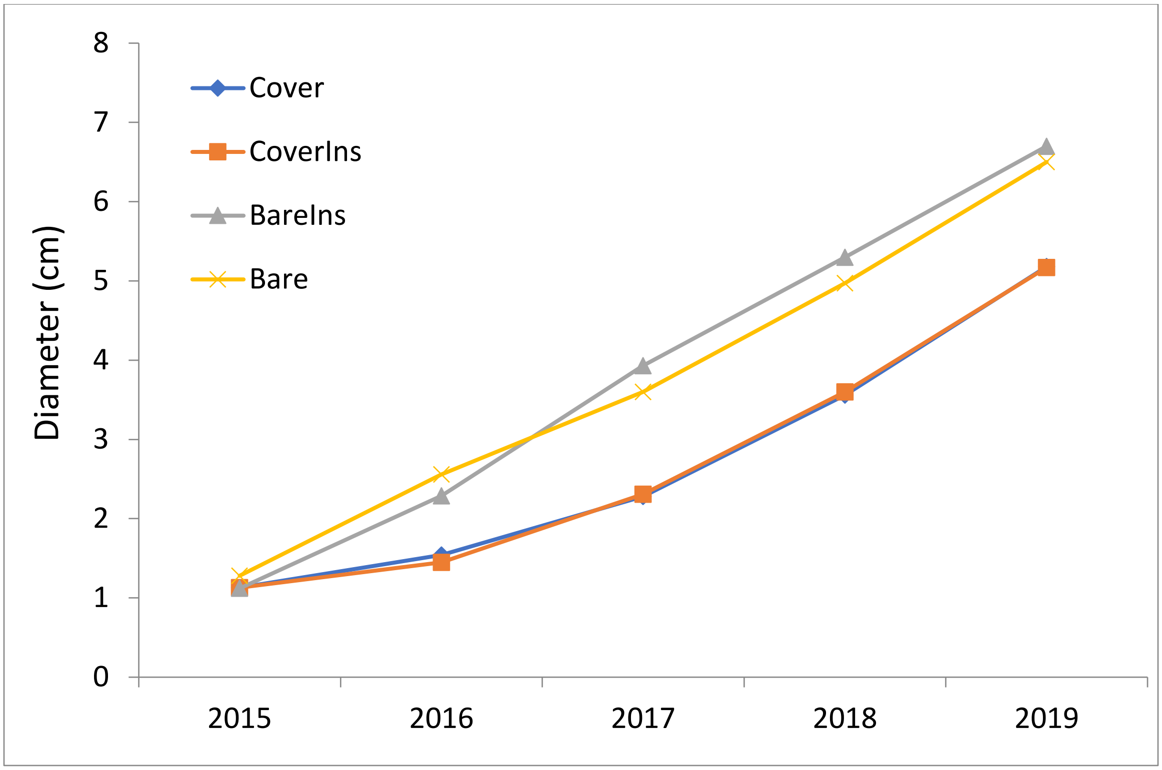

Figure 19. Tree caliper growth over time after 4-yr production. Treatments: 1) Herbicide + Insecticide (BareIns), 2) Herbicide (Bare), 3) Cover Crop + Insecticide (CoverIns) and 4) Cover Crop + non-insecticide (Cover). Cover crops used were winter wheat, crimson clover, and annual rye grass.

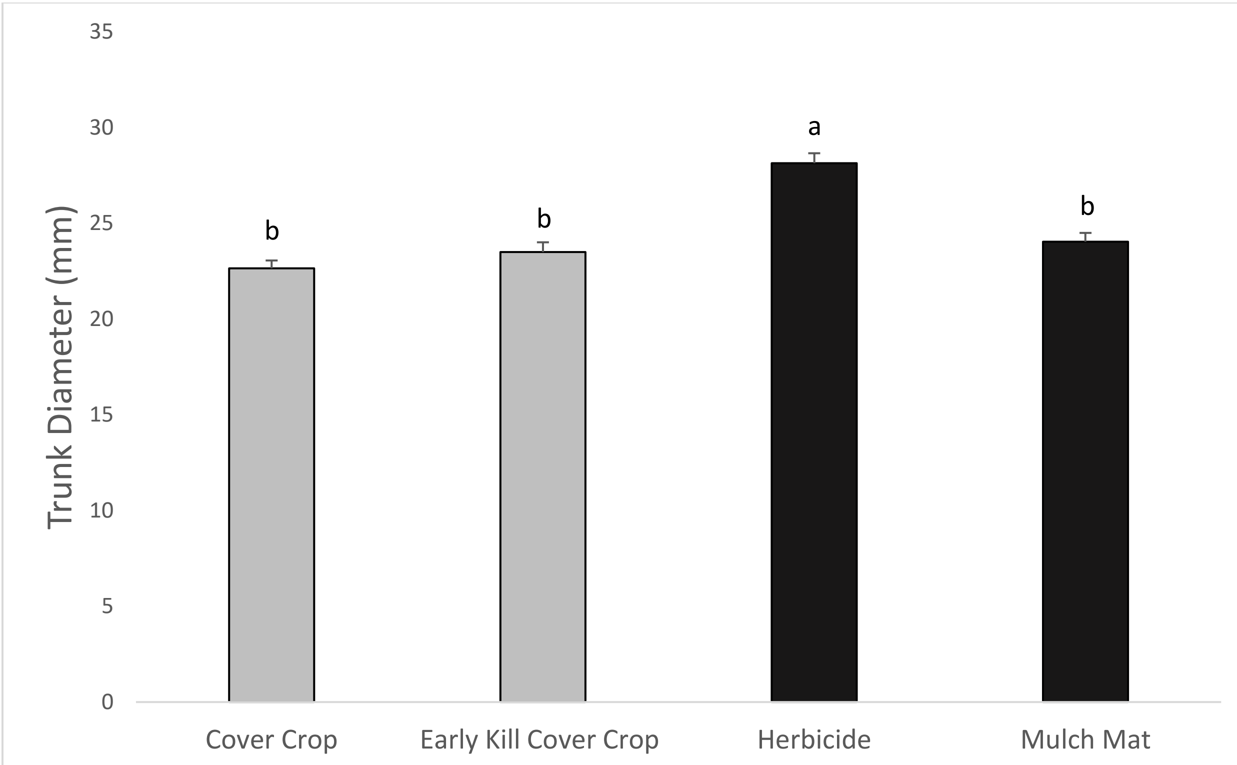

Figure 20. Final tree diameter after 1-yr. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 26.11$, df = 3, $P = 0.0001$). Treatments: 1) Cover Crop, 2) Early Kill Cover Crop, 3) Herbicide and 4) Mulch Mat. Cover crop used were crimson clover and triticale.

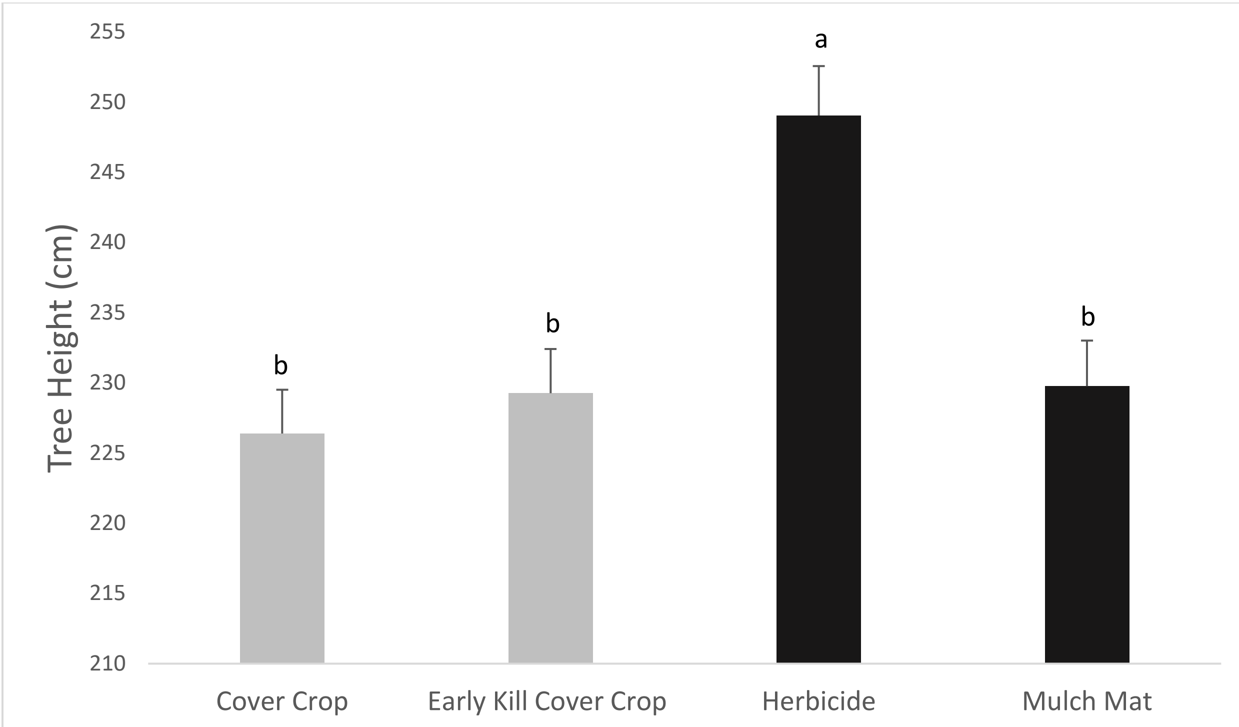

Figure 21. Final tree height after 1-yr. Values with different letters are statistically different by General Linear Model (GLM) with means separated by LSmeans adjusted Tukey analysis ($P < 0.05$) ($F = 10.12$, df = 3, $P = 0.0001$). Treatments: 1) Cover Crop, 2) Early Kill Cover Crop, 3) Herbicide and 4) Mulch Mat. Cover crop used were crimson clover and triticale.

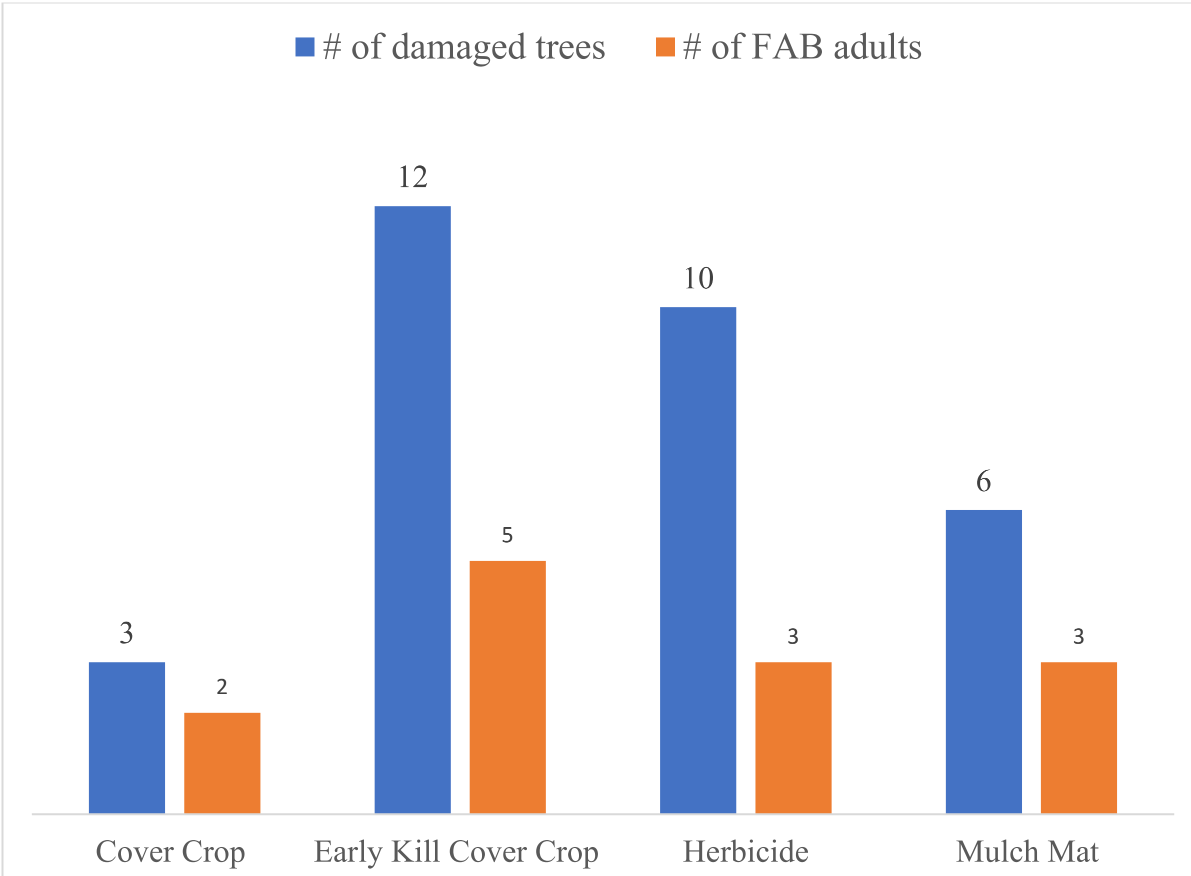

Figure 22. Total number of trees damaged by flatheaded appletree borer in treatments after 1-yr and number of FAB adults emerged from rearing cages in May 2020. Treatments: 1) Cover Crop, 2) Early Kill Cover Crop, 3) Herbicide and 4) Mulch Mat. Cover crop used were crimson clover and triticale.

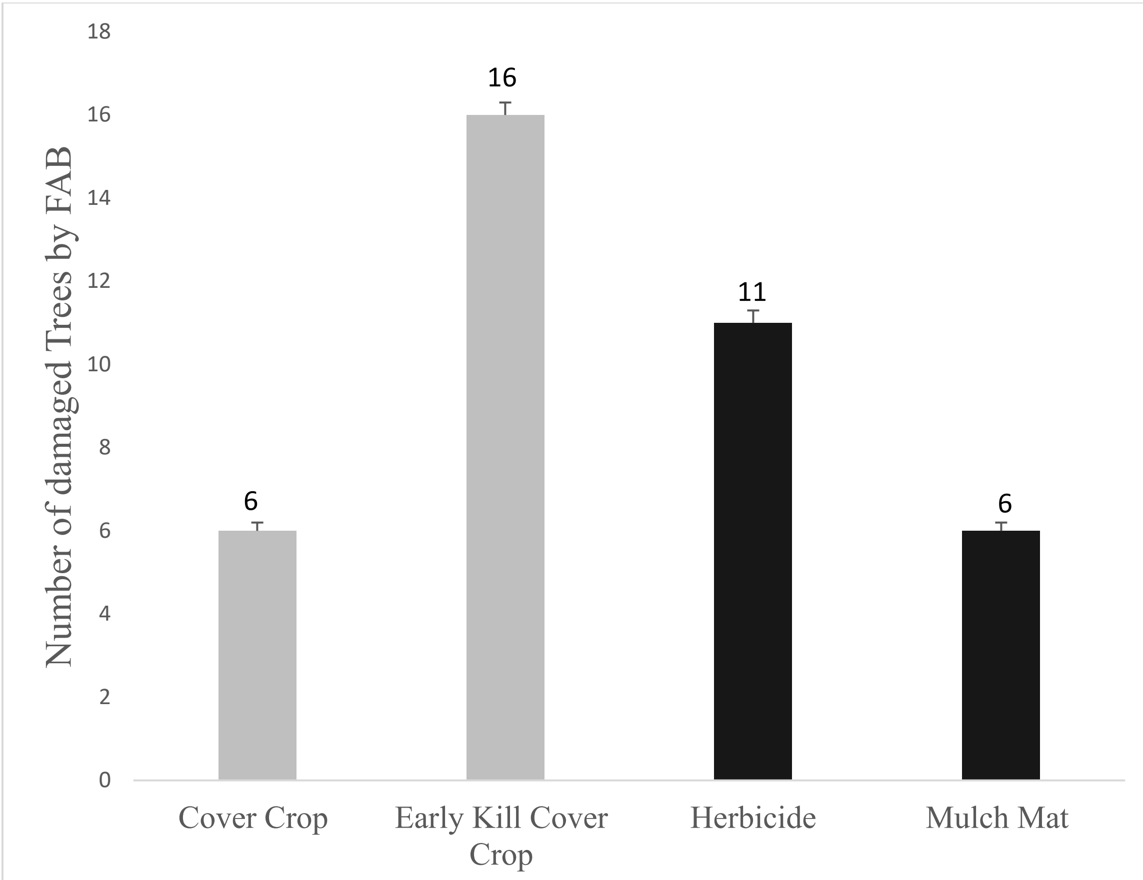

Figure 23. Total number of trees damaged by flatheaded appletree borer in treatments after 2-yr. Tree damage was analyzed by using a General Linear Model fitted to a negative binomial distribution (Proc Genmod) (Chi-Square = 6.81, df = 3, P = 0.0782). Treatments: 1) Cover Crop, 2) Early Kill Cover Crop, 3) Herbicide and 4) Mulch Mat. Cover crop used were crimson clover and triticale.

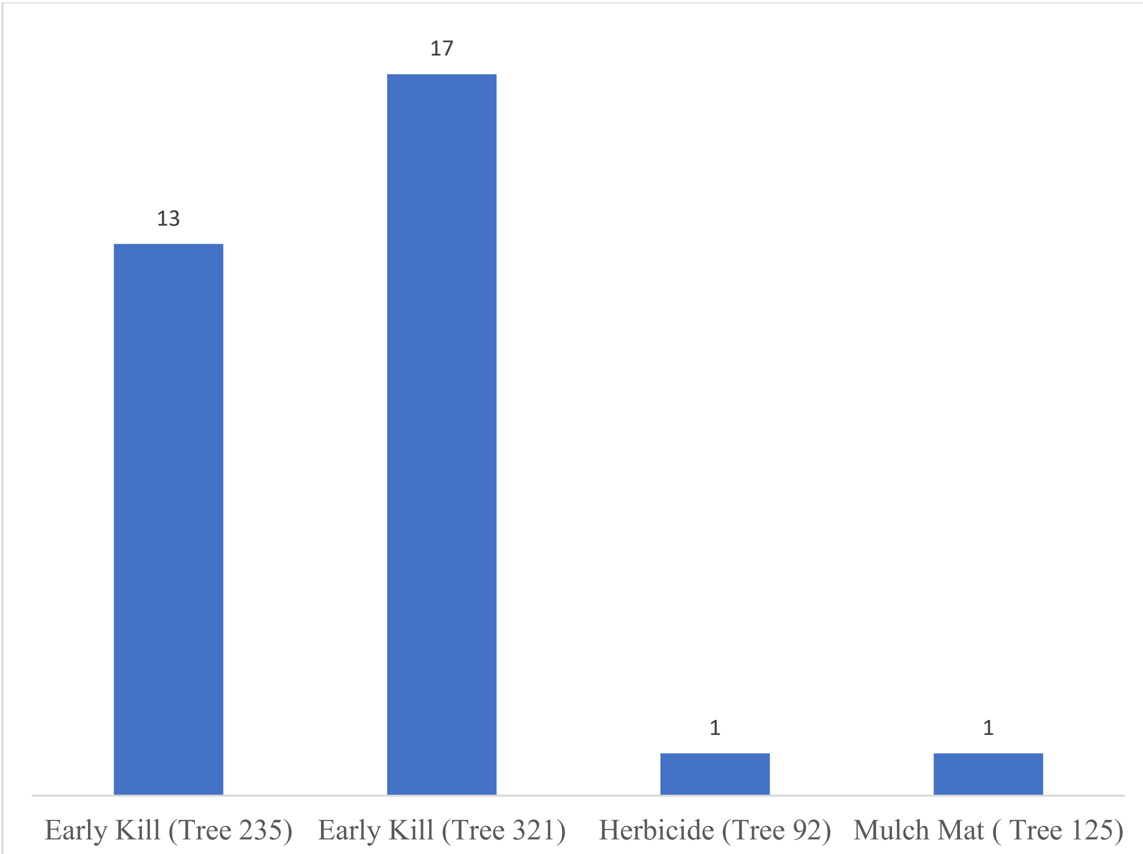

Figure 24. Total numbers of parasitoid wasps from harvested trees from year one. There were 30 (*Eusandalum* spp, Eupelmidae) from the Early Kill Cover Crop treatment, 1 (*Phasgonophora sulcata*, Chalcididae) from the Herbicide treatment and 1 (*Labena grallator*, Ichneumonidae) from the Mulch Mat treatment.