Combinations of Soil Dimpling and Mulch Type to Reduce Nutsedge (*Cyperus* spp.) Punctures in Polyethylene Mulched Beds

by

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Abstract

Growers use polyethylene (PE) mulch to maximize vegetable crop yields. Specifically, PE mulch provides earlier and higher yields, a cleaner and higher quality product, a more economical use of water and fertilizers, along with improved disease, insect, and weed control. Conversely, not all weed species are significantly controlled. Two of the most economically damaging weeds, yellow (*C. esculentus*) and purple (*C. rotundus*) nutsedge, can readily pierce and degrade PE mulch allowing competition with vegetable crops. While field research has been limited, different types of PE mulches have been assessed for controlling and altering growth of nutsedge. Results from these previous evaluations showed encouraging results prompting our research objectives.

The reduction efficacy of yellow and purple nutsedge punctures in PE mulched beds were evaluated using combinations of mulch type and soil dimpling. Yellow and purple nutsedge were evaluated separately at two different locations. Both experiments were setup as an augmented factorial treatment arrangement of two mulch types (white or infrared-transmitting (IRT) green) and three dimple sizes (none, small, and large). This was augmented by a commercial standard (white mulch with a preemergence (PRE) herbicide applied under mulch), giving a total of 7 treatments. Treatments were evaluated based on their ability to decrease nutsedge punctures. For the yellow nutsedge study, the main effects for mulch were significant; however, the main effects of dimples and the interaction between mulch and dimples were not significant for any response variables (punctures and weight of emerged and non-emerged shoots). Yellow nutsedge punctures 14, 28, and 60 days after treatment (DAT), dry weight of emerged and non-emerged yellow nutsedge shoots were reduced significantly by IRT-green PE mulch compared to white mulch and the standard treatment. Data for the purple nutsedge study were similar. Interactions of mulch x dimple treatments were not significant for any response variables; therefore, main effects were analyzed. Main effects for mulch and dimples (14 DAT only) were significant, therefore means were compared. Nutsedge punctures were significantly reduced in infrared mulch treatments compared to white mulch treatments and the standard treatment at all rating dates. Additionally, dry weight of emerged and non-emerged shoots were reduced in infrared mulch treatments compared to white mulch treatments and the standard treatment

The aforementioned results suggest that IRT-green PE mulch may suppress yellow and purple nutsedge populations regardless of dimples in PE mulched beds and successively reduce the impact on yield and quality of vegetable crops.

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Introduction and Literature Review

Growers around the world have many difficulties in their vegetable cropping systems. One of those major difficulties is weed control (Bell, 1997; Gilreath and Santos, 2004; Oerke, 2006). When weeds thrive in these systems, crop yield and profit potential are negatively affected. Despite the extensive use of technology and human labor, weeds consistently account for significant economic costs and crop yield losses globally (Shrestha and Grantz, 2005). Many vegetable crops do not possess the ability to outcompete weeds for light, nutrients, space and water (Earl et al., 2004; Gilreath and Santos, 2004). The introduction of polyethylene (PE) as a plastic mulch in the early 1950s transformed commercial production of vegetable crops (Lament, 1993). This product along with fertigation provides benefits such as earlier and higher yields, a cleaner crop, a more cost-effective use of fertilizer and water, and improved disease, insect and weed control (Lament, 1993). Even though polyethylene mulch works great as a tool for weed control, certain weed species are not controlled sufficiently. Nutsedge (*Cyperus* spp.) is one of the worst in plasticulture systems (Dittmar et al., 2012a; Earl et al., 2004). Purple nutsedge (*C. rotundus* L.) and yellow nutsedge (*C. esculentus* L.) are exotic invasive weeds that have become naturalized within the U.S. (Webster, 2005a). Nutsedge species are problematic because of their ability to penetrate and emerge through the plastic mulch easily, creating competition with the crop and degrading mulch durability, along with making cleanup more difficult (Adcock, 2007; Devkota et al., 2013; Henson and Little, 1969; Johnson and Mullinix, 2008; Webster, 2005a). Nutsedge has also been documented to have allelopathic compounds (Drost and Doll, 1980), as well as serving as an alternative host for plant pathogens such as fungal diseases and nematodes

(Miller and Dittmar, 2014). Yellow nutsedge has been shown to be competitively superior to many crop species because of its high photosynthetic rate, fast sprouting, and early growth rate (Ferrell et al., 2004). Providing the water and fertility requirements for vegetable crops leads to an ideal environment for rapid nutsedge development (Bradenberger et al., 2005; Masiunas et al., 1997). Chemical and cultural control of nutsedge is an absolute requirement (Kemble et al., 2004). A problem with controlling season-long nutsedge chemically is the cost and limited number of herbicides labeled for vegetable crops and the potential for herbicide carryover to other plants (Gilreath and Santos, 2004; Kemble et al., 2004).

Tomato (*Solanum lycopersicum* L.) growers in the past used methyl bromide for impactful management of yellow and purple nutsedge and other common weeds found in tomato fields (Locascio et al., 1997). Yet, methyl bromide production and its use in agriculture were banned on January 1, 2005, after the Montreal Protocol and U.S. Clean Air Act were enacted because of the chemical's contribution to stratospheric ozone depletion. The effectiveness that methyl bromide had on weeds resulted in limited or no registered chemical substitutes. Attempts have been made to control sedges in plastic mulch with other fumigants in combination with various herbicides, but results tend to underscore the need for fumigants in addition to herbicides for efficacy (Adcock, 2007). No single alternative technology has been able to replace methyl bromide while maintaining cost effectiveness and availability in polyethylene mulched tomato production (Culpepper et al., 2009). Consequently, infestations are a major concern for growers who want to use a PE mulch application for multiple growing seasons (i.e. multicropping) (Morales-Payan et al., 1997). Reuse of PE mulch and drip tape irrigation distributes the costs of these inputs over several seasons (Webster, 2005b). The best and most current non-fumigant nutsedge control measure consists of spraying a pre-emergent (PRE) herbicide such as halosulfuron (Sandea®; Gowan Co., Yuma, AZ) or S-metolachlor (Dual Magnum®; Syngenta Crop Protection, Greensboro, NC) to the top of preformed beds before PE mulch is applied. The condensation from drip irrigation under the mulch will activate the herbicide. However, the PRE-herbicide layer can be disturbed when polyethylene mulch is applied, resulting in reduced weed control (Bonanno, 1996). The herbicide layer can also be rendered useless after a long length of time under the plastic with increased soil temperatures combined with soil moisture constantly near field capacity from the drip irrigation (Adcock, 2007). Furthermore, herbicide spray treatments cannot be applied or reapplied under the plastic mulch, which can limit multi-crop use. Post-emergent (POST) herbicide options are very limited in plasticulture due to phytotoxicity potential of the crop or crops nearby. Some herbicide products considered non-residual POST herbicides, including glyphosate, become residual herbicides on plastic and do not wash off easily (Majek, 2014). These residual herbicides can eventually wash into the planting holes with rates far above the recommended use and intended application rates. Recent research on herbicides applied through drip tape (i.e. drip-applied) has gained significant interest in areas of fruit and vegetable production. Applying herbicides by drip-application provides many benefits compared to sprayed application (Thomas et al., 2003; Wang et al., 2009). Research has shown this method has potential in commercial vegetable production (Adcock, 2007; Dittmar et al., 2012a; Santos et al., 2008), but there are some concerns. One major concern using drip-applied herbicides in PE-mulched beds is the lack of herbicide movement throughout the beds, which leads to varying weed control (Monday, 2014). The U-shaped wetting front from drip irrigation has a vertical water movement that predominates over lateral movement (Csinos et al., 2002). Dittmar et al. (2012b) conducted a study on the tolerance of tomatoes to drip-applied herbicides that indicated reduced control of nutsedge further away from the emitters compared to the control closer to the drip emitters. A uniform application of herbicides across the beds was achieved by utilizing two drip tapes in their study. Using two or more drip tapes for herbicide application could be more effective; however production costs will increase and additional specialized equipment is needed. Mechanical weeding, such as tillage, hoeing, or flaming, is not practical because of the PE mulch on top of the beds. Hand weeding might not be feasible in a large-scale operation because of labor unavailability and higher cost for weed control with severe infestations (Devkota et al., 2013; Strange et al., 2000). Glucosinolate-producing cover crops have been shown to suppress some weeds (Boydston and Hang, 1995; Krishnan et al., 1998; Vaughn and Boyston, 1997), but are ineffective in controlling Palmer amaranth, large crabgrass, and nutsedge species in plasticulture tomato production (Bangarwa, 2010; Norsworthy et al., 2007). Research into new and cost effective methods are needed by growers so they can attain the greatest nutsedge control in mulched beds with the capability to use the mulch more than one season.

Chase et al. (1998) studied the effect of varying light levels through PE mulch on nutsedge morphogenesis using two studies. The effects of irradiance levels on nutsedge penetration of transparent low-density PE (LDPE) film was investigated with experiments in a greenhouse using five separate shade treatments (100%, 98%, 96%, 75%, and 67%) and an unshaded treatment (0%). Opaque white-on-black PE mulch was used as the dark treatment (100% shade). Four presprouted nutsedge tubers were planted in pots that were covered with a 30-μm clear LDPE film and placed under each shade treatment. After two weeks, nutsedge plants that emerged under the dark treatment had shoots that were tightly folded together in an upright manner and resulted in an 80% puncture rate of the clear LDPE film. Puncture rates in the 0% shade treatment were significantly less at only 8%. Initial results indicated that nutsedge penetration was reduced as light transmittance throughout the plastic increased. A follow-up study was completed due to concerns that the variability of photosynthetic active radiation (PAR) levels in the greenhouse could have affected the outcome and interpretation of the data. This study differed by having a 5- to 10-mm space left between the clear LDPE film and soil in each pot. That small space allowed room for nutsedge shoots to elongate, unfurl, and become trapped prior to contacting the mulch. Results from this study indicated all light levels decreased penetration when a space was left between the soil and plastic. The lowest (30-µmol m^{-2} s^{-1}) and highest (320-µmol m^{-2} s^{-1}) light levels were similar in the inhibition of nutsedge punctures. These studies revealed transparent mulches are less susceptible to penetration by nutsedge than opaque mulches of similar thickness due to a change in the pattern of plant development when the rhizome detects a light or temperature stimulus. Detection of the stimulus ceases rhizome growth and initiates basal bulb formation and leaf elongation (Stoller and Wooley, 1983). Cessation of rhizome growth and subsequent leaf unfurling due to an exposure of light results in a trapped nutsedge plant subjected to foliar scorching under transparent mulch (Chase et al., 1998).

Patterson (1998) evaluated how translucent mulches affect emergence, growth, and vegetative reproduction of purple nutsedge using three studies. In a greenhouse experiment, three purple nutsedge tubers were planted 2-cm deep within pots and then randomly assigned to either one of three different translucent mulches [0.0318-mm embossed bluish green film (IRT-76), 0.0254-mm brown film (AL-OR), 0.0318-mm silver reflective film] or a 0.0318-mm embossed white-on-black opaque mulch. Results indicated that translucent mulches significantly reduced purple nutsedge shoot emergence, growth, and vegetative reproductive development compared to the opaque mulch. Translucent mulches reduced shoot biomass, tuber and rhizome number, and tuber biomass 85−99% compared to opaque mulch. A growth chamber experiment was conducted to determine the role of light in the suppression of purple nutsedge shoot emergence by the same translucent mulches. Patterson (1998) reported that purple nutsedge could not penetrate with alternating mixtures of fluorescent and incandescent light, but could penetrate all mulch types when the growth chamber was not illuminated. A final field experiment further confirmed trends from both greenhouse and growth chamber studies. After 115 days in the field, IRT-76 significantly reduced nutsedge shoot emergence 88%, emerged shoot dry weight 86%, and live tuber number 76% compared to the opaque, white-on-black mulch. The data collected from the experiments in Patterson's (1998) research indicated that the suppression of nutsedge emergence and growth by translucent mulch could not be solely attributed to solarization effects. A likely cause of the observed suppression of nutsedge is a photomorphogenic effect on the shoot as it emerges from the soil under the translucent mulch (Majek and Neary, 1991; Patterson, 1998). Patterson (1998) concluded long-term use of translucent mulch, where possible, should significantly reduce populations of purple nutsedge tubers in the soil, particularly when combined with effective management during fallow periods.

Ngouajio and Ernest (2004) evaluated the light transmitted through PE mulches and the effects on weed populations under the mulch. Mulches tested included gray, IRT-brown, IRT-green, white, white-on-black, and black mulch. Light transmittance through the mulches ranged from 1% to 48% light in the 400 to 1100-nm waveband. Black and white-on-black had the greatest opacity with only 1% and 2% transmitted, respectively. Gray, IRT-brown, IRT-green, and white transmitted 17%, 26%, 42%, and 48% light, respectively. Additionally, the IRT-green mulch further reduced light transmission from 42% to 16% when only the PAR waveband was considered. While much data was generated by this trial, a few observations stood out. Weed populations were highest in the white mulch treatment, which was attributed to high light transmittance. Conversely, weed populations were significantly lower in the IRT-green mulch although total light transmittance was similar to that of the white mulch. This research suggests that the wavelengths of light transmitted through PE mulch plays a more significant role in weed emergence underneath mulch than the total amount of light transmitted.

Information gathered from the aforementioned studies show nutsedge species may stop rhizome elongation and begin leaf expansion when exposed to light. Infrared-transmitting mulches allow enough PAR to allow this process to happen. When nutsedge starts to expand its leaves, it is much less likely to penetrate mulch. The IRT mulch heats up enough underneath the plastic to scorch the trapped nutsedge, but can be penetrated if the plastic is tight against the soil. Leaving space between the soil and IRT mulch may allow enough time for nutsedge to transition from rhizome elongation to leaf expansion. Since mulch must have some contact with the bed surface to keep it pulled tight and secure, beds could be dimpled (i.e. golf ball surface) to create space for nutsedge to emerge while allowing plastic to be secured to the bedded surface. Therefore, the objective of this research is to evaluate yellow and purple nutsedge punctures with IRT mulched beds and soil dimpling while comparing viability to the current commercial standard consisting of a PRE-herbicide applied to the soil underneath white-on-black opaque mulched beds.

Nutsedge Overview. Yellow and purple nutsedge are C_4 grass-like, colony-forming plants that can be found throughout the world, especially where commercial vegetable crops are grown. These plant species belong to the Cyperaceae (sedge) family in the subclass Monocotyledoneae under the genus *Cyperus*. The southeastern U.S. has 17 of the 98 to 146 different genera in the sedge family (Mabberley, 1997; Monday, 2014). Several of the genera are weedy, but the most troublesome are found in *Cyperus* (Radford et al., 1968). 29 of 45 *Cyperus* species are found in the southeast U.S. as perennials. Yellow and purple nutsedge are two herbaceous perennials that are separated from the others because of their economic impact on agriculture (Webster, 2005a). In 1889, yellow nutsedge was first listed as a weed in the U.S. (Defelice, 2002); by 1939, uncontrolled purple nutsedge caused growers to abandon agricultural land (Godfrey 1939; Webster 2005b). With the rising amount of atmospheric CO_2, Rogers et al. (2008) and Marble et al. (2015) suggested nutsedge could become a greater nuisance in the future. Nutsedge serve as alternative hosts for plant parasitic nematodes such as Columbia lance nematode (*Hopolaimus columbus* Sher.) and Southern root-knot nematode (*Meloidogyne incognita*) (Hogger and Bird, 1976; Vencill et al., 1995). Both nutsedges can be difficult to distinguish, but there are differences. Native to tropical Eurasia, purple nutsedge has been cited as the world's worst and most costly weed because of the potential to cause severe losses, regardless of the control strategy, to a various range of crops in tropical, subtropical, and warm-temperate regions including the southern U.S. (Holm et al., 1991a; Marble et al., 2015). Yellow nutsedge, ranked the 16th worst weed in the world (Holm et al., 1991b; Negbi, 1992) and native to the eastern Mediterranean (Defelice, 2002; Mabberley, 1997), thrives throughout the U.S. and Canada (Else, 1996; Jansen 1973; Padget and Frazier, 1962; Ransom et al., 2009; Wilcut et al., 1991). Literature has shown yellow nutsedge's allelochemicals can harm various crops (Drost and Doll, 1980; Reinhardt and Bezuidenhout, 2001), including processes such as legume-rhizobia symbiosis and ectomycorrhizal growth (Mallik and Tesfai, 1988; Reinhardt and Bezuidenhout, 2001). The seed heads of these sedges are contrasted by the purple to reddish-brown color of purple nutsedge and the yellowish-brown color of yellow nutsedge (Colvin et al., 1992). Yellow nutsedge foliage has a "spring-green" color while purple nutsedge has darker green foliage (Schonbeck, 2013). Carbohydrate-storing tubers of purple nutsedge are born in chains with individual tubers set 5.08 to 25.4 cm apart along the rhizome, whereas yellow nutsedge tubers are born singly at the ends of rhizomes. Yellow nutsedge is more cold tolerant than purple nutsedge (Bendixen and Nandihalli, 1987); this advantage expands dissemination of yellow nutsedge by giving tubers the ability to withstand low air and soil temperatures (Stoller and Sweet, 1987). However, lower light levels reduce growth and reproduction of yellow nutsedge with a further reduction for the shade intolerant purple nutsedge (Santos et al., 1997). Purple nutsedge has been found to have greater vigor and a more competitive nature than yellow nutsedge when conditions are optimum (Bendixen, 1973). Purple nutsedge is also very heat tolerant in field conditions, but tubers can be killed either by desiccation to 15 to 24% moisture content in direct sun, or by exposure to 50°C for 12 hours (Holm et al., 1991b; Schonbeck, 2013; Webster, 2003). Some distinguishing characteristics of nutsedge species that set them apart from true grasses are their 3-ranked arrangement of leaves, simple leaf blades with no sheaths or collars, and triangular stems in a cross section. Nutsedge can be singled out by their tendency to primarily propagate asexually by tuber production, even though achenes are produced by their aerial inflorescences like grasses (Kemble et al., 2004; Mulligan and Junkins, 1976; Tumbleson and Kommendahl, 1961). Seed production is relatively insignificant in purple nutsedge (Thullen and Keeley, 1979); however, Tayyar et al. (2003) provided the first documentation of a new biotype of nutsedge, closely related to purple nutsedge, which may have come from either sexual reproduction or a hybridization event with yellow nutsedge. Sexual reproduction in this biotype could lead to greater weed control problems in the future in some areas. Research has shown that a single yellow nutsedge plant in a noncompetitive environment can produce 1,900 shoots and 7,000 additional tubers within a year (Earl et al., 2004; Hauser, 1963; Smith and Fick, 1937; Tumbelson and Kommedahl, 1961). Tuber production is confined to a soil depth of 20 cm

(Lapham, 1985) and tuber survival is greatest at deeper soil depths with tubers remaining viable up to 10 years (Defelice, 2002; Stoller and Sweet, 1987). Sprouting is defined as the growth of buds on tubers (Chase et al., 1998). The rhizomatous tissue of yellow nutsedge has numerous buds and carbohydrates that make it capable of resprouting if the parent shoot is removed or injured (Akin and Shaw, 2001; Felix and Newberry, 2012; Stoller et al., 1975). Most tubers germinate at a faster rate and seedling growth is better under alternating temperatures than under constant temperatures (Miles et al., 1996; Stoller and Woolley, 1983). In temperate regions after the spring frost date, rhizomes will emerge from the sprouted tuber buds, elongate towards the soil surface until a light stimulus is received, and then form a basal bulb from which the daughter shoot and fibrous roots will grow (Holm et al., 1977). Stoller and Woolley (1983) reported rhizome growth in soil occurs by internode elongation at stable temperatures at the soil surface. Penetration of PE mulch is caused by the apex of a growing rhizome that has a sheath of sharp pointed scale leaves surrounding the meristem (Wills et al., 1980). After internode elongation has stopped, a basal bulb is formed in response to light and optimal temperatures at the soil level (Stoller and Woolley, 1983). The basal bulbs typically are within 7.62 cm of the soil surface, although bulbs of purple nutsedge have occurred at 10.16 to 20.32 cm (Hauser, 1963; Holm et al., 1991b; William and Warren, 1975). New rhizomes from the original basal bulb will give rise to new basal bulbs and shoots after weeks of shoot growth. This process occurs continually throughout the growing season, during which a single overwintered tuber can spread to an area up to 5.5m^2 and produce 750 shoots within 24 weeks (Webster, 2005a).

Purple and yellow nutsedge are considered major problems in almost every agronomic and horticultural crop in subtropical and tropical areas around the world (Santos et al., 1997). In 2012, Florida was the second largest national producer of bell pepper (*Capsicum annuum* L.)

behind California with a value of $247 million and 7,082 hectares grown (Miller and Dittmar, 2014). A population of 63 purple nutsedge plants m^{-2} reduced pepper yield 10% and a population of 200 plants m^{-2} reduced yield up to 32% (Morales-Payan et al., 1997). Motis et al. (2003) published similar results of season-long nutsedge interference of 5 yellow nutsedge plants m^{-2} reducing pepper yield by 10%. Motis et al. (2004) determined 3 to 5 weeks after planting as the critical nutsedge-free period for bell pepper. Fresh market cucurbits (*Cucurbita* spp. L.) are another economically important crop family grown on plastic (Trader et al., 2008). Approximately 65,235 acres of cucurbit crops were grown in Georgia, with watermelon (*Citrullus* spp. L.) and cantaloupe (*Cucumis melo* L.) accounting for 62% of the acreage (Johnson and Mullinix, 2002). Additionally, Florida ranked second in the nation generating $72 million though watermelon production (Buker et al., 2003). Season-long yellow nutsedge interference reduced field-grown watermelon yields up to 94% (Buker et al., 1999). Over 40% yield loss occurred when 12 yellow nutsedge plants m^{-2} were competing against direct-seeded and transplanted watermelon (Buker et al., 2003). At high yellow nutsedge densities, competition and allelopathic effects have been shown to reduce cucumber (*Cucumis* spp. L.) yields up to 83% (Johnson and Mullinix, 1999). Nutsedge has been shown to negatively impact yields of other important crops as well. William and Warren (1975) conducted studies in Brazil that showed decreases in yields by season-long purple nutsedge competition by 89%, 62%, 39% and 50% of garlic (*Allium sativum* L.), okra (*Hibiscus esculentus* L.), and two carrot (*Daucus carota* L.) cultivars, respectively. Moreover, season-long interference in green bean (*Phaseolus vulgaris* L.), cucumber, cabbage (*Brassica oleracea* L.), and tomato yields were reduced by 41%, 43%, 35%, and 53%, respectively. Crops produced on PE mulch are not the only ones to have reductions from nutsedge. Keeley (1987) reported yield reductions as high as 79% in field grown corn (*Zea mays* L.), 59% in rice (*Oryza sativa* L.), and 87% in field-grown soybean (*Glycine max* L.) with season-long nutsedge interference. The yields of eggplant (*Solanum melongena* L.) have been reduced by 22% with season-long purple nutsedge (Morales-Payan and Stall, 1997).

Polyethylene Mulch. When PE is used in agriculture for modifying the crop microclimate to enhance quality and yield, it is known as plasticulture (Grubinger, 2004). Research, extension, industry personnel, and growers have reported many advantages since PE's introduction as plastic mulch in the early 1950s (Lament, 1993). Depending on the location, soil type, and PE mulch used, earlier yields (7 to 14 days and up to 21 days) and increased overall yields (two to three times that of bare ground) have been reported on crops such as sweet corn and eggplant (Pollack et al., 1969), tomatoes (Bhella, 1986), muskmelons (Schales and Sheldrake, 1966), peppers (Stephenson and Bergman, 1963), cucumbers (Paterson, 1980), summer squash (Bhella and Kwolek, 1984), okra (Brown et al., 1986), and watermelon (Bhella, 1986). Plastic mulch with drip irrigation underneath reduces evaporation from the soil and decreases irrigation requirements which showed water savings of 45% compared to over-head sprinkler irrigation (Clough et al., 1987; Hanlon and Hochmuth, 1989; Jones et al., 1977). Besides decreasing soil water evaporation, CO_2, released by roots and breakdown of organic matter in the soil, is retained and released through the planting holes in the plastic resulting in higher levels of CO_2 around the crop's leaves (Baron and Gorske, 1981; Hopen, 1965; Sheldrake, 1963). Better weed control, with the exception of nutsedge, is another great advantage to using PE mulch compared to bare ground. Fertilizers that are placed underneath the mulch are not lost to leaching, but rather are retained in the root-zone for more efficient use by the crop (Cannington et al., 1975; Locascio et al., 1985). Soil compaction is not an issue when PE is used because the soil remains loose, friable, and well aerated, which allows roots to freely access nutrients, oxygen, and beneficial microbes (Hankin et al., 1982; Lament, 1993). Growers that use PE mulch tend to have a cleaner crop with fewer soil-borne diseases from water splashed on the fruit and plants. The disadvantages to using PE mulch include a greater initial cost from buying the specialized equipment needed for application, and removal and disposal of the used plastic. The type of mulch should be considered in the initial costs. There are several types and colors of PE mulch that should be evaluated before making a choice. The wide variety of plastic mulch on the market can reflect, absorb, or transmit sunlight (Grubinger, 2004), which determines the microclimate around the crop. Opaque black, white, white-on-black, and clear plastic mulches are the colors that predominate commercial vegetable production today (Lament, 1993). Black plastic is a black body absorber and radiator that absorbs most UV, visible, and infrared wavelengths of incoming solar radiation (Lamont Jr., 1999). Most of the energy absorbed can be transferred to the soil by conduction since the soil has a high terminal conductivity. The soil temperature under black mulch can be up to 2.8°C warmer at a 5-cm depth and up to 1.7℃ at a 10-cm depth compared to bare ground at the same depths. Clear mulch, used in cooler climates, transmits 85% to 95% of solar radiation, but absorbs little. During the day, soil temperatures under clear plastic are about 4.4 to 7.8℃ and 3.3 to 5.0℃ higher at 5-cm and 10-cm depths respectively, compared to bare soil. White mulch, white-on-black, and silver reflective plastic films decrease soil temperatures 1.1℃ at a 2.5-cm depth or 0.4℃ at a 10-cm depth because they reflect most of the solar radiation into the plant canopy. Reflective mulches have been shown to repel aphids that transmit viruses in cucurbit crops, such as squash (George and Kring, 1971). Infrared-transmitting mulches, pigmented green or brown to reduce visible light transmittance and maximize infrared radiation, tend to warm the soil intermediate to clear and black mulches (Grubinger, 2004; Loy et al., 1989). The overall use of PE mulch has greatly improved commercial vegetable production and continues to provide many benefits to crops and growers around the world.

Literature Cited

Adcock, C.W. 2007. Combinations of selected sulfonylurea herbicides with S-metolachlor for nutsedge control in tomatoes. Electronic Thesis and Dissertation. Auburn, AL: Auburn University.

Akin, D.S. and D.R. Shaw. 2001. Purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) control in glyphosate-tolerant soybean (*Glycine max*). Weed Technol. 15:564–570.

Bangarwa, S.K. 2010. Integrated strategies for purple (*Cyperus rotundus* L.) and yellow nutsedge (*Cyperus esculentus* L.) management in tomato and bell pepper. Ph.D. Dissertation. Fayetteville, AR: University of Arkansas.

Baron, J.J. and S.F. Gorske. 1981. Soil carbon dioxide levels as affected by plastic mulches. 16th Natl. Agr. Plastics Congr. 149–155.

Bell, C.E. 1997. Weed management in vegetable crops, p. 30–41. In: M.E. McGiffen (ed.). Weed management in horticultural crops. ASHS Press, Alexandria, VA.

Bendixen, L.E. 1973. Anatomy and sprouting of yellow nutsedge tubers. Weed Sci. 21:501–503.

Bendixen, L.E., and U.B. Nandihalli. 1987. Worldwide distribution of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). Weed Technol. 1:61–65.

Bhella, H.S. 1986. Watermelon growth, yield, and nutrition as influenced by plastic mulch and trickle irrigation. 19th Nan. Agr. Plastics Congr. 295–301.

Bhella, H.S. 1986. Effect of plastic mulch and trickle irrigation on tomato growth, yield, and nutrition. 19th Nan. Agr. Plastic Congr. 80–86.

Bhella, H.S. and W.F. Kwolek. 1984. The effects of trickle irrigation and plastic mulch on zucchini. HortScience 19: 410–411.

Bonanno, A.R. 1996. Weed management in plasticulture. HortTechnology 6:186–189.

Boydston, R.A. and A. Hang. 1995. Rapeseed (*Brassica napus*) green manure crop suppresses weeds in potato (*Solanum tuberosum*). Weed Technol. 9:669–675.

Bradenberger, L.P., R.E. Talbert, R.P. Wiedenfeld, J.W. Shrefler, C.L. Webber III, and M.S. Malik. 2005. Effects of halosulfuron on weed control in commercial honeydew crops. Weed Technol. 19:346–350.

Brown, J.E., G.A. Lewis, and H.M. Bryce. 1986. Influence of black plastic mulch and row covers on the growth and performance of okra intercropped with turnip greens. 19th Nan. Agr. Plastics Congr. 148–157.

Buker, R.S., III. 1999. Interference of yellow nutsedge with watermelon. M.S. thesis. University of Florida, Gainsville, FL. 120 p.

Buker, R.S., III, W.M. Stall, S.M. Olson, and D.G. Schilling. 2003. Season-long interference of yellow nutsedge (*Cyperus esculentus*) with direct-seeded and transplanted watermelon (*Citrullus lanatus*). Weed Technol. 17:751–754.

Cannington, F., R.B. Duggings, and R.G. Roan. 1975. Florida vegetable production using plastic film mulch with drip irrigation. 12th Natl. Agr. Plastics. Congr. 11–15.

Chase, C.A., T.R. Sinclair, D.G. Shilling, J.P. Gilreath and S.J. Locascio. 1998. Light effects on rhizome morphogenesis in nutsedges (*Cyperus* spp): implications for control by soil solarization. Weed Sci. 46:575–580.

Clough, G.H., S.J. Locascio, and S.M. Olson. 1987. Continuous use of polyethylene mulched beds with overhead or drip irrigation for successive vegetable production. 20th Natl. Agr. Plastics Congr. 57–61.

Colvin, D.L., R. Dickens, J.W. Everest, D. Hall, and L.B. McCarty. 1992. Weeds of southern turfgrass. Alabama Coop. Ext. Syst. p. 14, 19.

Csinos, A.S., J.E. Laska, and S. Childers. 2002. Dye injection for predicting pesticide movement in micro-irrigated polyethylene film mulch beds. Pest Manag. Sci. 58:381–384.

Culpepper, A.S., T.L. Grey, and T.M. Webster. 2009. Vegetable response to herbicides applied to low-density polyethylene mulch prior to transplant. Weed Technol. 23:444–449.

Defelice, M.S. 2002. Yellow nutsedge *Cyperus esculentus* L. – Snack food of the gods. Weed Technol. 16:901–907.

Devkota, P.J., K. Norsworthy, and R. Rainy. 2013. Efficacy and economics of herbicide programs compared to methyl bromide for weed control in polyethylene-mulched tomatoes. Weed Technol. 27:580–589.

Dittmar, P.J., D.W. Monks, and K.M. Jennings. 2012a. Effect of drip-applied herbicides on yellow nutsedge (*Cyperus esculentus*) in plasticulture. Weed Technol. 26:243–247.

Dittmar, P.J., D.W. Monks, K.M. Jennings, and F.L. Booker. 2012b. Tolerance of tomato to herbicides applied through drip irrigation. Weed Technol. 26:243–247.

Drost, D.C. and J.D. Doll. 1980. The allelopathic effect of yellow nutsedge (*Cyperus esculentus*) on corn (*Zea mays*) and soybeans (*Gylcine max*). Weed Sci. 28:229−233.

Earl, H.J., J.A. Ferrell, W.K. Vencill, M.W. Van Iersel, M.A. Czarnota. 2004. Effects of three herbicides on whole plant carbon fixation and water use by yellow nutsedge (*Cyperus esculentus*). Weed Sci. 52:213–216.

Else, M.J. 1996. Preventing weed problems: five weeds to watch out for. Natural Farmer 2:10−11.

Felix, J. and G. Newberry. 2012. Yellow nutsedge control and reduced tuber production with S-metolachlor, halosulfuron plus dicamba, and glyphosate in furrow-irrigated corn. Weed Technol. 26:213–219.

Ferrell, J.A., H.J. Earl, and W.K. Vencill. 2004. Duration of yellow nutsedge (*Cyperus esculentus*) competitiveness after herbicide treatment. Weed Sci. 51:24–27.

George, W.L., Jr., and J.B. Kring. 1971. Virus protection of late season summer squash with aluminum mulch. Connecticut Agr. Expt. Station Bul. 239.

Gilreath, J.P. and B.M. Santos. 2004. Efficacy of methyl bromide alternatives on purple nutsedge control (*Cyperus rotundus*) in tomatoes and peppers. Weed Technol. 18:141–145.

Godfrey, G.H. 1939. The control of nutgrass with chloropicrin. Soil Sci. 47:391–395.

Grubinger, Vern. 2004. Plastic mulch primer. University of Vermont Extension. https://www.uvm.edu/vtvegandberry/factsheets/plasticprimer.html. Accessed: July 4, 2017.

Hankin, L., D.E. Hill, and G.R. Stephens. 1982. Effects of mulches on bacterial population and enzyme activity in soil and vegetable yields. Plant Soil Sci. 64:193–201.

Hanlon, E.A. and G.J. Hochmuth. 1989. Fertilizer recommendations for vegetables grown in polyethylene mulch. 21st Natl. Agr. Plastics. Congr. 165–171.

Hauser, E.W. 1963. Response of purple nutsedge to amitrole, 2,4-D, and EPTC. Weeds 11:251–252.

Henson, I.E. and C.S. Little. 1969. Penetration of polyethylene film by the shoots of *Cyperus rotundus*. PANS Pest Artic. News Summ. 15:64–66.

Hogger, C.H. and G.W. Bird. 1976. Weed and indicator hosts of plant-parasitic nematodes in Georgia cotton and soybean fields. Plant Dis. Rep. 60:223−226.

Holm, L.G., J.V. Pancho, J.P. Herberger, and D.L. Plucknett. 1991a. A geographical atlas of world weeds. Krieger Publ., Malabar, FL.

Holm, L.G., D.L. Plucknett, J.V. Pancho, and J.P. Herberger. 1991b. The world's worst weeds: Distribution and biology. Krieger Publ., Malabar, FL.

Holm, L.G., D.L. Plucknett, J.V. Pancho, and J.P. Herberger. 1977. The world's worst weeds: Distritubution and biology. United Press. Honolulu, HI.

Hopen, H.J. 1965. Effects of black and transparent polyethylene mulches on soil temperature, sweet corn growth and maturity in a cool growing season. J. Amer. Soc. Hort. Sci. 86: 415–423.

Jansen, L.L. 1973. Morphology and photoperiodic responses of yellow nutsedge. Weed Sci. 19:201–219.

Johnson, W.C., III and B.G. Mullinix, Jr. 2002. Weed management in watermelon (*Citrullus lanatus*) and cantaloupe (*Cucumis melo*) transplanted on polyethylene-covered seedbeds. Weed Technol. 16:860–866.

Johnson, W.C., III and B.G. Mullinix, Jr. 2008. Cultural control of yellow nutsedge (*Cyperus esculentus*) in transplanted cantaloupe (*Cucumis melo*) by varying application timing and type of thin-filmed mulches. Crop Protection. 27:735–739.

Johnson, W.C., III, and B.G. Mullinix, Jr. 1999. *Cyperus esculentus* interference in *Cucumis sativus*. Weed Sci. 47:327–331.

Jones, T.L., U.S. Jones, and D.O. Ezell. 1977. Effect of nitrogen and plastic mulch on properties of troup loamy sand and yield of Walter tomatoes. J. Amer. Soc. Hort. Sci. 102: 273–275.

Keeley, P.E. 1987. Interference and interaction of purple and yellow nutsedges (*Cyperus rotundus* and *C. esculentus*) with crops. Weed Technol. 1:74–81.

Kemble, J.M., M.G. Patterson, and J.W. Everest. 2004. Nutsedge control in commercial vegetables. Alabama Cooperative Extension System. Alabama A&M and Auburn Universities. ANR-1156.

Krishnan, G., D.L. Holshouser, and S.J. Nissen. 1998. Weed control in soybean (*Glycine max*) with green manure crops. Weed Technol. 12:97–102.

Lament, W.J., Jr., 1993. Plastic mulches for the production of vegetable crops. HortTechnology 3:35–39.

Lamont, W.J., Jr., 1999. The use of different colored mulches for yield and earliness. Proceedings of the New England Vegetable and Berry Growers Conference and Trade Show, Sturbridge, MA. pp. 299-302.

Lapham, J. 1985. Unrestricted growth, tuber formation, and spread of *Cyperus esculentus* L. in Zimbabwe. Weed Res. 25:323–329.

Locascio, S.J., J.G.A Fiskell, D.A. Graetz, and R.D. Hawk. 1985. Nitrogen accumulation by peppers as influenced by mulch and time of fertilizer application. J. Amer. Soc. Hort. Sci. 110:325–328.

Locascio S.J., R.J. Gilreath, D.W. Dickson, T.A. Kucharek, J.P. Jones, and J.W. Noling. 1997. Fumigant alternatives of methyl bromide for polyethylene mulched tomato. HortScience 32: 1208–1211.

Loy, B., J. Lindstrom, S. Gordon, D. Rudd, and O. Wells. 1989. Theory and development of wavelength selective mulches. 21st Natl. Agr. Plastics Congr. 193–197.

Mabberley, D.J. 1997. The plant-book: A portable dictionary of the vascular plants. 2nd ed. Cambridge, U.K.: Cambridge University Press. 858 p.

Majek, B. 2014. Weed control for crops commonly grown on plastic mulch. Rutgers University Cooperative Extension. https://plant-pest-advisory.rutgers.edu/weed-control-for-crops-commonly-grown-on-plastic-mulch. Accessed: October 30, 2017.

Majek, B. A. and P. E. Neary. 1991. Selective wavelength transmitting mulch for yellow nutsedge control. Brighton Crop Prot. Conf. Weeds. 1991:263–268.

Mallik, M. A. B. and K. Tesfai. 1988. Allelopathic effect of common weeds on soybean growth and soybean-Bradyrhizobium symbiosis. Plant Soil. 112:177−182.

Marble, S.C., S.A. Prior, B. Runion, and H.A. Torbert. 2015. Control of yellow and purple nutsedge in elevated CO_2 environments with glyphosate and halosulfuron. Frontiers Plant Sci. 6:1–6.

Masiunas, J., M. McGiffen, C. Wilen, C. Bell, T. Lanini, J. Derr, and G. Kolasani. 1997. Intergrated weed management in horticultural crops. *In* M.E. McGiffen, ed. Weed Management in Horticultural Crops: An American Society for Horticultural Science and Weed Science Society of America Joint Workshop. Alexandria, VA: ASHS. Pp. 15–16.

Miles, J.E., R.K. Nishimoto, and O. Kawabata. 1996. Diurnally alternating temperatures stimulate sprouting of purple nutsedge (*Cyperus rotundus*) tubers. Weed Sci. 44: 507–512.

Miller, M.R. and P.J. Dittmar. 2014. Effect of PRE and POST-directed herbicides for season-long nutsedge (*Cyperus* spp.) control in bell pepper. Weed Technol. 28: 518–526.

Monday, T.A. 2014. Effects of application method and surfactants on control of yellow nutsedge with drip-applied herbicides in polyethylene-mulched tomato. Electronic Thesis and Dissertation. Auburn, AL: Auburn University.

Motis, T.N., S.J. Locascio, and J.P. Gilreath. 2004. Critical yellow nutsedge-free period for polyethylene-mulched bell pepper. HortScience 39:1045–1049.

Motis, T.N., S.J. Locascio, J.P. Gilreath, and W. Stall. 2003. Season-long interference of yellow nutsedge (*Cyperus esculentus*) with polyethylene-mulched bell pepper (*Capsicum annuum*). Weed Technol. 17:543–549.

Morales-Payan, J.P., B.M. Santos, W.M. Stall, and T.A. Bewick. 1997. Effect of purple nutsedge (*Cyperus rotundus*) on tomato (*Lycopersicon esculentum*) and bell pepper (*Capsicum annum*) vegetative growth and fruit yield. Weed Technol. 11:672–676.

Morales-Payan, J.P. and W.M. Stall. 1997. Effect of purple nutsedge (*Cyperus rotundus*) population densities on the yield of eggplant (*Solanum melongena*). HortScience 32(abstr.):431.

Mulligan, G.A. and B.E. Junkins. 1976. The biology of Canadian weeds. 17. *Cyperus esculentus* L. Can. J. Plant Sci. 56:339–350.

Negbi, M. 1992. A sweetmeat plant, a perfume plant and their weed relatives: a chapter in the history of *Cyperus esculentus* L. and *Cyperus rotundus* L. Econ. Bot. 46:64−71.

Ngouajio, M. and J. Ernest. 2004. Light transmission through colored polyethylene mulches affects weed populations. HortScience 39:1302–1304.

Norsworthy, J.K., M.S. Malik, P. Jha, and M.B. Riley. 2007. Suppression of *Digitaria sanguinalis* and *Amaranthus palmeri* using autumn-sown glucosinolate-producing cover crops in organically grown bell pepper. Weed Res. 47:425–432.

Oerke, E.C. 2006. Crop losses to pests. J. Agric. Sci. Cambridge Press. 144:31–43.

Padget, J.H. and T.L. Frazier. 1962. The relationship between costs and pricing of woody ornamentals. Georgia Agr. Expt. Sta. Bul. N. Series 100.

Paterson, J.W. 1980. Fertilizing mulched and unmulched cucumbers. 15th Natl. Agr. Plastics Congr. 97–99.

Patterson, D.T. 1998. Suppression of purple nutsedge (*Cyperus rotundus*) with polyethylene film mulch. Weed Technol. 12:275–280.

Pollack, G.L., N.J. Smith, and J.C. Cialone. 1969. Summary of crop response to various agricultural film mulches. 9th Natl. Agr. Plastics Conf. 17–25.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. Manual of the vascular flora of the Carolinas. Univ. of North Carolina Press. Chapel Hill, NC. 1183 p.

Ransom, C.V., C.A. Rice, and C.C. Shock. 2009. Yellow nutsedge (*Cyperus esculentus*) growth and reproduction in response to nitrogen and irrigation. Weed Sci. 57:21–25.

Reinhardt, C.F. and S.R. Bezuidenhout. 2001. Growth stage of *Cyperus esculentus* influences its allelopathic effect on ectomycorrhizal and higher plant species. J. Crop Prod. 4:323−333.

Rogers, H.H., G.B. Runion, S.A. Prior, A.J. Price, H.A. Torbert, and D.H. Gjerstad. 2008. Effects of elevated atmospheric CO_2 on invasive plants: comparison of purple and yellow nutsedge (*Cyperus rotundus* L. and *C. esculentus* L.). J. Environ. Qual. 37:395–400.

Santos, B.M, J.P. Gilreath, M.L. Lugo, and L.E. Rivera. 2008. Managing weeds with drip-applied herbicides in tomato. Crop Prot. 27:101–103.

Santos, B.M., J.P. Morales-Payan, W.M. Stall, T.A. Bewick, and D.G. Shilling. 1997. Effects of shading on the growth of nutsedges (*Cyperus* spp.). Weed Sci. 45:670–673.

Schales, F.D. and R. Sheldrake Jr. 1966. Mulch effects on soil conditions and muskmelon response. J. Amer. Soc. Hort. Sci. 88:425–430.

Schonbeck, M., 2013. Weed profile: yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*C. rotundus*). eXtension. https://articles.extension.org/pages/66868/weed-profile:-

yellow-nutsedge-cyperus-esculentus-and-purple-nutsedge-c-rotundus. Accessed: October 30, 2017.

Sheldrake, R. 1963. Carbon dioxide levels in the microclimate influences insect control and yield in vegetables. J. Amer. Soc. Hort. Sci. 104:759–762.

Shrestha, A. and D.A. Grantz. 2005. Ozone impacts on competition between tomato and yellow nutsedge: above- and below-ground effects. Crop Sci. 45:1587–1595.

Smith, E.V. and G.L. Fick. 1937. Nutgrass eradication studies: I. Relation of the life history of nutgrass (*Cyperus rotundus* L.) to possible methods of control. J. Am. Soc. Agron. 29:1007−1013.

Stephenson, K.Q. and E.L. Bergman. 1963. Some mechanical and cultural developments on the Penn State transplanter mulcher. 4th Natl. Agr. Plastics Conf. 58–64.

Stoller, E.W. and R.D. Sweet. 1987. Biology and life cycle of purple and yellow nutsedges (*Cyperus rotundus* and *C. esculentus*). Weed Technol. 1:66–73.

Stoller, E.W., L.M. Wax, and R.L. Matthiesen. 1975. Response of yellow nutsedge and soybeans to bentazon, glyphosate, and perfluidone. Weed Sci. 23:215–221.

Stoller, E.W. and J.T. Woolley. 1983. The effects of light and temperature on yellow nutsedge (*Cyperus esculentus*) basal-bulb formation. Weed Sci. 31:148–152.

Strange, M.L., W.L. Schrader, and T.K. Hartz. 2000. Fresh-market tomato production in California. Vegetable Research and Information Center, Division of Agriculture and Natural Resources, Univ. of California, UC Davis. Publication 8017.

Tayyar, R.I., J.H.T. Nguyen, and J.S. Holt. 2003. Genetic and morphological analysis of two novel nutsedge biotypes from California. Weed Sci. 51:731–739.

Thomas, J.G., D.A. Pennington, A.M. Schmidt, and L. Pringle. 2003. Chemigation. Mississippi State Extension Service. Publication 1551.

Thullen, R.J. and P.E. Keeley. 1979. Seed production and germination in *Cyperus esculentus* and *C. rotundus*. Weed Sci. 27:502–505.

Trader, B.W., H.P. Wilson, and T.E. Hines. 2008. Control of yellow nutsedge (*Cyperus esculentus*) and smooth pigweed (*Amaranthus hybridus*) in summer squash with halosulfuron. Weed Technol. 22:660–665.

Tumbleson, M.E. and T. Kommedahl. 1961. Reproductive potential of *Cyperus esculentus* by tubers. Weeds 9:646−653

Vaughn, S.F. and R.A. Boydston. 1997. Volatile allelochemicals released by crucifer green manures. J. Chem. Ecol. 23:2107–2116.

Vencill, W.K., J.S. Richburg, III, J.W. Wilcut, and L.R. Hawf. 1995. Effect of Mon-12037 on purple (*Cyperus rotundus*) and yellow (*Cyperus esculentus*) nutsedge. Weed Technol. 9:148−152.

Wang, X., H. Zhu, M.E. Reding, J.C. Locke, J.E. Leland, R.C. Derksen, A.L. Spongberg, C.R. Krause. 2009. Delivery of chemical and microbial pesticides through drip irrigation systems. Appl. Engr. Agr. 25:883–893.

Webster, T.M. 2003. Nutsedge (*Cyperus* spp.) eradication: Impossible dream? Pages 21–25 *in* Riley L.E., R.K. Dumroese, T.D. Landis (eds.) National proceedings: Forest and Conservatory Nursery Association – 2002. Ogden, UT. Proceedings RMRS-P-28.

Webster, T.M. 2005a. Patch expansion of purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) with and without polyethylene mulch. Weed Sci. 53:839–845.

Webster, T.M. 2005b. Mulch type affects growth and tuber production of yellow (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*). Weed Sci. 53:834–838.

Wilcut, J.W., C.H. Gilliam, G.R. Wehtje, T.V. Hicks, and D.L. Berchielli. 1991. Yellow nutsedge control in landscape plants. HortScience 26:159–162.

William, R.D. and G.F. Warren. 1975. Competition between purple nutsedge and vegetables. Weed Sci. 23:317–323.

Wills, G.D., R.E. Hoagland, and R.N. Paul. 1980. Anatomy of yellow nutsedge (*Cyperus esculentus*). Weed Sci. 28:432–437.

Chapter II

Combinations of Soil Dimpling and Mulch Type to Reduce Yellow Nutsedge (*Cyperus esculentus* L.) Punctures in Polyethylene Mulched Beds

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Abstract

Polyethylene (PE) mulch provides farmers with a more cost-effective use of water and fertilizer, higher quality and yield of crops, and a greater suppression of most weeds; however, nutsedges (*Cyperus* spp.) can easily penetrate the mulch. Field studies were conducted to evaluate combinations of soil dimpling and mulch type with the goal of reducing yellow nutsedge punctures in polyethylene-mulched beds. Treatments were evaluated based on their effect on yellow nutsedge punctures through the polyethylene mulch. The experiment was an augmented factorial treatment arrangement of two mulch types (white or infrared-transmitting PE mulch (IRT-green)) and three dimples sizes (none, small, or large). This was augmented by a commercial standard (white mulch with a preemergence (PRE) herbicide applied under mulch), giving a total of 7 treatments. The main effect of mulch was significant, whereas the main effect of dimples and the interaction between mulch and dimples was not significant for all measurable outcomes (yellow nutsedge punctures (at all rating dates) and dry weight of emerged and non-emerged yellow nutsedge shoots). Yellow nutsedge punctures at 14, 28, and 60 days after treatment (DAT) and dry weight of emerged and non-emerged yellow nutsedge shoots collected

60 DAT were reduced in IRT-green PE mulch treatments compared to white mulch treatments and the standard treatment. These results suggest that IRT-green PE mulch may suppress yellow nutsedge populations in polyethylene-mulched beds and subsequently reduce the negative impact on yield of vegetable crops produced on PE mulch. Additional research is needed to determine the full implications of using IRT-mulches to grow fruits and vegetables in the southeastern United States.

Introduction

Weed control is an impediment to crop production for growers around the world (Bell, 1997; Gilreath and Santos, 2004; Oerke, 2006). Weeds that thrive in their operations negatively affect crop yield and profit potential. The substantial use of advanced technologies and human labor are still not enough to prevent weeds from causing significant costs and crop yield losses globally (Shrestha and Grantz, 2005). When weeds interfere with crops, they compete for resources such as water, nutrients, light, and space, thereby reducing quality and yield (Earl et al., 2004; Gilreath and Santos, 2004). Polyethylene (PE) mulch is a product that provides advantages for vegetable crops such as cleaner, earlier, and higher yields, a more cost effective use of fertilizer and water, and improved disease, insect, and weed control (Lament, 1993). In some cases, PE can last multiple seasons for growing crops (multicropping). However, nutsedge (*Cyperus* spp.) is one of the most problematic weeds in PE mulched systems (Dittmar et al., 2012; Earl et al., 2004). Two of the worst invasive weed species in the genus *Cyperus* are yellow nutsedge (*C. esculentus* L.) and purple nutsedge (*C. rotundus* L.) (Webster, 2005). These species become troublesome because of their ability to easily penetrate and emerge through PE mulch causing competition among crops and degradation of mulch durability, ultimately making cleanup more difficult (Adcock, 2007; Devkota et al., 2013; Henson and Little, 1969; Johnson and Mullinix, 2008; Webster, 2005). Both nutsedge species thrive under a wide range of conditions, yet yellow nutsedge is more tolerant to flooding, cold, and light shade (Schonbeck, 2013). Additionally, yellow nutsedge has been identified as competitively superior to many crop species because of its high photosynthetic rate, fast sprouting from underground tubers, and early growth rate (Ferrell et al., 2004). Buker et al. (2003) determined watermelon yield losses greater than 10% can be prevented by keeping yellow nutsedge populations below 2 plants/m^2 throughout the season. Motis et al. (2003) found a season-long yellow nutsedge population of 90 tubers/m^2 reduced spring-grown bell pepper yield by at least 70%. Lastly, Morales-Payan (1999) concluded the critical yellow nutsedge-free period to prevent 10% loss of tomato yield was between 3 and 6 weeks after crop planting. Chemical and cultural control is an absolute requirement to manage nutsedge infestations (Kemble et al., 2004). Soil fumigation before PE mulch application has been effective in controlling weeds and other pests in the past; however, the most effective fumigant methyl bromide (Mbr), has been banned. Effective herbicides for nutsedge control are limited due to the small number of herbicides labeled for vegetable crops (Kemble et al., 2004). Consequently, alternative methods are needed to control nutsedge in PE mulch growing systems. One potential option receiving attention is utilization of different PE mulches to modify growth and development of problematic weeds such as nutsedge underneath mulch. Previous research, while limited, has been promising.

Chase et al. (1998) explored whether the differential nutsedge penetration of transparent and opaque PE mulch was due to light effects on nutsedge rhizome morphogenesis using greenhouse and field experiments. A greenhouse study evaluated the impact of irradiance levels on nutsedge penetration of PE mulch using six shade treatments (0%, 67%, 75%, 96%, 98% and 100%). In that study, penetration increased with increasing levels of shade. For example, in the

100% shade treatment, 100% of emerged yellow nutsedge rhizomes penetrated the transparent mulch. Conversely, in the 0% shade treatment only 8% of rhizomes penetrated the mulch. A follow-up study was completed incorporating a 5- to 10-mm space between the soil surface and mulch. Shade treatments remained the same. When a space was left between the soil and mulch, penetration actually decreased at all light levels. The small space allowed room for nutsedge shoots to elongate, unfurl, and become trapped prior to contacting the mulch. Lastly, field studies showed transparent mulch penetration by nutsedge leaf tips to be more prevalent where the mulch had close contact with the soil. More than 95% of rhizomes that emerged beneath transparent PE mulch were trapped and scorched to death, whereas rhizomes that sprouted beneath black opaque mulch punctured the mulch, then underwent leaf expansion above the mulch. Chase et al. (1998) concluded that transparent mulches are less susceptible to penetration by nutsedge compared to opaque mulches due to a change in the pattern of plant development when the rhizomes detect light while emerging from the soil (but prior to mulch penetration). Conversely, the absence of light beneath opaque mulches delays photomorphogenesis and rhizome growth continues through the mulch. This research is in agreement with Stoller and Wooley (1983) who reported that the detection of a light stimulus ceases nutsedge rhizome growth and initiates basal bulb formation and leaf elongation. Cessation of nutsedge rhizome elongation and leaf expansion prior to mulch penetration results in nutsedge shoots unfurling, being trapped under the mulch, and subject to scorching with transparent mulches (Chase et al., 1998).

Ngouajio and Ernest (2004) determined the effect of light transmission through colored PE mulches on weed populations underneath various mulch types using field and laboratory experiments. Their laboratory study measured light transmission in the 400 to 1100 nm range through black, grey, infrared transmitting brown (IRT-brown), IRT-green, white, and white-on-black (co-extruded white/black) mulches. Mulch type greatly affected the amount of light transmitted. For example, black and white/black mulches transmitted 1 and 2% of light, respectively. Conversely, grey, IRT-brown, IRT-green, and white transmitted 17, 26, 42, and 48%, respectively. The results for black, grey, white/black, and IRT mulches are similar to the results found by Patterson (1998). It is interesting to note that IRT mulches allowed much less light in the photosynthetic active radiation (PAR) waveband compared to the 400 to 1100 nm waveband (Ngouajio and Ernest, 2004). IRT-green PAR light transmission decreased from 42% to 16%, whereas IRT-brown PAR light transmission decreased from 26% to 6%. Furthermore, field studies conducted by Ngouajio and Ernest (2004) also revealed mulch type impacted weed density and biomass. Weed density and biomass were higher under white mulch as compared to white-on-black mulch, despite having similar soil temperature. Higher weed populations in the white mulch treatment were attributed to greater light transmission through the white mulch. However, the relationship between light transmittance and weed populations may be more intricate in photo-selective mulches. For example, IRT-green and white mulch had similar total light transmittance, but weed density and biomass were significantly lower beneath IRT-green mulch. These results suggest the wavelengths transmitted through mulch could be as important as the total amount of light transmitted for weed germination and development.

Information gathered from these studies suggests yellow nutsedge will stop rhizome elongation and begin leaf expansion when exposed to PAR light. When leaf expansion of yellow nutsedge plants occurs prior to contact with PE mulch, the plants are less likely to pierce the mulch. Research has shown IRT mulches can allow enough PAR light transmission to initiate the leaf expansion process. However, a space left between the mulch and soil surface may be required to provide adequate time for light to contact nutsedge shoots and begin the leaf expansion process. At the same time, mulch must be secured firmly to the bedded surface. The objective of this study was to evaluate combinations of IRT mulches and soil dimpling for reducing yellow nutsedge punctures. Dimpling the soil should allow space for yellow nutsedge to transition from rhizome elongation to leaf expansion under the mulch while simultaneously allowing mulch to be secured to beds.

Materials and Methods

This research was conducted in the summers of 2017 and 2018 at the Old Agronomy Farm (OAF), Auburn, AL (N 32° 35’ 28.18”, W 85° 29’ 10.42”). Fields had a history of heavy yellow nutsedge infestation. In both years, soil was disked and formed into four raised beds approximately 33.53 m long, 121.92 cm wide, 13 cm high, and covered by either white polyethylene mulch or IRT-green mulch (both 1.25 mil; Berry Plastics Corp., Evansville, IN). Each of the four rows contained eight, 3.05-m long plots with a 0.91-m buffer zone between plots. Rows were spaced 1.83 m apart. In both years, crops were not planted in order to better evaluate dimple and PE mulch treatments on nutsedge punctures. Before mulches were applied, a single drip tape (Toro Ag., Bloomington, MN) was centered in each bed and buried approximately 5 cm. Drip tape emitters were spaced 30.5 cm apart delivering water at 1.02 L/hr.

The experimental design was a randomized complete block with four replications. The treatment design was an augmented factorial. The factorial portion of the treatment design consisted of 2 levels of mulch and 3 levels of dimples for a total of 6 combinations. This was augmented by a commercial standard (white mulch with a preemergence herbicide applied under mulch), giving a total of 7 treatments. The two levels of mulch consisted of 1.25-mil white-on-black embossed mulch (white side facing up) and 1.25-mil green-IRT embossed mulch. The three levels of dimple treatments were as follows: a) no dimples, b) small dimples (11.3 cm^2) (Figure 1): 3.8 cm wide x 2.5 cm deep dimples spaced 7.6 cm apart and c) large dimples (31.5 cm^2; Figure 2): 6.35 cm wide by 5.1 cm deep dimples spaced 10.2 cm apart. In order to dimple soil, 3.8 cm (small) and 6.35 cm (large) PCV pipe end caps were mounted to 30.4 cm x 30.4 cm square boards. Boards were pressed into pre-formed beds, thereby dimpling soil just prior to mulch application (Figures 1 and 2). The commercial standard treatment consisted of S-metolachlor (1400 g ai ha^{-1}) applied to pre-formed beds prior to mulch application. S-metolachlor was applied with a battery-powered backpack sprayer (SHURflo, Costa Mesa, CA) equipped with one 11004 flat-fan nozzle (Spraying Systems Co., Wheaton, IL) calibrated to deliver 224 L ha^{-1}. All treatments received drip irrigation on a 48-h schedule. Each irrigation cycle delivered 2,420 L ha^{-1}.

Treatments were applied on 29 May (2017) and 4 June (2018). In both years, yellow nutsedge punctures were counted at 14, 28, and 60 days after treatment (DAT) from a 1.0 m^2 section of each plot. At 60 DAT, yellow nutsedge shoots that punctured the mulch as well as living shoots (still green) trapped below mulch were clipped, dried, and weighed. Data was collected from the same 1.0-m^2 section of each plot.

To analyze this data and produce estimable least squares means, the variable called std_vs_trt was created. This variable had a categorical value of “std” when the treatment was the standard (that is, herbicide with white mulch), and a value of “trt” when the treatment was not the standard (that is, it is a combination of mulch and dimples). Thus, the mulch and dimples factors were nested within the “std” value of std_vs_trt. This method of analyzing an augmented factorial treatment design was based on Example 1 by Piepho et al. (2006). Analysis was conducted using linear mixed models (for continuous response data) and generalized linear models (for count data using the negative binomial distribution and log link function) with the GLIMMIX procedure of SAS (version 9.4; SAS Institute, Cary, NC). Starting with a full model, the interaction term std_vs_trt*mulch*dimples was removed from the model when not significant ($p \geq 0.05$). In the latter case, main effects were examined. All terms containing std_trt were retained in the final models. *P*-values for simultaneous mean comparisons were adjusted using the Shaffer-Simulated method ($\alpha = 0.05$).

Results

Interactions of mulch x dimple treatments (std_vs_trt*mulch*dimples) were not significant with any of the response variables; therefore, main effects were analyzed (Tables 1 and 2). Main effects for mulch were significant, therefore, means were compared (Tables 3, 4, and 5). Main effects for dimples were not significant for any of the response variables; however, means are presented in tables for informational purposes (Tables 3, 4, and 5).

Yellow Nutsedge Punctures. Counts of yellow nutsedge punctures were influenced by mulch type only (P value <0.0001 for all dates; Table 2). Nutsedge punctures were significantly reduced in infrared mulch treatments compared to white mulch treatments and the standard treatment at all rating dates (Table 3). Nutsedge punctures were reduced in infrared mulch treatments by 88 and 89% at 14 DAT, by 72 and 70% at 28 DAT, and by 87 and 85% at 60 DAT compared to white mulch treatments and the standard treatment, respectively. As noted above, dimple treatments did not influence counts of yellow nutsedge punctures.

Dry Weight of Emerged Yellow Nutsedge Shoots. Dry weight of emerged shoots was influenced by mulch type only (P value <0.0001; Table 1). Emerged dry weight was reduced in infrared mulch treatments (13 g m^{-2}) compared to white mulch treatments and the standard treatment (165.3 and 118.7 g m^{-2}, respectively; Table 4).

Dry Weight of Non-Emerged Yellow Nutsedge Shoots. Dry weight of non-emerged shoots was influenced by mulch type only (P value <0.0001; Table 1). Non-emerged dry weight was less in infrared mulch treatments (0.4 g m^{-2}) compared to white mulch treatments and the standard treatment (10.8 and 7 g m^{-2}, respectively).

Discussion

The objective of this research was to evaluate combinations of IRT-green mulch and soil dimpling for reducing yellow nutsedge punctures. Ultimately, yellow nutsedge punctures were reduced by IRT-green mulch, but not by dimple treatments. Previous research had indicated a space left between IRT-green mulch and soil led to a significant reduction in yellow nutsedge punctures (Chase et al., 1998). However, these studies were performed in a controlled greenhouse setting using pots. During collection of non-emerged nutsedge shoot data, it was noted that dimples were significantly less defined (Figure 3). Contrary to the aforementioned greenhouse study, these studies were performed in the field and mulched beds were exposed to outdoor elements such as rain, animals (rats), and wind. These elements may have resulted in disturbance of dimple structure. Additionally, irrigation lines moving under the mulch when irrigation was initiated daily and repeated soil saturation likely led to further degradation of dimple structure. The reduction in nutsedge punctures and corresponding shoot dry weight by IRT-green mulch was likely due to high temperatures generated by the mulch. Temperature data collected underneath IRT-green mulch (sensor placed between soil surface and mulch) showed temperatures reached ≥50°C during 36 days of the 60-day trial period. Previous research (Chase et al., 1999; Holt and Orcutt, 1996; Webster 2003) has shown nutsedge can be damaged at these temperatures. Additionally, these results are in agreement with previous research showing IRT-green mulch can reduce weed populations underneath mulch compared to opaque mulches (Ngouajio and Ernest, 2004), including nutsedge species (Patterson, 1998).

Literature Cited

Adcock, C.W. 2007. Combinations of selected sulfonylurea herbicides with S-metolachlor for nutsedge control in tomatoes. Electronic Thesis and Dissertation. Auburn, AL: Auburn University.

Bell, C.E. 1997. Weed management in vegetable crops, p. 30–41. In: M.E. McGiffen (ed.). Weed management in horticultural crops. ASHS Press, Alexandria, VA.

Buker, R.S., III, W.M. Stall, S.M. Olson, and D.G. Schilling. 2003. Season-long interference of yellow nutsedge (*Cyperus esculentus*) with direct-seeded and transplanted watermelon (*Citrullus lanatus*). Weed Technol. 17:751–754.

Chase, C.A., T.R. Sinclair, D.G. Shilling, J.P. Gilreath and S.J. Locascio. 1998. Light effects on rhizome morphogenesis in nutsedges (*Cyperus* spp): implications for control by soil solarization. Weed Sci. 46:575–580.

Chase, C.A., T.R. Sinclair, and S.J. Locascio. 1999. Effects of soil temperature and tuber depth on *Cyperus* spp. control. Weed Sci. 47:467–472

Devkota, P.J., K. Norsworthy, and R. Rainy. 2013. Efficacy and economics of herbicide programs compared to methyl bromide for weed control in polyethylene-mulched tomatoes. Weed Technol. 27:580–589.

Dittmar, P.J., D.W. Monks, and K.M. Jennings. 2012. Effect of drip-applied herbicides on yellow nutsedge (*Cyperus esculentus*) in plasticulture. Weed Technol. 26:243–247.

Earl, H.J., J.A. Ferrell, W.K. Vencill, M.W. Van Iersel, and M.A. Czarnota. 2004. Effects of three herbicides on whole plant carbon fixation and water use by yellow nutsedge (*Cyperus esculentus*). Weed Sci. 52:213–216.

Ferrell, J.A., H.J. Earl, and W.K. Vencill. 2004. Duration of yellow nutsedge (*Cyperus esculentus*) competitiveness after herbicide treatment. Weed Sci. 51:24–27.

Gilreath, J.P. and B.M. Santos. 2004. Efficacy of methyl bromide alternatives on purple nutsedge control (*Cyperus rotundus*) in tomatoes and peppers. Weed Technol. 18:141–145.

Henson, I.E. and C.S. Little. 1969. Penetration of polyethylene film by the shoots of *Cyperus rotundus*. PANS Pest Artic. News Summ. 15:64–66.

Holt, J. S. and D. R. Orcutt. 1996. Temperature thresholds for bud sprouting in perennial weeds and seed germination in cotton. Weed Sci. 44:523−533.

Johnson, III, W.C and B.G. Mullinix Jr. 2008. Cultural control of yellow nutsedge (*Cyperus esculentus*) in transplanted cantaloupe (*Cucumis melo*) by varying application timing and type of thin-filmed mulches. Crop Protection 27:735–739.

Kemble, J.M., M.G. Patterson, and J.W. Everest. 2004. Nutsedge control in commercial vegetables. Alabama Cooperative Extension System. Alabama A&M and Auburn Universities. ANR-1156.

Lament, W.J, Jr. 1993. Plastic mulches for the production of vegetable crops. HortTechnology 3:35–39.

Morales-Payan, J.P. 1999. Interference of purple and yellow nutsedges (*Cyperus rotundus* L. and *Cyperus esculentus* L.) with tomato (*Lycopersicon esculentum* Mill.). PhD diss. Univ. Fla., Gainesville.

Motis, T.N., S.J. Locascio, J.P. Gilreath, and W. Stall. 2003. Season-long interference of yellow nutsedge (*Cyperus esculentus*) with polyethylene-mulched bell pepper (*Capsicum annuum*). Weed Technol. 17:543–549.

Ngouajio, M. and J. Ernest. 2004. Light transmission through colored polyethylene mulches affects weed populations. HortScience 39:1302–1304.

Oerke, E.C. 2006. Crop losses to pests. J. Agric. Sci. Cambridge Press. 144:31–43.

Patterson, D.T. 1998. Suppression of purple nutsedge (*Cyperus rotundus*) with polyethylene film mulch. Weed Technol. 12:275–280.

Piepho, H.P., E.R. Williams, and M. Fleck. 2006. A note on the analysis of designed experiments with complex treatment structure. HortScience. 41:446−452.

Schonbeck, M., 2013. Weed profile: yellow nutsedge (*C. esculentus*) and purple nutsedge (*C. rotundus*). EXtension. https://articles.extension.org/pages/66868/weed-profile:-yellow-nutsedge-cyperus-esculentus-and-purple-nutsedge-c-rotundus. Accessed: October 30, 2017.

Shrestha, A., and D.A. Grantz. 2005. Ozone impacts on competition between tomato and yellow nutsedge: above- and below-ground effects. Crop Sci. 45:1587–1595.

Stoller, E.W, and J.T. Woolley. 1983. The effects of light and temperature on yellow nutsedge (*Cyperus esculentus*) basal-bulb formation. Weed Sci. 31:148–152.

Webster, T.M. 2003. High temperatures and durations of exposure reduce nutsedge (*Cyperus* spp.) tuber viability. Weed Sci. 51:1010–1015.

Webster, T.M. 2005. Patch expansion of purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) with and without polyethylene mulch. Weed Sci. 53:839–845.

Tables:

Table 1. ANOVA[a] results for emerged and non-emerged yellow nutsedge shoots.

Experiment Source	Term in SAS model statement	df	F	P > F
	Dry Weight of Emerged Shoots			
Standard vs Treatments	std_vs_trt	1	0.73	0.3978
Mulch	std_vs_trt*mulch	1	33.9	<0.0001
Dimples	std_vs_trt*dimples	2	0.45	0.6425
	Dry Weight of Non-Emerged Live Shoots			
Standard vs Treatments	std_vs_trt	1	0.46	0.4968
Mulch	std_vs_trt*mulch	1	41.1	<0.0001
Dimples	std_vs_trt*dimples	2	0.7	0.4973

[a]The interaction between mulch and dimples was not significant ($p \geq 0.05$) for dry weight of emerged and non-emerged yellow nutsedge shoots; therefore the interaction term std_vs_trt*mulch*dimples was removed from the full model and results are shown for terms in the reduced model.

Table 2. ANOVA[a] results for yellow nutsedge puncture counts.

Experiment Source	Term in SAS model statement	df	F	P > F
	14 DAT Puncture Count			
Standard vs Treatments	std_vs_trt	1	30.1	<0.0001
Mulch	std_vs_trt*mulch	1	102.52	<0.0001
Dimples	std_vs_trt*dimples	2	0.11	0.896
	28 DAT Puncture Count			
Standard vs Treatments	std_vs_trt	1	2.83	0.0989
Mulch	std_vs_trt*mulch	1	22.46	<0.0001
Dimples	std_vs_trt*dimples	2	0.04	0.9642
	60 DAT Puncture Count			
Standard vs Treatments	std_vs_trt	1	6.97	0.0112
Mulch	std_vs_trt*mulch	1	62.88	<0.0001
Dimples	std_vs_trt*dimples	2	0.2	0.8175

[a]The interaction between mulch and dimples was not significant ($p \geq 0.05$) for yellow nutsedge puncture counts (at all dates); therefore the interaction term std_vs_trt*mulch*dimples was removed from the full model and results are shown for terms in the reduced model.

Table 3. Yellow nutsedge puncture count means (no. m^{-2}) for mulch type and dimples.

Term	Level	Punctures
	14 DAT Puncture Count	
Mulch Type (std_vs_trt*mulch)	Standard[b]	18.9 a[a]
	White	16.4 a
	Infrared green	2.0 b
Dimples (std_vs_trt*dimples)	Standard	7.0 ns[c]
	None	4.3
	Small	6.6
	Large	5.8
	28 DAT Puncture Count	
Mulch Type (std_vs_trt*mulch)	Standard	17.4 a
	White	18.4 a
	Infrared green	5.2 b
Dimples (std_vs_trt*dimples)	Standard	17.4 ns
	None	10.2
	Small	9.3
	Large	9.8
	60 DAT Puncture Count	
Mulch Type (std_vs_trt*mulch)	Standard	65.1 a
	White	75.3 a
	Infrared green	9.5 b
Dimples (std_vs_trt*dimples)	Standard	65.1 ns
	None	25.1
	Small	30.1
	Large	25.4

[a]Means followed by the same letter do not differ according to the Shaffer-Simulated Method ($\alpha = 0.05$).
[b]White mulch with *S*-metolachlor (1400 g ai ha^{-1}) applied to non-dimpled beds prior to mulch application.
[c]Abbreviations: ns = no significant difference.

Table 4. Dry weight means (g m^{-2}) of emerged yellow nutsedge shoots for mulch type and dimples.

Term	Level	Dry Wt (g)
Mulch Type (std_vs_trt*mulch)	Standard[a]	118.7 a[b]
	White	165.3 a
	Infrared green	13.0 b
Dimples (std_vs_trt*dimples)	Standard	118.7 ns[c]
	None	98.4
	Small	97.4
	Large	71.7

[a]White mulch with *S*-metolachlor (1400 g ai ha^{-1}) applied to non-dimpled beds prior to mulch application.

[b]Means followed by the same letter do not differ according to the Shaffer-Simulated Method ($\alpha = 0.05$).

[c]Abbreviations: ns = no significant difference.

Table 5. Dry weight means (g m^{-2}) of non-emerged yellow nutsedge shoots for mulch type and dimples.

Term	Level	Dry Wt (g)
Mulch Type (std_vs_trt*mulch)	Standard[a]	7.0 a[b]
	White	10.8 a
	Infrared green	0.4 b
Dimples (std_vs_trt*dimples)	Standard	7.0 ns[c]
	None	4.3
	Small	6.6
	Large	5.8

[a]White mulch with *S*-metolachlor (1400 g ai ha^{-1}) applied to non-dimpled beds prior to mulch application.

[b]Means followed by the same letter do not differ according to the Shaffer-Simulated Method ($\alpha = 0.05$).

[c]Abbreviations: ns = no significant difference.

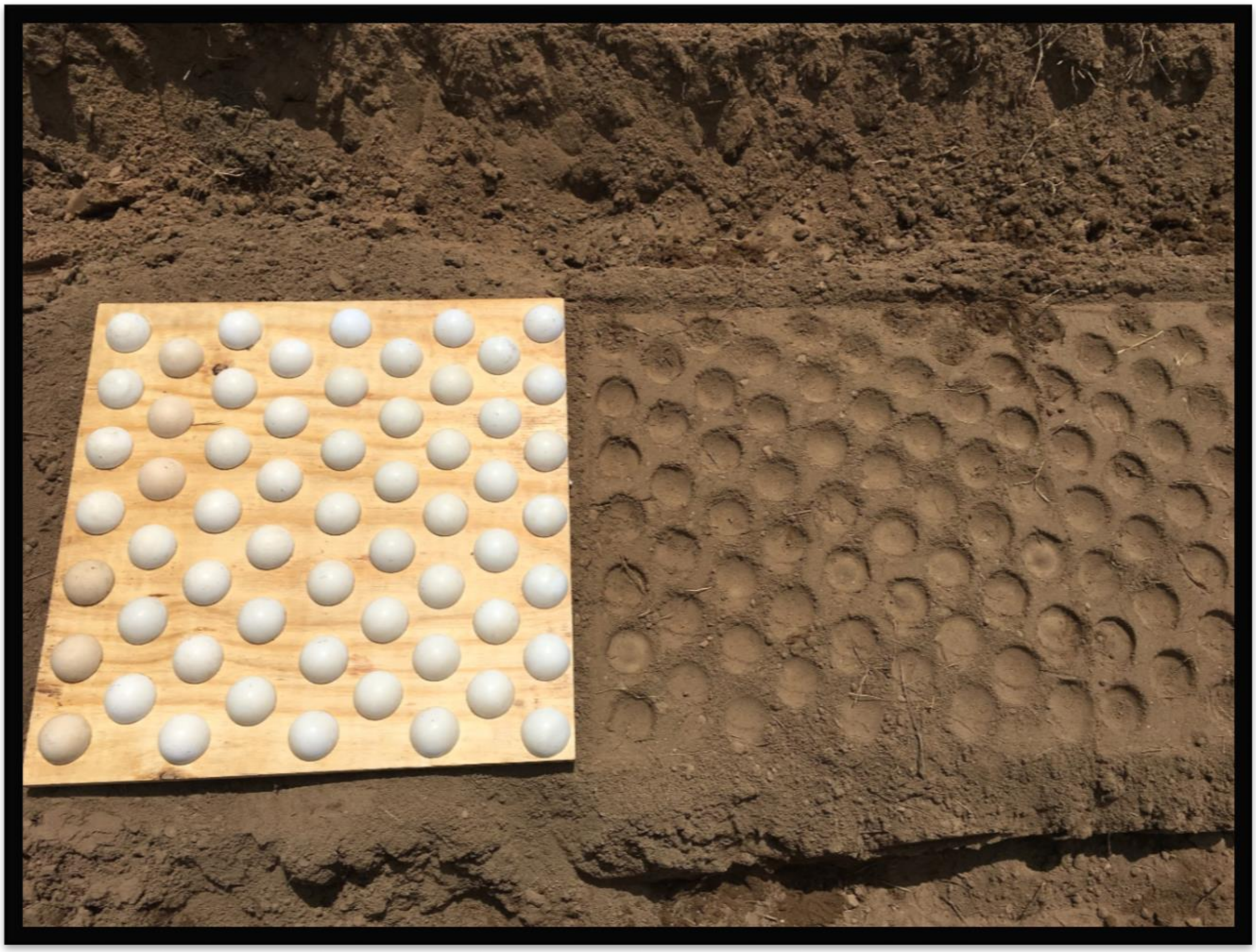

Figure 1. Small dimple treatments were applied by pressing a 30.4-cm x 30.4-cm board with 3.8-cm-wide x 2.5-cm-deep PVC end caps spaced 7.6 cm apart to pre-formed beds prior to application of polyethylene mulch.

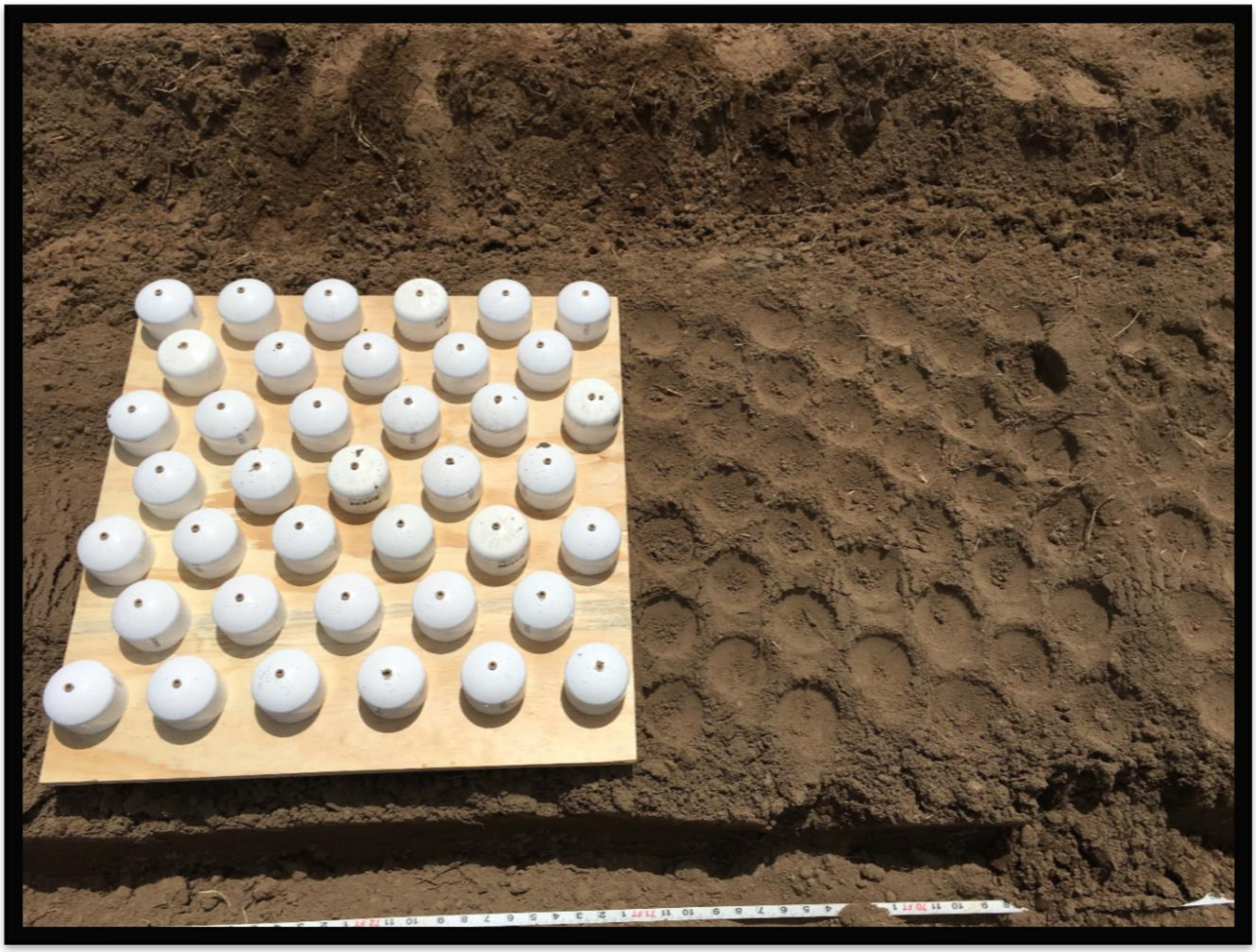

Figure 2. Large dimple treatments were applied by pressing a 30.4-cm x 30.4-cm board with 6.35-cm-wide x 5.1-cm-deep PVC end caps spaced 10.2 cm apart to pre-formed beds prior to application of polyethylene mulch.

Figure 3. External elements along with underground drip tape irrigation may have disturbed dimple structure.

Chapter III

Combinations of Soil Dimpling and Mulch Type to Reduce Purple Nutsedge (*Cyperus rotundus* L.) Punctures in Polyethylene Mulched Beds

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Abstract

Commercial vegetable growers utilize polyethylene (PE) mulch to maximize crop yield. PE mulch can reduce the incidences of diseases, insects, and most weed species; however, nutsedges (*Cyperus* spp.) often penetrate the mulch resulting in premature degradation. Field studies were conducted in the summers of 2017 and 2018 to evaluate combinations of soil dimpling and mulch type with the goal of reducing purple nutsedge punctures in PE-mulched beds. Treatments were assessed based on their ability to decrease purple nutsedge punctures of PE mulch. The experiment was an augmented factorial treatment arrangement of two mulch types (white or infrared-transmitting PE mulch (IRT-green) and three dimples sizes (none, small, or large). This was augmented by a commercial standard (white mulch with a preemergence herbicide applied under mulch), giving a total of 7 treatments. The interaction between mulch and dimples was not significant for all response variables (nutsedge punctures and dry weight of emerged and non-emerged nutsedge shoots), therefore main effects were analyzed. The main effect of dimples was significant for punctures counts collected at 14 days after treatment (DAT) only whereas the main effect of mulch was significant for all response variables. Purple nutsedge punctures at 14,

28, and 60 days after treatment DAT, and dry weight of emerged and non-merged purple nutsedge shoots collected 60 DAT were reduced by IRT-green PE mulch treatments compared to white mulch treatments and the standard treatment. The aforementioned results suggest that IRT-green PE mulch may suppress purple nutsedge populations in PE mulched beds and subsequently reduce the negative impact on yield and quality of vegetable crops produced on PE mulch. Additional research is needed to determine the full implications of using IRT-mulches to grow fruits and vegetables in the southeastern United States.

Introduction

Weeds are a common issue for growers in both industrialized and developing countries despite the use of technology and human labor (Buhler, 2003; Oerke, 2006). The competitive nature of weeds decreases the potential for high vegetable crop yields and profits. Vegetable crops must compete against weeds for necessary resources such as light, water, and nutrients to have marketable quality and yield (Earl et al., 2004; Gilreath and Santos, 2004). Polyethylene (PE) mulch allows growers to provide an advantageous environment for crops in which crops receive more of these resources more efficiently than do most weeds, while providing better protection against disease and insects (Lament, 1993). Ideally, PE can be used for multiple cropping seasons (multicropping), remunerating the cost of the mulch over several crops (Adcock, 2007). Yet, some weed species such as nutsedge (*Cyperus* spp.) are difficult to control since they can penetrate through PE mulch and compete with vegetable crops while also making cleanup more difficult (Adcock, 2007; Devkota et al., 2013). Two species of concern are purple nutsedge (*C. rotundus*) and yellow nutsedge (*C. esculentus*), which are two of the world's most problematic weeds (Hauser, 1963; Gilreath et al., 2005; Gilreath and Santos 2005; Miller and Dittmar, 2014). Rapid and abundant reproduction, widespread distribution, and difficulty to control permits nutsedge to successfully compete against a wide range of crops (Bewick et al., 1995; Holm et al., 1991; Morales-Payan et al., 2003). Purple nutsedge is known to be the more aggressive of the two in hotter climates (Wang et al., 2008). Although purple nutsedge has great heat tolerance in field conditions, tubers exposed to direct sunlight can be killed by either desiccation to 15 to 24% moisture content or by 12 hours of exposure to 50°C (Holm et al., 1991; Webster, 2003). When season-long purple nutsedge interfered with eggplant (*Solanum melongena* L.), bell pepper (*Capsicum annum* L.), and beans (*Phaseolus vulgaris* L.), yields were reduced 22%, 32%, and 81%, respectively (Morales-Payan and Stall, 1997; Morales-Payan et al., 1997a; William, 1973). Tomato yields in Brazil (William and Warren, 1975) and the Dominican Republic (Morales-Payan et al., 1997b) were reduced 53% and 40%, respectively, by season-long purple nutsedge. Appropriate management of purple nutsedge is threatened by restrictions on the use, cost, and potential carryover of herbicides (Gilreath and Santos, 2004; Kemble et al., 2004; Shrestha and Grantz, 2005; Szmedra, 1997), appearance of herbicide-resistant weed biotypes (Heap, 1997; Shrestha and Grantz, 2005), and indirectly by elements of global change (Fuhrer, 2003; Shrestha and Grantz, 2005). Therefore, growers need a successful alternative weed management technology to control purple nutsedge. The utilization of different types of PE mulches to alter growth and development of competitive weeds, such as purple nutsedge, underneath mulch is an option that has received attention and looks promising from the limited published research.

Chase et al. (1998) used greenhouse and field experiments to investigate if the variance in nutsedge penetration of translucent and opaque PE mulch was caused by light effects on nutsedge rhizome morphogenesis. Six shade treatments (0%, 67%, 75%, 96%, 98%, and 100%) were used in a greenhouse study to evaluate the impact of irradiance levels on nutsedge penetration of PE mulch. Results showed penetration increased with increasing levels of shade. In the 0% shade treatment, only 8% of purple nutsedge rhizomes penetrated the translucent mulch. Conversely, in the 100% shade treatment, 100% of emerged nutsedge rhizomes penetrated the mulch. A follow-up study with the same shade treatments was conducted with a 5- to 10-mm space left between the soil surface and mulch. The space between the soil and mulch resulted in a decrease in purple nutsedge penetration at all light levels. It was hypothesized that the added space provided enough time for purple nutsedge shoots to lengthen and expand prior to contacting the mulch, therefore reducing penetration. Shoots trapped underneath mulch are subject to scorching due to high temperatures. Lastly, field studies indicated purple nutsedge leaf tip penetration to be more prevalent where the mulch had close contact with the soil. Rhizomes that sprouted underneath black opaque mulch punctured the mulch, then underwent leaf expansion above the mulch. Chase et al. (1998) concluded that nutsedge is less likely to penetrate translucent mulches than opaque mulches due to a transformation in the pattern of plant development when the rhizomes sense light while emerging from the soil (but prior to mulch penetration).Yet, when light is lacking beneath opaque mulches, photomorphogenesis is delayed and rhizome growth continues through the mulch. The results of this research agrees with Stoller and Wooley (1983) who reported nutsedge rhizome growth stopped while basal bulb formation and subsequent leaf elongation was initiated when a light stimulus was detected. Chase et al. (1998) states cessation of nutsedge rhizome elongation and leaf expansion prior to mulch penetration results in nutsedge shoots unfolding, being confined beneath mulch and subjected to scorching with translucent mulches.

Effects of translucent PE mulches on purple nutsedge emergence, growth, and vegetative reproduction in field, greenhouse, and growth chamber experiments were assessed by Patterson

(1998) by first testing the spectral transmittance properties of three translucent PE mulches along with one opaque PE mulch. Translucent mulches, IRT-76 (green) and AL-OR, were wavelength selective whereas Silver Smooth was a reflective, nonselective translucent mulch. Opaque PE mulch used was a conventional, white-on-black (white/black) PE mulch. According to Ross (1975), the spectral quality of daylight is rather constant within the photosynthetically active waveband (400-700 nm), and most of the time the radiation level is clearly above the linear part of the photosynthesis response curve. Plants vary in the sensitivity of the photosynthetic apparatus to radiation of different wavelengths (Rabinowitch, 1951). Salisbury and Ross (1969) stated the action spectrum for photosynthesis in higher plants peaks at 440 and 560 nm and any wavelengths outside the 400 and 720 nm range are insignificant for photosynthesis. Patterson (1998) showed that all three translucent mulches blocked most of the PAR. The AL-OR mulch transmitted 1% or less of the radiation from 300 to 500 nm, then gradually increased to 9% at 900 nm, while the IRT-76 increased from 5% at 300 nm to an initial peak of 10% at 525 nm, then decreased to 6% at 625 nm. The greatest increase was to 29% at 900 nm. Silver Smooth transmitted 1.1 to 1.3% uniformly over the 300 to 900 nm spectrum. A follow-up greenhouse experiment evaluated these same mulches for controlling purple nutsedge emergence. Mulches were applied to tops of individual pots filled with soil in which three nutsedge tubers had been planted. The white/black mulch was placed with the white surface facing up. Patterson (1998) reported translucent mulches significantly reduced purple nutsedge shoots 85 to 99% and tuber number 86 to 97% compared to the white/black mulch. Under IRT-76, only one shoot from one tuber emerged after 68 d in the greenhouse. The role of light in the suppression of purple nutsedge by translucent mulch was tested further in growth chamber experiments. A non-illuminated growth chamber experiment showed purple nutsedge could readily penetrate all mulch types. However, when light was introduced, emerging purple nutsedge shoots did not penetrate translucent mulches. Field experiments further confirmed these trends with similar results (Patterson, 1998). After 115 d, IRT-76 and Silver Smooth mulches significantly reduced shoot emergence 88 and 76%, respectively, compared to white/black mulch. Live tuber numbers were also reduced 76 and 65% by IRT-76 and Silver Smooth, respectively, compared to white/black mulch. Patterson (1998) concluded that suppression of purple nutsedge shoot emergence and growth by translucent mulches could not be credited solely to solarization effects. The more probable cause of purple nutsedge suppression under translucent mulch is a photomorphogenic effect on the emerging shoot (Patterson, 1998; Majek and Neary, 1991).

Previous research suggests purple nutsedge will stop rhizome growth and start leaf expansion when a light stimulus is detected. Sufficient PAR light transmits through IRT mulches to initiate this process. Penetration of IRT mulch is less likely when purple nutsedge leaves expand prior to contacting the mulch. Temperatures are elevated enough under IRT mulch to scorch the purple nutsedge. However, IRT mulch is more likely to be penetrated when in close contact with the soil surface. Preliminary trials indicated that dimpling the soil surface prior to mulch application allows room for purple nutsedge to transition from rhizome elongation to leaf development underneath IRT mulched beds. Furthermore, dimpling the soil permits the mulch to stay in place by contacting the soil surface and allowing room for nutsedge leaf development. Thus, the objective of our research was to determine reduction efficacy on purple nutsedge punctures with combinations of IRT mulches and soil dimples compared with current commercial standard mulch (white opaque mulch) with a PRE-herbicide application underneath the mulch.

Materials and Methods

This research was conducted in the summers of 2017 and 2018 at the Plant Breeding Unit (PBU), Tallassee, AL (N 32° 28’ 57.94”, W 85° 53’ 17.56”). The field used had a history of heavy purple nutsedge infestation. In both years, the soil was disked and formed into four raised beds approximately 33.53 m long, 121.92 cm wide, 13 cm high, and covered by either white polyethylene mulch or IRT-green mulch (both 1.25 mil; Berry Plastics Corp., Evansville, IN). Each of the four rows contained eight, 3.05-m long plots with a 0.91-m buffer zone between plots. Rows were spaced 1.83 m apart. In both years, crops were not planted in order to provide a better evaluation of dimple and PE mulch treatments on nutsedge punctures. Before the mulches were applied, a single drip tape (Toro Ag., Bloomington, MN) was centered in each bed and buried approximately 5 cm. Drip tape emitters were spaced 30.5 cm apart delivering water at 1.02 L hr^{-1}.

The experimental design was a randomized complete block with four replications. The treatment design was an augmented factorial. The factorial portion of the treatment design consisted of 2 levels of mulch and 3 levels of dimples for a total of 6 combinations. This was augmented by a commercial standard (white mulch with a preemergence herbicide applied under mulch), giving a total of 7 treatments. The two levels of mulch consisted of 1.25-mil white-on black-embossed mulch (white side facing up) and 1.25-mil IRT-green embossed mulch. The three levels of dimple treatments were as follows: a) no dimples, b) small dimples (11.3 cm^{-2}): 3.8 cm wide x 2.5 cm deep dimples spaced 7.6 cm apart and c) large dimples (31.5 cm^{-2}): 6.35 cm wide by 5.1 cm deep dimples spaced 10.2 cm apart. In order to dimple soil, 3.8 cm (small) and 6.35 cm (large) PCV pipe end caps were mounted to 30.4 cm x 30.4 cm boards. Boards were pressed into pre-formed beds, thereby dimpling soil just prior to mulch application (Figures 1 and 2). The commercial standard treatment consisted of *S*-metolachlor (1400 g ai ha^{-1}) applied to pre-formed beds prior to white mulch application. *S*-metolachlor was applied with a battery-powered backpack sprayer (SHURflo, Costa Mesa, CA) equipped with one 11004 flat-fan nozzle (Spraying Systems Co., Wheaton, IL) calibrated to deliver 224 L ha^{-1}. All treatments received drip irrigation on a 48-h schedule. Each irrigation cycle delivered 2,420 L ha^{-1}.

Treatments were applied on 8 June (2017) and 3 May (2018) at PBU. In both years, purple nutsedge punctures were counted at 14, 28, and 60 days after treatment (DAT) from a 1.0-m^2 section of each plot. After 60 DAT, purple nutsedge shoots that punctured PE mulch were clipped above and below the mulch, dried, and then weighed from the same 1.0 m^2 section of each plot.

To analyze this data and produce estimable least squares means, the variable called std_vs_trt was created. This variable had a categorical value of "std" when the treatment was the standard (that is, herbicide with white mulch), and a value of "trt" when the treatment was not the standard (that is, it is a combination of mulch and dimples). Thus, the mulch and dimples factors were nested within the "std" value of std_vs_trt. This method of analyzing an augmented factorial treatment design was based on example on Example 1 by Piepho et al. (2006). Analysis was conducted using linear mixed models (for continuous response data) and generalized linear models (for count data using the negative binomial distribution and log link function) with the GLIMMIX procedure of SAS (version 9.4; SAS Institute, Cary, NC). Starting with a full model, the interaction term std_vs_trt*mulch*dimples was removed from the model when not significant ($p \geq 0.05$). In the latter case, main effects were examined. All terms containing std_trt were retained in the final models. *P*-values for simultaneous mean comparisons were adjusted using the Shaffer-Simulated method ($\alpha = 0.05$).

Results

Interactions of mulch x dimple treatments (std_vs_trt*mulch*dimples) were not significant for any of the response variables; therefore, main effects were analyzed (Tables 1 and 2). Main effects of mulch and dimples were significant for punctures counts at 14 DAT only and the main effect of mulch was significant for all other response variables, therefore, means were compared (Tables 3, 4, and 5).

Purple Nutsedge Punctures. Counts of purple nutsedge punctures were influenced by mulch type and dimples (Table 2). Nutsedge punctures were significantly fewer in infrared mulch treatments compared to white mulch treatments and the standard treatment at all rating dates (Table 3). Nutsedge punctures were reduced in infrared mulch treatments by 68 and 67% at 14 DAT, by 71 and 56% at 28 DAT, and by 75 and 63% at 60 DAT compared to white mulch treatments and the standard treatment, respectively. Significant differences among dimple treatments were only detected at 14 DAT. Purple nutsedge punctures were significantly reduced in plots with small and large dimples compared to treatments without dimples (none) and the standard treatment. Plots with small dimples had 39 and 47% less punctures compared to plots without dimples and the standard treatment, respectively. Likewise, plots with large dimples had 51 and 57% fewer punctures compared to plots without dimples and the standard treatment, respectively.

Dry Weight of Emerged Purple Nutsedge Shoots. Dry weight of emerged shoots was influenced by mulch type only (Table 1). Emerged dry weight was reduced in infrared mulch treatments (20 g m^{-2}) compared to white mulch treatments and the standard treatment (72.4 and 44.6 g m^{-2}, respectively; Table 4). Additionally, emerged dry weight was reduced in the standard treatment compared to white mulch treatments.

Dry Weight of Non-Emerged Purple Nutsedge Shoots. Dry weight of non-emerged shoots was influenced by mulch type only (Table 1). Non-emerged dry weight was reduced in infrared mulch treatments (4.1 g m^{-2}) compared to white mulch treatments and the standard treatment (14.0 and 15.5 g m^{-2}, respectively).

Discussion

The objective of this research was to evaluate combinations of IRT-green mulch and soil dimpling for reducing purple nutsedge punctures. Results from this experiment revealed purple nutsedge punctures were not reduced by dimple treatments, with the exception of data collected at 14 DAT treatment. Instead, IRT-green mulch caused the significant reduction in nutsedge punctures. Chase et al. (1998) suggested a decrease in purple nutsedge punctures may be attributed to a 5- to 10-mm space left between an IRT-green mulch and soil. Yet, Chase et al. (1998) carried out their studies in a controlled greenhouse with pots. When recording non-emerged nutsedge shoot data, it was noted that dimples were considerably less defined (Figure 3). In contrast to the greenhouse study mentioned above, our studies were carried out in the field and mulch beds were exposed to external elements such as animals, wind, and rain. Such elements may have led to a disturbance of the dimple structure. Irrigation lines moving under the mulch during daily irrigation, along with repeated soil saturation, probably led to further deterioration of the dimple structure. High temperatures generated by the IRT-green mulch likely decreased nutsedge punctures and analogous shoot dry weight. A temperature sensor placed between the soil surface and IRT-green mulch revealed temperatures reached ≥50°C on 36 days of the 60-day trial period. Nutsedge can be severely damaged when exposed to these temperature levels (Chase et al., 1999; Holt and Orcutt, 1996; Webster, 2003). Furthermore, our results are consistent with previous studies showing that the IRT green mulch can reduce weed population, including nutsedge species (Patterson, 1998) under the mulch compared to opaque mulch (Ngouajio and Ernest, 2004).

Literature Cited

Adcock, C.W. 2007. Combinations of selected sulfonylurea herbicides with S-metolachlor for nutsedge control in tomatoes. Electronic Thesis and Dissertation. Auburn, AL, Auburn University.

Bewick, T.A., K. Smith, W.M. Stall, and S.M. Olsen. 1995. Tomato (*Lycopersicon esculentum*) cultivar and weed sensitivity to DPX-E9636. Weed Technol. 9:499−503.

Buhler, D.D. 2003. Weed biology, cropping systems and weed management. J. Crop Prod. 8:245–270.

Chase, C.A., T.R. Sinclair, D.G. Shilling, J.P. Gilreath and S.J. Locascio. 1998. Light effects on rhizome morphogenesis in nutsedges (*Cyperus* spp): Implications for control by soil solarization. Weed Sci. 46:575–580.

Devkota, P.J., K. Norsworthy, and R. Rainy. 2013. Efficacy and economics of herbicide programs compared to methyl bromide for weed control in polyethylene-mulched tomatoes. Weed Technol. 27:580–589.

Earl, H.J., J.A. Ferrell, W.K. Vencill, M.W. Van Iersel, and M.A. Czarnota. 2004. Effects of three herbicides on whole plant carbon fixation and water use by yellow nutsedge (*Cyperus esculentus*). Weed Sci. 52:213–216.

Fuhrer, J. 2003. Agroecosystem response to combinations of elevated CO_2, ozone and global climate change. Agri. Ecosyst. Environ. 97:1−20.

Gilreath, J.P., T.N. Motis, and B.M. Santos. 2005. *Cyperus* spp. Control with reduced methyl bromide plus chloropicrin doses under virtually impermeable films in pepper. Crop Prot. 24:285−287.

Gilreath, J.P. and B.M. Santos. 2005. Efficacy of 1,3−dichloropropene plus chloropicrin in combination with herbicides on purple nutsedge (*Cyperus rotundus*) control in tomato. Weed Technol. 19:137–140.

Gilreath, J.P. and B.M. Santos. 2004. Efficacy of methyl bromide alternatives on purple nutsedge control (*Cyperus rotundus*) in tomatoes and peppers. Weed Technol. 18:141–145.

Hauser, E.W. 1963. Development of purple nutsedge under field conditions. Weeds 10:315–321.

Heap, I.M. 1997. The occurrence of herbicide-resistant weeds worldwide. Pestic. Sci. 51:235−243.

Holm, L.G., J.V. Pancho, J.P. Herberger, and D.L. Plucknett. 1991. A geographical atlas of world weeds. Krieger Publ., Malabar, FL.

Holt, J. S. and D. R. Orcutt. 1996. Temperature thresholds for bud sprout- ing in perennial weeds and seed germination in cotton. Weed Sci. 44: 523−533.

Kemble, J.M., M.G. Patterson, and J.W. Everest. 2004. Nutsedge control in commercial vegetables. Alabama Cooperative Extension System. Alabama A&M and Auburn Universities. ANR-1156.

Lament, W.J., Jr., 1993. Plastic mulches for the production of vegetable crops. HortTechnology 3:35–39.

Majek, B.A. and P.E. Neary. 1991. Selective wavelength transmitting mulch for yellow nutsedge control. Brighton Crop Prot. Conf. Weeds 1991:263−268.

Miller, M.R. and P.J. Dittmar. 2014. Effect of PRE and POST-directed herbicides for season-long nutsedge (*Cyperus* spp.) control in bell pepper. Weed Technol. 28:518–526.

Morales-Payan, J.P. and W.M. Stall. 1997. Effect of purple nutsedge (*Cyperus rotundus*) population densities on the yield of eggplant (*Solanum melongena*). HortScience 32:431.

Morales−Payan, J.P., W.M. Stall, D.G. Shilling, R. Charudattan, J.A. Dusky, and T.A. Bewick. 2003. Above- and belowground interference of purple and yellow nutsedge (*Cyperus* spp.) with tomato. Weed Sci. 51:181−185.

Morales-Payan, J.P., B.M. Santos, W.M. Stall, and T.A. Bewick. 1997a. Effect of purple nutsedge (*Cyperus rotundus*) on tomato (*Lycopersicon esculentum*) and bell pepper (*Capsicum annum*) vegetative growth and fruit yield. Weed Technol. 11:672–676.

Morales−Payan, J.P., W.M. Stall, D.G. Shilling, J.A. Dusky, and T.A. Bewick. 1997b. Influence of nitrogen on the interference of purple and yellow nutsedge (*Cyperus rotundus* and *Cyperus esculentus*) with tomato (*Lycopersicon esculentum*). HortScience 32:431.

Ngouajio, M. and J. Ernest. 2004. Light transmission through colored polyethylene mulches affects weed populations. HortScience 39:1302–1304.

Oerke, E.C. 2006. Crop losses to pests. J. Agric. Sci. Cambridge Press. 144:31–43.

Patterson, D.T. 1998. Suppression of purple nutsedge (*Cyperus rotundus*) with polyethylene film mulch. Weed Technol. 12:275–280.

Piepho, H.P., E.R. Williams, and M. Fleck. 2006. A note on the analysis of designed experiments with complex treatment structure. HortScience 41:446−452.

Rabinowitch, E. E. 1951. Photosynthesis and related processes: V. 2 Part 1. Spectroscopy and fluorescence of photosynthetic pigments: Kinetics of photosynthesis. Interscience, New York, pp 837–844.

Ross, J. 1975. Radiative transfer in plant communities. In: Monteith, J. (ed) Vegetation and the atmosphere V. 1. Academic Press, New York, pp 13–55.

Salisbury, F.B. and C. Ross. 1969. Plant Physiology. Belmont, CA: Wadsworth Publishing Company. 764 p.

Shrestha, A., and D.A. Grantz. 2005. Ozone impacts on competition between tomato and yellow nutsedge: above- and below-ground effects. Crop Sci. 45:1587–1595.

Stoller, E.W, and J.T. Woolley. 1983. The effects of light and temperature on yellow nutsedge (*Cyperus esculentus*) basal-bulb formation. Weed Sci. 31:148–152.

Szmedra, P. 1997. Banning 2,4−D and the phenoxy herbicides: potential economic impact. Weed Sci. 45:592−598.

Wang, G., M.E. McGriffen, Jr., and E.J. Ogbuchiekwe. 2008. Crop rotation effects on *Cyperus rotundus* and *C. esculentus* population dynamics in southern California vegetable production. Weed Res. 48:420−428.

Webster, T.M. 2003. High temperatures and durations of exposure reduce nutsedge (*Cyperus* spp.) tuber viability. Weed Sci. 51:1010–1015.

William, R.D. 1973. Competition between purple nutsedge (*Cyperus rotundus* L.) and beans (*Phaseolus vulgaris* L.). Rev. Ceres 20:424–432.

William, R.D. and G.F. Warren. 1975. Competition between purple nutsedge and vegetables. Weed Sci. 23:317–323.

Tables:

Table 1. ANOVA[a] results for emerged and non-emerged purple nutsedge shoots.				
Experiment Source	Term in SAS model statement	df	F	P > F
	Dry Weight of Emerged Shoots			
Standard vs Treatments	std_vs_trt	1	0.04	0.8346
Mulch	std_vs_trt*mulch	1	41.8	<0.0001
Dimples	std_vs_trt*dimples	2	2.65	0.0811
	Dry Weight of Non-Emerged Live Shoots			
Standard vs Treatments	std_vs_trt	1	2.6	0.113
Mulch	std_vs_trt*mulch	1	34.1	<0.0001
Dimples	std_vs_trt*dimples	2	0.77	0.4679

[a]The interaction between mulch and dimples was not significant ($p \geq 0.05$) for dry weight of emerged and non-emerged purple nutsedge shoots; therefore the interaction term std_vs_trt*mulch*dimples was removed from the full model and results are shown for terms in the reduced model.

Table 2. ANOVA[a] results for purple nutsedge puncture counts.				
Experiment Source	Term in SAS model statement	df	F	P > F
	14 DAT Puncture Count			
Standard vs Treatments	std_vs_trt	1	7.16	0.0102
Mulch	std_vs_trt*mulch	1	46.1	<0.0001
Dimples	std_vs_trt*dimples	2	6.41	0.0035
	28 DAT Puncture Count			
Standard vs Treatments	std_vs_trt	1	0.5	0.4841
Mulch	std_vs_trt*mulch	1	30.4	<0.0001
Dimples	std_vs_trt*dimples	2	3.13	0.0531
	60 DAT Puncture Count			
Standard vs Treatments	std_vs_trt	1	2.02	0.1614
Mulch	std_vs_trt*mulch	1	69.6	<0.0001
Dimples	std_vs_trt*dimples	2	2.4	0.1019

[a]The interaction between mulch and dimples was not significant ($p \geq 0.05$) for purple nutsedge puncture counts (at all dates); therefore the interaction term std_vs_trt*mulch*dimples was removed from the full model and results are shown for terms in the reduced model.

Table 3. Purple nutsedge puncture count means (no. m^{-2}) for mulch type and dimples.

Term	Level	Punctures
	14 DAT Puncture Count	
Mulch Type (std_vs_trt*mulch)	Standard[b]	10.6 a[a]
	White	10.9 a
	Infrared green	3.5 b
Dimples (std_vs_trt*dimples)	Standard	10.6 a
	None	9.2 a
	Small	5.6 b
	Large	4.5 b
	28 DAT Puncture Count	
Mulch Type (std_vs_trt*mulch)	Standard	9.5 a
	White	14.5 a
	Infrared green	4.2 b
Dimples (std_vs_trt*dimples)	Standard	9.5 ns[c]
	None	11.4
	Small	6.6
	Large	6.2
	60 DAT Puncture Count	
Mulch Type (std_vs_trt*mulch)	Standard	29.6 a
	White	43.9 a
	Infrared green	10.8 b
Dimples (std_vs_trt*dimples)	Standard	29.6 ns
	None	27.8
	Small	17.9
	Large	20.8

[a]Means followed by the same letter do not differ according to the Shaffer-Simulated Method ($\alpha = 0.05$).

[b]White mulch with *S*-metolachlor (1400 g ai ha^{-1}) applied to non-dimpled beds prior to mulch application.

[c]Abbreviations: ns = no significant difference.

Table 4. Dry weight means (g m^{-2}) of emerged purple nutsedge shoots for mulch type and dimples.

Term	Level	Dry Weight (g)
Mulch Type (std_vs_trt*mulch)	Standard[a]	44.6 b[b]
	White	72.4 a
	Infrared green	20.0 c
Dimples (std_vs_trt*dimples)	Standard	44.6 ns[c]
	None	59.7
	Small	40.2
	Large	38.8

[a]White mulch with *S*-metolachlor (1400 g ai ha^{-1}) applied to non-dimpled beds prior to mulch application.

[b]Means followed by the same letter do not differ according to the Shaffer-Simulated Method (α = 0.05).

[c]Abbreviations: ns = no significant difference.

Table 5. Dry weight means (g m^{-2}) of non-emerged purple nutsedge shoots for mulch type and dimples.

Term	Level	Dry Weight (g)
Mulch Type (std_vs_trt*mulch)	Standard[a]	14.0 a[b]
	White	15.5 a
	Infrared green	4.1 b
Dimples (std_vs_trt*dimples)	Standard	14.0 ns[c]
	None	11.5
	Small	8.7
	Large	9.3

[a]White mulch with *S*-metolachlor (1400 g ai ha^{-1}) applied to non-dimpled beds prior to mulch application.

[b]Means followed by the same letter do not differ according to the Shaffer-Simulated Method (α = 0.05).

[c]Abbreviations: ns = no significant difference.

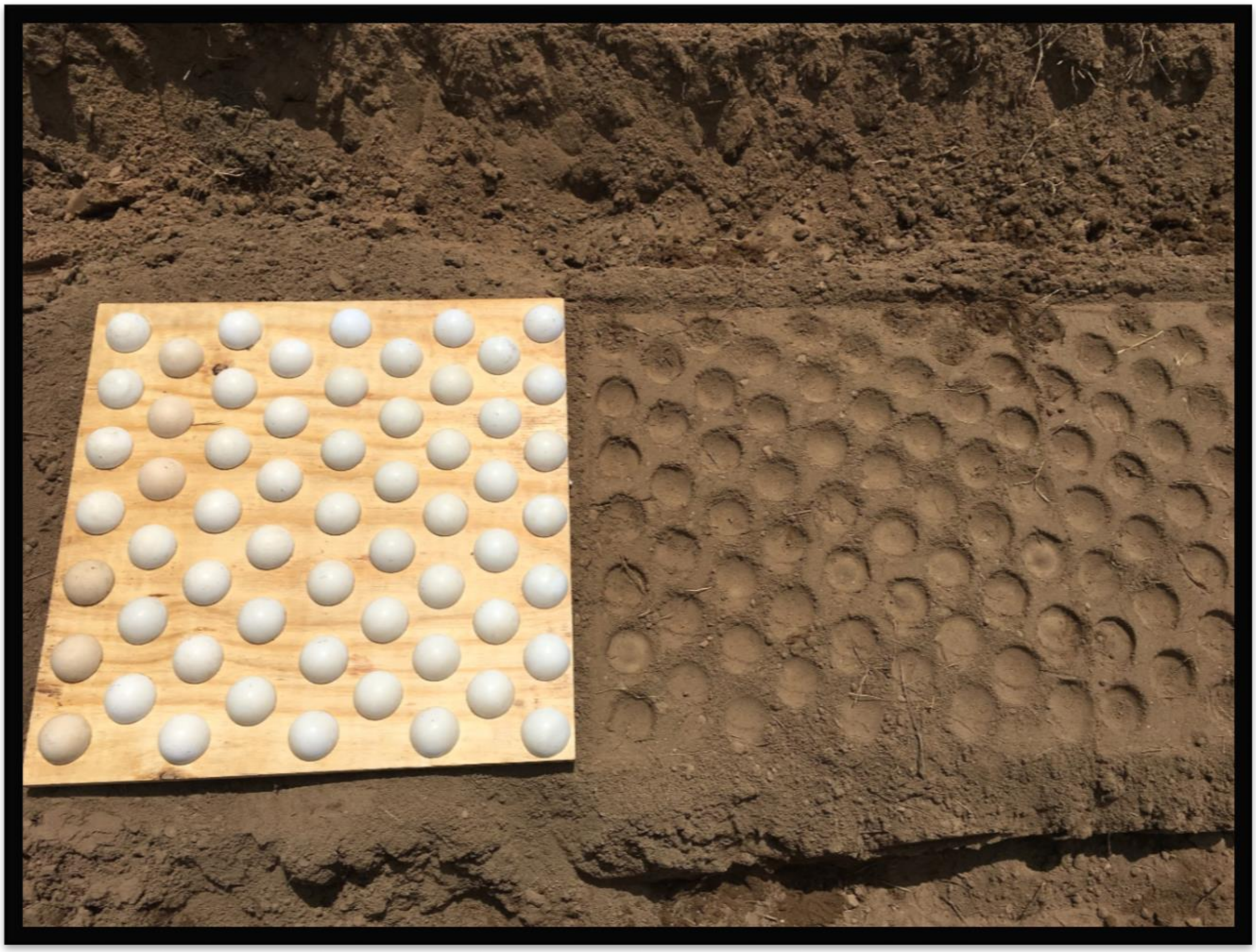

Figure 1. Small dimple treatments were applied by pressing a 30.4-cm x 30.4-cm board with 3.8-cm-wide x 2.5-cm-deep PVC end caps spaced 7.6 cm apart to pre-formed beds prior to application of polyethylene mulch.

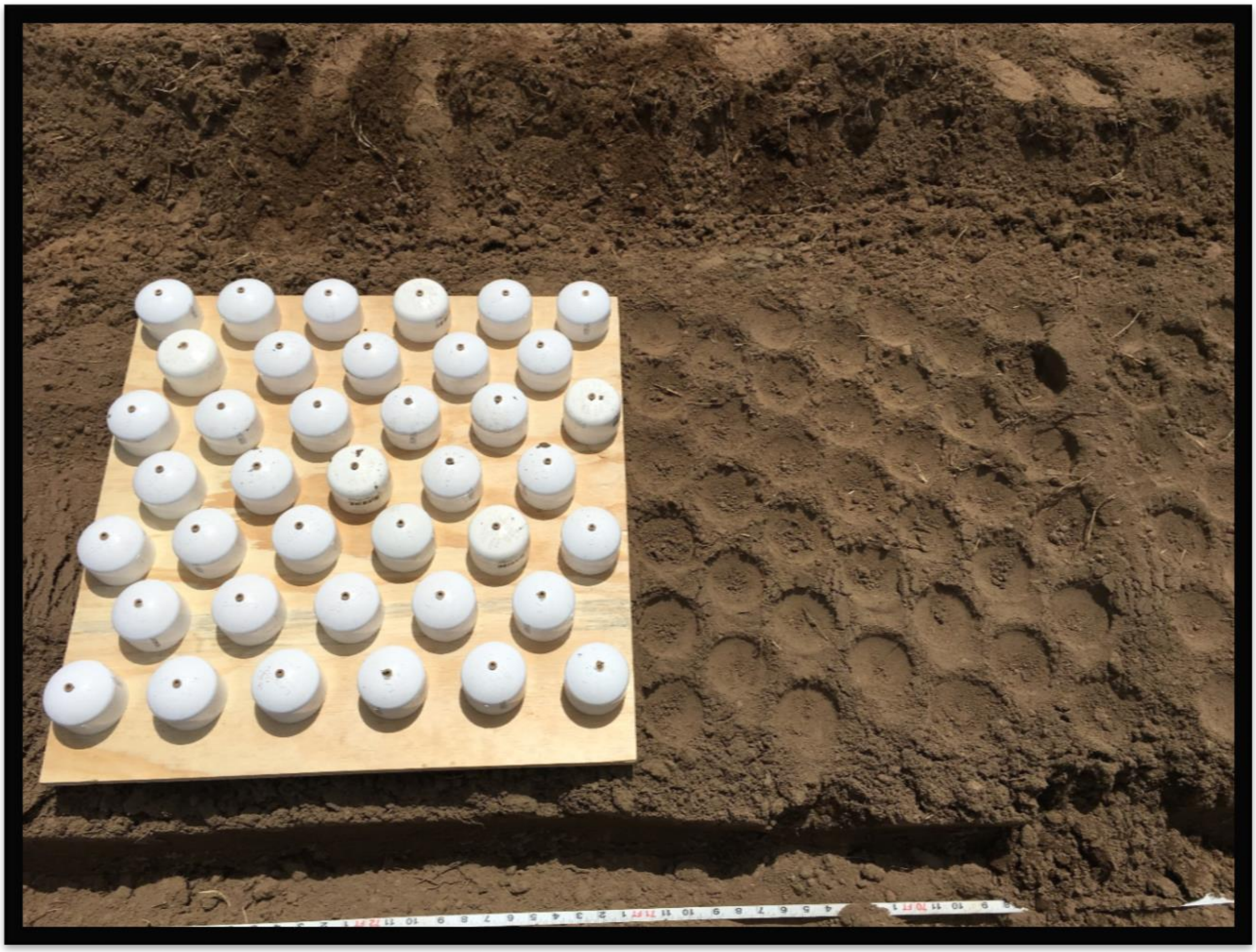

Figure 2. Large dimple treatments were applied by pressing a 30.4-cm x 30.4-cm board with 6.35-cm-wide x 5.1-cm-deep PVC end caps spaced 10.2 cm apart to pre-formed beds prior to application of polyethylene mulch.

Figure 3. External elements along with underground drip tape irrigation may have disturbed dimple structure.

Chapter IV

Final Discussion

Farmers utilize polyethylene (PE) mulch to achieve maximum production of vegetable crops. The use of PE mulch in commercial vegetable production contributes to earlier and higher yields, a cleaner and higher quality produce, a more cost-effective use of water and fertilizers, along with greater disease, insect, and weed control. However, not all weed species are adequately controlled with PE. Yellow (*C. esculentus*) and purple (*C. rotundus*) nutsedge, two of the most economically destructive weeds, can easily pierce and degrade PE mulch allowing competition with vegetable crops. While field research has been limited, different types of PE mulches with minimal cost differences have been evaluated for controlling and altering development of nutsedge. Results from these previous evaluations showed promising results prompting our research objectives.

In chapter II, the reduction efficacy of yellow nutsedge punctures were evaluated using combinations of mulch type and soil dimpling. The experiment was an augmented factorial treatment arrangement of two mulch types (white or infrared-transmitting (IRT) green) and three dimple sizes (none, small, and large). This was augmented by a commercial standard (white mulch with a preemergence (PRE) herbicide applied under mulch), giving a total of 7 treatments. The main effects for mulch were significant; however, the main effects of dimples and the interaction between mulch and dimples were not significant for any measurable outcomes. Yellow nutsedge punctures 14, 28, and 60 days after treatment (DAT), dry weight of emerged and non-emerged yellow nutsedge shoots were reduced significantly by IRT-green PE mulch treatments compared to white mulch treatments and the standard treatment. These results suggest that IRT-green PE mulch may suppress yellow nutsedge populations in PE mulched beds and successively reduce the impact on yield of vegetable crops.

In chapter III, field studies were conducted to evaluate combinations of mulch type and soil dimpling to reduce purple nutsedge punctures in PE mulched beds. Treatments were assessed based on their ability to decrease purple nutsedge punctures. Experimental setup was the same as in chapter II. Purple nutsedge punctures 14, 28, and 60 DAT, dry weight of emerged purple nutsedge shoots, and dry weight of non-emerged purple nutsedge shoots were significantly reduced by IRT-green PE mulch treatments compared to white mulch treatments and the standard treatment. The aforementioned results suggest that IRT-green PE mulch may suppress purple nutsedge populations in PE mulched beds and subsequently reduce the negative impact on yield and quality of vegetable crops produced using PE mulch.

Additional research is needed to determine the full implications of using IRT mulches to grow vegetables in the southeastern United States. Air space temperature (between the mulch and soil surface) was measured on an hourly basis with sensors placed between the bed surface and mulch. Temperatures directly underneath IRT-green mulch reached ≥50°C on 36 days of the 60-day trial period. Previous research reported temperatures reaching these levels were lethal to nutsedge. Consequently, these lethal temperatures could be detrimental to vegetable crops by damaging their root systems. However, earlier planting dates could offset concerns for excessive temperatures during crop production. Nutsedge typically germinates underneath mulch shortly after application in response to increased soil temperatures. Planting earlier could allow nutsedge to germinate and be suppressed by IRT mulches. As the crop matures, it would likely shade the IRT mulch reducing heat buildup underneath the mulch preventing damage to crops. Planting earlier could allow optimal plant growth prior to elevated temperatures experienced during the summer growing months. Additionally, planting holes in PE mulch further decrease temperatures by allowing heat to escape. Data from future research would allow better understanding of how high temperatures may affect crop development and yield in the southeastern United States. Dimple effects during purple nutsedge experiments were somewhat inconclusive. Purple nutsedge puncture counts were significantly influenced at 14 DAT and just outside the range of significance at 28 and 60 DAT. These results suggest a possible change to dimple size, spacing, and/or depth could have significant impacts on purple nutsedge control. Increasing the depth of dimples may reduce the impact of disturbances to dimple structure observed during our experiments. Research on potential dimple alterations would allow a greater understanding of viability of dimple applications. Lastly, future research on PRE-herbicide dissipation under IRT mulches would be beneficial. PRE-herbicides are additional tools utilized by farmers which aids weed management throughout the season. Previous research has indicated some herbicides breakdown prematurely when applied underneath PE mulch resulting in reduced weed control later in the season. The determination of the fate of commonly used PRE-herbicides applied under IRT mulch could provide useful data for making herbicide recommendations for PE mulch systems. The aforementioned future research studies could advance weed management systems in place today.