VISUAL MISCUING OF THRIPS TO REDUCE THE INCIDENCE OF TOMATO

SPOTTED WILT VIRUS IN TOMATOES

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VISUAL MISCUING OF THRIPS TO REDUCE THE INCIDENCE OF TOMATO SPOTTED WILT VIRUS IN TOMATOES

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Scott David Croxton was born on March 9, 1984 in Richland, South Carolina. He is the son of Harry and Karen Croxton. He has one sister, Margaret. He graduated from Lexington High School in May 2002 and entered Auburn University in June 2002. Scott graduated with a Bachelor of Science degree in Horticulture and a minor in Entomology in August of 2005. Scott entered graduate school at Auburn University in August 2005 and pursued a Master of Science Degree under the guidance and direction of Dr. Wheeler G. Foshee, III. While at Auburn, Scott was employed as a graduate research assistant and later as a graduate teaching assistant. He received his Master of Science Degree on May 10, 2008.

THESIS ABSTRACT

VISUAL MISCUING OF THRIPS TO REDUCE THE INCIDENCE OF TOMATO SPOTTED WILT VIRUS IN TOMATOES

Scott David Croxton

Master of Science, May 10, 2008
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Greenhouse studies were conducted evaluating selected tempera paints to determine effects on yield and plant growth of tomatoes (*Lycopersicon esculentum*). Tempera paints (ColArt Americas Inc, Piscataway, NJ) evaluated were: brilliant red, cerise, crimson, jazz orange, and purple which were applied weekly up to first harvest. Treatments were first applied three days after transplanting. Weekly plant heights were gathered three days before each treatment application. Tempera paints had minimal significant effects on yield and plant height.

Experiments were conducted to evaluate tempera paints applied directly to field grown tomatoes. Paints were applied weekly starting three days after transplanting. Paints selected for the field trials were the same as earlier greenhouse trials with brilliant red, cerise, crimson, jazz orange, and purple. Weekly thrips populations were gathered along with tomato yields. ELISA tests were run early-season and mid-season to test for TSWV. The paints did not reduce the occurrence of TSWV but neither did they negatively influence yield. Since the paints did not reduce yields a more ultra-violet reflective color may still prove to be a viable option.

Field studies were conducted to evaluate the influence of colored mulch plastic on thrips ability to locate tomatoes. Mulch colors were selected based on ultra violet reflectance which has been shown to repel thrips. Specially manufactured colored mulches (Pliant Corp, Washington, GA) were: silver, white, red 1, red 2, red 3, and violet. Yields were taken weekly as well as thrips population counts. Enzyme-linked immunosorbent assay (ELISA) tests were completed early-season and mid-season to test for *Tomato spotted wilt virus* (TSWV). Red 1 and red 2 mulches showed significant reduction in thrips populations and TSWV incidence compared to white in some cases. However, the silver mulch consistently reduced thrips populations compared to the other mulches, as well as reducing tomato fruit yield losses.

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First and foremost the author wishes to thank GOD. The author has been mentored by many over the course of his career at Auburn University and wishes to thank the Department of Horticulture in full for many wonderful years. Without the help of Wheeler G. Foshee, the author would not be where he is today and for that wishes to show extreme appreciation to him and his family for all of their guidance, wisdom, and patience. Thanks to Edgar for all his help and support. Thanks to John Murphy, Jeff Sibley, and Henry Fadamiro for guidance in research. He would also like to thank Jane Hoehaver, Eric Upchurch, and all of their student workers for helping make his graduate career a success. He wishes to show appreciation to Jason Burkett and workers for helping in any way possible. Thanks to his family (the utmost important people in his life), Mom, Margaret, Jane, and Grandmother for their love and support, through thick and thin. Finally a special thanks to his friends whose support was greatly appreciated.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Thrips are tiny insects in the order Thysanoptera with slender bodies and fringed wings. The term thrips is used to refer to both the singular and plural forms of the insect. Feeding of thrips occurs on a large variety of plants, causing damage mainly on developing flowers leading to discoloration, deformities, and reduced marketability of the crop. To date over five thousand species of thrips have been described by entomologists (Mortiz et al., 2001). Thrips are generally $\leq$1 mm long and are poor flyers, although they can be carried long distances by the wind or on clothing (Zitter et al., 1989).

Thrips feed on hundreds of different crop plants and weeds especially during the flowering period (Cho et al., 1989). Thrips feed by piercing plant cells with their maxillary stylets, which form a feeding tube. The mandibular stylet is used to pierce an entry hole in plant cells or pollen grains allowing the maxillary stylets to easily enter the cell and suck out the contents.

Thrips in the genera *Frankliniella* (flower thrips) serve as vectors for plant viruses in the genus, *Tospoviruses*. The western flower thrips (*Frankliniella occidentalis*) has a world wide distribution and is considered the primary vector of Tospoviruses. While feeding on the plant tissue thrips inject saliva which can carry over twenty plant infecting viruses, including *Tomato spotted wilt virus* (TSWV) and *Impatiens necrotic spot virus* which are very damaging to many commercial crops. TSWV has become a worldwide problem with western flower thrips being the predominant vector to tomato plants (Lewis, 1997; Puche et al., 1995). Western flower thrips are highly attracted to bright colors, and able to distinguish clearly between different colors as well as various shades of color (Brodsgaard, 1989). Western flower thrips occurred in lower numbers on red, orange, and copper colored flowers than on yellow, blue, or purple flowers. Western flower thrips prefer flowering plants and feed on the flowers (Blumthal et al., 2005). Results have indicated that highly reflective UV surfaces are repellent to thrips in the 350-390 nm range and more precisely those UV wavelengths between 350 and 370 nm (Lewis, 1997). UV aluminized mulches were shown to reduce thrips numbers (Brown and Brown, 1992; Greenough et al., 1990; Reitz et al., 2003; Scott et al., 1989).

Over wintering of most thrips species is achieved as either adults or as pupae on weed hosts or in ground litter (Jenser et al., 2002). Flower thrips generation time can be from 7-22 days depending on the temperature, with warmer temperatures inducing shorter generation times. The eggs are about 0.2 mm long, reniform shaped, and may take on average of three days to hatch. Thrips have two larval stages then go through a prepupal and a pupae stage before becoming an adult. Immature thrips in the first instar acquire TSWV from infected host plants. TSWV can only be transmittable if it is acquired at the larval stage but can be transmitted throughout the lifecycle after a three to ten day incubation period. TSWV is transmitted when an infected thrips feeds on a plant and the virus is passed on to the plant (Zitter et al., 1989). Planting seed from a plant infected with TSWV does not result in plants infected with the virus (Culbreath et al., 2003). TSWV is not known to be transmitted in water supplies or by contact, although it has been found in water supplies (Hong and Moorman, 2005). The virus replicates in the vector as it matures and subsequently viruliferous adults spread the virus when they move to other plants. Virus multiplication in the thrips vector makes managing the virus difficult because once infected, adult thrips can migrate long distances to new host plants and quickly transmit the virus before thrips can be controlled (Ullman et al., 1993).

TSWV was first described in Australia in 1919 and has a wide host range that is uncommon among plant infecting viruses with more than 200 plant species susceptible to TSWV (Cho et al., 1989; Zitter et al., 1989). TSWV was established in tomato fields as early as 1976 and has become a major problem worldwide in the past few decades (Kirk and Terry, 2003). Some crops affected by thrips and TSWV include bean, cauliflower, celery, cowpea, cucumber, eggplant, lettuce, peanut, pepper, potato, spinach, tobacco, and tomato (Zitter et al., 1989). In 1985, approximately 50% of the peanut crop in the production area of southern Texas was lost to TSWV, with losses near 100% reported in some individual fields (Culbreath et al., 2003). TSWV is a serious problem for tomato production causing as much as $8.8 million in losses in a single year in Georgia (Riley and Pappu, 2000).

TSWV transmission has been demonstrated for several species of thrips, *Thrips tabaci* (Onion thrips) (Pittman, 1927), *T. setosus* (Japanese flower thrips) (Kobatake, 1984), *Frankliniella fusca* (Tobacco thrips) (Sakimura, 1961), *F. occidentalis* (Western flower thrips) (Gardner et al., 1935), *F. schultzei* (Tomato thrips) (Samuel et al., 1930) and *Scirtothrips dorsalis* (Chilli thrips) (Amin et al., 1981) but not all transmit as readily as others. Western flower thrips was been identified as the predominant vector of TSWV (Cho et al., 1989). Thrips that cause prebloom inoculation of TSWV are very important in terms of impact on tomato yield (Chaisuekul et al., 2003). The younger the plant, the greater the impact TSWV has on the plant. Young transplants will usually die when infected with TSWV. TSWV symptoms expressed on leaves, petioles, stems, and fruit will vary depending on the stage when plants are infected. Stunting, one-sided growth, mottled fruit, ring spots, discoloration on fruit, and systemic necrosis are some symptoms caused by TSWV (Culbreath et al., 2003).

Weed hosts serve as important virus reservoirs for TSWV as well as providing over-wintering shelter for adult female thrips. Lambsquarter (*Chenopodium album*), morning glory (*Convolvulus* spp.), sweet yellow clover (*Melilotus officinalis*), pokeweed (*Phytolacca decandra*), coreopsis (*Coreopsis spp*.), common mallow (*M. rotundifolia*), common purslane (*Portulaca oleracea*), and chickweed (*Stellaria spp*.) can serve as over-wintering hosts for TSWV (Sether and DeAngelis, 1992). TSWV has also been shown to over-winter in the hibernating body of female thrips (Jenser et al., 2002). The survival of TSWV (over-wintering) in the body of thrips was demonstrated by the presence of the virus in the body of specimens collected in September, October and April, as well as successful transmissions carried out in spring and autumn (Jenser et al., 2002).

Control of TSWV is very difficult since the virus cannot be removed from a plant following infection. The host thrips, those harboring the virus, as well are problematic due to their small size, behavior, and high rate of reproduction. Early season control is critical for control of TSWV and reduces incidence as much as full season control (Riley, 2001). Some primary control tactics in tomatoes are reflective mulches (Brown and Brown, 1992; Greenough et al., 1990; Reitz et al., 2003; Stavisky, 2002), host plant resistance (Kumar et al., 1993), and insecticides combined with other tactics (Riley and

Pappu, 2000). To date, however, no single management tool provides adequate control, and resistant varieties are the most important factor in a control program for TSWV (Culbreath et al., 2003).

Studies have shown evidence that thrips search for a host based on color, with indications that UV-reflective mulch interfered with thrips host-seeking behaviour (Lewis, 1997). Results indicated that a highly reflective UV surface is repellent to thrips in the 350-390 nm range and more specifically those UV wavelengths between 350 and 370 nm (Lewis, 1997). Because of this, some success has been achieved in reducing thrips infestation and damage by using UV reflective sheets. Aluminum painted mulch in tomato plots reduced numbers of *F. fusca* (Scott et al., 1989). TSWV and thrips pressure is variable from year to year making it difficult to plan control methods and they need to be adjusted from year to year. Over a three year period, Riley and Pappu (2004) reported that the use of reflective mulch, resistant plants, and early season insecticides gave considerable economic incentive. Utilization of UV reflective surfaces and sheets around vents, doors, and other entryways to greenhouses can reduce thrips migration into the houses. Greenhouses covered with UV absorbing plastic have been shown to reduce thrips migration in the greenhouse (Costa and Robb, 1999).

Neonicotinoid sprays and sterilizing oils have had some effect on reducing transmission of TSWV by lowering the population of thrips. Insecticide treatments consistently reduce thrips and incidence of TSWV while increasing marketable yield (Riley and Pappu, 2000). Knowledge of which species are feeding on tomatoes is important for management since western flower thrips and tobacco thrips respond differently to insecticidal control. Imidicloprid reduced feeding in tobacco thrips while western flower thrips increased feeding (Riley and Pappu, 2004). The intensity of insecticide treatment and limited number of chemicals could lead to insecticide resistance as suggested by Kontsedalov et al. (1998).

Spinosad is a widely used thrips insecticide which gives control of immature thrips and provided the best control according Driesche et al. (2006). Some research with predatory mites has been conducted but increased predatory mites did not significantly change the incidence of TSWV as compared to applications of spinosad indicating biological control through the use of predators will not solve the problem of controlling thrips but can be used to reduce populations (Driesche et al., 2006).

UV reflective mulches have been shown to reduce TSWV incidence by nearly 50% (Stavisky et al., 2002). TSWV infection rates can also be lowered by early season thrips control in tomatoes. TSWV incidence was higher in early planted tomato than in tomatoes planted at a later date but the use of late planted tomatoes was not an effective control method for TSWV (Riley and Pappu, 2000). Another important management practice is to keep weeds controlled to reduce potential TSWV inoculum (Cho et al., 1989).

Roguing infected plants did not affect spread or occurrence of TSWV according to Cho et al. (1989). Cultivation and harvesting activity caused considerable thrips movement. Thrips were found to emerge from field-soil up to three weeks after crop residues were plowed and rototilled with a four-week fallow period was needed to reduce the incidence of TSWV (Cho et al., 1989). TSWV control was increased by crop rotation of nonsusceptible with susceptible crops when this rotation was done in such a way that multiple susceptible crops were not grown next to each other (Cho et al., 1989).

Higher numbers of thrips were constantly found on infected plants than noninfected plants indicating they had a preference for infected plants (Costa and Robb, 1999). The life cycle of thrips on infected plants was two days faster than on noninfected plants. The higher numbers of thrips offspring on infected plants revealed that TSWV may have improved host suitability for its vector western flower thrips (Maris et al., 2004). TSWV has no apparent deleterious effects on thrips when feeding on chrysanthemums since developmental time, reproduction rate, and survival rate were similar for viruliferous thrips and nonviruliferous thrips (Wijkamp et al., 1996). Consistently higher numbers of thrips were found on infected plants than on noninfected plants (Maris et al., 2004).

Excess nitrogen fertilization can also result in decreased yield because of a higher incidence of TSWV (Stavisky et al., 2002). Western flower thrips have been shown to prefer feeding on plants with higher levels of nitrogen (Schuch et al., 1998; Mollema and Cole, 1996; Brodbeck et al., 2001). Reductions in nitrogen fertilization and use of reflective mulches decreased incidence of TSWV (Stavisky et al., 2002).

Tomatoes prefer a well drained, sandy loam to a clay loam soil with a pH of 6.0 to 6.8. Tomatoes require 168 to 202 kg of N/ha and 224 to 280 kg of phosphorous (P_2O_5) and potash (K_2O) per ha (Kemble et al., 2004). Pre-plant 30 to 50% of the recommend N and K_2O and 100% of P_2O_5 is applied. The remaining fertilizer is injected through the irrigation lines. Tomatoes are planted on raised beds that are covered with polyethylene plastic mulch. These raised beds are 15 cm high and 74 to 91 cm wide. Polyethylene mulch is used to increase soil temperatures which accelerates the plants growth and development; it conserves soil moisture and can reduce common problems such as soil crusting and compaction, fertilizer leaching, and competition from weeds. Different colored plastic mulches are used depending on the season. Black plastic is used in the spring while white plastic is used for summer and fall plantings (Kemble et al., 2004). Tomatoes are 85 to 95% water and they need between one to four cm of water per week or approximately 666,468 L/ha/day. Drip irrigation is generally used underneath the plastic mulch in most commercial tomato production in the U.S. (Kemble et al., 2004). Using drip irrigation under plastic mulch enables tomatoes to produce approximately 42,038 to 56,050 kg/ha. There are two options frequently used when it comes to using drip irrigation in fresh market production, drip tape and in-line tubing.

Tomato transplants are planted with a spacing of 46 to 61 cm apart with a row spacing of 1.2 to 1.8 m (Kemble et al., 2004). Staking tomatoes improves fruit quality and yield by keeping the fruit off of the ground; it also helps make harvest easier. Staking commercial tomatoes to a series of wooden stakes, 1.2 to 1.5 m long by six cm square, are placed every other tomato plant and then are driven in the ground about 20 to 30.5 cm. Tomato twine is then used by tying off to the stake 20 to 25 cm above the soil and the twine is run down one side of the stake and plant, wrapping around each individual stake, until the end of the row is reached. It is then repeated the same way down the other side of the row. This is usually done up to three times in one season depending on the plant height (Kemble et al., 2004). Tomato plants should be suckered up to directly beneath the first flower cluster (Kemble et al., 2004).

Since no single control method exists the need to find alternative methods for thrips control in plasticulture tomato production is needed. Since both tempera paints and colored mulches have ultra-violet reflectance, the objectives of my studies were:

1) evaluate specially manufactured colored mulches in reducing TSWV on field-grown tomatoes, 2) determine phytotoxicty of selected tempera paints applied to tomatoes (greenhouse), 3) evaluate selected tempera paints effects on TSWV on field-grown tomatoes. It was hypothesized that the colored mulches and tempera paints would reduce thrips and TSWV incidence.

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CHAPTER II

EVALUATION OF SELECTED TEMPERA PAINTS APPLIED TO TOMATOES TO REDUCE THE OCCURENCE OF TOMATO SPOTTED WILT VIRUS

Abstract

Two greenhouse studies were conducted evaluating selected tempera paints to determine effects on growth and early yield of *Lycopersicon esculentum*. Tempera paints evaluated were: brilliant red, cerise, crimson, jazz orange, and purple which were applied weekly up to first harvest. Treatments were first applied to the foliage three days after transplanting. Weekly plant heights were gathered before each treatment application. Tempera paints had no effects on yield or plant height in the fall study. Reduced yields were observed in the spring study in the purple treatment while some minimal effects on yield from brilliant red, crimson, and jazz orange.

In addition to the greenhouse studies, field experiments were conducted to evaluate the same selected tempera paints (ColArt Americas Inc, Piscataway, NJ) applied directly to foliage of tomatoes as a continuation of previous greenhouse studies which showed no deleterious effects on plant growth for all but one selected paint. Paints were applied weekly starting three days after transplanting. Paint colors were selected based on ultra violet reflectance with a spectrophotometer which previously showed thrips repellency. Weekly thrips populations were gathered along with tomato yields. Enzyme-linked immunosorbent assay (ELISA) tests were run early-season and mid-season to

determine *Tomato spotted wilt virus* (TSWV) incididence. The paints did not reduce the occurrence of TSWV but neither did they negatively influence yield.

Introduction

Thrips are tiny insects in the order Thysanoptera with slender bodies and fringed wings. The term thrips is used to refer to both the singular and plural forms of the insect. Feeding of thrips occurs on a large variety of plants, causing damage mainly on developing flowers leading to discoloration, deformities, and reduced marketability of the crop. To date over five thousand species of thrips have been described by entomologists (Mortiz et al., 2001). Thrips are generally $\leq$1 mm long and are poor flyers, although they can be carried long distances by the wind or on clothing (Zitter et al., 1989).

Thrips feed on hundreds of different crop plants and weeds especially during the flowering period (Cho et al., 1989). Thrips feed by piercing plant cells with their maxillary stylets, which form a feeding tube. The mandibular stylet is used to pierce an entry hole in plant cells or pollen grains allowing the maxillary stylets to easily enter the cell and suck out the contents.

Thrips in the genera *Frankliniella* (flower thrips) spread plant diseases through the transmission of viruses such as tospoviruses. The western flower thrips (*Frankliniella occidentalis*) has a world wide distribution and is considered the primary vector of plant diseases caused by tospoviruses. While feeding on the plant tissue thrips inject saliva which can carry over twenty plant infecting viruses, including *Tomato spotted wilt virus* (TSWV) and *Impatiens necrotic spot* which are very damaging to many commercial crops. TSWV has become a worldwide pest problem with western flower thrips being the predominant vector of TSWV to tomato plants (Lewis, 1997; Puche et al., 1995). Western flower thrips are highly attracted to bright colors, which can distinguish clearly between different colors as well as various shades of color (Brodsgaard, 1989). Western flower thrips occurred in lower numbers on red, orange, and copper colored flowers than on yellow, blue, or purple flowers. Western flower thrips prefer flowering plants and feed on the flowers (Blumthal et al., 2005). Results have indicated that highly reflective UV surfaces are repellent to thrips in the 350-390 nm range and more precisely those UV wavelengths between 350 and 370 nm (Lewis, 1997).

Over-wintering of most thrips species is achieved as either adults or as pupae on weed hosts or in ground litter (Jenser et al., 2002). Flower thrips generation time will be from 7-22 days depending on the temperature, with warmer temperatures inducing shorter generation times. Thrips have two larval stages then go through a prepupal and a pupae stage before becoming an adult. Immature thrips in the first and second instars acquire TSWV from infected host plants. TSWV can only be acquired at the larval stage but can be transmitted throughout the lifecycle after a three to ten day incubation period. TSWV is transmitted when an infected thrips feeds on a plant and the virus is passed on to the plant (Zitter et al., 1989). The virus replicates in the vector as it matures and subsequently viruliferous adults spread the virus when they move to other plants. Virus multiplication in the thrips vector makes managing the virus difficult because once infected, adult thrips can migrate long distances to new host plants and quickly transmit the virus before thrips can be controlled (Ullman et al., 1993).

Thrips that cause prebloom inoculation of TSWV are very important in terms of impact on tomato yield (Chaisuekul et al., 2003). The younger the plant, the greater the impact TSWV has on the plant. Young transplants will usually die when infected with

TSWV. TSWV symptoms expressed on leaves, petioles, stems, and fruit will vary depending on the stage when plants are infected. Stunting, one-sided growth, mottled fruit, ring spots, discoloration on fruit, and systemic necrosis are some signs of TSWV (Culbreath et al., 2003).

Studies have indicated that a highly reflective UV surface is repellent to thrips in the 350-390 nm range and more specifically those UV wavelengths between 350 and 370 nm (Lewis, 1997). Because of this, some success has been achieved in reducing thrips infestation and damage by using UV reflective sheets. Aluminum painted mulch in tomato plots reduced numbers of *F. fusca* (Scott et al., 1989).

TSWV infection rates can be lowered by early season thrips control in tomatoes. Riley and Pappu (2000) reported that heavy applications of insecticides applied in the early-season did reduce thrips numbers and incidence of TSWV while increasing marketable yields. In a separate study, Riley and Pappu (2004) reported that over a three year period, the use of reflective mulch, resistant plants, and early-season insecticides gave considerable economic incentive to reducing TSWV in field-grown tomatoes. However, the intensity of insecticide treatment and limited number of chemicals could lead to insecticide resistance as suggested by Kontsedalov et al. (1998). Spinosad has been shown to be effective in controlling immature thrips according Driesche et al. (2006), but not against the viruliferous adult thrips. Some research with predatory mites has been conducted but increased predatory mites did not significantly change the incidence of TSWV as compared to applications of spinosad indicating biological control through predatory will not solve the problem of controlling thrips but can be used to reduce populations (Driesche et al., 2006).

Another important management practice is to control weeds which serve as a potential inoculum for TSWV (Cho et al., 1989). Rouging infected plants did not affect spread or occurrence of TSWV according to Cho et al. (1989). Cultivation and harvesting activity caused considerable thrips movement. Thrips were found to emerge from field-soil up to three weeks after crop residues were plowed and rototilled with a four-week fallow period was needed to reduce the incidence of TSWV (Cho et al., 1989). TSWV control was increased by crop rotation of nonsusceptible with susceptible crops when this rotation was done in such a way that multiple susceptible crops were not grown next to each other (Cho et al., 1989). Also, TSWV incidence was higher in early planted tomato than in tomatoes planted at a later date but the use of late planted tomatoes is not an effective control method for TSWV (Riley and Pappu, 2000).

Higher numbers of thrips were constantly found on infected plants than noninfected plants indicating they had a preference for infected plants (Costa and Robb, 1999). The life cycle of thrips on infected plants was two days faster than on noninfected plants. The higher numbers of thrips offspring on infected plants revealed that TSWV improved host suitability for its vector western flower thrips (Maris et al., 2004). TSWV has no apparent deleterious effects on thrips when feeding on chrysanthemums since developmental time, reproduction rate, and survival rate were similar for viruliferous thrips and nonviruliferous thrips (Wijkamp et al., 1996). Consistently higher numbers of thrips were found on infected plants than on noninfected plants (Maris et al., 2004).

Silver reflective mulches can be an effective control in reducing TSWV (Brown and Brown, 1992; Greenough et al., 1990; Reitz et al., 2003; Stavisky, 2002). However, silver reflective mulches can be difficult for workers due to the harsh glare of the mulch during sunny days. Ideally other control methods that would deter thrips cuing to the tomato plants (i.e. miscuing via highly UV reflective materials) would be a suitable alternative to the silver mulches. Since the best controls for TSWV have been silver mulches, resistant varieties and heavy insecticide applications a need exists to find alternatives and particular those that are non-chemical. To that end, the objectives of this study were: 1) evaluate the growth affects of applying selected tempera paints directly to tomatoes in a greenhouse environment; and 2) evaluate the efficacy of applying selected tempera paints to field-grown tomatoes to reduce the occurrence of TSWV. The stated hypothesis is that the selected tempera paints will decrease thrips populations and the occurrence of TSWV in tomato production.

Material and Methods

Greenhouse Studies

Greenhouse studies were conducted in the spring and fall of 2005 at the Plant Science Research Center (PSRC) located at Auburn University, AL (32.609N, -85.48W). Tomatoes, ‘Florida 91’, were seeded into Canadian Growing Mix 2 (Conrad Fafard Inc., Agawan, MA) in 72-cell flats at PSRC and transplanted into trade gallon pots after five weeks in accordance with standard transplant production (Kemble, 2004). Transplants were fertilized once a week with a 20N-4.4P-16.6K water soluble fertilizer (Peter’s Water Soluble Plant Food 20-10-20) (Scotts Co, Marysville, OH) at a rate of 265 mg/L of N. Plants were allowed to grow for three weeks and then potted into three-gallon (24.13 cm tall, 27.94 cm diameter, 11.36L) containers.

Plants were watered twice daily and fertigated weekly with 20N-4.4P-16.6K water soluble fertilizer (Peter’s Water Soluble Plant Food 20-10-20) (Scotts Co, Marysville, OH) at a rate of 265 mg/L of N. Tomato plants were staked with three foot bamboo stakes attached with twist ties. All suckers below the first flower cluster were removed in accordance with Kemble (2004). Treatments consisted of the following selected tempera paints (ColArt Americas Inc, Piscataway, NJ): brilliant red, cerise, crimson, jazz orange, purple, and a non-treated control. Treatments were randomly assigned to six individual plants in a completely randomized design with six replications. The plants were sprayed with the selected paints three days after transplanting to three-gallon pots and then once a week throughout the study at a rate of 80 mg of paint per 250 ml of municipal tap water (no surfactants were used in the study). The paint was applied with a two liter hand-held pump solo sprayer (Solo, Newport News, VA) pumped 12-15 times every 15 seconds.

Data gathered included weekly plant height (soil to apical bud) and a one time harvest where all tomatoes were removed, weighed, and graded. Plant height was measure three days before each weekly paint application. Grading was based on a fresh market marketable and non-marketable scale. Further harvest was unavailable due to size restriction of the tomato plants in the selected pots.

Field Studies

Field studies were conducted in the spring of 2006 (June, 8) and 2007 (April, 25) at the E.V. Smith Research Station (EVS), Auburn University, located in Shorter, AL (32.42N, 85.53W). A duplicate study was conducted at the Old Agronomy Farm (OAF), Auburn University, Auburn, AL (32.609N, 85.48W). A Marvyn sandy loam (fine-loamy, kaolinitic, thermic type Kanhapludults) was the soil type at both locations. The tomatoes, ‘Florida 91’, were seeded into Canadian Growing Mix 2 (Conrad Fafard Inc., Agawan, MA) in 72-cell flats at Plant Science Research Center in accordance with standard transplant production. Transplants were fertilized once a week with a 20N-4.4P-16.6K water soluble fertilizer (Peter's Water Soluble Plant Food 20-10-20) (Scotts Co, Marysville, OH) at a rate of 265 mg/L of N. The transplants were hardened off the week before planting according to Kemble (2004). At both locations the soil was prepared and shaped into a series of six parallel beds, approximately 100 m in length. The beds were covered with black low-density polyethylene mulch (Pliant Corp, Washington, GA), 0.46 m wide. A pre-emergent herbicide was applied (Dual-Magnum, Sygenta Corp, Greensboro, NC) and no soil fumigation was used. Tomatoes were fertigated weekly with potassium nitrate (KNO_3) alternated with calcium nitrate ($Ca(NO_3)_2$) using drip tape with a Dosatron (Clearwater, Fl) fertilizer injector. Alternating the two fertilizers was done for the duration of the experiment and was scheduled as described by Kemble (2004).

Treatments consisted of the following selected tempera paints (ColArt Americas Inc, Piscataway, NJ): purple, crimson, brilliant red, cerise, jazz orange, and a non-treated control. Treatments were randomly assigned to a plot of 12 tomato plants in a completely randomized block design with six replications. Four days after transplanting the first treatments were sprayed with selected the tempera paints at a rate of 80 ml of paint in 1 L of water. The plants were then sprayed once a week through-out the season until final harvest (total of 12 sprays). Treatments were applied with a CO_2 back pack sprayer set at 35 PSI, 140 L/ha equipped with one 8008 cone nozzle (Spray Systems, Wheaton, IL). Weekly thrips counts were gathered using the beat cup method until first flower (Riley and Pappu, 2004). Once the tomato plants began to flower, thrips counts were gathered by collecting ten open flowers from each plot and placing them in vials of alcohol according to Riley and Pappu (2004).

TSWV incidence (defined here as percent plants infected) was determined using a commercial enzyme-linked immunosorbent assay (ELISA) kit (Agdia, Inc., Elkhart, IN). The ELISA procedure was performed according to the manufacturer’s instructions. TSWV incidence was determined two times during the season: 42 days after plants were transplanted to the field and 63 days after being transplanted. A single leaf sample, consisting of the terminal leaflet of a newly formed leaf, was collected from each plant, wrapped in a dampened paper towel and placed on ice for transport to the laboratory. Each sample was processed for ELISA by grinding in 2 ml of general extraction buffer (as per manufacturer’s instructions) using a motorized leaf squeezing apparatus. Known healthy control samples and a known positive control sample were added to each microtiter plate. Upon adding substrate, reactions were allowed to develop at room temperature for 60 to 90 minutes and were then recorded using a Sunrise microtiter plate reader (Phenix Research Products, Hayward, CA). A sample was considered positive for the presence of virus if the ELISA absorbance value was greater than the average plus three standard deviations of the negative control samples.

Data gathered included marketable, non-marketable yields, and TSWV incidence. The experimental design was a randomized complete block design. Data was analyzed with the GLIMMIX procedure (June 2006 version) of SAS (version 9.1; SAS Institute, Inc., Cary, NC) using a generalized linear mixed model with the Poisson distribution and log link function, block as a random factor, and mulch color as the experimental factor. Data was analyzed separately for marketable, non-marketable yields, and TSWV incidence (both by individual collection date and using data from all corresponding collection dates as repeated measures) and by study location. Multiple-comparison-nonadjusted p values were obtained using the simulation-stepdown method.

Results and Discussion

Greenhouse

Statistical analysis revealed no differences within either repetition (spring and fall 2005) in plant height (Table 1). Early-yields were reduced in the purple treatment in the spring repetition with minimal effects on yield from brilliant red, crimson, and jazz orange. No visual growth differences were observed or abnormalities were observed. Tempera paints mixed easily in water with minimal shaking but was difficult to get a fine spray due to the high ratio of paint to water. The paints started to fade after four to five days which may reduce UV reflectance. First flower and fruit date was similar for all treatments and no abnormalities were observed in plant or fruit growth. The results from these two experiments established that the selected paints in a greenhouse environment did not appear to affect growth or early yields of tomatoes.

EVS 2006

For the two field studies in 2006 statistical analysis revealed significant interactions between the two locations; therefore data are presented separately. Marketable, non-marketable yields, and TSWV incidence were not affected by the selected paint treatments (Table 2). The application of the tempera paints did not adversely affect the yields of these field-grown tomatoes.

This study was planted on 8 June 2006, which is considered a late planting. Overall, TSWV incidence levels were observed, anecdotally, to be fairly low. This observation does not agree with Riley and Pappu (2000) who reported that later planted tomatoes can have lower TSWV incidence.

OAF 2006

Statistical analysis revealed no differences for marketable, non-marketable yields, or TSWV incidence (Table 3). Again the positive results revealed that the selected paints did not adversely affect yields (Table 3) which concurs with the E.V. Smith location. The results, previously unreported, revealed that tempera paints appeared to have no affects on yields.

EVS 2007

Statistical analysis revealed significant interactions between the two locations; therefore the data were not pooled by location for the 2007 studies. Marketable, non-marketable yields, marketable count, non-marketable count, TSWV incidence, and thrips counts were all unaffected by the treatments (Table 4). Overall TSWV incidence levels were considered high, ranging from 2.28% to 24.59%; however, the treatments did not affect these levels. This study was planted 25 April 2007 which is considered an early planting time. The TSWV incidence levels observed anecdotally were generally higher for this early planting date. Again, this conflicts with the results that Riley and Pappu (2000) reported in south Georgia, that earlier planted tomatoes had less TSWV incidence than later planted tomatoes.

Positive results from the yield data for this study again concurs with the 2006 data at both locations.

OAF 2007

Statistical analysis revealed no treatment differences for all variables tested (Table 5). One exception to this was that the late-season thrips flower counts revealed that the purple paint treatment had higher thrips counts than the non-treated control (Table 5). Again, the same observation (not statistically verified) appeared to show that TSWV incidence levels were much higher than the 2006 experiments. TSWV incidence ranged from 13.64 – 27.9% for this study.

Overall, the four field studies conducted with the same selected tempera paints showed no positive results in reducing thrips counts or incidence of TSWV as hypothesized. No published data is currently listed in the literature on this topic. These experiments established that field grown tomatoes can be grown successfully with multi-applications of tempera paint without adverse effect on growth or yields. The selection of a paint that has higher reflectance in the 370-390 nm range and a longer residence to fading could hold promise for further research. Furthermore, these results would also appear to be more practical as a possible fit for small organic or home garden production tomato production if a suitable paint can be discovered that would decrease TSWV incidence.

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Table 1. Effect of tempera paint on the growth and early yield of tomatoes grown inside a greenhouse, spring and fall, 2005, at the Plant Sciences Research Center, Auburn, AL.

Treatment	Spring 05		Fall 05	
	Ht (cm)	Yeild (g)	Ht (cm)	Yeild (g)
Non Treated Control	103.2	767.4a	111.8	374.8
Purple	108.8	580.6b	115.2	253.6
Brilliant Red	105.8	702.0ab	120.0	274.4
Crimson	102.0	668.0ab	110.6	259.2
Cerise	98.0	757.6a	112.2	384.2
Jazz Orange	89.8	737.0ab	124.4	235.4

[a] Means separation ($P \leq 0.05$) Waller Duncan.

Table 2. Least squares means of yield, grade, and TSWV incidence in field grown tomatoes using five colors of tempera paint, E.V. Smith Research Station, Shorter, AL, 2006, with significance of mean comparisons between a non-treated control and other colors of tempera paint.

	Yield				TSWV Incidence (%)
Paint color	Marketable wt.	Non-marketable wt.	Marketable count	Non-marketable count	9/11/2006
Control	1.2683	2.0900	7.7165	20.1488	3.24
Purple	2.1383	1.9267	11.8210	16.6445	2.97
Brilliant Red	1.9467	2.4583	11.6568	16.5848	1.41
Crimson	1.3933	2.2217	9.6866	18.6231	5.92
Cerise	1.0317	2.0100	6.7314	15.6377	2.88
Jazz Orange	0.6850	0.7450	4.5970	10.1352	15.43
Treatment effects	0.5315	0.4954	0.6402	0.6755	0.1611
Comparisons[1]:					
Control vs. Puple	0.3132	0.8564	0.4308	0.6487	0.0676
Control vs. Brilliant Red	0.4298	0.6835	0.4471	0.6426	0.5711
Control vs. Crimson	0.8836	0.8840	0.6857	0.8503	0.4771
Control vs. Cerise	0.7818	0.9293	0.8238	0.5470	0.9783
Control vs. Jazz Orange	0.4965	0.1446	0.4521	0.1160	0.9390

[1]Significance of pairwise comparisons are reported as unadjusted multiple-comparison p values obtained using the simulation-stepwise method.

Table 3. Least squares means of yield, grade, and TSWV incidence in field grown tomatoes using five colors of tempera paint, Old Agronomy Farm, Auburn, AL, 2006, with significance of mean comparisons between a non-treated control and other colors of tempera paint.

	Yield				TSWV Incidence (%)
Paint color	Marketable wt.	Non-marketable wt.	Marketable count	Non-marketable count	9/11/2006
Control	4.2100	3.6733	23.2497	35.0000	6.57
Purple	3.6067	3.5050	19.9997	33.3333	7.80
Brilliant Red	3.7150	1.9433	19.4255	21.3333	11.12
Crimson	6.2817	4.1300	31.2311	36.1667	9.67
Cerise	4.0500	1.8917	26.4800	21.8333	10.69
Jazz Orange	6.0533	2.5717	31.8874	22.5000	3.14
Treatment effects	0.2624	0.1722	0.3757	0.3916	0.7494
Comparisons[1]:					
Control vs. Puple	0.6777	0.8715	0.6086	0.8882	0.8240
Control vs. Brilliant Red	0.7330	0.1055	0.5421	0.1669	0.5095
Control vs. Crimson	0.1612	0.6613	0.3105	0.9246	0.4725
Control vs. Cerise	0.9121	0.0960	0.6540	0.1865	0.6049
Control vs. Jazz Orange	0.2107	0.2951	0.2780	0.2148	0.4433

[1]Significance of pairwise comparisons are reported as unadjusted multiple-comparison p values obtained using the simulation-stepwise method.

Table 4. Least squares means of yield, grade, and TSWV incidence in field grown tomatoes using five colors of tempera paint, E.V. Smith Research Station, Shorter, AL, 2007, with significance of mean comparisons between a non-treated control and other colors of tempera paint.

	Yield				TSWV Incidence (%)		Thrips Count	
Paint color	Marketable wt.	Non-marketable wt.	Marketable count	Non-marketable count	6/5/2007	6/26/2007	Cup 5/23-6/21	Flower 6/21-7/6
Control	22.5367	4.9350	106.8000	39.1667	6.83	17.81	19.9689	10.2070
Purple	16.6600	3.2550	80.2844	24.0000	6.00	21.57	15.2270	8.3110
Brilliant Red	19.1633	3.5517	95.5763	31.3333	6.09	12.55	11.2979	9.8282
Crimson	20.3083	4.2850	93.8900	32.5000	2.28	9.28	12.1929	10.0548
Cerise	27.7333	5.8300	122.5100	37.1667	15.64	24.59	17.9542	12.0596
Jazz Orange	26.4717	4.2800	121.1900	31.8333	13.35	16.45	11.5798	10.1155
Treatment effects	0.5719	0.4975	0.6995	0.5888	0.2999	0.4551	0.3535	0.7858
Comparisons[1]:								
Control vs. Puple	0.1659	0.4697	0.1798	0.3204	0.2932	0.5559	0.4158	0.8964
Control vs. Brilliant Red	0.2979	0.6065	0.4328	0.9547	0.2975	0.6037	0.9425	0.9992
Control vs. Crimson	0.8559	0.2775	0.9712	0.5772	0.8010	0.3754	0.1636	0.8964
Control vs. Cerise	0.5722	0.6430	0.6746	0.4560	0.3622	0.8680	0.0852	0.9992
Control vs. Jazz Orange	0.3785	0.9972	0.3997	0.9406	0.0676	0.3033	0.8782	0.9992

[1]Repeated measures analysis using counts from four or three collection dates (thrips collected from cups or flowers, respectively).
[2]Significance of pairwise comparisons are reported as unadjusted multiple-comparison p values obtained using the simulation-stepwise method.

Table 5. Least squares means of yield, grade, and TSWV incidence in field grown tomatoes using five colors of tempera paint, Old Agronomy Farm, Auburn, AL, 2007, with significance of mean comparisons between a non-treated control and other colors of tempera paint.

	Yield				TSWV Incidence (%)		Thrips Count	
Paint color	Marketable wt.	Non-marketable wt.	Marketable count	Non-marketable count	6/5/2007	6/26/2007	Cup 5/23-6/21	Flower 6/21-7/6
Control	19.7733	3.2683	93.8049	27.3670	27.90	27.03	40.1459	6.3012
Purple	23.2333	4.0100	110.0300	29.0118	14.13	11.19	29.7369	7.7935
Brilliant Red	21.1733	4.5600	100.0300	35.2277	28.20	30.74	25.3963	4.4771
Crimson	24.3767	5.0850	115.8200	35.0040	18.25	19.44	27.7041	6.7986
Cerise	20.4500	3.6367	100.7900	30.1241	16.21	13.64	30.2394	6.1353
Jazz Orange	19.2217	4.1550	91.8940	33.3863	18.97	14.25	23.3471	4.4771
Treatment effects	0.5169	0.5657	0.5083	0.8524	0.7592	0.4820	0.1964	0.1710
Comparisons[1]:								
Control vs. Puple	0.2046	0.8891	0.1964	0.5625	0.6352	0.9245	0.2779	0.0304
Control vs. Brilliant Red	0.5320	0.6973	0.5390	0.8227	0.4665	0.5377	0.7082	1.0000
Control vs. Crimson	0.6934	0.6190	0.5039	0.6705	0.7940	0.9488	0.2305	0.2247
Control vs. Cerise	0.8593	0.3972	0.8815	0.4153	0.4780	0.6501	0.0147	0.1867
Control vs. Jazz Orange	0.1066	0.3749	0.0998	0.8435	0.9473	0.9245	0.4414	0.1043

[1] Repeated measures analysis using counts from four or three collection dates (thrips collected from cups or flowers, respectively).

[2] Significance of pairwise comparisons are reported as unadjusted multiple-comparison p values obtained using the simulation-stepwise method.

CHAPTER III

EVALUATION OF SPECIALLY FORMULATED COLORED MULCHES TO REDUCE THRIPS AND TOMATO SPOTTED WILT VIRUS IN TOMATOES

Abstract

Field studies were conducted to evaluate the influence of colored plastic mulch on thrips' ability to locate tomatoes. Mulch colors were selected based on ultra violet reflectance previously shown to repel thrips. Specially manufactured colored mulches (Pliant Corp, Washington, GA) were: silver, white, red 1, red 2, red 3, and violet. Tomato fruit yields were taken weekly as well as thrips population density counts. Enzyme-linked immunosorbent assay (ELISA) tests were conducted early-season and mid-season to test for *Tomato spotted wilt virus* (TSWV). Silver mulch consistently reduced thrips numbers and in some cases TSWV incidence while reducing tomato yield losses. Red 1 and Red 2 mulches showed a reduction in thrips populations and TSWV incidence in some cases comparable to white mulch.

Introduction

Thrips are tiny insects in the order Thysanoptera with slender bodies and fringed wings. Feeding of thrips occurs on a large variety of plants, causing damage mainly on developing flowers leading to discoloration, deformities, and reduced marketability of the crop. To date over five thousand species of thrips have been described by entomologists

(Mortiz et al., 2001). Thrips feed on hundreds of various crop and weeds especially during the flowering period (Cho et al., 1989). Thrips feed by piercing plant cells with their maxillary stylets, which form a feeding tube. The mandibular stylet is used to pierce an entry hole in plant cells or pollen grains allowing the maxillary stylets to easily enter the cell and suck out the contents.

Over wintering of most thrips species is achieved as either adults or as pupae on weed hosts or in ground litter (Jenser et al., 2002). Flower thrips generation time will be from 7-22 days depending on the temperature, with warmer temperatures inducing shorter generation times. The eggs are about 0.2 mm long, reniform shaped, and may take on average of three days to hatch. Thrips have two larval stages then go through a prepupal and a pupae stage before becoming an adult. Immature thrips in the first and second instars acquire TSWV from infected host plants. TSWV can only be acquired at the larval stage but can be transmitted throughout the lifecycle after a three to ten day incubation period. TSWV is transmitted when an infected thrips feeds on a plant and the virus is passed on to the plant (Zitter et al., 1989). The virus replicates in the vector as it matures and subsequently viruliferous adults spread the virus when they move to other plants. Virus multiplication in the thrips vector makes managing the virus difficult because once infected, adult thrips can migrate long distances to new host plants and quickly transmit the virus before thrips can be controlled (Ullman et al., 1993).

TSWV was first described in Australia in 1919 and has a wide host range that is unique among plant infecting viruses with more than 200 plant species susceptible to TSWV (Cho et al., 1989; Zitter et al., 1989). TSWV is a tospovirus and is the only virus transmitted by thrips that is an ssRNA membrane coded virus (Zitter et al., 1989).

TSWV transmission has been demonstrated for several species of thrips, *Thrips tabaci* (Onion thrips) (Pittman, 1927), *T. setosus* (Japanese flower thrips) (Kobatake, 1984), *Frankliniella fusca* (Tobacco thrips) (Sakimura, 1961), *F. occidentalis* (Western flower thrips) (Gardner et al., 1935), *F. schultzei* (Tomato thrips) (Samuel et al., 1930) and *Scirtothrips dorsalis* (Chilli thrips) (Amin et al., 1981) while not all transmit as readily as others. Western flower thrips has been identified as the predominant vector of TSWV (Cho et al., 1989). Thrips that cause prebloom inoculation of TSWV are very important in terms of impact on tomato yield (Chaisuekul et al., 2003). The younger the plant, the greater the impact TSWV has on the plant. Young transplants will usually die when infected with TSWV. TSWV symptoms expressed on leaves, petioles, stems, and fruit will vary depending on the stage when plants are infected. Stunting, one-sided growth, mottled fruit, ring spots, discoloration on fruit, and systemic necrosis are some signs of TSWV (Culbreath et al., 2003).

TSWV has become a worldwide pest problem with western flower thrips (*Frankliniella occidentalis*) being the predominant vector of TSWV to tomato plants (Lewis, 1997; Puche et al., 1995). Western flower thrips are highly attracted to bright colors, which can distinguish clearly between different colors as well as various shades of color (Brodsgaard, 1989). Western flower thrips occurred in lower numbers on red, orange, and copper colored flowers than on yellow, blue, or purple flowers. Results have indicated that highly reflective UV surfaces are repellent to thrips in the 350-390 nm range and more precisely those UV wavelengths between 350 and 370 nm (Lewis, 1997). UV aluminized mulches have been shown to reduce thrips numbers (Brown and Brown, 1992; Greenough et al., 1990; Reitz et al., 2003; Scott et al., 1989).

Studies have shown evidence that thrips search for a host based on color, with indications that UV-reflective mulch interfered with thrips host-seeking behaviour (Lewis, 1997). Results indicated that a highly reflective UV surface is repellent to thrips in the 350-390 nm range and more specifically those UV wavelengths between 350 and 370 nm (Lewis, 1997). Because of this, some success has been achieved in reducing thrips infestation and damage by using UV reflective sheets. Aluminum painted mulch in tomato plots reduced numbers of *F. fusca* (Scott et al., 1989). TSWV and thrips pressure is variable from year to year making it difficult to plan control methods and they need to be adjusted from year to year. Over a three year period, Riley and Pappu (2004) reported that the use of reflective mulch, resistant plants, and early season insecticides gave considerable economic incentive. Utilization of UV reflective surfaces and sheets around vents, doors, and other entryways to greenhouses can reduce thrips migration into the houses. Greenhouses covered with UV absorbing plastic have been shown to reduce thrips migration into the greenhouse (Costa and Robb, 1999).

Control of TSWV is very difficult since the virus cannot be removed from a plant following infection. The host thrips, those harboring the virus, as well are problematic due to their small size, behavior, and high rate of reproduction. Early season control is critical for control of TSWV and reduces incidence as much as full season control (Riley, 2001). Some primary control tactics in tomatoes are reflective mulches (Brown and Brown, 1992; Greenough et al., 1990; Reitz et al., 2003; Stavisky, 2002), host plant resistance (Kumar et al., 1993), and insecticides combined with other tactics (Riley and Pappu, 2000). However to date, no single management tool provides adequate control, and resistant varieties are the most important factor in control of TSWV (Culbreath et al., 2003). UV reflective mulches have been shown to reduce TSWV incidence by nearly 50% (Stavisky et al., 2002). TSWV infection rates can also be lowered by early season thrips control in tomatoes. TSWV incidence was higher in early planted tomato than in tomatoes planted at a later date but the use of late planted tomatoes is not an effective control method for TSWV (Riley and Pappu, 2000). Another important management practice is to keep weeds controlled to reduce potential innoculum (Cho et al., 1989).

Insecticide treatments consistently reduce thrips and incidence of TSWV while increasing marketable yield according to Riley and Pappu (2000). Imidicloprid reduced feeding in tobacco thrips while western flower thrips increased feeding (Riley and Pappu, 2004). The intensity of insecticide treatment and limited number of chemicals could lead to insecticide resistance as suggested by Kontsedalov et al. (1998). Spinosad is a widely used thrips insecticide which gives control of immature thrips and provided the best control according Driesche et al. (2006). Some research with predatory mites has been conducted but increased predatory mites did not significantly change the incidence of TSWV as compared to applications of spinosad indicating biological control through predatory will not solve the problem of controlling thrips but can be used to reduce populations (Driesche et al., 2006).

Higher numbers of thrips were constantly found on infected plants than noninfected plants indicating they had a preference for infected plants (Costa and Robb, 1999). The life cycle of thrips on infected plants was two days faster than on noninfected plants. The higher numbers of thrips offspring on infected plants revealed that TSWV improved host suitability for its vector western flower thrips (Maris et al., 2004). TSWV has no apparent deleterious effects on thrips when feeding on chrysanthemums since developmental time, reproduction rate, and survival rate were similar for viruliferous thrips and nonviruliferous thrips (Wijkamp et al., 1996). Consistently higher numbers of thrips were found on infected plants than on noninfected plants (Maris et al., 2004).

Based on work presented by Lewis (1997) highly reflective UV surfaces in the 350-370 nm range are repellent to thrips as mentioned above, specially manufactured colored plastic was produced by Pliant Corp. (Washington, GA) (red 1, red 2, red 3, and violet) that was intended to have enhanced reflectance in the 350-370 nm range. Therefore, the objectives of this study was to determine the effect of the specially manufactured colored plastics along with silver and white mulches (standard checks) on the effect of thrips numbers, TSWV incidence and yields of tomatoes.

Material and Methods

Field studies were conducted in the spring of 2006 and 2007 at the Old Agronomy Farm (OAF), Auburn University, Auburn, AL (32.609N, 85.48W). The study was repeated in 2007 at the E.V. Smith Research Station (EVS), Auburn University, located in Shorter, AL (32.42N, 85.53W). A marvyn sandy loam (fine-loamy, kaolinitic, thermic type Kanhapludults) was the soil type at both locations. The tomatoes, ‘Florida 47’, were seeded into Canadian Growing Mix 2 (Conrad Fafard Inc., Agawan, MA) in 72-cell flats at the Plant Sciences Research Center (PSRC) five weeks prior to transplanting and were grown according to recommended practices. Transplants were fertilized once a week with a 20N-4.4P-16.6K water soluble fertilizer (Peter’s Water Soluble Plant Food 20-10-20) (Scotts Co, Marysville, OH) at a rate of 265 mg/L of N. The transplants were hardened off the week before planting according to Kemble (2004). At both locations the soil was prepared and shaped into a series of twelve 1.22 m wide beds parallel beds, approximately 100 m in length.   A pre-emergent herbicide was applied (Dual-Magnum, Sygenta Corp, Greensboro, NC) and no soil fumigation was used. Treatments consisted of specially manufactured (Pliant Corp, Washington, GA) polyethylene plastic mulch (1.25 mil thickness, 1.52 m wide) based of laboratory analysis to closely fit the colors to spectral reflectance as based on Lewis (1997). Tomatoes were fertigated weekly with potassium nitrate (KNO_3) alternated with calcium nitrate ($Ca(NO_3)_2$) using drip tape with a Dosatron (Clearwater, Fl) fertilizer injector. Alternating the two fertilizers was done for the duration of the experiment and was scheduled as described by Kemble (2004).

The specific treatments were: white (standard control), silver (recommended control), violet, red 1, red 2, and red 3 plastic mulches. The 2006 study at the OAF had the same colors (silver, white, red 1, red 2, red 3, violet); however, they were not dyed onto white plastic mulch. Therefore, they were more transparent than the 2007 plastics which were dyed onto white plastic. Treatments were randomly assigned to a plot of 12 tomato plants in a randomized complete block design with four replications. Each replication consisted of three parallel rows and data were gathered from the center row to reduce variation. Weekly thrips counts were gathered from each plant using the beat cup method until first flower as described by Riley and Pappu (2004). Once the tomato plants began to flower, thrips counts were gathered by collecting ten open flowers from each plot and placing them in vials of alcohol according to Riley and Pappu (2004).

TSWV incidence (percent plants infected) was determined using a commercial enzyme-linked immunosorbent assay (ELISA) kit (Agdia, Inc., Elkhart, IN). The ELISA procedure was performed according to the manufacturer’s instructions. TSWV incidence was determined two times during the season: 42 days after plants were transplanted to the field and 84 days after being transplanted. A single leaf sample, consisting of the terminal leaflet of a newly formed leaf, was collected from each plant, wrapped in a dampened paper towel and placed on ice for transport to the laboratory. Each sample was processed for ELISA by grinding in 2 ml of general extraction buffer (as per manufacturer's instructions) using a motorized leaf squeezing apparatus. Known healthy control samples and a known positive control sample were added to each microtiter plate. Upon adding substrate, reactions were allowed to develop at room temperature for 60 to 90 minutes and were then recorded using a Sunrise microtiter plate reader (Phenix Research Products, Hayward, CA). A sample was considered positive for the presence of virus if the ELISA absorbance value was greater than the average plus three standard deviations of the negative control samples.

Data gathered included marketable, non-marketable yields, and TSWV incidence. The experimental design was a randomized complete block design. Data was analyzed with the GLIMMIX procedure (June 2006 version) of SAS (version 9.1; SAS Institute, Inc., Cary, NC) using generalized linear mixed model with the Poisson distribution and log link function, block as a random factor, and mulch color as the experimental factor. Data was analyzed separately for marketable, non-marketable, and TSWV incidence (both by individual collection date and using data from all corresponding collection dates as repeated measures) and by study location. Multiple-comparison-nonadjusted p values were obtained using the stimulation-stepdown method.

Results and Discussion

OAF 2006

The 2006 field study conducted at the OAF revealed treatment differences for marketable weights, non-marketable weights, marketable fruit counts, and non-marketable fruit counts. TSWV incidence was not affected by the treatments (Table 6). Silver and white mulches had higher marketable yields than violet, crimson, red A and red B. Non-marketable yields were higher in silver plots than violet, crimson, red A and red B. Marketable yields and non-marketable yields were greater than all of the specially made mulches (Table 6).

The violet, crimson, red A, and red B mulches failed very early in the season which caused increased weed pressure and reduced the reflective ability of the plastic. This failure was due to the mulches being dyed on to clear plastic and not onto white plastic which was accomplished for the 2007 studies.

OAF 2007

Statistical analysis revealed treatment differences for yields and thrips counts at this location. Yields and thrips numbers were affected by plastic mulch but TSWV infection rates were not (Table 7). Tomatoes grown on silver plastic mulch had higher marketable yields than violet, red 1, and red 3 (Table 7). Marketable yields were similar for those tomato plants grown on silver mulch and red 2 mulch. Non-marketable weights were affected by the treatments. Tomatoes grown on silver and white mulches had higher non-marketable yields than all other treatments (Table 7).

Tomatoes grown on silver mulch had higher marketable fruit counts than red 1 (213 vs. 151) and the white mulch had higher counts than the violet (240 vs. 157) and red

1 (240 vs. 151). Non-marketable fruit counts were affected by mulches. Silver mulch had higher non-marketable fruit counts than tomatoes grown on violet (50 vs. 25) and red 1 (47 vs. 25) (Table 7).

Thrips overall cup counts collected in the early season (before tomatoes bloomed) were lower for the silver mulch as compared to the all treatments (Table 8) (Figure 1). On individual collection dates thrips cup counts were lower for silver on 23 May 2007 as compared to white, violet, and red 3 (Table 8) (Figure 1). On 1 June 2007, silver mulch had lower thrips counts than red 2 and red 3. Conversely, on 8 June 2007, the white mulch was lower than silver, violet, red 1, and red 2 (table 8) (Figure 1). On 21 June 2007, silver was lower in thrips counts than white or violet (Table 8) (Figure 1). The white mulch had lower thrips cup counts on 21 June 2007 than the violet mulch treatment (Table 8) (Figure 1).

Overall thrips flower counts showed that silver mulch was lower than white and red 1 (Table 8) (Figure 2). Selected differences were observed on individual dates. The 29 June 2007 survey revealed that silver mulch had lower thrips flower counts than all other mulches except red 3 (Table 8) (Figure 2). On 6 July 2007, silver mulch was lower than white and red 1 mulches for thrips flower counts (Table 8) (Figure 2). White mulch had higher flower thrips counts than violet, red 1, red 2, and red 3 on the same date (Table 8) (Figure 2).

Overall the silver mulch had lower thrips cup and flower counts as previously shown (Brown and Brown, 1992: Greenough et al., 1990; Reitz et al., 2003; Scott et al., 1989). Failures of the colored plastic mulches (i.e. red 1, red 2, red 3, and violet) led to increased weed pressure and reduced the reflectance ability of the mulches. This could partially explain the difference in yields and the inconsistency in repelling the thrips and/or TSWV incidence levels.

<u>EVS 2007</u>

Statistical analysis revealed treatment differences at the EVS location in 2007 for all variables measured. Marketable yields, non-marketable yields and non-marketable counts were affected by the treatments (Table 9). Noteworthy was differences for the silver mulch which had higher marketable tomato weights than the white and red 2 mulches (Table 9). This could be explained due to the tomatoes grown on the white mulch had a 25% TSWV incidence level (Table 9). Silver had higher non-marketable tomato weights than the red 2 mulch and the white mulch had higher non-marketable tomato counts than the red 2 mulch.

Silver mulch again was consistent in lowering early season thrips cup counts. The overall thrips cups counts were all lower for the tomatoes grown on silver mulch as compared to all other mulches (Table 10) (Figure 3). This reduction in thrips populations to non-flowering tomatoes was not translated into lower numbers when thrips flower counts were measured for all comparisons. Silver did lower overall thrips flower counts as compared to red 1 and red 3 (Table 10) (Figure 4).

TSWV was affected by the mulches at this location for 2007. The early season TSWV incidence taken on 11 June 2007 revealed no differences in virus levels. The late season analysis showed that the tomatoes grown on silver mulch had reduced TSWV incidence as compared to the white, violet, and red 3 mulches (Table 9). Noteworthy was the red 1 mulch which had lower TSWV incidence as compared to the standard white mulch (3.8% vs. 25.2%) (Table 9). Red 1, red 2 and silver were all similar in TSWV incidence levels (3.8%, 6.3%, and 3.9%, respectively) which is positive data for the selected colored mulches (Table 9).

Overall, these three field experiments agreed with previous work that showed that silver mulches (Brown and Brown, 1992; Greenough et al., 1990; Reitz et al., 2003; Scott, 1989) were the best colored mulch in reducing thrips. However, silver mulch was not as consistent in reducing TSWV incidence in these studies. The only differences observed were at the E.V. Smith location in 2007. Exceptionally high levels of TSWV were observed at E.V. Smith (2007) with the white mulch at 25% incidence levels. However, the Old Agronomy Farm location in 2007, had levels as high as 38% for the red 1 and red 3 mulches but no TSWV incidence difference was observed. In 2006, the tomato crop was planted much later and the highest TSWV incidence level was only 4.7% and no differences were observed. Also, later planted tomatoes have been shown by Riley and Pappu (2000) to have lower TSWV incidence levels however the authors acknowledged that late planted tomatoes would not reduce TSWV to acceptable levels. In regard to the specially manufactured colored mulches these results were highly variable. Much of this variability could be due to the fact that all of these mulches deteriorated after about 2 months in the field; therefore, the full season effect was not measured. The red 1 which was lower in TSWV incidence (E.V. Smith, 2007) than the white mulch ($P \leq 0.05$) and the red 2 which was lower ($P \leq 0.10$) than the white mulch appear to hold some promise. Further testing of these colors with plastic mulch that has a UV stability to allow for season-long duration would be of interest in determining if this concept has merit.

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Table 6. Least squares means of yield, grade, and TSWV incidence in field grown tomatoes using six colors of plastic mulch, Old Agronomy Farm, Auburn, AL, 2006, with significance of mean comparisons between silver and white plastic mulches and other colors of plastic mulch.

	Yield				TSWV Incidence (%)
Mulch color	Marketable wt.	Non-marketable wt.	Marketable count	Non-marketable count	9/6/2006
Silver	18.1075	2.7300	101.8000	16.2299	1.78
White	14.0450	1.3600	82.7898	8.5215	2.18
Violet	3.1675	0.6825	18.3728	3.4999	4.64
Crimson	3.5575	0.2950	17.9726	1.4147	4.68
Red A	6.1475	1.0275	29.1068	4.7294	2.52
Red B	6.2575	0.6050	36.0372	3.0864	4.69
Treatment effects	0.0023	0.0436	0.0457	0.0669	0.3905
Comparisons[1]:					
White vs. Silver	0.2525	0.0720	0.7346	0.3489	0.7807
White vs. Violet	0.0061	0.3536	0.0257	0.2285	0.2167
White vs. Crimson	0.0077	0.1531	0.0239	0.0356	0.2097
White vs. Red A	0.0353	0.6452	0.1038	0.4104	0.8336
White vs. Red B	0.0375	0.3029	0.1875	0.1762	0.1998
Silver vs. Violet	0.0005	0.0111	0.0130	0.0441	0.1364
Silver vs. Crimson	0.0007	0.0036	0.0121	0.0063	0.1319
Silver vs. Red A	0.0032	0.0295	0.055	0.0918	0.6249
Silver vs. Red B	0.0034	0.0089	0.1049	0.0326	0.1247

[1]Repeated measures analysis using counts from four or three collection dates (thrips collected from cups or flowers, respectively).

[2]Significance of pairwise comparisons are reported as unadjusted multiple-comparison p values obtained using the simulation-stepwise method.

Table 7. Least squares means of yield, grade, and TSWV Incidence in field plantings of tomatoes grown using six colors of plastic mulch, Old Agronomy Farm, Auburn, AL. in 2007, with significance of mean comparisons between silver and white plastic mulches and other colors of plastic mulch.

	Yield				TSWV Incidence (%)	
Mulch color	Marketable wt.	Non-marketable wt.	Marketable count	Non-marketable count	6/11/2007	7/23/2007
Silver	48.5333	9.5400	213.00	50.1748	3.01	3.12
White	46.6800	7.1933	240.33	47.0675	5.47	9.11
Violet	27.4333	2.9867	157.33	25.5296	8.63	13.14
Red 1	26.9600	3.7600	151.33	25.3489	8.84	38.53
Red 2	35.1100	4.2719	181.00	28.8435	1.97	0.34
Red 3	35.1400	3.9400	181.67	28.5793	7.10	33.88
Treatment effects	0.0145	0.0007	0.0687	0.0791	0.8383	0.1974
Comparisons[1]:						
Silver vs. White	0.7490	0.0425	0.4125	0.8010	0.6473	0.5238
Silver vs. Violet	0.0045	0.0001	0.0633	0.0279	0.4031	0.3791
Silver vs. Red 1	0.0040	0.0003	0.0410	0.0267	0.3922	0.0922
Silver vs. Red 2	0.0612	0.0012	0.3329	0.0869	0.7863	0.3395
Silver vs. Red 3	0.0409	0.0003	0.2918	0.0550	0.5028	0.1333
White vs. Violet	0.0075	0.0022	0.0156	0.0424	0.6855	0.7912
White vs. Red 1	0.0066	0.0072	0.0102	0.0407	0.6696	0.2264
White vs. Red 2	0.0985	0.0292	0.1074	0.1244	0.4834	0.1425
White vs. Red 3	0.0701	0.0096	0.0793	0.0834	0.8200	0.3105

[1]Repeated measures analysis using counts from four or three collection dates (thrips collected from cups or flowers, respectively).
[2]Significance of pairwise comparisons are reported as unadjusted multiple-comparison p values obtained using the simulation-stepwise method.

Table 8. Least squares means of collected from cups and flowers in field grown tomatoes using six colors of plastic mulch, Old Agronomy Farm, Auburn, AL 2007, with significance of mean comparisons between silver and white plastic mulches and other colors of plastic mulch.

	Thrips collected from cups (no.)					Thrips collected from flowers (no.)			
Mulch color	23 May	1 June	8 June	21 June	Overall[1]	21 June	29 June	6 July	Overall[1]
Silver	2.0	2.3	4.0	0.5	1.8	9.9	3.7	3.5	5.7
White	8.2	3.1	1.0	2.7	3.5	28.8	12.4	7.4	15.3
Violet	5.6	6.4	5.9	5.9	5.9	24.8	8.1	2.7	9.0
Red 1	4.5	6.7	4.3	1.7	3.7	18.1	16.1	12.8	15.4
Red 2	4.7	8.5	4.2	0.7	3.4	26.3	8.7	3.5	10.4
Red 3	9.9	8.5	3.4	0.7	4.3	14.2	10.1	4.9	8.5
Treatment effects	0.0456	0.1058	0.1896	0.0024	0.0175	0.3223	0.0055	0.0004	0.0188
Comparisons[2]:									
Silver vs. white	0.0092	0.5695	0.0460	0.0424	0.0440	0.0569	0.0018	0.0326	0.0033
Silver vs. violet	0.0526	0.0650	0.3799	0.0042	0.0006	0.0968	0.0345	0.5584	0.1507
Silver vs. red 1	0.1183	0.0565	0.8464	0.1390	0.0275	0.2680	0.0003	0.0006	0.0026
Silver vs. red 2	0.1034	0.0215	0.8965	0.6633	0.0491	0.0784	0.0218	1.0000	0.0596
Silver vs. red 3	0.0038	0.0222	0.7457	0.6633	0.0086	0.5078	0.0075	0.3223	0.1901
White vs. violet	0.3236	0.1689	0.0114	0.0490	0.0437	0.7666	0.1142	0.0123	0.0650
White vs. red 1	0.1533	0.1482	0.0339	0.3647	0.8079	0.3715	0.2698	0.0299	0.9880
White vs. red 2	0.1762	0.0587	0.0374	0.0646	0.9579	0.8571	0.1757	0.0326	0.1615
White vs. red 3	0.6003	0.0604	0.0763	0.0646	0.3965	0.1838	0.4206	0.1805	0.0389

[1]Repeated measures analysis using counts from four or three collection dates (thrips collected from cups or flowers, respectively).
[2]Significance of pairwise comparisons are reported as multiple-comparison-adjusted p values obtained using the simulation-stepwise method.

Table 9. Least squares means of yield, grade, and TSWV incidence in field grown tomatoes using six colors of plastic mulch, E.V. Smith Research Station, Shorter, AL, 2007, with significance of mean comparisons between silver and white plastic mulches and other colors of plastic mulch.

	Yield				TSWV Incidence (%)	
Mulch color	Marketable wt.	Non-marketable wt.	Marketable count	Non-marketable count	6/11/2007	7/23/2007
Silver	52.8950	10.9300	192.33	71.7500	1.60	3.85
White	28.5175	8.9700	146.85	76.0000	25.50	25.15
Violet	43.5600	7.2850	156.49	53.7500	4.96	24.17
Red 1	39.1950	11.3125	183.99	89.2500	9.68	3.78
Red 2	20.1500	4.2075	95.94	40.000	10.0	6.26
Red 3	36.1225	8.0175	188.25	57.2500	8.41	28.47
Treatment effects	0.0434	0.2099	0.4271	0.1742	0.6084	0.0633
Comparisons[1]:						
Silver vs. White	0.0193	0.5075	0.4675	0.8502	0.0947	0.0465
Silver vs. Violet	0.3316	0.2260	0.5772	0.3535	0.5265	0.0514
Silver vs. Red 1	0.1615	0.8963	0.9040	0.4761	0.3039	0.9864
Silver vs. Red 2	0.0031	0.0343	0.0748	0.0741	0.2856	0.6532
Silver vs. Red 3	0.0915	0.3290	0.9534	0.4651	0.3550	0.0362
White vs. Violet	0.1267	0.5681	0.8630	0.2684	0.2160	0.9433
White vs. Red 1	0.2690	0.4298	0.5428	0.5979	0.4247	0.0454
White vs. Red 2	0.3826	0.1198	0.2601	0.0519	0.4268	0.0927
White vs. Red 3	0.4264	0.7460	0.5031	0.3613	0.3848	0.8180

[1]Significance of pairwise comparisons are reported as unadjusted multiple-comparison p values obtained using the simulation-stepwise method.

Table 10. Least squares means of collected from cups and flowers in field grown tomatoes using six colors of plastic mulch, E.V. Smith Research Station, Shorter, AL 2007, with significance of mean comparisons between silver and white plastic mulches and other colors of plastic mulch.

	Thrips collected from cups (no.)					Thrips collected from flowers (no.)			
Mulch color	23 May	1 June	8 June	20 June	Overall[1]	20 June	29 June	5 July	Overall[1]
Silver	3.3	3.5	1.5	0.5	1.8	8.9	13.8	3.5	7.5
White	4.4	10.0	4.7	1.2	4.0	9.9	14.0	7.8	9.9
Violet	9.9	8.0	4.2	1.5	5.0	10.6	12.7	5.6	9.0
Red 1	9.5	16.0	5.3	2.7	6.4	12.5	21.0	6.7	11.7
Red 2	5.4	11.5	5.6	2.5	4.8	7.2	12.3	6.4	7.7
Red 3	6.0	11.7	5.7	2.0	5.1	8.9	27.4	11.4	13.2
Treatment effects	0.3509	0.0056	0.2183	0.3134	0.0031	0.8687	0.0603	0.1518	0.0434
Comparisons[2]:									
Silver vs. white	0.6224	0.0063	0.0436	0.2998	0.0068	0.8203	0.9640	0.0698	0.1539
Silver vs. violet	0.0689	0.0280	0.0679	0.2075	0.0008	0.6966	0.7933	0.2847	0.3505
Silver vs. red 1	0.0788	0.0002	0.0267	0.0473	0.0001	0.4425	0.1636	0.1401	0.0303
Silver vs. red 2	0.4112	0.0024	0.0217	0.0605	0.0011	0.6464	0.7090	0.1680	0.8528
Silver vs. red 3	0.3189	0.0020	0.0203	0.1095	0.0007	0.9942	0.0271	0.0106	0.0076
White vs. violet	0.1587	0.4114	0.7876	0.7767	0.2509	0.8698	0.7587	0.3951	0.5939
White vs. red 1	0.1797	0.0606	0.7676	0.1857	0.0251	0.5838	0.1761	0.6846	0.3741
White vs. red 2	0.7327	0.5792	0.6743	0.2460	0.3333	0.4950	0.6760	0.6054	0.2100
White vs. red 3	0.6003	0.5189	0.6440	0.4523	0.2190	0.8264	0.0294	0.3129	0.1228

[1]Repeated measures analysis using counts from four or three collection dates (thrips collected from cups or flowers, respectively).

[2]Significance of pairwise comparisons are reported as multiple-comparison-adjusted p values obtained using the simulation-stepwise method.

Figure 1. Effect of colored mulch on thrips ability to locate field grown tomatoes, 2007, Old Agronomy Farm, Auburn, AL.

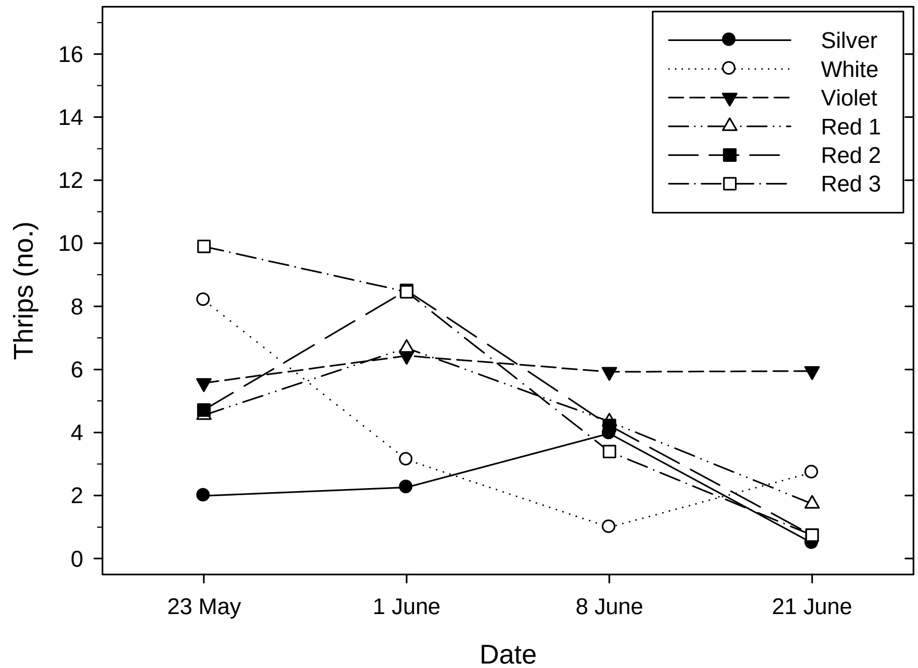


Figure 2. Effect of colored mulch on thrips ability to locate field grown tomatoes, 2007, Old Agronomy Farm, Auburn, AL.

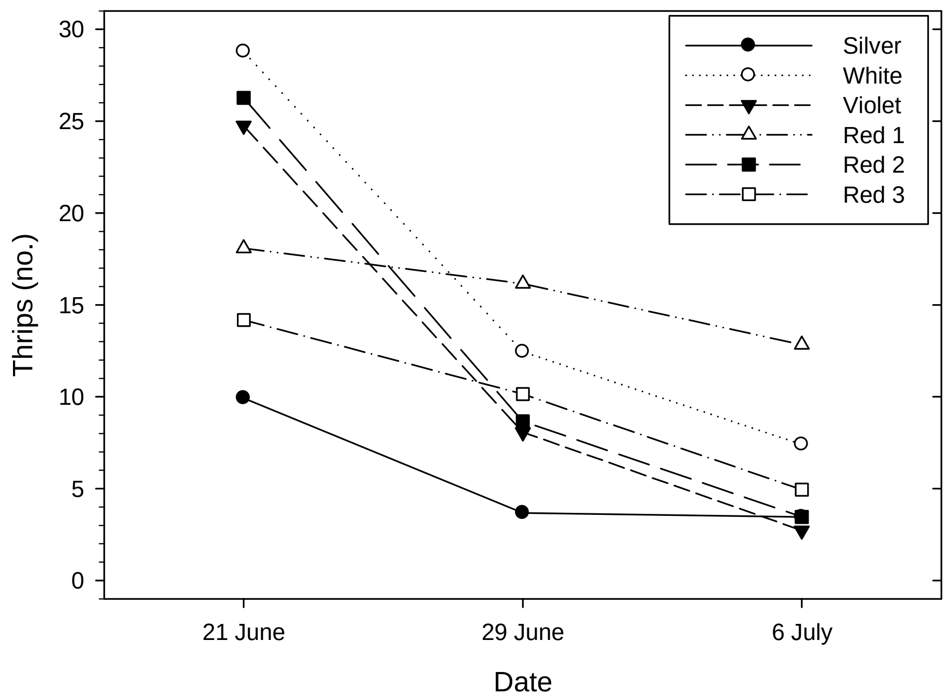


Figure 3. Effect of colored mulch on thrips ability to locate field grown tomatoes, 2007, E.V. Smith Research Station, Shorter, AL.

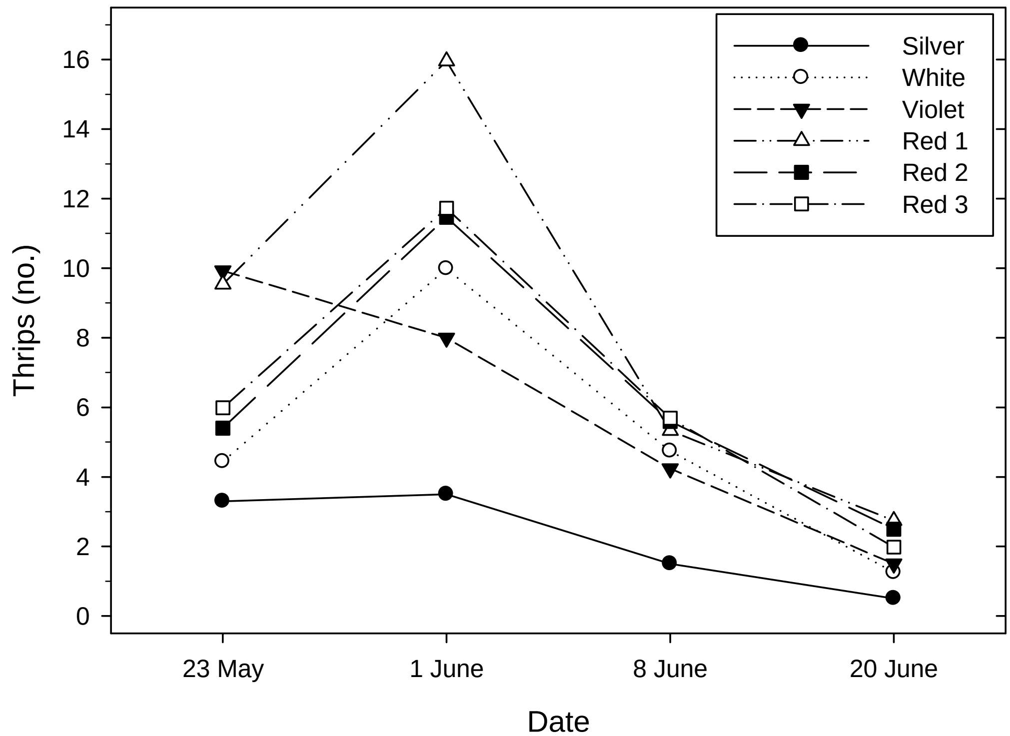
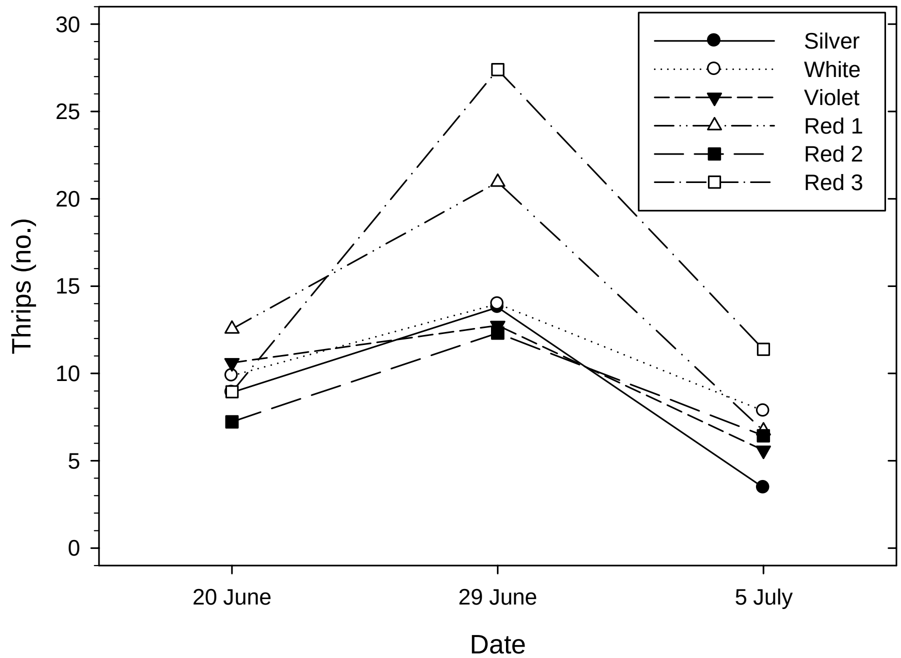


Figure 4. Effect of colored mulch on thrips ability to locate field grown tomato flowers, 2007, E.V. Smith Research Station, Shorter, AL.



CHAPTER IV

FINAL DISCUSSION

Tomato spotted wilt virus (TSWV) has become the major pest problem of tomatoes in the southeastern U.S. Many growers have reported that fresh-market profits have been reduced due to this disease. Control of thrips and subsequently TSWV infection has been studied by many researchers. Prior to these experiments no studies have been reported using tempera paint applied directly to tomatoes or these specially formulated colored plastic mulch designed to repel thrips without the adverse affects of glare to workers.

During these experiments, the selected tempera paints applied to two greenhouse studies and subsequently, four field studies, revealed that the paints did not affect growth and yield. However, these paints did not reduce thrips numbers or TSWV incidence in the field as hypothesized. The positive results from the growth and yield data established that this applying tempera paints multiple times could hold promise if an effective paint color could be determined that would deter thrips through strong UV reflectance, such as a metallic silver or glitter paint. Adding titanium dioxide, commonly used in plastics, exterior paints, and sun screen, may be another alternative method to increase the UV reflectance of the paints. The most promising application of this technique (if a suitable paint to deter thrips can be determined) would be for homeowners or organic producers who wish to grow older tomato varieties which do not have TSWV resistance.

In regards to the specially formulated colored plastic mulches our hypothesis was that a color, other than silver (which reflects all light and the glare is bothersome to workers), would reflect light in the 350-390 nm range could potentially repel thrips and reduce TSWV. The most effective plastic mulch in reducing TSWV was silver which agrees with the research of others (Brown and Brown, 1992; Greenough et al., 1990; Reitz et al., 2003; Scott, 1989). The silver plastic mulches on average had lower thrips and TSWV in most instances than the other plastic mulches studied.

However, the results indicated that red 1 and red 2 mulches repelled thrips and reduced TSWV incidence on a similar level as silver mulch in many comparisons and lower than white mulch in some cases. The color mulches did breakdown from photodegredation at a rapid rate before the growing season was complete. This led to weed problems and possibly reduced the effect of the color in deterring thrips. These colored mulches did last long enough to reduce thrips feeding in the early season when TSWV has the most impact on growth and production. If these mulches were to last longer the reduced yields might be minimized. Further experiments with more durable mulches would prove useful in fully evaluating colored mulches effectiveness in reducing the occurrence of TSWV.

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