The Effects of Polyethylene and Cereal Rye Mulch, Tillage, and Herbicides on Tomato and Watermelon Yield and Weed Control

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Masters of Science

Auburn, Alabama
May 6, 2017

Keywords: conservation tillage, tomato,
watermelon, cover crop, mulch, rye

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Abstract

Cereal rye, polyethylene mulching, and tillage all have an impact on the yield and growth of weeds. Herbicides have been used to control weed growth for decades. Using these in conjunction can possibly demonstrate ways to reduce reliance on herbicides and reduce herbicide selection pressure. Overuse of herbicides in many systems has led to the development of herbicide resistant weeds. The objective of this project was to examine new ways to suppress weed growth in production systems. In separate studies, tomato and watermelon were grown 2014, 2015, and 2016 near Shorter, AL. The tomato (*Solanum lycopersicum* L.) and watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) studies were laid out in a split-strip design. The main strip was mulching system. Mulching systems used were conservation tillage with Wrens Abruzzi cereal rye (*Secale cerale* L.) drilled at 100.8 kgs/hectare, conventional tillage that was turned and disked before planting with and without polyethylene mulch, and polyethylene integrated with conservation tillage. The herbicide systems used included 1) halosulfuron (52.5 grams ai ha^{-1}) for tomato; halosulfuron (26.3 grams ai ha^{-1}) for watermelon applied PRE, 2) trifloxysulfuron (10.5 grams ai ha^{-1}) applied POST in tomato; halosulfuron (26.3 grams ai ha^{-1}) applied POST in watermelon, 3) a combination of PRE and POST, and 4) a non-treated control arranged in a full factorial. Use of polyethylene mulch significantly increased tomato yield over conventional tillage and conservation tillage without polyethylene. The effect of polyethylene can also be seen in the herbicide interaction. Herbicides were much less effective at increasing

yield and controlling weeds compared to use of polyethylene. Weed control ratings revealed similar results, with treatments that included polyethylene having higher weed control. In watermelon, yield was also significantly increased by the use of polyethylene mulch, similar to that observed in tomato. Weeds were also controlled under polyethylene mulch similar to that measured with tomato.

Acknowledgments

I am thankful to my God who has repeatedly blessed me and given me opportunities to serve him. I could not have made it on my own without his love and grace. I give him all the glory for what I have been able to accomplish.

I'd like to thank my parents and family members who have always been a help to me and have strived to challenge me and push me to become the man that I am today. I'd also like to thank Kathryn for the help and listening ear that she has been.

I am very thankful to Trent Morton for all the help that he's given me in my research in the field and in the lab. Thank you to Jessica Kelton for the help that she's given on writing.

I am thankful to my major advisor Dr. Price for the guidance that he's given to me and the opportunities that he's given to me to achieve this master's degree. Thank you to my committee for the knowledge and expertise that they have provided along the way, through undergraduate and graduate school.

Table of Contents

List of Tables

List of Abbreviations

PRE	Pre-emergent herbicide
POST	Post-emergent herbicide
kg	Kilogram
ha	Hectare
cwt	Hundred weight

Literature Review

Watermelon and Tomato Production

Watermelon and tomato are important specialty crops in the southeastern US. Both are commonly produced and consumed in the region and exported throughout the US. Both watermelon and tomato crops are produced with similar management practices including: use of transplants, raised beds, drip irrigation, and use of polyethylene mulch. All of these practices provide significant yield and grade benefits (Mitchell et al. 2008). Watermelon production encompassed 44,131 hectares in 2014, producing 14.5 million cwt in the United States. The leading producers by state in 2014 were Texas (9,510 hectares; 2.4 million cwt), Florida (8,498 hectares; 2.2 million cwt), and Georgia (7,689 hectares; 2.3 million cwt). Alabama had 1,093 hectares in watermelon production in 2014 and produced 0.21 million cwt (NASS 2015).

Tomato production falls into two categories: fresh market or processing. Fresh market production in the United States in 2014 was on 39,497 hectares, producing 12.4 million cwt. Tomatoes for processing was on 123,874 hectares producing 132.8 million cwt. By state, the production of fresh market tomatoes was led by Florida (13,355 hectares; 4.2 million cwt) and California (13,071 hectares; 4.6 million cwt) in 2014. Processing tomato production by state was led by California (116954 hectares; 127.1 million cwt). In 2014, Alabama produced 190,509 cwt on 486 hectares (NASS 2015).

Transplanting is usually recommended for tomatoes and watermelon for a number of reasons (Hoyt 1999). Use of transplants aids in improved weed control due to competitive advantage, an earlier harvest date (up to two weeks), and improved plant establishment compared to seeded watermelon and tomato. Transplants have a greater chance of surviving and producing fruit in less ideal conditions such as cooler soil temperatures or poor soil quality (Johnson et al. 2001). Utilization of transplants increases the percentage of plants will be able to survive to fruit- bearing stage without the need to replant. The time from transplant to harvest for tomatoes is typically 70-90 days and watermelon is 80-90 days (Smith et al. 2013).

The transplanting date for watermelon and tomato is typically in late spring or early summer depending on market timing goals, and use in tomatoes. In Alabama, both crops are typically transplanted in April or early May depending on latitude, and thus air and soil temperature. A minimum of 1.5 meters between rows is recommended within row spacing of 46-61 centimeters for tomatoes. In watermelon, 1.5 to 1.8 meters is recommended between rows and 61centimeters between plants in row. These spacings are generally based off of agronomic considerations and equipment parameters.

Polyethylene mulch is often used in tomato and watermelon production. Polyethylene mulch will help to suppress weed growth and increase production (Vicari 1986). Raised beds must be used with polyethylene mulch or winter cover crops to maintain the integrity of the soil bed (Price et al. 2013). Raised beds are typically eight to twenty centimeters off the ground to facilitate appropriate water drainage, as tomato and watermelon do not grow well in excessively wet soils. The increased drainage may mean that more irrigation is needed, which is typically supplied through drip irrigation. Polyethylene mulch may also partially solarize the soil, resulting in heated soil which will allow an earlier planting date and quicker growth. Early transplanting leads to an earlier harvest, which allows producers to sell their crops usually at a premium price.

Polyethylene mulch and drip irrigation are typically used in conjunction with each other for specialty crop production. Drip irrigation is necessary to supply water to plants with roots positioned underneath the polyethylene. Drip irrigation may be installed up to four centimeters deep and the polyethylene cover is applied over the drip irrigation. Utilizing drip tape allows for efficient use of irrigation and reduction of runoff and reduces excessive water application.

As with every agricultural production system, there are sustainability challenges. The use of non-biodegradable polyethylene mulch creates substantial waste. There have been attempts to create biodegradable material that can be utilized in specialty crop production, but there are no commercially viable alternatives available. Currently, there is biodegradable polyethylene on the market. However according to literature, these biodegradable mulches degrade too quickly, which leads to inconsistent, ineffective weed control in growing season (Lament 1993).

Drip irrigation and polyethylene mulch are two important cultural components for weed control. Both of these limit crucial elements that are necessary for plant growth. Drip irrigation limits the water that is available to weeds for growing by placing it directly at the roots of the growing watermelon or tomato, thus excluding irrigating inter-row space. The polyethylene mulch limits availability of sunlight to weed seeds, germinated weeds, and acts as a physical barrier except for the hole where the transplant is placed and between row areas. Without sunlight, weeds are unable to grow in the planted row, unless the weeds can puncture through the polyethylene (Lament 1993). Yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*) are some of the few weeds that have the ability to puncture polyethylene mulch.

Weed control is important to all crop production. Weeds will compete with crops for critical growth elements such as nutrients, sunlight, and water. Weeds are often able to outcompete crops because of their fast growing “weedy” nature. If weeds are able to establish in a field, they can shade out the crops that are being grown (Monks et al. 1998). As mentioned earlier, drip irrigation is able to limit the water that is available to weeds (Shrestha et al. 2007).

In the southeast and other high rainfall production areas, relying on drip irrigation will not provide sufficient weed control alone.

There are some challenges when using polyethylene mulch and drip irrigation to grow watermelon or tomatoes. One of the challenges with using polyethylene in production is the expense in purchase, installation, and removal of polyethylene. Additionally, there is increased erosion utilizing polyethylene due to the amount of tillage required. Intensive tillage is required to create the beds necessary to support the polyethylene beds. Another challenge concerning drip irrigation is a loss in water pressure. For the water to emit from the drip tape, the drip tape must be pressurized with water. If there is a hole in the drip tape, then the pressure will drop and water will not emit further down the line. A hole in the drip tape can also cause the water to excessively emit in that location and possibly drown any plants that are in the vicinity. Therefore, drip irrigation should be checked regularly for holes (Price and Norsworthy 2013).

Harvesting of watermelon and tomato is generally done by hand. Tomatoes may be harvested multiple times because they do not all ripen at the same time. The level of ripeness that tomatoes are harvested at depends on their purpose. Tomatoes that are going to be shipped are generally picked more green and will ripen off the vine, while tomatoes to be sold locally are allowed to ripen on the vine longer. Tomatoes may then be graded based on a standard USDA scale into: cull, small, medium, large, or extra-large (Kemble et al. 2004). Watermelon are ready for harvest when the tendril closest to the fruit has turned brown and shriveled.

Recently farm to table enterprises and low cost production have become popular options for consumers and producers. Farm to table is beneficial to consumers and producers because it allows consumers to rediscover from where food comes. Farm to table is beneficial to farmers because it creates a market for small farms. Many corporate farms have such high introductory costs that it is impractical for new individuals to begin farming. However, the low cost of production and the decreased need for expensive machinery and many acres of land allows new farmers to join the market (Schoenfeld 2011). Some low cost production methods are double cropping or multiple cropping systems. Systems like these allow farmers to now stay productive year round so that they can reestablish the connection with consumers (Tilman et al. 2002).

Agricultural Tillage Systems

There are a variety of different types of tillage that producers use. Some examples are winter fallow, conventional tillage, and conservation tillage. Each type has its own benefits and challenges. Conventional tillage involves planting into tilled bare soil. A field is tilled with inversion prior to planting, which reduces the weed population because a majority of weed seed is buried beyond germination depth. Conventional tillage creates a residue free seed bed that is optimal for soil to seed contact and reduced weed competition with the crop at planting. Yields can be expected to be higher from this kind of tillage than conservation tillage with winter fallow (Price et al. 2007). While conventional tillage does have some benefits, it is also very damaging to soil health, resulting in erosion, compaction, and nutrient loss (Roberts et al. 1999).

Conventional tillage requires high inputs of herbicides to provide adequate weed control. Historically, growing crops following conventional tillage can result in a higher yield, because of the clean and friable bed created by intensive tillage and lack of management knowledge in conservation peanut systems, but again higher inputs are needed for weed control and field preparation in conventional tillage. (Colvin et al. 1988). More recent research has shown that conservation tillage compares favorably with conventional tillage (Aulakh et al. 2015; Sorensen et al. 2010; Aulakh et al. 2011; Balkcom 2010). The need for higher inputs of herbicides can lead to increased weed resistance due to increased selection pressure, a growing concern.

Conservation tillage is an alternative tillage practice that can be employed to reduce the negative effects noted in conventional tillage systems. With conservation tillage, the goal is to provide some amount of soil covering throughout the year and limit the amount of surface tillage usage. Conservation tillage combined with cover crop use can improve soil quality and soil moisture holding capacity. Conservation tillage is also associated with saving cost because of the reduced number of passes required by farm equipment. There are a number of different methods of conservation tillage including no-till, reduced-till, strip-till, and terra-till (Grichar 2006). Each of these tillage systems has a different impact on the soil. All conservation tillage types reduce the number of passes made by farm equipment over the field which can help in the reduction of soil compaction (Russo et al. 2007). Conservation tillage by some definitions incorporates the use of cover crops.

Winter fallow conservation systems are not planted with any cover after harvest and weeds are allowed to grow during the winter months. This winter weed community provides some cover to the soil that prevents erosion. When the field is ready to be planted again, weed growth is tilled into the soil or terminated with an herbicide application. Winter fallow systems generally result in earlier weed competition for the crop, because some winter weeds are hard to terminate. In 2007, Price et al. found that use of black oat, rye, and wheat as cover crops provided better within crop weed control than a winter fallow system. Winter fallow can provide coverage of the soil in a manner similar to a cover crop, however, the weeds likely provide less allelopathic activity compared to rye and black oats. Weed cover is also less reliable than a cover crop as it can be patchy and not as dense as a cover crop, providing less if any effective weed control.

Strip tillage is the most common conservation tillage practice used in in peanut production (Johnson III et al. 2001). A common strip tillage system involves planting a winter cover crop, cover crop termination, non-inversion within-row tillage, and planting peanut into the tilled zone leaving desiccated residue between rows. Terminating the cover crop is accomplished by either spraying a non-selective herbicide like glyphosate, using a roller crimper to kill the cover crop, or both. Utilizing a strip tillage implement, a continuous vertical line is broken in the soil and cover crop. The crop can be planted into this tilled zone. The desiccated rye is left between the strips. By disturbing less soil, the soil structure can be maintained while reducing compaction and maintaining the water holding capacity of the soil (Price et al. 2015).

Conservation tillage returns more carbon to the soil by allowing the organic matter to accumulate in the soil (Balkcom et al. 2013). The soil organic matter has a high cation exchange capacity that enables the soil to retain more nutrients and directly affects soil productivity. Also, soil organic matter has a higher water holding capacity compared to other soil properties. Thus, the increased water holding capacity makes the residue and soil organic matter a buffer against short term drought. Soil organic matter comes from decomposing plant and animal residue. When plant residue is continually removed season after season through tillage and crop removal, soil organic matter will likely become depleted. The organic matter needs time to be able to replete. Organic matter increase is a case of equilibrium with the decomposing material. The Southeastern U.S. generally has low levels of soil organic matter because of high summer temperatures and high levels of rainfall, which increase the rate of organic matter decomposition. Conservation tillage also increases the ability of soil microbes to create soil organic matter. Therefore, conservation tillage is an extremely important conservation consideration in any long term agriculture setting that requires tillage (Fageria 2012).

The increased adoption of conservation tillage has coincided with an increased use of herbicides. In the past, tillage has been used as a method of weed control. But in situations using no-till or reduced tillage, other cultural methods of weed control are being utilized. This adoption has led to integration of cover crops and intensive use of herbicides. Effective weed control can be obtained by use of season long herbicide regimes, but with the selection for of herbicide-resistant weeds like Palmer amaranth, movements towards more sustainable use of herbicides have been made. This presents a challenge for producers needing to use high inputs of herbicide to gain adequate levels of weed control.

With the increase in herbicide resistant weeds the popularity of conservation tillage among farmers has been dropping, in favor of conventional tillage to gain weed control. More tillage allows farmers to bury weed seeds, but also is destructive to soil health (Price et al. 2011). Palmer amaranth (*Amaranthus palmeri*) is one example of a weed that has developed glyphosate resistance and had developed into the most important problem for row crop producers and extension in the Southeast and Mid-South. In 2016, Price et al. showed that in fields with high densities of glyphosate resistant Palmer amaranth, the most effective method of reducing emergence and growth of this troublesome weed was through having a high residue cover crop when compared with winter fallow.

In 2015, Boscutti et al. conducted a study to determine if conservation tillage impacted density and the species composition of weeds in (list crop or state non-crop). The study took place over five years and contained plots that were in both conservation tillage and conventional tillage. Samples were taken in the spring, summer, and autumn to record plant species present. The percentage of cover created by these weeds was also recorded. The researchers concluded that conservation tillage did affect weed species diversity compared to conventional tillage.

Species composition was reported as mostly annual grasses and perennial weeds in conservation tillage whereas, conventional tillage was mostly consisted of annual plant species. The weeds associated with conservation tillage in this test are generally more nutrient demanding, which increases the competition between weeds and crop. It was also reported that the conventional tillage had a higher percent coverage of weeds at the end of the study than conservation tillage.

Results have shown that conservation tillage with a cover crop resulted in more soil organic carbon (Balkcom et al. 2013). Increases in soil organic carbon was also reported. In this study the initial levels of soil organic carbon were so low that any change to a conservation system resulted in a statistically significant increase of soil organic carbon. The researchers noted that carbon sequestration decreased with soil depth. The highest sequestration occurred in the top 0-5 centimeters of soil. Moderate sequestration happened in the 5-10 centimeter zone, and little in the 10-15 zone, after six years regardless of the intensity of tillage used. To increase soil organic Carbon to that depth would take many years of conservation tillage. The southeastern United States again has very low soil organic carbon levels. However, that also means that these soils have some of the highest potential for improvement.

In 1988, Colvin et al. conducted an experiment on the effects of different types of surface and subsurface tillage on peanut yield and root strength. The tillage that was used was either strip-tillage or no-tillage. They reported that emergence of peanut was more uniform under conventional tillage because of the clean seed bed that was created. The stubble left from a cover crop under conservation tillage made the field uneven and caused problems for uniform planting. They also reported that surface tillage was very important for yields in peanut. In addition, they reported in dry years some type of subsurface tillage is critical to break up hard pans formed by dry sandy soils. Hard pans could lead to shallower roots, resulting in plants that are not as hardy and drought resistant. The researchers also recommended that some slit (strip) tillage to plant the peanut is very beneficial, but caution must be used in rocky soils as the rocks can be detrimental to the equipment. In contrast in 2008, Jordan et al. published a studying showing that reduced tillage and conventional tillage did not affect peanut yield. The conclusion drawn was that yield differences from other studies was because of fine textured soils found in those studies. Jordan et al.'s study sought to establish the effects of tillage and crop rotation on yield, development of disease, cumulative net return, and bulk density in the pegging zone. Conventional and reduced tillage were the two tillage systems evaluated and the rotation was a peanut, cotton, corn rotation. They did find that adding years between peanut plantings boosted peanut yield.

In 2012, Bates et al. demonstrated that weed control can be obtained through use of herbicides alone. In fact, it was found that better weed control can be obtained through the use of high herbicide input intensity than through tillage alone. Bates et al. recommended a combination of tillage and herbicide input to gain the most economic weed control. However, this increases the complexity of weed control. Based on tillage alone, Bates et al reported that the more tillage resulted in better weed control.

Cover Crops

Cover crops are an essential part of conservation tillage. There are several different types of plant species that can be used. There are generally two groups of covers: legumes and cereal grains. Common legume cover crops are vetch, crimson clover, and cowpea. Commonly used cereal grains are winter wheat, rye, black oats, and barley. The goal of cover crops is to create ground cover to suppress weeds and reduce erosion among others.

Cover crops can be planted in either winter or summer. In southern states winter cover crops are more common to allow the planting of a summer cash crop. Summer and winter cover crops serve similar purposes in terms of soil quality preservation and in providing Nitrogen to crops. Sudangrass and cowpea are both options for summer cover crops in southern states. Cereal rye and hairy vetch are winter cover crop options (Snapp et al. 2005).

Legume cover crops provide ground cover as well as supply additional nitrogen to the soil. The additional nitrogen can be used by the subsequent crop grown. This can reduce the amount of nitrogen that a producer needs to add to the field. However, legumes also have a low carbon to nitrogen ratio. This low ratio means that legume covers will degrade more quickly over the course of the growing season. A faster degradation rate means that legume covers will not be able to provide residual cover for as long. With a smaller period of residual cover provided, legumes will not be able to provide season long weed protection (Hamido et al. 2009).

Cereal grains have a higher carbon to nitrogen ratio and therefore, they do not degrade as quickly and will provide ground cover for a longer time during the growing season (Monday et al. 2015). Unlike legumes, they will not fix nitrogen. Rye and black oats have also been shown to have allelopathic effects on plants around them. Allelopathy can be a useful tool in weed suppression in that it can be used to reduce the amount of weeds that grow if they are susceptible to the specific allelopathic compounds; most cover crops contain allelopathic chemicals (Kelton et al. 2012). Allelopathy can also have detrimental effects on the intended crop if it is susceptible to the allelopathic effects of the cover crop, especially small seeded crops. Allelopathic effects are very specific to plant species, therefore it should be investigated if there have been any detrimental effects reported on the crop that is intended to be grown (Hoyt et al. 1994). The planting and termination date of the cover is important as this has an impact on the biomass produced which will, in turn, affect weed growth (Sullivan et al. 2008; Saini et al. 2008).

Cover crops are capable of providing biomass cover that can reduce weed pressure on crops. Usually herbicides are still needed to have an economically comparable yield to conventional tillage (Colvin et al. 1988). The reduced reliance on herbicides, however, can help increase the sustainability of a production system and decrease herbicide resistance selection pressure. As discussed previously, using conservational tillage can change the composition of weed populations over time. Annual grasses and perennial broadleaf weeds usually will become more prevalent over time when conservational tillage is used (Masiunus et al. 1995). In conservation tillage, with cover crops being used, herbicides that are affective against these types of weeds should be used. It is important to have a good stand of cover crop residue in conservation tillage otherwise weed control will be very difficult due to weed emergence in residue gaps. With reduced tillage, a producer cannot create a weed free bed from tillage, instead they must rely on the cover crop and herbicides providing enough coverage to reduce weed pressure (Rutledge et al. 1999). Using cover crops eliminates the producers' ability to use pre-applied herbicides that need to be incorporated into the soil. An example of this is members of the Dinitroanilines group of herbicides.

Rye contains compounds called Benzoxazinoids (BX) have been noted to suppress plant growth. In 2012, Rice et al. found twelve compounds that contribute to allelopathy. Rice conducted an experiment that involved incorporating rye into the ground and leaving it on the surface to determine which would provide better weed suppression. One thing researchers noted is that BX amounts decline as the plant begins to mature. They reported that control plots without rye also contained BX compounds. However, the plots containing rye had higher levels of BX for two weeks before returning to control levels. Rice found that plots with the rye incorporated into the soil lost peak levels of BX much quicker than plots where the rye was laying on the top of the soil. It was also reported that when rye laid on top of the soil, its suppressive power was not changed for 26 days. As this is longer that BX persists in the soil, the conclusion is that rye not only controls weed growth by allelopathic suppression, but also by physical properties. When rye was incorporated into the soil weed suppression was only effective for 2 weeks, which coincides with the longevity of BX compounds.

It should be noted that the activity of BX compounds is not equal even within a species that is being targeted due to many reasons. BX activity has been shown to generally more effective against dicots than monocots (Kelton et al. 2012). Even with BX being more effective against dicots, there is variation in species ability to detoxify BX. In the future crop cultivars may be bred that are able to detoxify BX. This may be part of the reason why there has been a shift in weed ecology with grasses becoming more problematic pests.

By providing coverage of the soil even during the winter months, cover crops reduce soil erosion (Grichar et al. 1987). Bare soil is extremely susceptible to erosion by both wind and rainfall. The topsoil that is carried off in erosion is usually the most nutrient laden portion of the soil. Therefore, erosion can drastically affect soil quality. Cover crops will also increase the water holding capacity of the soil by increasing organic matter (Canali et al. 2013). Organic matter will retain more water than the mineral fraction of the soil (Siri-Prieto et al. 2007).

Despite major benefits, cover crops also have some disadvantages. One of these is the potential for decreased yield when compared to conventional tillage in peanut, likely due to inadequate management knowledge (Colvin et al. 1988). Although reduced yield is disputed by more recent research (Aulakh et al. 2015; Sorensen et al. 2010; Zhao et al. 2009). Conventional tillage creates an easily managed seed bed for the crop establishment, whereas residue containing seedbeds require different management knowledge. In addition, a clean seed bed allows the crop to grow without competition, compared to when herbicides are ineffective in conservation systems at controlling winter or emerged weeds at time of planting. Another disadvantage is that there is a perceived grade decrease when using cover crops in peanuts. Some producers believe that the grade of their harvest will be decreased because cover crops can provide over wintering habitat to some pests and diseases (Sorensen et al. 2010; Grichar et al. 1987). These pests are able to resume growth during the growing season and have a detrimental effect on the crop. There is research, however, that shows no actual change in peanut grade as the result of having a cover crop (Johnson III et al. 2001; Zhao et al. 2009).

Sullivan et al. (2008) showed that termination date is very important in growing a cover crop. The longer that a cover has to grow the greater the amount of residue left on the field. Sullivan et al. found that using a cover crop in corn will result in not as much cover being present because of the earlier planting date, and therefore earlier termination date required in corn when compared to peanut and cotton. Balkcom et al. (2016) also showed that termination date is very important in determining the quality of residue left. If the crop is terminated too late then there could be issues with crop emergence, too early and the benefits associated with a cover crop are diminished.

In 2008, Sullivan et al also reported that conventional tillage consistently resulted in less crop residue when compared to no till and no till with subsoiling. All three of these tillage systems had a rye cover crop planted. Sullivan et al. also reported that strip tillage usually resulted in better crop residue than conventional tillage, but was not as effective as no till or no till with subsoiling. The method used to determine the amount of crop residue present uses satellite imagery and measures the wavelengths to determine the amount of crop residue present. This study did not find any significant differences between the amounts of surface water in any of the treatments. Indicating that the different types of tillage did not affect the way in which water is absorbed into the soil.

In 2009, Zhao et al. found that tillage type does not have any effect on peanut grade. The experiment was conducted in a bahiagrass based sod crop rotation. In 2001, Johnson et al. also found that peanut grade was not affected by tillage or a rye cover crop. Johnson et al. used minimum tillage, and reduced tillage, both of which contained a cover crop. There was no statistically significant difference when compared to the conventional tillage plots. The tillage type did have an impact on the control of tomato spotted wilt, with the minimum and reduced tillage having significantly less than the conventional tillage. Rhizoctonia limb rot and stem rot were not significantly different base on tillage.

In 2012, Price et al. found that using high residue cover crops in coordination with conservation tillage increased net returns over conventional tillage, even in fields with glyphosate resistant Palmer amaranth. Therefore, it is important to remember that the use of conservation tillage and high residue cover crops should not be overlooked within the increase occurrence of herbicide resistant weeds. Instead, diversification of tactics to broaden weed control is needed. More research is needed to show that conservation agriculture is a necessary part of future weed control systems to protect the soil quality for years to come.

The Effects of Polyethylene and Cereal Rye Mulch, Tillage, and Herbicides on Yield and Weed Control in Tomato

Abstract

Currently not many producers in the Southeast U.S. use conservation tillage methods in vegetable production. The lack of conservation usage in vegetable production is likely due to the difficulty in profitably producing vegetables with conservation tillage. Other methods of production, such as conventional tillage with polyethylene are so productive that other methods of production are not encouraged, because of their lack of production. The objective of this experiment was to determine is conservation tillage practices could be incorporated into tomato production. Tomato (*Solanum lycopersicum* L.) was grown 2014 and 2016 near Shorter, AL. The tomato study was laid out in a split-strip design. The main strip was mulching system. Mulching systems used were 1) conservation tillage with Wrens Abruzzi cereal rye (*Secale cerale* L.) drilled at 100.8 kgs/hectare, 2) conventional tillage that was turned and disked before planting with and 3) without polyethylene mulch, 4) and polyethylene integrated with conservation tillage. The herbicide systems used included 1) halosulfuron (52.5 grams ai ha^{-1}) applied PRE, 2) trifloxysulfuron (10.5 grams ai ha^{-1}) applied POST, 3) halosulfuron and trifloxysulfuron both applied, and 4) a non-treated control arranged in a full factorial. Use of polyethylene mulch significantly increased tomato yield over conventional tillage and conservation tillage without polyethylene. The effect of polyethylene can also be seen in the herbicide interaction. Herbicides were much less effective at increasing yield and controlling weeds compared to use of polyethylene. Weed control ratings revealed similar results, with treatments that included polyethylene having higher weed control. The results of this experiment showed that progress still needs to be made in developing conservation systems for vegetable production. However, the results of the polyethylene over rye showed that this mulching system could have potential in conservation vegetable production.

Introduction

Conservation tillage improves soil quality by increasing organic matter, preserving soil structure, and increasing soil biota activity. Cover crops are an integral part of conservation tillage because they increase soil organic matter, soil surface residue, reduce runoff, and increasing nutrient cycling. However, tomato production does not commonly involve conservation tillage.

Weed control is important in tomato because it is not very competitive by nature. Tomato plants are susceptible to competition from faster growing weedy plants that can shade out the tomato. If weeds are allowed to compete with tomato, yield and grade will be reduced. In 1983 Weaver et al. found that tomatoes are affected by weed interference from the shading ability of the weeds and not through water stress. The critical weed free period was determined to be 28-35 days after transplanting. If tomato plants were weed free for that time there is not be a significant reduction in tomato dry weight. Bhowmik et al. in 1988 found that with common lambsquarter 16 plants/m row would reduce tomato yield by 17%. Qasem in 1992 found that tomato needs to have a weed free period of 28-35 days for pigweed to not have reduced yield and that weeds emerging later than that time had no significant effect on yield.

By providing coverage of the soil even during the winter months, cover crops reduce soil erosion (Grichar et al. 1987). Bare soil is extremely susceptible to erosion by both wind and rainfall. The topsoil that is carried off in erosion is usually the most nutrient laden portion of the soil. Therefore, erosion can drastically affect soil quality. Cover crops will also increase the water holding capacity of the soil by increasing organic matter (Canali et al. 2013). Organic matter will retain more water than the mineral fraction of the soil (Siri-Prieto et al. 2007). Cover crop residue can reduce weed pressure if residue is sufficient (Masiunas 1995; Aulakh et al. 2015; Mulvaney et al. 2011).

There are concerns of grade and marketability of tomatoes grown in a conservation cover crop system. Even when yield is comparable to tomatoes grown in polyethylene mulch but the grade is diminished, then the profitability is reduced (Roberts et al. 1999). Therefore, more research needs to be done to determine if integrated conservation tillage is a suitable alternative to the industry standard conventional tillage with polyethylene mulch in tomato. In this experiment, the effects of different levels of herbicide use intensity in conjunction with different mulching systems was evaluated on yield, tomato quality, and weed control.

Materials and Method

Field Site Description and Experimental Approach. Bella Rosa tomato cultivar (*Solanum lycopersicum* L.) were transplanted 2015 and 2016 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center Plant Breeding Unit, located near Shorter Alabama. In 2014 the same variety was planted at the Alabama Agricultural Experiment Station's E.V. Smith Research Center Field Crops Unit also located near Shorter, AL. The soil at both locations was Pacolet sandy loam (siliceous, semiactive, thermic Typic Hapudult). The pH of these soils is 6 with 0.5 – 2.0% organic matter. The experiment was arranged as a split-strip plot within a randomized complete block design, with mulching system serving as the main strip plot and herbicide system serving as the sub strip plot. The experiment had three treatment replications.

For the mulching system there were four systems used. The first system was the industry standard conventional tillage with polyethylene mulch on raised beds. The second system was conservation tillage containing a cereal rye cover crop. The third system was conventional tillage. The fourth system was cereal rye containing conservation tillage plots integrated with polyethylene mulch. These plots were installed on flat soil due to the difficulty in tilling and raising beds that contained. Rye was terminated with glyphosate applied at 1.12 kg ae ha^{-1}a and rolled before transplanting tomatoes.

The herbicide treatments were: 1) halosulfuron (52.5 grams ai ha^{-1}; Sandea®, Gowan The GoTo Company, Yuma, AZ 85364) applied PRE, 2) trifloxysulfuron (10.5 grams ai ha^{-1}; Envoke®, Syngenta, Greensboro, NC 27419-8300) applied POST, or 3) halosulfuron applied PRE followed by rifloxysulfuron applied POST. Preemergent treatments were applied one week before planting date. Postemergent treatments were applied 4 weeks after transplanting (Table 1.1, 1.2). A non-treated control was included for comparison. Clethodim (140.1 gram ai ha^{-}1; Select®, Valent, Walnut Creek, CA 94596-8025) was applied twice in all years to suppress weedy grass growth.

Plots were 5.5 meters long and 2.1 meters wide with a 61 centimeter feet alley between each plot. Tomatoes were transplanted with 0.5 meters between plants to give plants room to grow. Stakes were placed as typical in the industry between the tomatoes and then twine was strung between the stakes to provide a stable structure for holding the tomato vines.

The strips with conservation tillage with rye cover crop and polyethylene over rye were planted with the cereal rye cultivar Wrens Abruzzi drilled at 102.1 kg/ha in the fall. Prior to termination, cereal rye samples were collected to determine biomass grown prior to termination. Plots to be covered in polyethylene mulch were terminated earlier so that the polyethylene mulch could be installed while the rye was still relatively short. Nutrient management was maintained as recommended by the Alabama Cooperative Extension System soil test recommendations (Anonymous 2012).

In 2014 tomato were transplanted on May 14. Tomato was transplanted May 5 in 2016. All plants were irrigated upon transplanting. Drip irrigation was installed on all strips to provide plants with water and fertigation. Drip irrigation was applied four times a day, seven days a week, for fifteen minutes each application on an automatic timer. Fertilizer was supplied during the season using soluble fertilizer through the drip irrigation. Insecticides and fungicides were also applied as needed throughout the season (Table 1.3, 1.4). In 2014 tomato was harvested on July 16, July 23, and July 30. In 2016 tomatoes were harvested at four separate times, July 12, July 18, July 25, and July 29, depending on the ripeness of the tomatoes. In 2015 there was no harvest of tomatoes due to the field not producing any tomatoes because of the excessive growth of crabgrass (*Digitaria sanguinalis* (L.) Scop).

Data collection. Weed ratings were performed on tomato plots to determine the extent of weed control for major weeds found in each of the plots. Ratings were done visually to measure the amount of control different treatment combinations provided. In the ratings 0% meant that there was no control of the weed in that plot and the plot was overgrown with that weed, a rating of 100% meant that the weed was completely controlled in the plot and not visible.

Yield data was collected from tomato. Tomatoes were harvested four times as the crop ripened. After harvest the tomatoes were graded using the U.S. Standards for Grades of Fresh Tomatoes. The sizes were small, medium, large, extra-large, and cull. Cull tomatoes are not desirable for purchase, having some kind of defect such as disease, insect damage, or being too small. Market tomatoes are comprised of small, medium, large, and extra-large tomatoes. Total harvest is market tomatoes in addition to culls.

Statistical Analysis. Data was analyzed in SAS 9.4 using procedure GLIMMIX. Differences between least significant means were calculated in SAS using the LSMEANS function. The mulching and herbicide systems used were the fixed effects and the replication was the random effect. LSD values were calculated using Excel.

Results and Discussion

Tomato Weed Control. The weeds rated in 2014 were pigweed (*Amaranthus* spp. S. Wats.), carpetweed (*Mullugo verticillata* L.), purslane (*Portulacca* spp. L.), crabgrass (*Digitaria sanguinalis* L. Scop.), morningglory (*Ipomoea* spp. L.), coffee senna (*Senna occidentalis* L. Link), and nutsedge (*Cyperus* spp. L.). In many cases there was a significant interaction between mulch type and herbicide. This interaction was because the conventional tillage system and no herbicide had no weed control (Table 1.5). The presence of rye, polyethylene mulch, and their combination reduced weed pressure. The only exception to this reduction was in coffee senna, which often had poor control, in any system. Use of polyethylene mulch did not provide effective control of purslane (55% control), and inclusion of rye did not provide effective control of morningglory (56% control) (Table 1.6).

Late weed control showed significance in the interaction with purslane having significantly less control in the non-treated with polyethylene mulch treatment (Table 1.7). The effectiveness of herbicides in non-treated was significantly less than other treatments for pigweed, carpetweed, purslane, crabgrass, and nutsedge control. Morningglory and coffee senna populations were not affected by herbicides. In the mulching systems conventional tillage had significantly less weed control in pigweed, carpetweed, purslane, coffee senna, and nutsedge than the other mulching systems. The inclusion of polyethylene mulch, conservation tillage with rye cover crop, and polyethylene over rye was more effective at controlling weeds, except in morningglory where conservation tillage with rye cover crop had the least control (46%) (Table 1.8).

Six weeds were present in 2016: Palmer amaranth (*Amaranthus palmeri* S. Watson); large crabgrass (*Digitaria sanguinalis* L. Scop.); cutleaf evening primrose (*Oenothera laciniata*

Hill); purple nutsedge (*Cyperus rotundus* L.); sicklepod (*Senna obtusifolia* L. Irwin & Barneby); and arrowleaf sida (*Sida rhombifolia* L.). These weeds were rated for analysis of weed control.

Early Palmer amaranth control showed no significance in the interaction between herbicide and mulching system, mulching system, or herbicide system except for the conventional tillage plots, without herbicides not having any control (Table 1.9). When examined by the main effect of tillage, those plots with conventional tillage had the best weed control (72%). When examined by herbicide treatment poorest control was found in non-treated plots (73%) (Table 1.10). Late Palmer amaranth control was less in the polyethylene mulch mulching system and conventional tillage (80% and 69%, respectively). Use of polyethylene mulch and rye produced significantly higher weed control (97% and 96%, respectively). Herbicide intensity did not affect Palmer amaranth control except in the non-treated (Table 1.11). There was also no significance in the control of Palmer amaranth in the interaction of herbicide by mulching system, except for conventional tillage non-treated plots in which there was no weed control (Table 1.12).

Early crabgrass control had significance in only the mulching systems. Crabgrass was not as effectively controlled in conservation tillage with rye cover crop and polyethylene over rye (74% and 66%, respectively) compared to conventional tillage without and with polyethylene mulch (91% and 93%, respectively) (Table 1.10). There was no other significance in early crabgrass control. For late season crabgrass control, there was some significance in the interaction, with the highest control coming from coming from conventional tillage non-treated (Table 1.12). Similar to Palmer amaranth, mulching system was significant while the herbicide system was not. conventional tillage had the greatest control of crabgrass. The polyethylene over rye system resulted in the least control of crabgrass providing only 23% control (Table 1.11).

Early sicklepod control only had significance in the interaction of conservation tillage with rye cover crop and a PRE at 69% control (Table 1.9). The mulching system was significant with conventional tillage providing the least weed control (Table 1.10). Late season mulching systems resulted in differences for sicklepod control with polyethylene mulch, and polyethylene over rye providing effective control, while conservation tillage with rye cover crop alone and conventional tillage provided less effective control (72% and 73%, respectively). No differences were noted in control for herbicide treatments except for the non-treated (Table 1.11). There was no significance in the interaction between herbicide and mulching system (Table 1.12).

Early purple nutsedge control has significance in the interaction. The most variability was found in the plots with conventional tillage only a PRE having the second lowest control (57% control), and conventional tillage non-treated having the least control (0% control) (Table 1.9). The mulching system has significance with conventional tillage (49% control) being the lowest, and polyethylene mulch (82% control) having the highest control (Table 1.10). Herbicide systems have no significance except for the non-treated. Purple nutsedge control in the late season in the interactions on conventional tillage non-treated having the least control (Table 1.12). POST herbicide created more effective control than only a PRE or non-treated. Control was significant in the mulching systems with conservation tillage with rye cover crop and polyethylene over rye providing the highest control (63% and 62%, respectively). conventional tillage provided the least effective control (39%) (Table 1.11).

Early arrowleaf sida control had significance in the interaction. conventional tillage with non-treated and conventional tillage with a PRE had the lowest control (49%) (Table 1.9). There was also significance in the mulching system. polyethylene mulch and polyethylene over rye had the highest control (84% and 95% respectively). Herbicide system was significant with POST and POST with PRE providing the highest weed control (87% and 88% respectively). Non-treated had the least control (61%) (Table 1.10). Late season arrowleaf sida control was greatest in the interaction in polyethylene over rye with a POST application (Table 1.12). There were differences in mulching system. polyethylene over rye had the greatest control (89%). conventional tillage and polyethylene mulch had the lowest control (35% and 53% respectively), showing that the rye likely contributed to the control of arrowleaf sida. Herbicide system had differences with both of the treatments including a POST application having better control than only a PRE or non-treated (Table 1.11).

Early cutleaf evening primrose control had significance in the interaction. The conservation tillage with rye cover crop had lower control that the other interactions, with the least control coming in the rye with POST, outside of the conventional tillage (Table 1.9). conservation tillage with rye cover crop had the least control in the mulching systems at 70%. Herbicide system was not significant except for non-treated (Table 1.10). Cutleaf evening primrose control in the late season had significance due to the mulch type, with the polyethylene over rye system providing the highest control (81%). Weed control was lowest in plots in which the mulch system was conservation tillage and rye (49%). There were no differences for control due to herbicide applications except for non-treated being the lowest control (Table 1.11). There was no significance in weed control in the interaction of mulch and herbicide except for conventional tillage non-treated (Table 1.12).

Tomato Yield. Tomato yield was determined for total yield and market yield. Tomatoes are graded based on size, and analysis was done on the different grades of tomatoes. Tomato yield in 2014 was significantly affected by the interaction of mulch and herbicide. The highest yield was found with the polyethylene mulch mulch with both a PRE and POST herbicide treatment (25,362 kg/ha) (Table 1.13). Tomatoes from the conventional tilled treatments had the lowest yield in the interaction. In the individual effects polyethylene mulch, conservation tillage with rye cover crop, and polyethylene over rye were non-significant. conventional tillage was significantly less (1,974 kg/ha) (Table 1.14). Herbicide treatments had little effect on yield, with only marketable yield having differences due to herbicide. Plots receiving only a POST application had significantly less yield than those that received a PRE only or a PRE and POST.

Based on mulching system, Tomatoes grown in either conventional tillage or conservation tillage had reduced yield regardless of size. The polyethylene mulch and polyethylene over rye systems produced a similar yield, except in medium sized tomatoes. Total yield was significantly different between systems that contained polyethylene mulch, but the market yield was not significantly different. There was no significance in yield found from the different herbicide systems in any of the different grades (Table 1.15).

In the interaction of mulching and herbicide systems for culls, the only treatment that was significant was polyethylene mulch with a POST herbicide treatment as it was significantly higher (7,477 kg/ha) than all other treatments. In the small grade tomatoes grown under plastic had greater yield than those grown without polyethylene. Similar results were observed in the medium grade. Large and extra-large grades were unaffected by treatment. In total yield, tomatoes grown under the polyethylene mulch with a POST herbicide had significantly greater yield than all other treatments. In marketable yield polyethylene mulch with a POST were significantly different from all of the conventional tillage treatments and different from all the conservation tillage with rye cover crop mulching system treatments except for the one containing both a PRE and a POST herbicide (Table 1.16).

Discussion

Overall results show that weed control was not greatly influenced by herbicide system revealing that PRE and POST herbicides were equally effective against the weeds present and the combination did not increase control. However, mulching system did influence weed control. conventional tillage provided higher purple nutsedge control late in the season. The presence of rye seemed to be beneficial in the control of arrowleaf sida. Sicklepod was much better controlled under polyethylene regardless of the presence of a cover crop. Crabgrass was difficult to control regardless of the mulching system used. This resilience speaks to the hardiness of crabgrass as a weed.

In the interaction more intensive tillage and higher amounts of herbicide input did not correlate to significantly better weed control. This is something that producers need to consider when growing crops and investigating methods of weed control. Non-treated consistently had the lowest weed control across all weed types. Some weeds, like purslane, had better control when a PRE was applied. This could be due the efficacy of halosulfuron against purslane or to do with the timing of the emergence of purslane.

In terms of yield the two mulching systems that had polyethylene on them are comparable for the market yield. The polyethylene mulch only had the highest yield across all grades, but was not always significantly higher. The market yield showed more yield in polyethylene mulch only but was not statistically significant from the polyethylene with rye system.

The interaction for yield showed that conventional tillage or conservation tillage with rye cover crop are not very effective systems at producing tomatoes. The interaction also showed that there was no significant difference between the different herbicide systems in either mulching system receiving polyethylene. Demonstrating again that more intensive herbicides do not necessarily correlate to higher yields.

Conservation tillage would be a boon to tomato production if it could be done in a feasible manner. The carbon to nitrogen is extremely important in being able to produce tomato with a cover crop. Tomato requires high amounts of nitrogen to grow. A cover crop that is high in carbon will tie up large amounts of the nitrogen available. This dilemma is one problem with growing tomato under conservation tillage The termination date is also very crucial in cover crop production and tomato production. If the cover is terminated too early then regrowth is possible and will interfere with tomato yield (Madden 2004).

Other research done has also shown that the increase rainfall capacity of soils with a cover crop can lead to difficulties with stand establishment and therefore yield reduction in tomato. Past research has also suggested that is rye is left on the soil surface addition management from producers will be required because of potential yield reductions (Masiunas 1995).

In light of the research shown here and past research conservation tillage and cover crop usage has more development required before it becomes an effective system for producers. Termination date of the rye and nutrient management in tomato are of paramount importance. Otherwise, tomato establishment and therefore yield will be adversely affected. If conservation tillage system was able to able to produce in a manner similar to production involving polyethylene, then tomato production would be more feasible for many producers looking to become involved in farm-to-table production.

The polyethylene over a rye cover crop used in this study showed potential of becoming a system that could be used by producers that is more environmentally friendly and capable of yielding tomato. The polyethylene over rye system would still need work to improve soil drainage, as it is a flat bedded system. Raised beds with a rye cover crop are a potential solution to the drainage problem, but creating raised beds requires more intensive tillage. More research is required to further develop these systems that would successfully incorporate tomato production into conservation tillage.

Table 1.1 Dates of treatment and tillage in tomato – E.V. Smith (Field Crops Unit) 2014

Treatment	Date
Cover Crop Planted	11/6/13
Fertilizer	3/11/14
Tillage	4/24/14
Cover Crop Terminated	4/24/14
PRE	4/23/14
Polyethylene Laid	4/24/14, 5/7/14
Transplant	5/14/14
Replant	5/21/14
POST	6/4/14
Select Sprayed	6/8/14
Harvest	7/16/14, 7/23/14, 7/30/14

Table 1.2. Dates of treatment and tillage in tomato – E.V. Smith (Plant Breeding Unit) 2016

Treatment	Date
Cover Crop Planted	12/8/15
Fertilizer	3/10/16
Tillage	4/19/16
Cover Crop Terminated	4/19/16, 4/27/16
PRE	3/8/16, 4/26/16
Polyethylene Laid	4/27/16, 3/10/16
Transplant	5/5/16
Replant	5/9/16
POST	6/1/16
Section Sprayed	5/9/16, 6/10/16
Harvest	7/12/16, 7/18/16, 7/25/16, 7/29/16

Table 1.3. Fertilizer and pesticide dates for tomato 2014

Date	Fertilizer	Fungicide	Insecticide
5/22/14	2.3 kg 20-20-20		
5/24/14		Mancozeb 2.7 kg ai/ha	
5/29/14	2.3 kg 20-20-20		
6/3/14		Copper Hydroxide 753.6 grams ai/ha	
6/4/14	2.3 kg 20-20-20		
6/5/14	2.3 kg 20-20-20		Imidacloprid 457.7 grams ai/ha
6/17/14	2.3 kg 20-20-20	Chlorothalonil 2.2 kg ai/ha	
6/18/14	2.3 kg calcium nitrate		
6/19/14			Bifenthrin 89.7 grams ai/ha; Bacillus thuringiensis 1.2 kg ai/ha
6/24/14	2.3 kg calcium nitrate	Azoxystrobin 13.4 kg ai/ha	Bacillus thuringiensis 1.2 kg ai/ha
6/27/14	2.3 kg calcium nitrate		
7/1/14	2.3 kg calcium nitrate	Mancozeb 2.7 kg ai/ha	Bacillus thuringiensis 1.2 kg ai/ha
7/6/14		Azoxystrobin 13.4 kg ai/ha	Bacillus thuringiensis 1.2 kg ai/ha
7/13/14	2.3 kg calcium nitrate		
7/16/14	2.3 kg calcium nitrate		
7/11/14	2.3 kg calcium nitrate		
7/17/14	2.3 kg calcium nitrate 2.3 kg potassium nitrate		

Table 1.4. Fertilization, fungicide, and insecticide application information for tomato 2016

Date	Fertilizer	Insecticide	Fungicide
5/10/16	2.3 kg 20-20-20		
5/13/16	2.3 kg 20-20-20		
5/16/16	2.3 kg 20-20-20		
5/18/16			Mancozeb 2.7 kg ai/ha; Basic Copper Sulfate 1lb/acre
5/20/16	2.3 kg 20-20-20		
5/23/16	2.3 kg 20-20-20		
5/26/16		Imidacloprid 7 oz/acre	
5/27/16	2.3 kg 20-20-20		
6/1/16	2.3 kg 20-20-20		
6/3/16		Thiamethoxam 52.5 grams ai/ha	Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha
6/4/16	2.3 kg 20-20-20		
6/7/16	2.3 kg 20-20-20		
6/10/16	2.3 kg 20-20-20	Bifenthrin 89.7 grams ai/ha	Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha
6/14/16	2.3 kg 15.5-0-0		
6/17/16	3.8 Liter 13-0-46	Bifenthrin 89.7 grams ai/ha	Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha
6/21/16	2.3 kg 15.5-0-0		
6/24/16	3.8 liter 13-0-46		
6/25/16		Bifenthrin 89.7 grams ai/ha	Mancozeb 2.7 kg ai/ha
6/28/16	2.3 kg 15.5-0-0		
7/1/16		Thiamethoxam 52.5 grams ai/ha	Mancozeb 2.7 kg ai/ha
7/4/16	3.8 liter 13-0-46		
7/9/16	2.3 kg 15.5-0-0		
7/11/16		Bifenthrin 89.7 grams ai/ha	Mancozeb 2.7 kg ai/ha
7/13/16	3.8 liter 13-0-46		
7/15/16	2.3 kg 15.5-0-0		
7/19/16	3.8 liter 13-0-46		
7/22/16	2.3 kg 15.5-0-0		
7/26/16	3.8 liter 13-0-46		
7/29/16	2.3 kg 15.5-0-0	Bifenthrin 89.7 grams ai/ha	Mancozeb 2.7 kg ai/ha

Table 1.5. Early weed control of different mulching systems and herbicides in tomato – E.V. Smith (Field Crops Unit) 2014

		% Weed Control				
		Herbicide treatment[3]				
Mulching System[1]	Weed Species[2]	Non-treated	Sandea	Envoke	S + E	*LSD (α=0.1)*
Conventional Tillage	PW	0^{b}	99^{a}	80^{a}	66^{ab}	40
	CW	0^{b}	99^{a}	66^{a}	85^{a}	30
	PS	0^{b}	99^{a}	47^{ab}	99^{a}	33
	CG	0^{c}	99^{a}	99^{a}	99^{a}	30
	MG	0^{b}	90^{a}	99^{a}	96^{a}	40
	CS	0^{b}	57^{ab}	58^{ab}	70^{ab}	35
	NS	0^{b}	99^{a}	99^{a}	99^{a}	4
Polyethylene	PW	99^{a}	99^{a}	66^{ab}	99^{a}	-
	CW	58^{a}	80^{a}	91^{a}	80^{a}	-
	PS	37^{ab}	62^{ab}	73^{a}	50^{ab}	-
	CG	33^{bc}	99^{a}	99^{a}	99^{a}	-
	MG	99^{a}	99^{a}	79^{ab}	99^{a}	-
	CS	66^{ab}	99^{a}	99^{a}	99^{a}	-
	NS	99^{a}	99^{a}	99^{a}	99^{a}	-
Conservation Tillage	PW	66^{ab}	99^{a}	96^{a}	99^{a}	-
	CW	91^{a}	99^{a}	94^{a}	99^{a}	-
	PS	77^{a}	99^{a}	57^{ab}	99^{a}	-
	CG	17^{bc}	99^{a}	99^{a}	99^{a}	-
	MG	66^{ab}	48^{ab}	58^{ab}	53^{ab}	-
	CS	93^{a}	99^{a}	98^{a}	60^{ab}	-
	NS	99^{a}	99^{a}	93^{a}	99^{a}	-
Polyethylene + Rye	PW	99^{a}	99^{a}	99^{a}	66^{ab}	-
	CW	99^{a}	99^{a}	99^{a}	90^{a}	-
	PS	90^{a}	98^{a}	99^{a}	99^{a}	-
	CG	58^{abc}	99^{a}	76^{ab}	99^{a}	-
	MG	66^{ab}	85^{a}	99^{a}	99^{a}	-
	CS	99^{a}	93^{a}	98^{a}	99^{a}	-
	NS	99^{a}	99^{a}	99^{a}	98^{a}	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Pigweed, carpetweed, purslane, crabgrass, morningglory, coffee senna, nutsedge

[3]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 1.6. Early weed control effects of different mulching and herbicide systems in tomato – E.V. Smith (Field Crops Unit) 2014

	% Weed Control						
Mulching System[1]	Pigweed	Carpetweed	Purslane	Crabgrass	Morningglory	Coffee Senna	Nutsedge
Conventional Tillage	61[b]	62[b]	61[bc]	74[a]	71[ab]	46[b]	74[b]
Polyethylene	91[a]	77[b]	55[c]	83[a]	94[a]	91[a]	99[a]
Conservation Tillage	90[a]	96[a]	83[ab]	78[a]	56[b]	87[a]	97[a]
Polyethylene + Rye	91[a]	97[a]	96[a]	83[a]	87[a]	97[a]	98[a]
LSD (α=0.1)	20	13	16	15	20	17	2
Herbicide System[2]							
Non-treated	66[b]	62[b]	51[b]	27[b]	58[b]	64[a]	74[b]
Sandea	99[a]	94[a]	89[a]	99[a]	80[ab]	87[a]	99[a]
Envoke	85[ab]	88[a]	69[ab]	93[a]	84[ab]	88[a]	97[a]
S + E	83[ab]	88[a]	87[a]	99[a]	87[a]	64[a]	99[a]
LSD (α=0.1)	20	13	16	15	20	17	2

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 1.7. Late weed control of different mulching systems and herbicides in tomato – E.V. Smith (Field Crops Unit) 2014

		% Weed Control				
		Herbicide System[3]				
Mulching System[1]	Weed Species[2]	Non-treated[5]	S[6]	E[7]	S + E	*LSD (α=0.1)*
Conventional Tillage[1]	PW	0[b]	99[a]	73[ab]	66[ab]	42
	CW	0[b]	93[a]	99[a]	83[a]	29
	PS	0[d]	75[ab]	0[d]	85[a]	26
	CG	0[a]	99[a]	66[a]	89[a]	45
	MG	0[a]	80[a]	99[a]	86[a]	52
	CS	0[b]	45[ab]	55[ab]	55[ab]	35
	NS	0[b]	99[a]	99[a]	94[a]	8
Polyethylene[2]	PW	89[a]	99[a]	66[ab]	99[a]	-
	CW	57[ab]	83[a]	90[a]	72[a]	-
	PS	30[bcd]	45[abcd]	82[ab]	17[d]	-
	CG	66[a]	99[a]	99[a]	89[a]	-
	MG	89[a]	99[a]	66[a]	99[a]	-
	CS	66[ab]	99[a]	99[a]	99[a]	-
	NS	99[a]	99[a]	99[a]	90[a]	-
Conservation Tillage[3]	PW	66[ab]	99[a]	96[a]	99[a]	-
	CW	90[a]	94[a]	80[a]	63[a]	-
	PS	72[abc]	96[a]	20[cd]	93[a]	-
	CG	66[a]	99[a]	99[a]	99[a]	-
	MG	66[a]	28[a]	55[a]	33[a]	-
	CS	89[a]	96[a]	98[a]	48[ab]	-
	NS	95[a]	96[a]	89[a]	99[a]	-
Polyethylene + Rye[4]	PW	94[a]	99[a]	98[a]	66[ab]	-
	CW	99[a]	90[a]	99[a]	86[a]	-
	PS	86[a]	83[a]	98[a]	98[a]	-
	CG	33[a]	100[a]	65[a]	99[a]	-
	MG	33[a]	73[a]	66[a]	99[a]	-
	CS	94[a]	89[a]	89[a]	96[a]	-
	NS	96[a]	99[a]	99[a]	95[a]	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Pigweed, carpetweed, purslane, crabgrass, morningglory, coffee senna, nutsedge

[3]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

Table 1.8. Late weed ontrol effects of different mulching and herbicide systems in tomato – E.V. Smith (Field Crops Unit) 2014

	% Weed Control						
Mulching System	Pigweed	Carpetweed	Purslane	Crabgrass	Morningglory	Coffee Senna	Nutsedge
Conventional Tillage	60[b]	69[b]	40[c]	64[a]	66[ab]	39[b]	73[b]
Polyethylene	88[ab]	75[ab]	43[c]	88_a	88[a]	91[a]	97[a]
Conservation Tillage	90[a]	82[ab]	70[b]	91[a]	46[b]	83[a]	95[a]
Polyethylene + Rye	89[ab]	94[a]	91[a]	74[a]	68[ab]	93[a]	97[a]
LSD (α=0.1)	21	15	13	23	26	18	4
Herbicide System							
Non-treated	62[b]	61[a]	47[b]	41[b]	47[a]	62[a]	72[b]
Sandea	99[a]	90[a]	75[a]	99[a]	70[a]	82[a]	98[a]
Envoke	83[ab]	91[a]	50[b]	82[a]	71[a]	86[a]	97[a]
S + E	83[ab]	76[ab]	73[a]	94[a]	79[a]	75[a]	94[a]
LSD (α=0.1)	21	15	13	23	26	18	4

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

Table 1.9. Early weed control of different mulching systems and herbicides in tomato – E.V. Smith (Plant Breeding Unit) 2016

		% Weed Control				
		Herbicide System[3]				
Mulching System[1]	Weed Species[2]	Non-treated	S	E	S + E	*LSD (α=0.1)*
Conventional Tillage	CG	94[a]	92[a]	92[a]	86[a]	21
	SP	0[c]	97[a]	97[a]	97[a]	13
	PNS	0[c]	57[b]	71[ab]	69[ab]	9
	AS	0[c]	49[b]	83[a]	76[ab]	17
	PR	0[d]	94[a]	92[abc]	93[a]	11
	PA	0[b]	97[a]	95[a]	96[a]	5
Polyethylene	CG	95[a]	92[a]	93[a]	93[a]	-
	SP	98[a]	98[a]	98[a]	97[a]	-
	PNS	77[a]	84[a]	84[a]	82[a]	-
	AS	70[ab]	83[a]	87[a]	94[a]	-
	PR	87[abcd]	91[abc]	95[a]	94[a]	-
	PA	95[a]	91[a]	95[a]	91[a]	-
Conservation Tillage	CG	79[a]	63[a]	72[a]	82[a]	-
	SP	79[ab]	69[b]	80[ab]	86[ab]	-
	PNS	77[ab]	70[ab]	74[ab]	79[a]	-
	AS	77[ab]	69[ab]	81[ab]	87[a]	-
	PR	71[cd]	71[bcd]	69[d]	71[bcd]	-
	PA	98[a]	96[a]	97[a]	98[a]	-
Polyethylene + Rye	CG	64[a]	67[a]	62[a]	70[a]	-
	SP	85[ab]	91[ab]	94[ab]	96[a]	-
	PNS	82[a]	79[a]	72[ab]	68[ab]	-
	AS	96[a]	91[a]	96[a]	96[a]	-
	PR	91[abc]	92[ab]	93[a]	93[a]	-
	PA	98[a]	99[a]	99[a]	99[a]	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Large crabgrass, sicklepod, purple nutsedge, arrowleaf sida, cutleaf evening primrose, Palmer amaranth

[3]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 1.10. Early weed control effects of different mulching and herbicide systems in tomato – E.V. Smith (Plant Breeding Unit) 2016

	% Weed Control					
Mulching System[1]	Crabgrass	Sicklepod	Purple Nutsedge	Arrowleaf Sida	Cutleaf Evening Primrose	Palmer Amaranth
Conventional Tillage	91[a]	73[b]	49[c]	52[c]	70[b]	72[c]
Polyethylene	93[a]	98[a]	82[a]	84[ab]	92[a]	93[b]
Conservation Tillage	74[b]	79[a]	74[b]	79[b]	70[b]	97[a]
Polyethylene + Rye	66[b]	91[a]	75[b]	95[a]	92[a]	99[a]
LSD (α=0.1)	11	6	4	8	5	2
Herbicide System[2]						
Non-treated	83[a]	90[a]	58[b]	61[c]	62[b]	73[b]
Sandea	79[a]	89[a]	72[a]	73[b]	87[a]	96[a]
Envoke	80[a]	92[a]	75[a]	87[a]	87[a]	97[a]
S + E	83[a]	94[a]	74[a]	88[a]	88[a]	96[a]
LSD (α=0.1)	11	6	4	8	5	2

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

Table 1.11. Late weed control effects of different mulching and herbicide systems in tomato – E.V. Smith (Plant Breeding Unit) 2016

	% Weed Control					
Mulching System[1]	Crabgrass	Sicklepod	Purple Nutsedge	Arrowleaf Sida	Cutleaf Evening Primrose	Palmer Amaranth
Conventional Tillage	53[a]	73[b]	39[b]	35[d]	55[b]	69[b]
Polyethylene	33[bc]	92[a]	52[a]	53[c]	56[b]	80[b]
Conservation Tillage	40[ab]	72[b]	63[a]	72[b]	49[b]	97[a]
Polyethylene + Rye	23[c]	91[a]	62[a]	89[a]	81[a]	96[a]
LSD (α=0.1)	10	10	8	10	13	11
Herbicide System[2]						
Non-treated	39[a]	62[b]	47[b]	47[b]	48[b]	67[b]
Sandea	32[a]	87[a]	52[ab]	56[b]	69[a]	91[a]
Envoke	34[a]	86[a]	59[a]	73[a]	65[ab]	97[a]
S + E	44[a]	92[a]	59[a]	73[a]	61[ab]	88[a]
LSD (α=0.1)	10	10	8	10	13	11

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 1.12. Late weed control of different mulching systems and herbicides in tomato – E.V. Smith (Plant Breeding Unit) 2016

		% Weed Control				
		Herbicide System[3]				
Mulching System[1]	Weed Species[2]	Non-treated[5]	A[6]	B[7]	A + B	*LSD (α=0.1)*
Conventional Tillage	CG[8]	63[a]	47[abc]	50[abc]	53[ab]	21
	SP[9]	0[b]	97[a]	97[a]	97[a]	20
	PNS[10]	0[c]	57[ab]	43[b]	57[ab]	17
	AS[11]	0[e]	27[e]	70[abc]	42[cde]	21
	PR[12]	0[b]	82[a]	73[a]	65[a]	27
	PA[13]	0[b]	97[a]	97[a]	81[a]	23
Polyethylene	CG	37[abc]	28[abc]	38[abc]	28[abc]	-
	SP	96[a]	96[a]	79[a]	96[a]	-
	PNS	60[ab]	48[ab]	50[ab]	52[ab]	-
	AS	42[de]	50[bcd]	45[bcd]	73[abc]	-
	PR	67[a]	57[a]	57[a]	45[ab]	-
	PA	75[a]	74[a]	95[a]	77[a]	-
Conservation Tillage	CG	40[abc]	39[abc]	39[abc]	40[abc]	-
	SP	72[a]	63[a]	73[a]	80[a]	-
	PNS	60[ab]	47[ab]	67[ab]	78[a]	-
	AS	63[abcd]	63[abcd]	79[abc]	83[abc]	-
	PR	47[ab]	62[a]	43[ab]	45[ab]	-
	PA	97[a]	97[a]	97[a]	97[a]	-
Polyethylene + Rye	CG	15[bc]	15[bc]	10[c]	53[ab]	-
	SP	80[a]	92[a]	95[a]	96[a]	-
	PNS	67[ab]	57[ab]	77[ab]	48[ab]	-
	AS	82[abc]	86[ab]	97[a]	93[ab]	-
	PR	77[a]	75[a]	86[a]	87[a]	-
	PA	95[a]	97[a]	97[a]	97[a]	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).
[2]Large crabgrass, sicklepod, purple nutsedge, arrowleaf sida, cutleaf evening primrose, Palmer amaranth
[3]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied
[*]LS-Means with the same letter are not significantly different.
[**]Proc glimmix was used in SAS for all statistical analysis.

Table 1.13. Agronomics of tomato production from different mulching and herbicide systems – E.V. Smith (Field Crops Unit) 2014

	Tomato Yield (kg/ha)				
	Tomato Grades[2]				
Mulching + Herbicide Combination[1]	S	M	L	XL	Market
Conventional Tillage + Non-treated	967[a]	731[a]	234[c]	53[b]	1884[c]
Conventional Tillage + Sandea	279[a]	339[a]	520[bc]	53[b]	1190[c]
Conventional Tillage + Envoke	354[a]	151[a]	90[c]	181[b]	776[c]
Conventional Tillage + Sandea + Envoke	151[a]	512[a]	595[bc]	2788[ab]	4046[bc]
Polyethylene + Non-treated	1401[a]	2637[a]	2162[abc]	9863[a]	16064[abc]
Polyethylene + Sandea	2162[a]	3021[a]	2999[abc]	7814[ab]	15996[abc]
Polyethylene + Envoke	1462[a]	1665[a]	1959[abc]	5101[ab]	10187[abc]
Polyethylene + Sandea + Envoke	1341[a]	3617[a]	4732[a]	15672[a]	25362[a]
Conservation Tillage + Non-treated	1748[a]	1605[a]	2004[abc]	7346[ab]	12704[abc]
Conservation Tillage + Sandea	2524[a]	2750[a]	3873[ab]	14542[a]	23689[ab]
Conservation Tillage + Envoke	482[a]	437[a]	1047[bc]	2366[ab]	16034[abc]
Conservation Tillage + Sandea + Envoke	1288[a]	2185[a]	1876[abc]	10684[ab]	16034[abc]
Polyethylene + Rye + Non-treated	1831[a]	1552[a]	1914[abc]	8582[ab]	13879[abc]
Polyethylene + Rye + Sandea	1974[a]	2373[a]	1829[abc]	8130[ab]	14406[abc]
Polyethylene + Rye + Envoke	1665[a]	2110[a]	1952[a]	5267[ab]	10993[abc]
Polyethylene + Rye + Sandea + Envoke	2615[a]	1763[a]	2117[abc]	2599[ab]	9094[abc]
LSD (α = 0.10)	1478	1847	1756	7087	9929

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene). Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

[2]Tomato grades are USDA standards based on tomato size. Market is the total yield.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 1.14. Agronomics of tomato production from different mulching and herbicide systems – E.V. Smith (Field Crops Unit) 2014

	Tomato Yield (kg/ha)				
	Tomato Grades[2]				
Mulching System[1]	S	M	L	XL	Market
Conventional Tillage	413[b]	433[b]	360[b]	769[b]	1974[b]
Polyethylene	1592[a]	2735[a]	2963[a]	9612[a]	16902[a]
Conservation Tillage	1511[a]	1744[a]	2200[a]	8735[a]	14190[a]
Polyethylene + Rye	2021[a]	1950[a]	1978[a]	6145[a]	12093[a]
LSD (α = 0.10)	739	924	878	3544	4964
Herbicide System[3]					
Non-treated	1462[a]	1631[a]	1579[a]	6461[a]	11133[ab]
Sandea	1735[a]	2121[a]	2330[a]	7635[a]	13821[a]
Envoke	991[a]	1091[a]	1262[a]	3229[a]	6572[b]
S + E	1349[a]	2019[a]	2330[a]	7936[a]	13634[a]
LSD (α = 0.10)	739	924	878	3544	4964

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2] Tomato grades are USDA standards based on tomato size. Market is the total yield.

[3]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 1.15. Agronomics of tomato production from different mulching and herbicide systems – E.V. Smith (Plant Breeding Unit) 2016

	Tomato Yield (kg/Ha)						
	Tomato Grades[2]						
Mulching System[1]	Cull	S	M	L	XL	Total	Market
Conventional Tillage	30[c]	24[b]	0[c]	0[b]	27[b]	82[c]	51[b]
Polyethylene	4294[a]	466[a]	1157[a]	1426[a]	2406[a]	9750[a]	5456[a]
Conservation Tillage	539[c]	55[b]	163[c]	383[b]	321[b]	1460[c]	921[a]
Polyethylene + Rye	2231[b]	314[a]	744[b]	1249[a]	1712[a]	6249[b]	4019[a]
LSD (α = 0.10)	1105	129	274	442	911	2411	1450
Herbicide System[3]							
Non-treated	1372[a]	196[a]	408[a]	578[a]	976[a]	3531[a]	2158[a]
S	1554[a]	173[a]	380[a]	783[a]	859[a]	3749[a]	2195[a]
E	2307[a]	237[a]	552[a]	736[a]	1266[a]	5097[a]	2790[a]
S + E	1861[a]	254[a]	724[a]	961[a]	1364[a]	5163[a]	3303[a]
LSD (α = 0.10)	1105	129	274	442	911	2411	1450

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2] Tomato grades are USDA standards based on tomato size. Market is the total yield.

[3]Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

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**Proc glimmix was used in SAS for all statistical analysis.

Table 1.16. Agronomics of tomato production from different mulching and herbicide systems – E.V. Smith (Plant Breeding Unit) 2016

Mulching + Herbicide Combination[1]	Tomato Yield (kg/Ha) Cull	S	M	L	XL	Total	Market[8]
Conventional Tillage[1] + Non-treated[2]	0^{b}	0^{c}	0^{c}	0^{b}	0^{b}	0^{c}	0^{b}
Conventional Tillage + Sandea[3]	76^{b}	22^{c}	0^{c}	0^{b}	109^{b}	208^{c}	131^{b}
Conventional Tillage + Envoke[4]	0^{b}	0^{c}	0^{c}	0^{b}	0^{b}	0^{c}	0^{b}
Conventional Tillage + Sandea + Envoke	46^{b}	74^{c}	0^{c}	0^{b}	0^{b}	119^{c}	74^{b}
Polyethylene[5] + Non-treated	2735^{b}	502^{abc}	1007^{abc}	1250^{ab}	1430^{ab}	6925^{abc}	4190^{ab}
Polyethylene + Sandea	2735^{b}	70^{c}	670^{abc}	847^{ab}	861^{ab}	5183^{bc}	2448^{ab}
Polyethylene + Envoke	7477^{a}	663^{a}	1354^{a}	2148^{a}	3783^{a}	15424^{a}	7947^{a}
Polyethylene + Sandea + Envoke	4230^{ab}	629^{ab}	1597^{a}	1459^{ab}	3551^{ab}	11467^{ab}	7237^{a}
Conservation Tillage[6] + Non-treated	45^{b}	0^{c}	28^{c}	0^{b}	0^{b}	73^{c}	28^{b}
Conservation Tillage + Sandea	960^{b}	107^{c}	150^{c}	762^{ab}	246^{ab}	2224^{bc}	1264^{b}
Conservation Tillage + Envoke	195^{b}	114^{bc}	405^{bc}	685^{ab}	1039^{ab}	3195^{bc}	152^{b}
Conservation Tillage + Sandea + Envoke	955^{b}	114^{bc}	405^{bc}	685^{bc}	1039^{ab}	3195^{bc}	2241^{ab}
Polyethylene + Rye[7] + Non-treated	2710^{b}	282^{abc}	598^{a}	1061^{ab}	2474^{ab}	7126^{abc}	4415^{ab}
Polyethylene + Rye + Sandea	2447^{b}	493^{abc}	699^{abc}	1521^{ab}	2222^{ab}	7383^{abc}	4936^{ab}
Polyethylene + Rye + Envoke	1553^{b}	285^{abc}	784^{abc}	713^{a}	1281^{ab}	4616^{bc}	3063^{ab}
Polyethylene + Rye + Sandea + Envoke	2213^{b}	197^{abc}	894^{abc}	1700^{ab}	869^{ab}	5873^{abc}	3660^{ab}
LSD (α = 0.10)	2210	258	547	884	1823	4823	2899

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene). Non-treated plots had no herbicides applied, halosulfuron (52.5 grams ai ha^{-1}) was applied pre-emergence, trifloxlysulfuron (10.5 grams ai ha^{-1}) was applied post-emergence, or both halosulfuron and trifloxysulfuron applied.

[2]Tomato grades are USDA standards based on tomato size. Market is the total yield.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

The Effects of Polyethylene and Cereal Rye Mulch, Tillage, and Herbicides on Yield and Weed Control in Watermelon

Abstract

Currently not many producers in the Southeast U.S. use conservation tillage methods in vegetable production. The lack of conservation usage in vegetable production is likely due to the difficulty in profitably producing vegetables with conservation tillage. Other methods of production, such as conventional tillage with polyethylene are so productive that other methods of production are not encouraged, because of their lack of production. The objective of this experiment was to determine is conservation tillage practices could be incorporated into watermelon production. Watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) was grown 2014 and 2016 near Shorter, AL. The watermelon study was laid out in a split-strip design. The main strip was mulching system. Mulching systems used were 1) halosulfuron (26.3 grams ai ha^{-1}) applied PRE, 2) halosulfuron (26.3 grams ai ha^{-1}) applied POST, 3) halosulfuron PRE and POST, and 4) a non-treated control. Use of polyethylene mulch significantly increased watermelon yield over conventional tillage and conservation tillage without polyethylene. The effect of polyethylene can also be seen in the herbicide interaction. Herbicides were much less effective at increasing yield and controlling weeds compared to use of polyethylene. Weed control ratings revealed similar results, with treatments that included polyethylene having higher weed control. The results of this experiment showed that progress still needs to be made in developing conservation systems for vegetable production. However, the results of the polyethylene over rye showed that this mulching system could have potential in conservation vegetable production.

Introduction

Conservation tillage improves soil quality by increasing organic matter and preserving soil structure by reducing the number of equipment passes equipment. Common practices in watermelon production, such as intensive tillage and use of polyethylene mulch, reduces soil quality due to erosion and loss of soil structure (Lament Jr. et al. 1993). Cover crops reduce erosion by lowering the impact of rainfall on soil and reducing surface run off (Zuazo et al. 2008).

Conservation tillage has become more common in many row crops due to the popularity of genetically modified crops tolerant to effective over the top herbicides. Watermelon weed control includes many challenges because this crop does not appear on many herbicide labels compared to larger acreage crops such as corn, soybean, or cotton. Thus, conservation system adoption in watermelon had been slow. However, growers are more likely to control weeds if they employ a number of different integrated strategies to obtain effective weed control (Monday et al. 2015).

Weed control is important in watermelon because of its growth habit. Being a creeping vine, watermelon is not a very competitive crop, and can be easily shaded out by faster vertically growing weeds. Weeds can be controlled by between row tillage or by mowing until watermelons produce runners that vine across the inter-row area (Monday et al. 2015). Buker et al. in 2003 found that watermelon are very poor competitors with yellow nutsedge (*Cyperus esculentus*). Their research showed that 12 yellow nutsedge plants per square meter could reduce yield in transplanted watermelon by 40%. Monks et al. in 1998 found that marketable yield of watermelon was decreased by 5,582 kg/ha for every week that large crabgrass (*Digitaria sanguinalis*) remained in watermelon. Monks et al. determined that from zero to six weeks after transplanting watermelon needs to remain large crabgrass free to maximize yield.

Cover crops are not often used in watermelon production due to the dominance and effectiveness of polyethylene for weed control. Installing polyethylene mulch has been accomplished in the past utilizing a clean, weed free bed made by intensive tillage. Conservation tillage may result in tomato yields being more unpredictable (Masiunas et al. 1995). However, in some cases using cereal rye as a cover crop may preserve the structure of raised beds used in production (Roberts et al. 1999). In 2008 Keshavarzpour et al. conducted a study using different tillage treatments and evaluating the yield. They found that conventional tillage was the most effective in terms of yield compared to reduced tillage, minimum tillage, and no tillage. However, it should be noted that none of the tillage methods in this study used a cover crop. In 2004 Madden et al. demonstrated that in vegetable production timely termination and adept use of a cover crop can provide weed control in conservation tillage. In this study, herbicides integrated with different types of tillage and mulch systems were evaluated to determine impact on weed control and watermelon yield.

Material and Methods

Field Site Description and Experimental Approach. Crimson sweet watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai var. *lanatus*) were planted in 2014 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center Field Crops Unit, and in 2015 and 2016 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center Plant Breeding unit in central Alabama. The soil was a Pacolet loamy sand (siliceous, semiactive, thermic Typic Hapudult). The soil had a pH of 6 and 0.5 – 2.0% organic matter. The experiment was arranged in a split strip plot within a randomized complete block design, with mulching system serving as the main plot and herbicide system serving as the sub strip plot. The experiment had three repetitions of treatment.

There were four mulching systems. The first system was the industry standard polyethylene mulch on a 7.62 centimeter raised bed. The second system was conservation tillage with rye cover crop with a cover crop of rye (*Secale cerale* L.). The third system was conventional tillage. The fourth system was polyethylene over rye. These plots had flat beds because of the difficulty in creating raised beds with a cover crop. The rye was terminated with glyphosate applied at 1.12 kg ae ha^{-1} and rolled before transplanting watermelon.

The herbicide treatments for watermelon were: 1) halosulfuron (26.3 grams ai ha^{-1}; Sandea®, Gowan The GoTo Company, Yuma, AZ 85364) applied PRE, 2) halosulfuron (26.3 grams ai ha^{-1}) applied POST, 3) halosulfuron PRE and POST, and 4) a non-treated control. Preemergent treatments were sprayed one week before planting date. Postemergent treatments were applied 4 weeks after transplanting. A non-treated plot was included for comparison. Clethodim (140.1 gram ai ha^{-}1; Select®, Valent, Walnut Creek, CA 94596-8025) was applied twice to suppress weedy grass growth. Section (Clethodim) (Table 2.1, 2.2, 2.3).

In 2014 and 2015, plots were 5.49 meters long and 1.83 meters wide with a 61 centimeter alley between each plot. There was a 1.83 meters border on each side of the field. In 2016 plots were 5.49 meters long and 2.13 meters wide with a 61 centimeter alley between each plot. There were no borders in 2016. Watermelon were transplanted with a spacing of 91 centimeters between plants.

The strips with conservation tillage with rye cover crop and polyethylene over rye were planted with cereal rye cultivar Wrens Abruzzi that was drilled in at 102.05 kg/ha in the fall. Prior to termination, rye samples were collected to determine the biomass grown prior to termination. Plots with polyethylene mulch were terminated earlier so that the polyethylene mulch could be installed while the rye was still relatively short. Nutrient management, fungicides, and insecticides were maintained as recommended by the Alabama Cooperative Extension System (Anonymous 2012) (Table 2.4, 2.5, 2.6).

Watermelon was transplanted May 14, 2014, May 1, 2015, and May 5, 2016. All plants received water at planting. Drip irrigation was installed on all plots to provide plants with water. Drip irrigation was applied four times a day for fifteen minutes each time seven days a week. The irrigation was set on a timer. Fertilizer was applied throughout the season using soluble fertilizer through the drip irrigation. Insecticides and fungicides were applied as needed to the plots (Table 19, 27, 36). In 2014 watermelon was harvested on July 23, 2015 watermelon was harvested July 16, and 2016 watermelon was harvested July 13. In all years watermelon was all harvested at one time and weighed.

Data collection. In 2014 and 2016 weed ratings were performed on the watermelon plots to determine the extent of weed control for major weeds found in each of the plots. Ratings were done visually to measure the amount of control different treatment combinations provided. In the ratings performed a rating of 0% meant that there was no control of the weed in that plot, a rating of 100% meant that the weed was completely controlled in the plot. Yield data was collected from watermelon.

Statistical Analysis. Data was analyzed in SAS 9.4 using procedure GLIMMIX. Differences between least significant means were calculated in SAS using the LSMEANS function. The mulching and herbicide systems used were the fixed effects and the replication was the random effect. LSD values were calculated using Excel.

Results and Discussion

Watermelon Weed Control. The 2014 weed control ratings had morningglory (*Ipomoea* spp. L.), coffee senna (*Senna occidentalis* L. Link), carpetweed (*Mollugo verticillata* L.), crabgrass (*Digitaria sanguinalis L.)*, and purslane (*Portulacca* spp. L.) early and late. There was no significance in the early weed control interaction in 2014 (Table 2.7). Herbicide system also had no significance, except for the not-treated plots having less weed control in coffee senna, carpetweed, and crabgrass. The mulching systems had significance in all weeds except crabgrass. In morningglory conventional tillage and conservation tillage with rye cover crop were significantly lower control than the other mulching systems (Table 2.8).

In the late weed control interaction there was significance in crabgrass control with non-treated plots having less weed control than the treated plots in all of the mulching systems (Table 2.9). Herbicide system was significant in coffee senna and crabgrass. In coffee senna the non-treated (70%) and PRE only (72%) were significantly lower control than the other systems. Crabgrass non-treated was significantly less control (22%). Mulching system was also significant in all systems except for carpetweed with conventional tillage providing the least weed control of any system across the board (Table 2.10).

In 2016 large crabgrass (*Digitaria sanguinalis* L.), cutleaf eveing primrose (*Oenothera laciniata* Hill), purple nutsedge (*Cyperus rotundus* L.), sicklepod (*Senna obtusifolia* L.), and arrowleaf sida (*Sida rhombifolia* L.) were all rated. In watermelon 2016 weed control crabgrass, cutleaf evening primrose, purple nutsedge, sicklepod, and arrowleaf sida were evaluated early and late. Early rating occurred after all the herbicide applications. The late rating occurred one week before harvest.

In early crabgrass control there was only significance found in the mulching system. conventional tillage and polyethylene mulch had better control (90% and 92% respectively) (Table 2.11). There was no significance in the interaction (Table 2.12). For late crabgrass control there was a significant difference in mulching system with polyethylene over rye and conservation tillage with rye cover crop not having as effective of control as polyethylene mulch and conventional tillage. No herbicide system performed better than any other. (Table 2.13). There was also no significance for the interaction of mulching system and herbicide system (Table 2.14).

Early control of cutleaf evening primrose showed significance in the interaction between the mulching systems that were planted with rye. In the interaction it seems that the plots with rye had less control. However, conventional tillage non-treated plots had the least control (Table 2.12). There was also significance in the mulching systems with polyethylene mulch having the highest control (97%). polyethylene over rye had the next highest (85% control) and conservation tillage with rye cover crop had the least control (62%) (Table 2.11). Herbicide was only significant in the non-treated being lower than all other treatments. Late cutleaf evening primrose control had significant control differences in the tillage with polyethylene mulch providing the highest weed control (95%), respectively. conservation tillage with rye cover crop provided the least effective weed control (40%). There were no differences in the weed control from herbicides except for non-treated having the least control (Table 2.13). Only the plots with rye on them had any significance in the interaction. Plots with rye had significantly less control. The conventional tillage non-treated also had very poor control (Table 2.14).

Early purple nutsedge control had significance in the mulching system. conservation tillage with rye cover crop and polyethylene over rye had the highest control (83%) and (81%). conventional tillage had the least control (66%). In herbicide systems the non-treated had the least control (60%) (Table 2.11). There was no significance in the interaction except for conventional tillage non-treated having the least control (Table 2.12). Late Purple nutsedge control showed the highest control in conservation tillage with rye cover crop (81%). There was no significance in the herbicide treatments for purple nutsedge control except for the non-treated

(Table 2.13). The interaction had some significance. Mainly the polyethylene over rye with PRE and POST herbicides had less control and so did polyethylene mulch with a PRE only (Table 30).

Early sicklepod control has significance in the interaction. conventional tillage non-treated was found to be less than all other treatments (Table 2.12). There was also significance in the mulching systems with conventional tillage providing less control than other treatments (65% control). Herbicide showed no significance except for the non-treated (Table 2.11). Early sicklepod control was generally good. Late sicklepod control in the interaction was significant with the conventional tillage having the least control, especially the conventional tillage with a PRE (52% control) (Table 2.14). The mulching systems were only significantly different in the conventional tillage which provided less control than all the other systems. Herbicides were non-significant except in the non-treated (Table 2.13).

Early arrowleaf sida control had significance in the herbicide system and the mulching system used. Mulching system had significantly more control in polyethylene mulch and polyethylene over rye than the other systems at 97% and 98% respectively. Herbicide system showed that plots receiving any herbicide application had better control than the non-treated (Table 2.11). The interaction had significance. The conservation tillage with rye cover crop non-treated had the lowest control (90%) except for the conventional tillage non-treated (Table 2.12). Late arrowleaf sida control showed mulching system significance in the systems without polyethylene not having as effective of control as the systems containing polyethylene. There was significance for the herbicide with the non-treated having the least control (63%) (Table 2.13). There was no significance in the interaction for arrowleaf sida except for the conventional tillage non-treated (Table 2.14).

Watermelon Yield. In 2014 there was significance in the interaction in watermelon yield. conventional tillage with any kind of herbicide treatments did not yield. The conservation tillage with rye cover crop non-treated also did not yield. polyethylene mulch with a PRE yielded the highest amount of watermelon (41,911) kg/ha (Table 2.15). The mulching system was significant with polyethylene mulch being the most effective at increasing yield. polyethylene mulch produced 30,661 kg/ha. The other mulching systems were not effective significant from each other. Herbicide system was not significant (Table 2.16).

In 2015 watermelon yield was found to be significantly different between mulching systems. The polyethylene mulch system had the highest yield. The conservation tillage with rye cover crop system and polyethylene over rye system were not significantly different from each other. conventional tillage had the lowest yield. Herbicide treatment was non-significant (Table 2.17).

In the interaction between mulching system and herbicide system all the conventional tillage treatments were significantly different from polyethylene mulch, which was the highest yielding. All of the conservation tillage with rye cover crop mulching system treatments are statistically similar to all the polyethylene over rye treatments. The polyethylene mulch plus POST herbicide was the highest yield treatment and statistically significant from all other combinations of treatments (Table 2.18).

In 2016 the polyethylene mulch and polyethylene over rye mulching systems were again the highest yielding systems being significant from the other systems. Herbicide systems were non-significant (Table 2.19).

As in 2015, yields were the highest on the interaction when plots had polyethylene on them, regardless of herbicide treatment. The polyethylene mulch mulching system was significant from all the conservation tillage with rye cover crop and conventional tillage treatments (Table 2.20).

Discussion. This research indicates that using polyethylene is the most beneficial practice for growing watermelon. In 2016 there was no significant difference between the polyethylene mulch and polyethylene over rye treatments, showing that polyethylene over rye could be an alternative form of mulching for watermelon production that yields well and also protects the environment. polyethylene over rye was the most consistent yielding system across the different years. In the herbicide systems there was no significance indicating that mulching system is the most important factor in increasing yield between herbicide and mulching system.

The interaction between herbicide system and mulching system showed that it was the mulching system that was the predominant factor in improving yield. The systems including polyethylene had the greatest yield and yield were generally not boosted by including a PRE and POST application.

PRE and POST had similar levels of control in all weeds. Control was not increased by including PRE and POST applications. Polyethylene over rye and polyethylene mulch was an effective weed control practice in most situations except for nutsedge, which is able to penetrate the polyethylene. The interaction between herbicide system and mulching system shows that increasing herbicide intensity does not increase weed control regardless of tillage system.

Past research has shown that watermelon grown under conventional tillage than under conservation tillage (Keshavarzpur and Rashidi 2008). This difference could be because watermelon has deep growing roots that thrive in a friable bed created by intensive tillage. Past research has also shown that using polyethylene will greatly increase yield of watermelon, because of the weed control and heating of the soil caused by polyethylene (Soltani 1995).

Advancements in using conservation tillage in watermelon would make it a more environmentally friendly crop, and one that could be more easily produced in farm-to-table scenarios. Farm-to-table would open possibilities for watermelon to be grown by small farmers with more profitability. However, more research needs to be done to show that watermelon can be grown under conservation tillage.

From the work done in this experiment it can be seen that using conservation tillage and a rye cover crop under polyethylene has potential to address some of the issues solved by conservation tillage, while maintaining a high yield. The polyethylene over rye used in this experiment used flat beds, which could lead to drainage problems with the soil later on in the growing season. Raised beds with rye and polyethylene are a possible solution to the soil drainage, but they would also require more intensive tillage.

The timing of cover crop termination is very important in conservation tillage. Rye can create interference if it is terminated too early and regrowth occurs. Regrowth would create competition for the watermelon and use tie up more nitrogen that would not be available to the watermelon. Therefore, more research is needed to develop a functional system that producers could use to incorporate conservation tillage and watermelon production.

Table 2.1. Dates of treatment and tillage in watermelon – E.V. Smith (Field Crops Unit) 2014

Treatment	Date
Cover Crop Planted	11/6/13
Fertilizer	3/11/14
Tillage	4/24/14
Cover Crop Terminated	4/24/14
PRE	4/23/14
Polyethylene Laid	4/24/14, 5/7/14
Transplant	5/14/14
Replant	5/21/14
POST	6/4/14
Select Sprayed	6/9/14
Harvest	7/23/14

Table 2.2. Dates of treatment and tillage in watermelon – E.V. Smith (Plant Breeding Unit) 2015

Treatment	Date
Cover Crop Planted	11/24/14
Tillage	4/24/15
Cover Crop Terminated	4/24/15
PRE	4/24/15
Polyethylene Laid	3/25/15, 4/24/15
Transplant	5/1/15
Replant	5/14/15
POST	6/2/15
Select Sprayed	6/3/15
Harvest	7/16/15

Table 2.3. Dates of treatment and tillage in watermelon – E.V. Smith (Plant Breeding Unit) 2016

Treatment	Date
Cover Crop Planted	12/8/15
Fertilizer	3/10/16
Tillage	4/19/16
Cover Crop Terminated	4/19/16, 4/27/16
PRE	3/8/16, 4/26/16
Polyethylene Laid	4/27/16, 3/10/16
Transplant	5/5/16
Replant	5/9/16
POST	6/1/16
Section Sprayed	5/9/16, 6/10/16
Harvest	7/13/16

Table 2.4. Fertilizer and pesticide application dates for watermelon 2014

Date	Fertilizer	Fungicide	Insecticide
5/22/14	2.3 kg 20-20-20		
5/24/14		Mancozeb 2.7 kg ai/ha	
5/29/14	2.3 kg 20-20-20		
6/3/14		Copper Hydroxide 753.6 grams ai/ha	
6/4/14	2.3 kg 20-20-20		
6/5/14	2.3 kg 20-20-20		Imidacloprid 457.7 gram ai/ha
6/17/14	2.3 kg 20-20-20	Chlorothalonil 2.2 kg ai/ha	
6/18/14	2.3 kg calcium nitrate		
6/19/14			Bifenthrin 89.7 grams ai/ha; Bacillus thuringiensis 1.2 kg ai/ha
6/24/14	2.3 kg calcium nitrate	Azoxystrobin 13.4 kg ai/ha	Bacillus thuringiensis 1.2 kg ai/ha
6/27/14	2.3 kg calcium nitrate		
7/1/14	2.3 kg calcium nitrate	Mancozeb 2.7 kg ai/ha	Bacillus thuringiensis 1.2 kg ai/ha
7/6/14		Azoxystrobin 13.4 kg ai/ha	Bacillus thuringiensis 1.2 kg ai/ha
7/13/14	2.3 kg calcium nitrate		
7/16/14	2.3 kg calcium nitrate		
7/11/14	2.3 kg calcium nitrate		
7/17/14	2.3 kg calcium nitrate 2.3 kg potassium nitrate		

Table 2.5. Fertilizer and pesticide dates for watermelon 2015

Date	Fertilizer	Fungicide	Insecticide
5/15/15	2.3 kg 20-20-20	Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha	Imidacloprid 457.7 gram ai/ha
5/18/15	2.3 kg 20-20-20		
5/20/15	2.3 kg 20-20-20		
5/21/15		Basic Copper Sulfate 1.1 kg ai/ha; Chlorothalonil 2.2 kg ai/ha	Methoxyfenoxide 140.1 gram ai/ha
5/22/15	2.3 kg 20-20-20		
5/26/16	2.3 kg 20-20-20		
5/28/15	2.3 kg 20-20-20		
5/29/15		Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha	Esfenvalerate 55.5 grams ai/ha
6/1/15	2.3 kg 20-20-20		
6/4/15	2.3 kg 20-20-20		
6/9/15	2.3 kg 20-20-20		
6/12/15	2.3 kg 20-20-20	Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha	
6/16/15	3.8 liter 13-0-46		
6/19/15		Azoxystrobin 13.4 kg ai/ha; Penthiopyrad 234.2 grams ai/ha	Esfenvalerate 55.5 grams ai/ha
6/22/15	3.8 liter 13-0-46		
6/26/15	3.8 liter 13-0-46		
6/30/15	3.8 liter 13-0-46		
7/6/15	3.8 liter 13-0-46		
7/8/15	3.8 liter 13-0-46		
7/13/15	3.8 liter 13-0-46		
7/15/15	3.8 liter 13-0-46		

Table 2.6. Fertilization, fungicide, and insecticide application information for watermelon 2016

Date	Fertilizer	Insecticide	Fungicide
5/10/16	2.3 kg 20-20-20		
5/13/16	2.3 kg 20-20-20		
5/16/16	2.3 kg 20-20-20		
5/18/16			Mancozeb 2.7 kg ai/ha; Basic Copper Sulfate 1.1 kg ai/ha
5/20/16	2.3 kg 20-20-20		
5/23/16	2.3 kg 20-20-20		
5/26/16		Imidacloprid 7 oz/acre	
5/27/16	2.3 kg 20-20-20		
6/1/16	2.3 kg 20-20-20		
6/3/16		Thiamethoxam 52.5 grams ai/ha	Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha
6/4/16	2.3 kg 20-20-20		
6/7/16	2.3 kg 20-20-20		
6/10/16	2.3 kg 20-20-20	Bifenthrin 89.7 grams ai/ha	Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha
6/14/16	2.3 kg 15.5-0-0		
6/17/16	3.8 Liter 13-0-46	Bifenthrin 89.7 grams ai/ha	Basic Copper Sulfate 1.1 kg ai/ha; Mancozeb 2.7 kg ai/ha
6/21/16	2.3 kg 15.5-0-0		
6/24/16	3.8 liter 13-0-46		
6/25/16		Bifenthrin 89.7 grams ai/ha	Mancozeb 2.7 kg ai/ha
6/28/16	2.3 kg 15.5-0-0		
7/1/16		Thiamethoxam 52.5 grams ai/ha	Mancozeb 2.7 kg ai/ha
7/4/16	3.8 liter 13-0-46		
7/9/16	2.3 kg 15.5-0-0		
7/11/16		Bifenthrin 89.7 grams ai/ha	Mancozeb 2.7 kg ai/ha
7/13/16	3.8 liter 13-0-46		

Table 2.7. Early weed control of different mulching systems and herbicides in watermelon – E.V. Smith (Field Crops Unit) 2014

		% Weed Control				
		Herbicide Systems[3]				
Mulching System[1]	Weed Species[2]	Non-treated	PRE-S	POST-S	PRE-S + POST-S	*LSD (α=0.1)*
Conventional Tillage	MG[8]	0[a]	42[a]	56[a]	0[a]	52
	CS[9]	0[b]	57[a]	99[a]	99[a]	26
	CW[10]	0[b]	99[a]	66[a]	99[a]	20
	CG[11]	0[b]	99[a]	99[a]	99[a]	25
	PS[12]	0[c]	17[bc]	0[c]	33[abc]	44
Polyethylene	MG	99[a]	66[a]	66[a]	99[a]	-
	CS	99[a]	99[a]	99[a]	99[a]	-
	CW	93[a]	60[a]	80[a]	90[a]	-
	CG	0[b]	99[a]	99[a]	99[a]	-
	PS	73[abc]	83[abc]	83[abc]	47[abc]	-
Conservation Tillage	MG	58[a]	33[a]	13[a]	60[a]	-
	CS	99[a]	66[a]	99[a]	91[a]	-
	CW	99[a]	99[a]	99[a]	94[a]	-
	CG	30[b]	99[a]	99[a]	99[a]	-
	PS	37[abc]	83[abc]	30[abc]	66[abc]	-
Polyethylene + Rye	MG	83[a]	66[a]	96[a]	99[a]	-
	CS	99[a]	99[a]	94[a]	99[a]	-
	CW	99[a]	99[a]	98[a]	99[a]	-
	CG	30[b]	99[a]	99[a]	99[a]	-
	PS	99[a]	99[a]	99[a]	93[ab]	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Morningglory, coffee senna, carpetweed, crabgrass, purslane

[3]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

Table 2.8. Agronomic and early weed control effects of different mulching and herbicide systems in watermelon – E.V. Smith (Field Crops Unit) 2014

		% Weed Control				
Mulching System[1]	Yield kg/Ha	Morningglory	Coffee senna	Carpetweed	Crabgrass	Purslane
Conventional Tillage[1]	0[c]	25[b]	64[b]	66[b]	74[a]	12[c]
Polyethylene[2]	30661[a]	83[a]	99[a]	80[ab]	74[a]	72[ab]
Conservation Tillage[3]	6825[bc]	41[b]	89[a]	98[a]	82[a]	54[b]
Polyethylene + Rye[4]	17526[bc]	86[a]	98[a]	99[a]	82[a]	98[a]
LSD (α=0.1)	9278	26	13	14	12	20
Herbicide System[2]						
Non-treated[5]	7716[a]	60[a]	74[b]	73[b]	15[b]	51[a]
PRE-S[6]	17333[a]	52[a]	80[ab]	89[ab]	99[a]	70[a]
POST-B[7]	18883[a]	58[a]	98[a]	86[ab]	99[a]	53[a]
PRE-S + POST-B	11080[a]	64[a]	97[a]	96[a]	99[a]	60[a]
LSD (α=0.1)	9278	26	13	14	12	20

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 2.9. Late weed control of different mulching systems and herbicides in watermelon – E.V. Smith (Field Crops Unit) 2014

		% Weed Control				
		Herbicide Systems[3]				
Mulching System[1]	Weed Species[2]	Non-treated[5]	PRE-S[6]	POST-B[7]	PRE-S + POST-B	*LSD (α=0.1)*
Conventional Tillage[1]	MG[8]	0[a]	33[a]	33[a]	0[a]	52
	CS[9]	0[c]	37[bc]	94[a]	94[a]	24
	CW[10]	0[b]	99[a]	66[ab]	66[ab]	43
	CG[11]	0[c]	99[a]	99[a]	66[ab]	32
	PS[12]	0[b]	0[b]	0[b]	25[ab]	46
Polyethylene[2]	MG	99[a]	66[a]	66[a]	99[a]	-
	CS	99[a]	99[a]	99[a]	99[a]	-
	CW	99[a]	58[ab]	80[ab]	66[ab]	-
	CG	0[c]	99[a]	94[a]	99[a]	-
	PS	53[ab]	40[ab]	53[ab]	0[b]	-
Conservation Tillage[3]	MG	28[a]	33[a]	8[a]	50[a]	-
	CS	83[ab]	52[ab]	94[a]	89[a]	-
	CW	83[ab]	99[a]	83[ab]	58[ab]	-
	CG	28[bc]	99[a]	99[a]	99[a]	-
	PS	28[ab]	50[ab]	27[ab]	33[ab]	-
Polyethylene + Rye[4]	MG	83[a]	66[a]	50[a]	99[a]	-
	CS	99[a]	99[a]	93[a]	99[a]	-
	CW	99[a]	99[a]	94[a]	86[ab]	-
	CG	61[abc]	99[a]	99[a]	99[a]	-
	PS	99[a]	83[ab]	96[a]	83[ab]	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Morningglory, coffee senna, carpetweed, crabgrass, purslane

[3]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 2.10. Agronomic and late weed control effects of different mulching and herbicide systems in watermelon – E.V. Smith (Field Crops Unit) 2014

		% Weed Control				
Mulching System	Yield kg/Ha	Morningglory	Coffee senna	Carpetweed	Crabgrass	Purslane
Conventional Tillage[1]	0[c]	17[b]	56[c]	58[a]	66[b]	6[b]
Polyethylene[2]	30661[a]	83[a]	99[a]	76[ab]	73[ab]	37[b]
Conservation Tillage[3]	6825[bc]	30[b]	80[b]	81[ab]	81[ab]	34[b]
Polyethylene + Rye[4]	17526[bc]	74[a]	97[a]	58[b]	90[a]	90[a]
LSD (α=0.1)	9278	26	12	22	16	23
Herbicide System						
Non-treated[5]	7716[a]	53[a]	70[b]	70[a]	22[b]	45[a]
PRE-S[6]	17333[a]	50[a]	72[b]	89[a]	99[a]	43[a]
POST-B[7]	18883[a]	39[a]	95[a]	81[a]	98[a]	44[a]
PRE-S + POST-B	11080[a]	62[a]	95[a]	69[a]	91[a]	35[a]
LSD (α=0.1)	9278	26	12	22	16	23

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 2.11. Agronomic and early weed control effects of different mulching and herbicide systems in watermelon – E.V. Smith (Plant Breeding Unit) 2016

		% Weed Control				
Mulching System	Yield kg/Ha	Crabgrass	Cutleaf Evening Primrose	Purple Nutsedge	Sicklepod	Arrowleaf Sida
Conventional Tillage[1]	10938[b]	90[a]	72[c]	66[c]	65[b]	71[c]
Polyethylene[2]	36275[a]	92[a]	97[a]	74[b]	97[a]	97[a]
Conservation Tillage[3]	5311[b]	68[b]	62[c]	83[a]	92[a]	93[b]
Polyethylene + Rye[4]	31657[a]	62[b]	85[b]	81[a]	98[a]	98[a]
LSD (α=0.1)	4624	12	7	4	5	1
Herbicide System						
Non-treated[5]	20391[a]	81[a]	57[b]	60[b]	72[b]	71[b]
PRE-S[6]	20352[a]	78[a]	83[a]	82[a]	90[a]	95[a]
POST-B[7]	23022[a]	76[a]	85[a]	80[a]	94[a]	96[a]
PRE-S + POST-B	20417[a]	76[a]	90[a]	82[a]	95[a]	97[a]
LSD (α=0.1)	4624	12	7	4	5	1

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

Table 2.12. Early weed control of different mulching systems and herbicides in watermelon – E.V. Smith (Plant Breeding Unit) 2016

		% Weed Control				
		Herbicide Systems[3]				
Mulching System[1]	Weed Species[2]	Non-treated[5]	PRE-S[6]	POST-S[7]	PRE-S + POST-S	*LSD (α=0.1)*
Conventional Tillage[1]	CG[8]	93[a]	85[a]	93[a]	87[a]	23
	PR[9]	0[e]	95[ab]	96[a]	96[a]	15
	PN[10]	0[b]	84[a]	91[a]	89[a]	9
	SP[11]	0[c]	75[b]	91[ab]	93[ab]	10
	AS[12]	0[e]	93[bcd]	93[bcd]	96[abc]	3
Polyethylene[2]	CG	92[a]	92[a]	93[a]	90[a]	-
	PR	97[a]	97[a]	97[a]	97[a]	-
	PN	75[a]	75[a]	73[a]	74[a]	-
	SP	96[a]	97[a]	97[a]	97[a]	-
	AS	97[abc]	97[abc]	96[abc]	96[abc]	-
Conservation Tillage[3]	CG	69[a]	65[a]	65[a]	74[a]	-
	PR	53[cd]	51[d]	65[bcd]	80[abcd]	-
	PN	83[a]	84[a]	78[a]	85[a]	-
	SP	93[ab]	91[ab]	91[ab]	91[ab]	-
	AS	90[d]	93[cd]	96[abc]	96[abc]	-
Polyethylene + Rye[4]	CG	70[a]	71[a]	53[a]	54[a]	-
	PR	79[abcd]	88[ab]	82[abc]	89[ab]	-
	PN	84[a]	83[a]	78[a]	81[a]	-
	SP	97[a]	98[a]	98[a]	99[a]	-
	AS	98[ab]	98[abc]	98[ab]	99[a]	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Crabgrass, cutleaf evening primrose, purple nutsedge, sicklepod, and arrowleaf sida

[3]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

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Table 2.13. Agronomic and late weed control effects of different mulching and herbicide systems in watermelon – E.V. Smith (Plant Breeding Unit) 2016

		% Weed Control				
Mulching System	Yield kg/Ha	Crabgrass	Cutleaf Evening Primrose	Purple Nutsedge	Sicklepod	Arrowleaf Sida
Conventional Tillage[1]	10938[b]	33[a]	68[b]	60[b]	50[b]	50[c]
Polyethylene[2]	36275[a]	28[ab]	95[a]	60[b]	96[a]	94[a]
Conservation Tillage[3]	5311[b]	25[b]	40[c]	81[a]	89[a]	67[b]
Polyethylene + Rye[4]	31657[a]	21[b]	75[b]	61[b]	96[a]	89[a]
LSD (α=0.1)	4624	5	10	7	9	11
Herbicide System						
Non-treated[5]	20391[a]	27[a]	54[b]	52[b]	69[b]	63[b]
PRE-S[6]	20352[a]	28[a]	74[a]	70[a]	83[a]	77[ab]
POST-B[7]	23022[a]	26[a]	73[a]	73[a]	88[a]	76[ab]
PRE-S + POST-B	20417[a]	25[a]	76[a]	70[a]	92[a]	84[a]
LSD (α=0.1)	4624	5	10	7	9	11

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

Table 2.14. Late weed control of different mulching systems and herbicides in watermelon – E.V. Smith (Plant Breeding Unit) 2016

Mulching System[1]	Weed Species[2]	% Weed Control Non-treated	PRE-S	POST-B	PRE-S + POST-B	*LSD (α=0.1)*
Conventional Tillage	CG	33[a]	33[a]	32[a]	32[a]	10
	PR	0[e]	82[ab]	93[a]	95[a]	20
	PN	0[e]	77[abcd]	87[ab]	88[a]	13
	SP	0[c]	52[b]	67[ab]	82[ab]	17
	AS	0[b]	63[a]	58[a]	77[a]	22
Polyethylene	CG	27[a]	28[a]	27[a]	28[a]	-
	PR	95[a]	93[a]	95[a]	96[a]	-
	PN	62[abcd]	58[cd]	62[abcd]	60[bcd]	-
	SP	95[a]	97[a]	95[a]	97[a]	-
	AS	97[a]	95[a]	93[a]	91[a]	-
Conservation Tillage	CG	23[a]	27[a]	27[a]	23[a]	-
	PR	42[bcd]	42[bcd]	37[de]	40[cde]	-
	PN	78[abcd]	83[abc]	82[abc]	80[abc]	-
	SP	87[a]	87[ab]	92[a]	90[a]	-
	AS	70[a]	65[a]	60[a]	73[a]	-
Polyethylene + Rye	CG	25[a]	25[a]	17[a]	17[a]	-
	PR	80[ab]	80[ab]	67[abcd]	71[abcd]	-
	PN	69[abcd]	61[bcd]	63[abcd]	52[d]	-
	SP	94[a]	96[a]	97[a]	97[a]	-
	AS	83[a]	87[a]	91[a]	95[a]	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Morningglory, coffee senna, carpetweed, crabgrass, purslane

[3]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 2.15. Agronomics of watermelon production from different mulching and herbicide systems – E.V. Smith (Field Crops Unit) 2014

	Watermelon Yield (kg/Ha)			
	Mulching System[1]			
Herbicide System[2]	Conventional Tillage	Polyethylene	Conservation Tillage	Polyethylene + Rye
Non-treated	0[b]	19432[ab]	0[b]	19342[ab]
PRE-S	0[b]	52653[a]	15062[ab]	19387[ab]
POST-B	0[b]	50920[a]	6231[ab]	37742[ab]
PRE-S + POST-B	0[b]	31073[ab]	13005[ab]	11604[ab]
LSD (α = 0.10)	23313	-	-	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 2.16. Agronomics of watermelon production from different mulching and herbicide systems – E.V. Smith (Field Crops Unit) 2014

	Agronomics
Mulching System[1]	Watermelon Yield (kg/Ha)
Conventional Tillage	0[c]
Polyethylene	38520[a]
Conservation Tillage	8575[bc]
Polyethylene + Rye	22018[b]
LSD (α = 0.10)	11657
Herbicide System[2]	
Non-treated	9693[a]
PRE-S	21775[a]
POST-B	23723[a]
PRE-S + POST-B	13920[a]
LSD (α = 0.10)	11657

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 2.17. Agronomics of watermelon production from different mulching and herbicide systems – E.V. Smith (Plant Breeding Unit) 2015

	Agronomics
Mulching System[1]	Watermelon Yield (kg/Ha)
Conventional Tillage	11859[c]
Polyethylene	61223[a]
Conservation Tillage	28455[b]
Polyethylene + Rye	34146[b]
LSD (α = 0.10)	8421
Herbicide System[2]	
Non-treated[5]	28467[a]
PRE-S[6]	29440[a]
POST-B[7]	38899[a]
PRE-S + POST-B	38878[a]
LSD (α = 0.10)	8421

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

Table 2.18. Agronomics of watermelon production from different mulching and herbicide systems – E.V. Smith (Plant Breeding Unit) 2015

	Watermelon Yield (kg/Ha)			
	Mulching System[1]			
Herbicide System[2]	Conventional Tillage	Polyethylene	Conservation Tillage	Polyethylene + Rye
Non-treated	16059[de]	51762[abc]	14763[de]	31283[bcde]
PRE-S	8530[e]	52434[abc]	36064[bcde]	20731[cde]
POST-B	9358[e]	77761[a]	29340[bcde]	39135[bcde]
PRE-S + POST-B	13491[de]	62932[ab]	33653[bcde]	45434[abcd]
LSD (α = 0.10)	16842	-	-	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

Table 2.19. Agronomics of watermelon production from different mulching and herbicide systems – E.V. Smith (Plant Breeding Unit) 2016

	Agronomics
Mulching System[1]	Watermelon Yield (kg/Ha)
Conventional Tillage	10938[b]
Polyethylene	36275[a]
Conservation Tillage	5311[b]
Polyethylene + Rye	31657[a]
LSD (α = 0.10)	4624
Herbicide System[2]	
Non-treated	20391[a]
PRE-S	20352[a]
POST-B	23022[a]
PRE-S + POST-B	20417[a]
LSD (α = 0.10)	4624

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

[*]LS-Means with the same letter are not significantly different.

[**]Proc glimmix was used in SAS for all statistical analysis.

Table 2.20. Agronomics of watermelon production from different mulching and herbicide systems – E.V. Smith (Plant Breeding Unit) 2016

	Watermelon Yield (kg/Ha)			
	Mulching System[1]			
Herbicide System[2]	Conventional Tillage	Polyethylene	Conservation Tillage	Polyethylene + Rye
Non-treated	10726[cde]	29500[ab]	3828[e]	37511[a]
PRE-S	10882[cde]	40554[a]	6543[de]	23429[abcd]
POST-B	9669[cde]	39444[a]	3888[e]	39086[a]
PRE-S + POST-B	12478[bcde]	35604[a]	6983[de]	26602[abc]
LSD (α = 0.10)	9248	-	-	-

[1]In conventional tillage plots were roto-tilled prior to planting; in polyethylene black polyethylene was laid over the plots mechanically prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene); in conservation tillage Rye (Wrens Aruzzi) was planted at 90 lbs/A in the Fall of 2015, then rolled flat prior to planting; in polyethylene + rye black polyethylene was mechanically laid over standing rye (early) prior to planting (all pre-emergence herbicide treatments were applied prior to laying the polyethylene).

[2]Non-treated plots had no herbicides applied, halosulfuron (26.3 grams ai ha^{-1}) was applied pre-emergence, halosulfuron (26.3 grams ai ha^{-1}) was applied post-emergence, or both PRE and POST applied.

*LS-Means with the same letter are not significantly different.

**Proc glimmix was used in SAS for all statistical analysis.

*LS-Means with the same letter are not significantly different.

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