Evaluation of preemergence herbicides applied pre- and post-crimp in a rye (*Secale cereale* L.) cover crop system for control of broadleaf weeds in watermelons (*Citrullus lanatus* (Thunb.) Matsum. and Nakai)

by

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Abstract

Field studies were conducted the spring of 2016 and 2017 at the Old Agronomy Farm (OAF) in Auburn, Alabama, and the Plant Breeding Unit (PBU) in Tallassee, Alabama to evaluate the effect of preemergence herbicide applications pre- and post-crimp in a cereal rye cover crop for control of escape weeds in watermelons. The trial consisted of an augmented factorial treatment arrangement of 3 levels of preemergence herbicides, two levels of application timing, and a nontreated control. Application timings were pre-crimp (herbicide applied prior to crimping and rolling of the cover crop) and post-crimp (herbicide applied after crimping and rolling of the cover crop). Preemergence herbicide options were ethalfluralin (1,470 g ai·ha^{-1}), fomesafen (180 g ai·ha^{-1}), and halosulfuron (39 g ai·ha^{-1}). A nontreated cover crop only treatment was also included yielding a total of seven treatments. Treatments were arranged in a randomized complete block design with four replications.

There were no interactions among application timing and herbicide, therefore data was pooled by location. Results at the OAF location indicate application timing did not influence total weed coverage, nutsedge density, or watermelon yield. Broadleaf weed density was lower in post-crimp applied treatments 6 weeks after treatment (WAT) while grass density was lower in pre-crimp applied treatments 4 WAT. Differences were not observed at any other rating dates. Comparing individual treatments at OAF revealed yield was greatest in treatments containing fomesafen. Results at the PBU location indicated application timing did not influence nutsedge

density or watermelon yield. Total weed coverage was lowest in pre-crimp applied treatments at 2, 4 and 6 WAT. Broadleaf weed density and grass density was lowest in post-crimp applied treatments 8 WAT. Comparing individual treatments revealed no significant differences among herbicides at PBU; however, all herbicides increased yield compared to the nontreated plots.

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Introduction and Literature Review

Yield losses in watermelons due to weed competition in the southeastern United States (GA, FL, AL, SC) are estimated to be 15% annually (Chandler et al. 1984). Weed control in vegetable production can be difficult due to the slow growth of the crops and the limited number of herbicides registered in vegetables (Gilreath and Santos 2004). Weeds also increase costs due to difficulty in harvesting as well as reduction in crop quality and yield (Brandenberger et al. 2005). These trends hold true for watermelon production.

Conservation tillage offers many benefits to growers including increased soil organic matter, improved water holding capacity, and improved nutrient availability (Blevins et. al. 1983). While many vegetable growers are interested in conservation tillage, weed control poses a challenge (Walters et al. 2004, Walters et al. 2007).

Cover crops play a vital role in conservation tillage systems by assisting with erosion control, reduced runoff, improved infiltration, soil moisture retention, improved soil structure, nutrient enhancement, and weed control (Teasdale 1996). When cover crops are combined with herbicides, it is possible to achieve adequate weed control in some vegetables. In a study (Walters et al. 2005) evaluating squash planted into a cereal rye cover crop in conjunction with preemergence herbicides, smooth crabgrass and redroot pigweed were adequately controlled (up to 95%). This was also demonstrated in similar studies with fresh market cucumbers (Walters et al. 2007), as well as pumpkins (Walters et al. 2008).

Broadleaf weed control in watermelons planted behind a rye cover crop has been attempted previously. Monday et al. (2015) conducted a study utilizing a cereal rye cover crop along with a preemergence herbicide and postemergence spot treatments to control pigweed and yellow nutsedge. Best nutsedge control was achieved with no preemergence application and halosulfuron applied as a spot treatment. Best pigweed control was achieved with a preemergence application of ethalfluralin accompanied with glufosinate applied as a spot treatment, which resulted in greatest crop value and fruit number. Broadleaf weed control in watermelons has also been attempted using different mulching techniques, tillage methods, and herbicide application timings. Williams et. al. (2017) tested four mulching systems: conventional tillage, polyethylene mulch, conservation tillage with a cover crop mulch, and polyethylene mulch over a rye cover crop mulch. It was reported that purple nutsedge was controlled best in a conservation tillage system. Sicklepod control in a conservation tillage system was similar to that of the polyethylene mulch and the polyethylene mulch over rye. Although application timings of halosulfuron were tested, no differences were found in either early or late weed control.

Cover crop management can influence weed control. In a study conducted on Palmer amaranth control in peanuts, differing cover crop management systems were tested along with differing preemergence herbicides (Dobrow, Jr. et al. 2011). Preemergence herbicides were applied with no cover crop, with the cover crop rolled, and with the cover crop still standing. The longest period of Palmer amaranth-free days occurred when the preemergence herbicide was applied and the cover crop was left standing.

Although cover crops provide many benefits, herbicide behavior can be influenced by residues left on the soil surface (Teasdale et al., 2003). The primary effect that cover crop residue can have is interception of the herbicide, reducing its efficacy. Teasdale et al. (2003) reported that hairy vetch increased decomposition rates and decreased initial soil solution of metolachlor. As a result, grass control was reduced and pigweed emergence was increased in one of three years (Teasdale et al., 2003).

Multiple preemergence herbicides have been evaluated for use in watermelons and compared based on plant injury and yield (Brandenberger et al. 2005). Halosulfuron applied at any rate caused plant injury, but in most cases plants recovered by 5-7 WAT. The same trend was reported when halosulfuron was tank mixed with other preemergence herbicides. Greatest weed control and highest watermelon yield occurred with a tank mix of clomazone, ethalfluralin, and halosulfuron. This treatment caused a significant amount of plant injury (30% at 2-4 WAT, and 26% at 5-7 WAT); however, yield was not affected.

Weed control is difficult in watermelons due to the vining growth habit, wide row spacing, and slow growth, but early weed free periods are critical for maximum yields (Terry et al. 1997). Transplanted watermelons competing with large crabgrass have a critical weed free period of 0-6 weeks (Monks and Schultheis 1998) while direct seeded watermelon competing with smooth pigweed has a critical weed free period of 0-3 weeks (Terry et. al. 1997). In Alabama, there are a limited number of registered herbicides in watermelons that will control problematic weeds (Kemble et al. 2013). Most herbicides registered in watermelons are preemergence with few postemergence options. To achieve broadleaf weed control long enough to maintain 90% of the potential yield for watermelons, there is a need to combine cultural and chemical practices.

Cover Crop Benefits. Benefits of growing a cover crop include: improved soil structure, conservation of soil moisture, improved nutrient availability, erosion control, improved water infiltration rate, reduced runoff, and improved weed control (Teasdale 1996). Common cover crops include crimson clover, hairy vetch, tillage radish, wheat and cereal rye. Rye is the most widely adapted member of the cereal grain crops (Busuk 1976) displaying extreme winter hardiness and the ability to grow on marginal soils. It is also the most drought resistant cereal grain due to its extensive root system. In addition, rye also produces a large amount of biomass, and has been shown to produce allelopathic compounds that can reduce weed competition (Barnes 1987).

A study conducted in the Wiregrass region of Alabama evaluating rye as a cover crop reported a biomass average of 6,250 $kg \cdot ha^{-1}$ (Reeves et al. 2005). At these biomass levels, rye has demonstrated the ability to reduce palmer amaranth emergence by up to 50% (Webster et. al. 2016). This reduction can be attributed to the proximity of the site of seed germination which limits light transmittance, hence germination of some species (Teasdale and Mohler 1993). Although cover crop residues do not eliminate germination of weed seeds in all cases, seeds that do germinate must grow through a thick layer of mulch, often exhausting all of the seedling's energy reserves (Teasdale and Mohler 1993). Therefore, the cover crop can alter the microenvironment around the seed enough to possibly reduce or delay weed emergence.

Plants compete for light, water, and mineral nutrients, but there are more subtle mechanisms of interference between them (Putnam and DeFrank 1983). Allelopathy can be defined as a chemical release from a plant or its residues into the environment that can affect the germination or development of the recipient plant (Putnam and DeFrank 1983). Allelopathic properties of cereal rye are due to the formation of cyclic hydroxamic acids, phenylacetic acid, 4-phenylbutyric acid, and a few different benzoic and cinnamic acids (Mwaja et. al. 1995). Although rye can potentially produce each of these phytotoxic chemicals, the two main chemicals produced are benzoxazinone compounds: 2,4-dihydroxy-1,4(2H)-benzoxazin-3-one (DIBOA), and its decomposition product 2(3H)-benzoxazolinone (BOA) (Mwaja et. al. 1995). DIBOA and BOA are the most prevalent, but there have been multiple studies that show that in the presence of a soil-borne bacteria (*Acinetobacter calcoaceticus*), BOA can be transformed into 2,2'-oxo-1,1'-azobenzene (AZOB) (Chase et al. 1991a), which is far more toxic to weeds and more biologically active than either BOA or DIBOA (Chase et al. 1991b). Research conducted by Mwaja et al., revealed BOA is produced at higher levels than DIBOA in fall planted, field grown rye (Mwaja et. al. 1995).

While they all function to inhibit growth of competitive weed species, the efficacy of each of these allelopathic chemicals depends on the species targeted for control. DIBOA was the most effective allelochemical in inhibiting germination of large crabgrass (*Digitaria sanguinalis*) and proso millet (*Panicum miliaceum*) (Barnes 1987). BOA was more effective on the inhibition of dicot germination, but both DIBOA and BOA had a significant effect in reducing dicot seedling growth (Barnes 1987). When these two chemicals were compared to AZOB, the results showed that AZOB alone was a more powerful chemical than DIBOA and BOA on the root and shoot growth of barnyard grass (*Echinocloa crus-galli*) and garden cress (*Lepidium sativum*) (Chase et al. 1991). It was also observed that these allelochemicals have a greater effect on reducing plant growth than reducing overall plant number. Selectivity from the allelopathic chemicals is based on seed size and placement, which is similar to synthetic preemergence herbicides (Chase et al. 1991).

Cover crops provide a physical barrier, block light from seeds, and produce allelopathic compounds, but they only help with early season weed control (Teasdale 1996). These traits of cover crops mainly affect small seeded species of weeds, however, a number of escapes is likely. The escapes can compensate for the lack of competition by having greater growth per plant. Therefore, in a system in which cover crops are utilized as a weed control strategy there is still a need to provide season long control of weeds. The most successful cover crop systems include the application of a preemergence herbicide (Teasdale 1996).

Herbicides Utilized in Experiments. Glyphosate is classified as a non-selective, foliar applied material, and is a systemic herbicide. Glyphosate's mode of action is inhibition of 5-enolpyruvlshikimate-3-phosphate (EPSP) synthase, which is involved in the production of the aromatic amino acids tryptophan, tyrosine, and phenylalanine. EPSP synthase produces EPSP from shikimate-3-phosphate and phosphoenolpyruvate in the shikimic acid pathway, thus EPSP inhibition causes the depletion of tryptophan, tyrosine, and phenylalanine, which are each required for protein synthesis and normal growth in plants (Senseman 2007). Growth is halted in the plant soon after application, chlorosis of the foliage of the plant follows within a week, followed by plant death (Senseman 2007). Glyphosate is an effective burn down material due to its non-selective nature. A burn down herbicide is used to kill all vegetation prior to planting. It is used for that purpose in many crops, and it is also used in glyphosate resistant crops. Due to its extensive use, there have been cases of herbicide resistance documented in several weeds.

Ethalfluralin is a dinitroanaline (DNA) herbicide. The mode of action of this herbicide is the disruption of mitosis through the inhibition of the microtubule protein tubulin. The herbicide binds to tubulin and inhibits the elongation of microtubules at the site in which they are produced, thus leading to a loss of function (Senseman 2007). Annual grass species and small seeded broadleaf species are most susceptible to this herbicide. Like all DNA herbicides, ethalfluralin is applied primarily as a preemergence material and creates a chemical barrier at the soil surface through which a germinated seed of a susceptible species often fails to grow through. Although it is used primarily as a preemergence material, there are cases where DNA herbicides can be applied postemergence. One study reported that the least amount of damage in transplanted watermelons occurred when ethalfluralin was applied postemergence (Mitchem et. al. 1997). Other DNA herbicides can be applied post-directed in crops such as corn and sorghum for extended residual control. Ethalfluralin can present some carryover issues the next season to extremely susceptible crops. Ethalfluralin is used extensively in cucurbit crop production. On multiple occasions, ethalfluralin has been used in combination with other herbicides to achieve exceptional weed control in several cucurbit crops (Brandenberger et al. 2005; Walters et al. 2005; Walters et al. 2007; Walters et al. 2008).

Halosulfuron-methyl is a sulfonylurea herbicide, whose mode of action is acetolactase synthase (ALS) inhibition. Halosulfuron-methyl inhibits branched chain amino acid production (leucine, isoleucine, and valine) in plants by inhibition of the ALS enzyme, and death to the plant is caused by depletion of these amino acids. Preemergence applications cause the shoot growing point to become chlorotic and necrotic soon after seedling emergence (Russell et al. 2002). The herbicide is absorbed more readily through the leaves than the roots, but there is absorption in both, and it translocates throughout the plant (Senseman 2007). This material does not have a residual as long as other preemergence materials, but it can have a half-life ranging anywhere from 4-34 days depending on soil pH, organic matter percentage, and soil type (Senseman 2007). This herbicide is most active on *Cyperus* spp., a genus that is notoriously difficult to control. Halosulfuron is a great candidate for watermelon production due to its extensive use in similar cucurbit crops. It causes injury to watermelon when applied preemergence at any level (Brandenberger et. al. 2005), but in multiple studies this herbicide was used in the tank mix that provided greatest weed control in multiple cucurbit crops such as watermelons, pumpkins, and cucumbers (Brandenberger et. al. 2005; Walters et. al. 2007; Walters et. al. 2008).

Although it is a viable option for preemergence weed control, studies have shown that halosulfuron when applied early or late postemergence can cause significant damage to watermelon plants (Macrae et. al. 2008). At two weeks after treatment, the early post and late post application caused 45 and 34% damage, respectively. Watermelon fruit number and total weight were reduced 21 and 26% by early post treatments, and total weight was reduced 18% by the late post application (Macrae et. al. 2008).

Fomesafen is a diphenylether herbicide whose mode of action is protoporphyrinogen oxidase inhibition, or PROTOX inhibition. PROTOX is an enzyme found in chlorophyll and heme biosynthesis, which catalyzes the conversion of protoporphyrinogen IX to protoporphyrin IX (Senseman 2007). This type of inhibition leads to the buildup of protoporphyrin IX, which is a light absorbing chlorophyll precursor. The buildup of protoporphyrin IX absorbs a large amount of light and produces energy that cannot be properly utilized. Therefore, it is converted into oxygen singlets which lead to membrane destruction, ending in death of the plant

(Senseman 2007). It controls a large number of annual broadleaf weeds such as morningglory and pigweed, but does not have much activity on grass species. This material is persistent in the soil and can present carryover issues in susceptible crops. Fomesafen has been tested as a viable herbicide option in multiple cucurbit crops (Peachey et. al. 2012). When fomesafen alone was applied, up to 99% weed control was achieved when observing annual grasses, pigweed, and common purslane. These treatments also provided close, if not greater, yield to that of the industry standard in most cucurbit crops (Peachey et. al. 2012). It has been reported that fomesafen and ethalfluralin tank-mixed can reduce Palmer amaranth incidents to less than 0.2 plants·m^2 in a cotton-cantaloupe intercropping system (Eure et. al. 2015).

Clethodim is a cyclohexandione herbicide whose mode of action is acetyl CoA carboxylase inhibition. Acetyl CoA carboxylase is an enzyme which catalyzes the first step in fatty acid synthesis. Inhibition of Acetyl CoA carboxylase prevents the building of phospholipids used in new membranes for cell growth (Senseman 2007). Most broadleaf species are immune to this type of herbicide. Clethodim is rapidly absorbed into the plant, but it can take 1-3 weeks for death to occur (Senseman 2007). Little is known about clethodim translocation through the plant, but it is assumed that it is similar to that of sethoxydim. Sethoxydim is a systemic material which translocates through the xylem and phloem and accumulates in the growing tissues (Senseman 2007). This material has an extremely short soil half-life, meaning that it has little, if any, soil activity. A critical weed free period of 0-6 weeks must be reached for watermelon competing with large crabgrass (*Digitaria* *sanguinalis*) (Monks and Schultheis 1998), therefore making a graminicide application critical to achieving maximum yield.

Problematic Weeds in Watermelon Production. Sicklepod (*Senna obtusifolia*) is listed as one of the top ten most troublesome weeds in cucurbit crops in Alabama (Burgos 2014). It is a summer annual that can grow from 0.3-2.0 m tall (Steckel 2006) and presents several challenges to growers seeking to control it. For example, Senseman and Oliver (1993) reported that sicklepod can produce up to 1,000 flowers and more than 11,000 seeds per plant. Sicklepod seed can germinate in temperatures as low as 18°C, and as high as 36°C, and although the optimal temperature range for germination was found to be 24-33°C, the ability of sicklepod seed to germinate at such a wide range of temperatures is what makes it a major weed in summer crops (Creel et al. 1968). Sicklepod seed has a hard, waxy seed coat, and in most cases scarification is needed to break dormancy (Creel et al. 1968, Bararpour and Oliver 1998). This results in a large supply of seed accumulating in the soil seed bank presenting a problem for growers for a substantial period of time (Bararpour and Oliver 1998). Egley and Chandler (1983) reported that sicklepod seeds can remain viable in the soil for up to 6 years.

Morningglory (*Ipomea* spp.) is also listed as one of the top ten most troublesome weeds in cucurbit crops in the state of Alabama (Burgos 2014). Morningglory is a summer annual with a vining growth habit. It has been shown to produce up to 2,500 flowers, which led to over 16,000 seeds per plant (Senseman and Oliver 1993). With seed production being so high, morningglory is a weed that can cause problems for a long time due to buildup in the soil seed bank. Morningglory seed can remain up to 13% viable when buried for 5.5 years (Egley and Chandler 1983). Crowley and Buchanan (1978) reported that tall morningglory (*Ipomea purpurea*) reduced cotton yields by 22% and 33% at 8 and 16 plants per 15 m of row, respectively, and negatively affected harvesting efficiency.

Palmer amaranth (*Amaranthus palmeri*) is among the most troublesome weeds throughout the Southeast (Burgos 2014). It is a summer annual that can reach heights of over 1.5 m (Rowland et al. 1999). Due to its growth habit, Palmer amaranth can have a negative effect on crop growth and yield by competing with crop plants for resources needed for growth (Rowland et al. 1999). Palmer amaranth has dioecious flowers, which contribute to its ability to be extremely genetically diverse (Sprauge 2013). One of the largest problems with Palmer amaranth is herbicide resistance. Since the late 1980s two populations of Palmer amaranth have developed herbicide resistance to five different modes of action: ALS-inhibitors, Microtubule inhibitors, Photosystem II inhibitors, Glyphosate, and HPPD inhibitors (Sprauge 2013). Palmer amaranth also produces substantial numbers of seed. A study evaluating planting date and seed production of Palmer amaranth showed that plantings from March to June produced 200,000 to 600,000 seed per plant while plantings from July to September resulted in 115 to 80,000 seeds per plant (Keeley et. al. 1987). Seed will not remain viable if buried (Egley and Chandler 1983), but can cause problems if left on the soil surface. Cotton yield was evaluated with multiple herbicides in a Palmer amaranth infested field. When untreated with herbicides, Wiggins and others (2016) reported that Palmer amaranth reduced yield by 250 $kg \cdot ha^{-1}$. This shows that the effect Palmer amaranth has on yield warrants finding a way to control it.

Yellow nutsedge (*Cyperus esculentus*) is listed as one of the top ten most problematic weeds throughout most states in the southeast due to its perennial nature and ability to spread quickly (Burgos 2014). In a study investigating the reproductive capabilities of yellow nutsedge, Tumbleson and Kommedahl reported that one tuber can produce almost 2,000 shoots and nearly 7,000 tubers in one year over 3 m^2 (1961). Tillage can be effective in reducing nutsedge populations (Glaze 1987); however, this practice is not a viable option in minimal-till situations. In many cases herbicides are the primary means for nutsedge control (Earl et al. 2004).

Watermelon Production. Watermelons belong to the *Cucurbitaceae* family and are closely related to squash, pumpkins, cantaloupes, and cucumbers. They grow well on any well-drained soil with a pH of 6.0-6.5. When planted, the soil temperature should be high enough to ensure rapid germination. Watermelon seeds can germinate in soil temperatures as low as 20°C and as high as 35°C (Boyhan et al. 2013). Transplants should be planted after the danger of frost has passed and when the soil temperatures are likely to remain above 20°C (Hemphill 2010). Plant spacing is dependent upon the growing environment and the type of watermelon being grown. In the state of Georgia it is recommended that watermelons be planted at 0.9 m spacing in the row, and 1.5-2 m between rows (Boyhan et al. 2013). Pollination is extremely important in all cucurbit crops, and bees play an important role in that.

Research has shown that fruit set in watermelons is superior when the flower is visited 8 or more times by bees compared to 4 or less visits (Alderz 1966).

In Georgia more than 3,642 hectares (25% of the total area) of watermelons are grown on plastic mulch (Boyhan et. al. 2013). Plastic mulch provides many advantages to growers including early harvest, sufficient weed control of grasses and broadleaves, and water conservation. Although it is more expensive, many growers can justify plastic mulches due to the premium price for early watermelons.

Water is extremely important when producing watermelons. Many factors play into evapotranspiration (ET) rates of plants. Watermelon ET rates can reach as high as 0.76 cm per day (Boyhan et al. 2013). Irrigation can be applied in many ways depending upon the production system. In a bareground system, irrigation is typically applied overhead. In a plasticulture system, irrigation is applied through drip emitters under the plastic. Water demands increase as the watermelon plant gets closer to maturity: 1.25 cm every 5-6 days until the plant begins to vine, 2.0 cm every 5 days from vining to first bloom, and 2.5 cm every 4 days from first bloom until harvest (Boyhan et al. 2013).

Weed control in watermelons is important because of the negative impact weeds can have on yield. Watermelon yield can be reduced by 10%, 66%, or 90% by 2 yellow nutsedge plants·m^{-2}, 37 nutsedge plants·m^{-2}, or 6 smooth pigweed plants·m^{-2}, respectively (Buker et al. 2003; Terry et al. 1997). It is critical to have a weed control program that can mitigate losses from problematic weeds. The objective of this study is to implement cultural and chemical weed control practices in a watermelon production system, and evaluate the effectiveness of application timing of preemergence herbicides pre- and post-crimp of a cereal rye cover crop for control of broadleaf weeds and nutsedge.

Literature Cited

Alderz WC (1966) Honey bee visit numbers and watermelon pollination. Jour Econ Ent 59: 28-30

Bararpour MT, and Oliver LR (1998) Effect of tillage and interference on common cocklebur (*Xanthium stumarium*) and sicklepod (*Senna obtusifolia*) population, seed production, and seedbank. Weed Sci 46:424-431

Barnes JP, and Putnam AR (1987) Role of benzoxazinones in allelopathy by rye (*Secale cereale* L.). J Chem Ecol 13:889-906

Blevins RL, Smith MS, Thomas GW, and Frye WW (1983) Influence of conservation tillage on soil properties. J Soil Water Cons 38(3):301-305

Brandenberger LP, Shrefler JW, Webber III CL, Talber RE, Payton ME, Wells LK, and McClelland M (2005) Preemergence weed control in direct seeded watermelon. Weed Tech 19:706-712

Boyhan GE, Granberry DM, and Kelly WT (2014) Commercial watermelon production. UGA Extension Bulletin 996. Univ. of GA, Athens, GA

Buker III RS, Stall WM, Olson SM and Schilling DG (2003) Season long interference of yellow nutsedge (*Cyperus esculentus*) with direct-seeded and transplanted watermelon (*Citrullus lanatus*). Weed Tech 17:751-754

Bushuk W, ed (1976) Rye: Production, Chemistry, and Technology. American Association of Cereal Chemists, Incorporated. St. Paul, Minnesota. Pp 22

Burgos NR, ed. (2014) The southern states 10 most common and troublesome weeds in cucurbit crops. Pages 285-287 in Proceedings of the Southern Weed Science Society. Birmingham, AL: Southern Weed Science Society

Chandler JM, Hamel AS, and Thomas AG (1984) Crop losses due to weeds in Canada and the United States. Presentation at the Weed Science Society of America meeting, Champaign, Ill.

Chase WR, Muraleedharan GN, and Putnam AR (1991a) 2,2'-oxo-1, 1'-azobenzene: Selective toxicity of rye (*Secale cereale* L.) allelochemicals to weed and crop species: II. J Chem Ecol 17:9-19

Chase WR, Muraleedharan GN, Putnam AR, and Mishra SK (1991b) 2,2'-oxo-1, 1'-azobenzene: Microbial transformation of rye (*Secale cereale* L.) allelochemical in field soils by *Acinetobacter calcoaceticus*: III. J Chem Ecol 17:1575-1584

Creel Jr. JM, Hoveland CS and Buchanan GA (1968) Germination, growth, and ecology of sicklepod. Weed Sci 16:396-400

Crowley RH and Buchanan GA (1978) Competition of four morningglory (*Ipomea* spp.) species with cotton (*Gossypium hirsutum*). Weed Sci 26:484-488

Dobrow Jr. MH, Ferrell JA, Faircloth WH, MacDonald GE, Brecke BJ, and Erickson JE (2011) Effect of cover crop management and preemergence herbicides on the control of ALS-resistant palmer amaranth in peanut. Peanut Sci 38:73-77

Earl HJ, Ferrell JA, Vencill WK, van Iersel MW and Czarnota MA (2004) Effects of three herbicides on whole-plant carbon fixation and water use by yellow nutsedge (*Cyperus esculentus*). Weed Sci 52:213-216

Egley GH and Chandler JM (1983) Longevity of weed seeds after 5.5 years in the Stoneville 50-year buried-seed study. Weed Sci 31:264-270

Eure PM, Culpepper AS, Merchant RM, Roberts PM, and Collins GC (2015) Weed Control, Crop Response, and Profitability When Intercropping Cantaloupe and Cotton. Weed Tech 29:217-225

Gilreath JP and Santos BM (2004) Efficacy of methyl bromide alternatives on purple nutsedge (*Cyperus rotundus*) control in tomato and pepper. Weed Technol 18:341-345

Glaze NC (1987) Cultural and mechanical manipulation of Cyperus spp. Weed Tech 1:82-83

Hemphill D (2010) Watermelon. Oregon State Extension. http://horticulture.oregonstate.edu/content/watermelon-0. Accessed July 17, 2017

Keeley PE, Carter CH, and Thullen RJ (1987) Influence of planting date on growth of palmer amaranth (*Amaranthus palmeri*). Weed Sci 35:199-204

Kemble J, Sikora EJ, and Majumdar A (2013) Commercial Vegetables: Insect, Disease, and Weed Control recommendations for 2013. Alabama Cooperative Extension System

Macrae AW, Culpepper AS, Batts RB, and Lewis KL (2008) Seeded watermelon and weed response to halosulfuron applied preemergence and postemergence. Weed Tech 22:86-90

Mitchem WE, Monks DW, and Mills RJ (1997) Response of transplanted watermelon (Citrullus lanatus) to ethalfluralin applied PPI, PRE, and POST. Weed Tech 11:88-91

Monday TA, Lawrence DA, Foshee III WG, Wehtje GR, and Gilliam CH (2015) Pre and post herbicides in combinations with a rye cover crop for control of yellow nutsedge and pigweed in watermelon. International Journal of Vegetable Science 21:264-271

Monks DW and Schultheis JR (1998) Critical weed-free period for large crabgrass (*Digitaria sanguinalis*) in transplanted watermelon (*Citrullus lanatus*). Weed Sci 46:530-532

Mwaja VN, Masiunas JB, and Weston LA (1995) Effects of fertility on biomass, phytotoxicity, and allelochemical content of cereal rye. J Chem Ecol 21:81-96

Peachey E, Doohan D, and Koch T (2012) Selectivity of fomesafen based on systems for preemergence weed control in cucurbit crops. Crop Prot 40:91-97

Putnam AR, and DeFrank J (1983) Use of phytotoxic plant residues for selective weed control. Crop Prot 2:173-181

Reeves DW, Price AJ, and Patterson MG (2005) Evaluation of three winter cereals for weed control in conservation-tillage nontransgenic cotton. Weed Tech 19:731-736

Rowland MW, Murray DS and Verhalen LM (1999) Full-season palmer amaranth (*Amaranthus palmeri*) interference with cotton (*Gossypium hirsutum*). Weed Sci 47:305-309

Russell MH, Saladin JL, Lichtner F (2002) Sulfonylurea herbicides. Pesticide Outlook. August 2002. Pp. 166-172

Senseman SA, and Oliver LR (1993) Flowering patterns, seed production, and somatic polymorphism of three weed species. Weed Sci 41:418-425

Senseman SA, ed. (2007) Herbicide Handbook. 9th edn. Champaign, IL: Weed Science Society of America

Sprauge C, ed. (2013) Palmer amaranth management in soybeans. United Soybean Board. http://iwilltakeaction.com/uploads/files/50737-3-ta-factsheet-palmeramaranth-lr_1.pdf. Accessed on September 18, 2016

Steckel L (2006) Sicklepod. University of Tennessee Extension. Publication 06-00311

Teasdale JR (1996) Contribution of cover crops to weed management in sustainable agriculture systems. J Prod Agric 9:431-479

Teasdale JR and Mohler CL (1993) Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. Agron J 85:673-680

Teasdale JR, Shelton DR, Sadeghi AM, and Isensee AR (2003) Influence of hairy vetch residue on atrazine and metolachlor soil solution concentration and weed emergence. Weed Sci 51:628-634

Terry ER, Stall WM, Shilling DG, Bewick TA and Kostewicz SR (1997) Smooth Amaranth (*Amaranthus hybridus* L.) interference with watermelon (*Citrullus lanatus* L.) and muskmelon (*Cucumis melo* L.) production. Hortic Sci 32:620-632

Tumbleson ME and Kommedahl T (1961) Reproductive potential of *Cyperus esculentus* by tubers. Weed Sci 9:646-653

Walters AS, Nolte SA, and Young BG (2005) Influence of winter rye and preemergence herbicides on weed control in no-tillage zucchini squash production. HortTech 15(2):238-243

Walters AS, Young BG and Krausz RF (2008) Influence of tillage, cover crop, and preemergence herbicides on weed control and pumpkin yield. International Journal of Vegetable Science 14(2):148-161

Walters AS, Young BG, and Nolte SA (2007) Cover crop and preemergence herbicide combinations in no-tillage fresh market cucumber production. J Sust Agric 30(3):5-19

Webster TM, Simmons DB, Culpepper AS, Grey TL, Bridges DC, and Scully BT (2016) Factors affecting potential for Palmer amaranth (*Amaranthus palmeri)* suppression by winter rye in Georgia, USA. Field Crop Res 192:103-109

Williams JP, Price A, Guertal E, and McElroy J (2017) The Effects of Polyethylene and Cereal Rye Mulch, Tillage, and Herbicides on Tomato and Watermelon Yield and Weed Control. M.S. thesis. Auburn, AL: Auburn University

Chapter II

Evaluation of preemergence herbicides applied pre- and post-crimp in a rye (*Secale cereale* L.) cover crop system for control of escape weeds in watermelons (*Citrullus lanatus* (Thunb.) Matsum. and Nakai)

(In the format appropriate for submission to Weed Technology)

Evaluation of preemergence herbicides applied pre- and post-crimp in a rye (*Secale cereale* L.) cover crop system for control of escape weeds in watermelons (*Citrullus lanatus* (Thunb.) Matsum. and Nakai)

Lavesta C. Hand, Wheeler G. Foshee III, Tyler A. Monday, Daniel E. Wells, and Dennis P. Delaney*

Abstract

Field studies were conducted the spring of 2016 and 2017 at the Old Agronomy Farm (OAF) in Auburn, Alabama and the Plant Breeding Unit (PBU) in Tallassee, Alabama to evaluate the effect of preemergence herbicide applications pre- and post-crimp in a cereal rye cover crop for control of escape weeds in watermelons. The trial consisted of an augmented factorial treatment arrangement of 3 levels of preemergence herbicides, two levels of application timing, and a nontreated control. Application timings were pre-crimp (herbicide applied prior to crimping and rolling of the cover crop) and post-crimp (herbicide applied after crimping and rolling of the cover crop).

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Preemergence herbicide options were ethalfluralin (1,470 g ai ha^{-1}), fomesafen (180 g ai ha^{-1}), and halosulfuron (39 g ai ha^{-1}). A nontreated cover crop only treatment was also included yielding a total of seven treatments. Treatments were arranged in a randomized complete block design with four replications.

There were no interactions among application timing and herbicide, therefore data was pooled by location. Results at OAF location indicate application timing did not influence total weed coverage, nutsedge density or watermelon yield. Broadleaf weed density was lower in post-crimp applied treatments 6 weeks after treatment (WAT) while grass density was lower in pre-crimp applied treatments 4 WAT. Differences were not observed at any other rating dates. Comparing individual treatments at OAF revealed yield was greatest in treatments containing fomesafen. Results at the PBU location indicated application timing did not influence nutsedge density or watermelon yield. Total weed coverage was lowest in pre-crimp applied treatments at 2, 4 and 6 WAT. Broadleaf weed density and grass density was lowest in post-crimp applied treatments 8 WAT. Comparing individual treatments revealed no significant differences among herbicides at PBU; however, all herbicides increased yield compared to the nontreated plots.

Introduction

Yield losses in watermelons due to weed competition in the southeast (GA, FL, AL, SC) are estimated to be 15% annually (Chandler et al., 1984). Weed control in vegetable crops can be difficult due to the slow growth of the crops and the limited number of registered herbicides (Gilreath and Santos, 2004). Weed pressure increases costs and reduces profit margin due to control costs, difficulty harvesting, and reduction in crop quality and yield (Brandenberger et al., 2005).

Weed control is especially difficult in watermelons due to their vining growth habit as cultivation can't be conducted after the vines begin to spread into the row middles, due to crop injury. The combination of wide row spacing and slow growth of watermelon complicates weed control measures (Terry et al. 1997). Previous research has shown the detrimental impacts of weed pressure on watermelon production. Yellow nutsedge can reduce watermelon yield 10% at 2 plants m^{-2}, and 66% at 37 plants m^{-2} (Buker et. al. 2003).Transplanted watermelons competing with crabgrass have a critical weed free period of 0-6 weeks (Monks and Schultheis, 1998). Direct seeded watermelon competing with smooth pigweed has a critical weed free period of 0-3 weeks (Terry et al., 1997). A blend of chemical and cultural controls is needed to reach this critical weed free period (Monday et. al. 2015).

Cover crops have been used in numerous cropping systems to improve weed control. In addition to providing weed suppression, benefits to growing a cover crop include improved soil structure, preservation of soil moisture, erosion control, improved water infiltration, and reduced runoff (Teasdale 1996). Teasdale and Mohler (1993) reported that cover crop residues have an influence on weed populations due to the residue proximity to the site of seed germination. Some weed seeds require light transmittance to germinate, and cover crop residue can reduce the amount of light reaching the soil. Once seeds germinate, they must emerge through a thick layer of mulch likely utilizing much of the seedlings' energy reserves (Teasdale and Mohler, 1993). Therefore, the cover crop can alter the microenvironment around the seed enough to possibly reduce or delay weed emergence (Teasdale and Mohler, 1993).

Due to its production of large amounts of biomass and allelopathic compounds, cereal rye is an excellent cover crop (Barnes, 1987). With an average biomass of 6,250 kg•ha^{-1}, cereal rye alone can reduce Palmer amaranth emergence up to 50% (Reeves et al., 2005; Webster et al., 2016). Additionally, cereal rye produces allelopathic compounds (Mwaja et al., 1995). Although there are many benefits to growing a cover crop, they only assist in early season weed control (Teasdale, 1996). Therefore, there is a need for herbicides in these systems to maximize weed control.

Multiple preemergence herbicides have been evaluated for use in watermelons and compared based on plant injury and yield (Brandenberger et al., 2005). Halosulfuron applied at any rate caused plant injury; however, in most cases plants recovered by 5-7 WAT. This trend held true when halosulfuron was tank mixed with other preemergence herbicides. Greatest watermelon yield, as well as best weed control, occurred with a tank mix of clomazone, ethalfluralin, and halosulfuron. This treatment caused a significant amount of plant injury (30% at 2-4 WAT, and 26% at 5-7 WAT), but had no effect on marketable yield (Brandenberger et al., 2005).

When cover crops are combined with herbicides, it is possible to achieve satisfactory weed control in vegetables. In a study evaluating squash, planted behind high biomass varieties of cereal rye, smooth crabgrass and redroot pigweed were adequately controlled (up to 95%) when preemergence herbicides were used in conjunction with the mulch (Walters et al., 2005). This was also demonstrated in similar studies with fresh market cucumbers (Walters et al., 2007), and pumpkins (Walters et al., 2008).

Cover crop management can also affect on weed control. In a study conducted on Palmer amaranth control in peanuts, different cover crop management systems were tested in combination with different preemergence herbicides (Dobrow, Jr. et al., 2011). Preemergence herbicides were applied with no cover crop, with the cover crop rolled, and with the cover crop still standing. The longest period of Palmer amaranth-free days occurred when the preemergence herbicide was applied with the cover crop left standing.

Although cover crops provide many benefits, herbicide behavior can be influenced by cover crop residues left on the soil surface (Teasdale et al., 2003). High residue cover crops can intercept herbicides and reduce efficacy of soil-active herbicides. The herbicide’s sorption to the cover crop can render it less active or physically inhibit it from reaching the soil to control emerging weeds (Locke and

Bryson, 1997). Teasdale et al. (2003) reported that hairy vetch increased decomposition rates and initial soil solution of metolachlor. Due to this, grass control was reduced and in one of three years pigweed emergence was increased (Teasdale et al., 2003). Due to this issue, there is a need to evaluate preemergence herbicide application methods to reduce interception and sorption by the cover crop.

The objective of this study was to implement cultural and chemical weed control practices in a watermelon production system, and evaluate the application timing of preemergence herbicides pre- and post-crimp in a cereal rye cover crop for control of broadleaf weeds and nutsedge.

Materials and Methods

Field studies were conducted in the summer of 2016 and 2017 at the Old Agronomy Farm (OAF) in Auburn, AL and the Plant Breeding Unit (PBU) in Tallassee, AL to evaluate the effectiveness of applying preemergence herbicides pre- and post-crimp in a cereal rye cover crop for control of broadleaf weeds and nutsedge in watermelon. Troublesome weed species in this area included sicklepod (*Senna obtusifolia*), morningglory (*Ipomea* spp.), pigweed (*Amaranthus* spp.), and nutsedge (*Cyperus* spp.). Soil type in both locations is a Marvyn sandy loam with a pH of 5.8 at OAF and a pH of 6.2 at PBU. Winter cover crops were planted in both locations during the second week of September. Cereal rye was planted with a grain drill at a rate of 69.5 $kg \cdot ha^{-1}$ and managed according to commercial standards. The cover crop was terminated in the last week of April when rye had reached the soft dough stage.

Glyphosate (1.12 kg ae·ha^{-1}) was mixed with each treatment to kill the cover crop. After the pre-crimp treatments were applied, a cover crop roller was attached to a tractor and used to roll and crimp the cereal rye, creating an organic mulch.

The trial was an augmented factorial treatment arrangement of 3 levels of preemergence herbicides, combined with two levels of application timing, and a nontreated control. Application timings were pre-crimp (herbicide applied prior to crimp and rolling of the cover crop) and post-crimp (herbicide applied after crimping and rolling of the cover crop). Preemergence herbicides used were ethalfluralin (1,470 g ai·ha^{-1}), fomesafen (180 g ai·ha^{-1}), and halosulfuron (39 g ai·ha^{-1}). A nontreated cover crop only treatment was also included for a total of seven treatments. Treatments were arranged in a randomized complete block design with four replications. Treatments were applied with a 190-liter sprayer, calibrated to deliver 280 L·ha^{-1}. The sprayer was equipped with Tee-Jet XR 8004 nozzles. Preemergence herbicides were applied one week prior to planting.

A personal sized watermelon (cv. Sugar Baby) was chosen for this study because of its desirable fruit. Watermelons were direct seeded and maintained according to commercial standards (Boyhan et. al. 2014). Nitrogen (30-0-0) and muriate of potash (0-0-60) were applied at 45 kg·ha^{-1} N and K pre-plant along with another 45 kg·ha^{-1} N and K six weeks after planting. Two seeds were planted every 1.2-m in parallel rows with 5 plants per plot. Four, 75-m rows were formed, each consisting of seven plots, 7.6-m long with a 1.8-m buffer between plots. Rows were spaced 7.6-m apart to minimize the potential for drift.

All broadleaf weeds and nutsedge plants within a randomly selected $1m^2$ section were counted biweekly for eight weeks. Total weed coverage was recorded as a percentage. Crop yield and fruit number were measured at the end of the season. Data were subjected to analysis of variance in PROC GLIMMIX in SAS (Version 9.4; SAS Institute, Cary, NC) with the normal distribution and identity link function for yield and negative binomial distribution and log link function for weed coverage, grass, broadleaf, and nutsedge density, and watermelon count. Total weed coverage, broadleaf weed count, grass percentage, nutsedge count, melon count, and melon yield were the response variables, and block and year were included in the models as random factors. Differences among individual treatment least squares means were compared and adjusted using the Shaffer-Simulated method (α=0.10).

Results and Discussion

OAF: Auburn, AL

No measurable outcomes were influenced by an interaction of herbicide and application timing; therefore, main effects were analyzed.

Total weed coverage. Total weed coverage was influenced by herbicide, but not application timing (Table 1). Fomesafen (2.5%) reduced total weed coverage compared to ethalfluralin (4.3%), and was similar to halosulfuron (3.0%) at 4 WAT (Table 1). At 6 WAT, fomesafen (5.1%) and halosulfuron (5.8%) reduced total weed coverage compared to ethalfluralin (8.8%). At 8 WAT, halosulfuron (8.1%) and fomesafen (9.3%) reduced total weed coverage compared to ethalfluralin (13.7%). Comparisons among individual treatments revealed differences at 6 and 8 WAT(Table 1). At 6 WAT, halosulfuron applied pre-crimp (5.5%) and fomesafen applied post-crimp (4.1%) reduced total weed coverage compared to nontreated plots (12.5%). At 8 WAT, fomesafen applied post-crimp (5.4%) reduced total weed coverage compared to nontreated plots (19.8%). Differences among individual treatments were not observed across all other rating dates.

Broadleaf weed density. Broadleaf weed density was influenced by both herbicide and application timing (Table 2). Broadleaf weed density was reduced in the post-crimp applied treatments (2.4 no. m^{-2}) compared to the pre-crimp applied treatments (3.1 no. m^{-2}) at 6 WAT. Differences in application timing were not observed across all other rating dates. Moreover, fomesafen (1.0 no. m^{-2}) reduced broadleaf weed density compared to ethalfluralin (2.8 no. m^{-2}) at 4 WAT. Differences in herbicide levels were not observed across all other rating dates. Comparisons among individual treatments revealed significant differences at 4 WAT only (Table 2). Fomesafen applied both pre-crimp (0.9 no. m^{-2}) and post-crimp (1.0 no. m^{-2}) reduced broadleaf weed density compared to ethalfluralin applied post-crimp (3.6 no. m^{-2}).

Grass weed density. Grass weed density was influenced by application timing only (Table 3). At 4 WAT, pre-crimp applied treatments (0.3%) reduced grass weed density compared to post-crimp applied treatments (0.8%). Herbicides alone showed no significant effects. Comparisons among individual treatments revealed differences at 6 WAT only (Table 3). Ethalfluralin applied pre-crimp (0.9%), fomesafen applied pre-crimp (0.6%), and fomesafen applied post-crimp (0.5%) reduced grass weed compared to nontreated plots (2.0%).

Nutsedge density. Nutsedge density was influenced by herbicide only (Table 4). At 4 WAT, halosulfuron (4.3 no. m^{-2}) reduced nutsedge density compared to ethalfluralin (14.5 no. m^{-2}). At 8 WAT, fomesafen (22.3 no. m^{-2}) reduced nutsedge density compared to ethalfluralin (53.0 no. m^{-2}). Differences in herbicide level were not observed across all other rating dates. Comparisons among individual treatments revealed differences at 4, 6, and 8 WAT (Table 4). At 4 WAT, halosulfuron applied pre-crimp (4.3 no. m^{-2}), halosulfuron applied post-crimp (4.3 no. m^{-2}), and fomesafen applied post-crimp (5.6 no. m^{-2}) reduced nutsedge density compared to nontreated plots (17.6 no. m^{-2}). At 6 WAT, fomesafen applied post-crimp (10.9 no. m^{-2}) reduced nutsedge density compared to nontreated plots (41.6 no. m^{-2}). This same trend was reported at 8 WAT as fomesafen post-crimp (15.1 no. m^{-2}) reduced nutsedge density compared to nontreated plots (57.1 no. m^{-2}).

Watermelon yield and melon count. Watermelon yield and melon count were influenced by herbicide only (Table 5). Fomesafen (11.7) and halosulfuron (10.1) increased melon count compared to ethalfluralin (6.0). Fomesafen (17,330 kg ha^{-1}) increased watermelon yield compared to halosulfuron (6,980 kg ha^{-1}) and ethalfluralin (8,800 kg ha^{-1}). Comparisons among individual treatments revealed significant differences (Table 5). Fomesafen applied post-crimp (12.9) increased melon count compared to the nontreated plots (5.4). Watermelon yield was higher in plots treated with ethalfluralin applied pre-crimp, fomesafen applied pre-crimp, and fomesafen applied post-crimp (11,940; 16,500; and 18,160 kg ha^{-1}, respectively) compared to nontreated plots (7,120 kg ha^{-1}).

PBU: Tallassee, AL

No measurable outcomes were influenced by an interaction of herbicide and application timing; therefore, main effects were analyzed.

Total Weed Coverage. Total weed coverage was influenced by both herbicide and application timing (Table 6). At 2, 4, and 6 WAT, pre-crimp applied treatments (0.9%, 1.8%, and 3.9%, respectively) reduced weed coverage compared to post-crimp applied treatments (1.8%, 2.3%, and 8.8%, respectively) (Table 6). Differences in application timing were not observed across all other rating dates. Moreover, halosulfuron (0.7%) reduced total weed coverage compared to both ethalfluralin (1.7%) and fomesafen (1.7%) at 2 WAT. Differences in herbicide level were not observed across all other rating dates. Comparisons among individual treatments revealed differences at 6 WAT (Table 6). Ethalfluralin applied pre-crimp (4.5%), fomesafen applied pre-crimp (3.1%), and halosulfuron applied pre-crimp (4.1%) provided the best weed control, although all were similar to nontreated plots (7.9%). Differences among individual treatments were not observed across all other rating dates.

Broadleaf weed density Broadleaf weed density was influenced by both application timing and herbicide (Table 7). At 8 WAT, post-crimp applied treatments (2.1 no. m^{-2}) reduced broadleaf weed density compared to pre-crimp applied treatments (4.4 no. m^{-2}) (Table 7). Differences in application timing were not observed across all other rating dates. Moreover, fomesafen (1.4 no. m^{-2}) provided the lowest broadleaf weed density compared to ethalfluralin (4.2 no. m^{-2}) and halosulfuron (4.1 no. m^{-2}) at 8 WAT. Differences in herbicide level were not observed across all other rating dates. Comparisons among individual treatments revealed differences at 8 WAT (Table 7). Fomesafen applied post-crimp (0.4 no. m^{-2}) provided the lowest broadleaf weed density, and was similar to halosulfuron applied post-crimp (1.5 no. m^{-2}), fomesafen applied pre-crimp (2.5 no. m^{-2}), and the nontreated plots (2.5 no. m^{-2}).

Grass weed density Grass weed density was influenced by both herbicide and application timing (Table 8). Post-crimp applied treatments (5.8%) provided greater grass control than pre-crimp applied treatments (8.4%) at 8 WAT. Differences in application timing were not observed across all other rating dates. Moreover, fomesafen (3.1%) demonstrated greatest grass control compared to ethalfluralin (8.3%) or halosulfuron (9.8%) at 8 WAT. Differences in herbicide level were not observed across all other rating dates. Comparisons among individual treatments revealed differences at 8 WAT only (Table 8). Grass weed control was improved in treatments receiving fomesafen applied post-crimp (1.7%) compared to nontreated plots (15.0%).

Nutsedge density. Nutsedge density was influenced by herbicide only (Table 9). At 4 WAT, halosulfuron (4.6 no. m^{-2}) provided greatest nutsedge control compared to ethalfluralin (14.8 no. m^{-2}) or fomesafen (25.1 no. m^{-2}). At 6 WAT, halosulfuron (16.7 no. m^{-2}) provided greatest nutsedge control compared to fomesafen (47.3 no. m^{-2}), although both were similar to ethalfluralin (29.7 no. m^{-2}). At 8 WAT, halosulfuron (30.2 no. m^{-2}) provided greatest nutsedge control compared to ethalfluralin (57.2 no. m^{-2}) and fomesafen (71.5 no. m^{-2}). Comparisons among individual treatments revealed differences (Table 9). At 4 WAT, halosulfuron applied post-crimp (2.8 no. m^{-2}) provided lowest nutsedge density. However, nutsedge control was similar to halosulfuron applied pre-crimp (6.4 no. m^{-2}), the nontreated (9.0 no. m^{-2}), and ethalfluralin applied pre-crimp (11.9 no. m^{-2}). At 6 WAT the same trend was recorded. Halosulfuron applied post-crimp (14.8 no. m^{-2}), halosulfuron applied pre-crimp (18.7 no. m^{-2}), and the nontreated (17.2 no. m^{-2}) provided lowest nutsedge density. Control in the aforementioned treatments was similar to ethalfluralin applied pre-crimp (24.9 no. m^{-2}), fomesafen applied pre-crimp (31.5 no. m^{-2}), and ethalfluralin applied post-crimp (34.5 no. m^{-2}). Trends held true at 8 WAT. Halosulfuron applied post-crimp (20.3 no. m^{-2}) provided the lowest nutsedge density. However, nutsedge control was similar in the nontreated (23.0 no. m^{-2}), halosulfuron applied pre-crimp (40.1 no. m^{-2}), ethalfluralin applied post-crimp (41.5 no. m^{-2}), fomesafen applied pre-crimp (61.3 no. m^{-2}), and ethalfluralin applied pre-crimp (73.0 no. m^{-2}).

Watermelon yield and melon count. Watermelon yield and melon count were not influenced by either herbicide or application timing (Table 10). Comparisons among individual treatments revealed no significant differences (Table 10).

Implications for control. The primary goal of this research was to determine if applying a preemergence herbicide pre-crimp in a rye cover crop system would increase preemergence weed control compared to traditional post-crimp applied herbicides. The results of this trial revealed that application timing had no effect on yield. Although pre-crimp applied treatments reduced total weed coverage at most rating dates at PBU, data were inconsistent at both locations. This could be due differences in weed population at both locations. These results are similar to that of previous research done on different cover crop management techniques and preemergence herbicide combinations in peanuts (Dobrow, Jr. et. al. 2011). Palmer amaranth-free days increased when applying flumioxazin with the cover crop still standing, however Palmer amaranth-free days were similar to flumioxazin applied after the rolling and crimping the cover crop. Other preemergence herbicides applied alone demonstrated no differences in Palmer amaranth-free days whether they were applied with no cover crop, cover crop rolled, or cover crop left standing.

Although adequate preemergence weed control has been achieved in cucurbit crops on multiple occasions with ethalfluralin, fomesafen, and halosufluron (Brandenberger et al. 2005; Peachey et al. 2012; Walters et al. 2005; Walters et al. 2007; Walters et al. 2008), these herbicides were often contained in tank-mixes that provided the greatest weed control. This study isolated these herbicides, which is not desirable for any preemergence weed control program. Tank-mixes provide longer residual control of problematic weeds and mitigate herbicide resistance by incorporating multiple modes of action.

Herbicide application method should be evaluated to resolve some of the issues that were observed. When applying the pre-crimp treatments, the spray pattern was disturbed by the stems of the cereal rye cover crop, resulting in non-uniform spray coverage. A possibility for future research is strip tilling the cover crop before planting. This will provide a clean seedbed, resulting in greater seedling vigor for direct-seeded watermelons. In the strip tilled area the preemergence herbicide would obtain better soil contact with the possibility of greater weed control. Although this research isolated single preemergence herbicides for weed control, it is desirable to have multiple modes of action to control a broader spectrum of weeds. Future research should evaluate preemergence herbicide tank-mixes used in conjunction with a cover crop as well as measuring herbicide concentration in the soil solution when applied with a cover crop.

Literature Cited

Barnes JP, and Putnam AR (1987) Role of benzoxazinones in allelopathy by rye (*Secale cereale* L.). J Chem Ecol 13:889-906

Brandenberger LP, Shrefler JW, Webber III CL, Talber RE, Payton ME, Wells LK, and McClelland M (2005) Preemergence weed control in direct seeded watermelon. Weed Tech 19:706-712

Boyhan GE, Granberry DM, and Kelly WT (2014) Commercial watermelon production. UGA Extension Bulletin 996. Univ. of GA, Athens, GA

Buker III RS, Stall WM, Olson SM and Schilling DG (2003) Season long interference of yellow nutsedge (*Cyperus esculentus*) with direct-seeded and transplanted watermelon (*Citrullus lanatus*). Weed Tech 17:751-754

Chandler JM, Hamel AS, and Thomas AG (1984) Crop losses due to weeds in Canada and the United States. Presentation at the Weed Science Society of America meeting, Champaign, Ill.

Dobrow Jr. MH, Ferrell JA, Faircloth WH, MacDonald GE, Brecke BJ, and Erickson JE (2011) Effect of cover crop management and preemergence herbicides on the control of ALS-resistant palmer amaranth in peanut. Peanut Sci 38:73-77

Gilreath JP and Santos BM (2004) Efficacy of methyl bromide alternatives on purple nutsedge (*Cyperus rotundus*) control in tomato and pepper. Weed Technol 18:341-345

Locke, M.A. and C.T. Bryson. 1997. Herbicide-soil interactions in reduced tillage and plant residue management systems. Weed Sci. 45:307-320.

Monday TA, Lawrence DA, Foshee III WG, Wehtje GR, and Gilliam CH (2015) Pre and post herbicides in combinations with a rye cover crop for control of yellow nutsedge and pigweed in watermelon. International Journal of Vegetable Science 21:264-271

Monks DW and Schultheis JR (1998) Critical weed-free period for large crabgrass (*Digitaria sanguinalis*) in transplanted watermelon (*Citrullus lanatus*). Weed Sci 46:530-532

Mwaja VN, Masiunas JB, and Weston LA (1995) Effects of fertility on biomass, phytotoxicity, and allelochemical content of cereal rye. J Chem Ecol 21:81-96

Reeves DW, Price AJ, and Patterson MG (2005) Evaluation of three winter cereals for weed control in conservation-tillage nontransgenic cotton. Weed Tech 19:731-736

Teasdale JR and Mohler CL (1993) Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. Agron J 85:673-680

Teasdale JR (1996) Contribution of cover crops to weed management in sustainable agriculture systems. J Prod Agric 9:431-479

Teasdale JR, Shelton DR, Sadeghi AM, and Isensee AR (2003) Influence of hairy vetch residue on atrazine and metolachlor soil solution concentration and weed emergence. Weed Sci 51:628-634

Terry ER, Stall WM, Shilling DG, Bewick TA and Kostewicz SR (1997) Smooth Amaranth (*Amaranthus hybridus* L.) interference with watermelon (*Citrullus lanatus* L.) and muskmelon (*Cucumis melo* L.) production. Hortic Sci 32:620-632

Walters AS, Nolte SA, and Young BG (2005) Influence of winter rye and preemergence herbicides on weed control in no-tillage zucchini squash production. HortTech 15(2):238-243

Walters AS, Young BG, and Nolte SA (2007) Cover crop and preemergence herbicide combinations in no-tillage fresh market cucumber production. J Sust Agric 30(3):5-19

Walters AS, Young BG and Krausz RF (2008) Influence of tillage, cover crop, and preemergence herbicides on weed control and pumpkin yield. International Journal of Vegetable Science 14(2):148-161

Webster TM, Simmons DB, Culpepper AS, Grey TL, Bridges DC, and Scully BT (2016) Factors affecting potential for Palmer amaranth (*Amaranthus palmeri)* suppression by winter rye in Georgia, USA. Field Crop Res 192:103-109

Table 1. Total weed coverage as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Old Agronomy Farm in Auburn, AL. Data for 2016 and 2017 are pooled.

Treatment			Total weed coverage			
Timing[a]	Herbicide	Rate	2 WAT[b]	4 WAT	6 WAT	8 WAT
Comparisons among main effects:						
		g ai ha^{-1}	%			
Pre-crimp			1.4 ns[b]	3.4 ns	7.0 ns	12.6 ns
Post-crimp			1.0	3.1	6.2	8.1
	Ethalfluralin	1470	1.6 ns	4.3 a[c]	8.8 a	13.7 a
	Fomesafen	180	1.1	2.5 b	5.1 b	9.3 b
	Halosulfuron	39	0.9	3.0 ab	5.8 b	8.1 b
Comparisons among individual treatments:						
Pre-crimp	Ethalfluralin	1470	1.4 ns	4.1 ns	9.3 ab	17.8 ab
	Fomesafen	180	1.6	3.1	6.1 ab	13.2 abc
	Halosulfuron	39	1.1	3.0	5.5 b	6.8 bc
Post-crimp	Ethalfluralin	1470	1.7	4.5	8.4 ab	9.6 abc
	Fomesafen	180	0.5	1.9	4.1 b	5.4 c
	Halosulfuron	39	0.8	2.9	6.1 ab	9.3 abc
-	Nontreated	-	1.5	4.9	12.5 a	19.8 a

[a] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[b] Abbreviations: WAT = weeks after treatment; ns = not significant

[c] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

Table 2. Broadleaf weed density[a] as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Old Agronomy Farm in Auburn, AL. Data for 2016 and 2017 are pooled.

Treatment			Broadleaf weed density			
Timing[b]	Herbicide	Rate	2 WAT[c]	4 WAT	6 WAT	8 WAT
Comparisons among main effects:						
		g ai ha^{-1}	no. m^{-2}			
Pre-crimp			0.8 ns[c]	1.4 ns	3.1 a	2.5 ns
Post-crimp			0.5	2.3	2.4 b	2.2
	Ethalfluralin	1470	1.0 ns	2.8 a	3.3 ns	2.8 ns
	Fomesafen	180	0.4	1.0 b	2.1	2.0
	Halosulfuron	39	0.4	1.9 ab	2.9	2.4
Comparisons among individual treatments:						
Pre-crimp	Ethalfluralin	1470	1.1 ns	2.0 ab	3.8 ns	2.8 ns
	Fomesafen	180	0.5	0.9 b	2.3	2.4
	Halosulfuron	39	0.8	1.4 ab	3.1	2.3
Post-crimp	Ethalfluralin	1470	1.0	3.6 a	2.8	2.8
	Fomesafen	180	0.3	1.0 b	1.8	1.5
	Halosulfuron	39	0.1	2.4 ab	2.6	2.4
-	Nontreated	-	1.0	2.5 ab	2.5	3.0

[a] Broadleaf weed species present at this site included: *Amaranthus* spp., *Ipomea* spp., and *Senna obtusifolia* .

[b] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[c] Abbreviations: WAT = weeks after treatment; ns = not significant

[d] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

Table 3. Grass weed density[a] as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Old Agronomy Farm in Auburn, AL. Data for 2016 and 2017 are pooled.

Treatment			Grass weed density			
Timing[b]	Herbicide	Rate	2 WAT[c]	4 WAT	6 WAT	8 WAT
Comparisons among main effects:						
		g ai ha^{-1}	------------------------------%	------------------------------		
Pre-crimp			0.1 ns[c]	0.3 b[d]	0.9 ns	1.4 ns
Post-crimp			0.3	0.8 a	0.9	1.5
	Ethalfluralin	1470	0.3 ns	0.5 ns	1.0 ns	1.6 ns
	Fomesafen	180	0.1	0.3	0.6	1.0
	Halosulfuron	39	0.3	0.7	1.1	1.7
Comparisons among individual treatments:						
Pre-crimp	Ethalfluralin	1470	0.1 ns	0.1 ns	0.9 b	1.5 ns
	Fomesafen	180	0.1	0.3	0.6 b	1.0
	Halosulfuron	39	0.2	0.6	1.3 ab	1.7
Post-crimp	Ethalfluralin	1470	0.5	1.0	1.1 ab	1.7
	Fomesafen	180	0.1	0.5	0.5 b	1.0
	Halosulfuron	39	0.4	0.9	1.0 ab	1.7
-	Nontreated	-	0.4	1.1	2.0 a	2.2

[a] Grass weed species present at this site included: *Cynodon dactylon*, *Digitaria* spp., *Eleusine indica* and *Urochloa platyphylla*.

[b] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[c] Abbreviations: WAT = weeks after treatment; ns = not significant

[d] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

Table 4. Nutsedge[a] density as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Old Agronomy Farm in Auburn, AL. Data for 2016 and 2017 are pooled.

Treatment			Nutsedge weed density		
Timing[b]	Herbicide	Rate	4 WAT	6 WAT	8 WAT
Comparisons among main effects:					
		g ai ha^{-1}	no. m^{-2}		
Pre-crimp			10.8 ns[c]	27.2 ns	33.2 ns
Post-crimp			7.5	21.5	33.7
	Ethalfluralin	1470	14.5 a[d]	32.9 ns	53.0 a
	Fomesafen	180	8.6 ab	18.2	22.3 b
	Halosulfuron	39	4.3 b	23.6	31.6 ab
Comparisons among individual treatments:					
Pre-crimp	Ethalfluralin	1470	16.4 a	36.0 a	50.3 a
	Fomesafen	180	11.6 ab	27.2 ab	29.3 ab
	Halosulfuron	39	4.3 b	18.8 ab	22.6 ab
Post-crimp	Ethalfluralin	1470	12.7 ab	30.0 ab	55.7 a
	Fomesafen	180	5.6 b	10.9 b	15.1 b
	Halosulfuron	39	4.3 b	27.2 ab	40.7 ab
-	Nontreated	-	17.6 a	41.6 a	57.1 a

[a]Nutsedge species present at this site included: *Cyperus esculentus* and *Cyperus rotundus*.

[b] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[c]Abbreviations: WAT = weeks after treatment; ns = not significant

[d] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

Table 5. Watermelon yield as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Old Agronomy Farm in Auburn, AL. Data for 2016 and 2017 are pooled.

Treatment			Watermelon yield		
Timing[a]	Herbicide	Rate	Count	Weight	Yield increase[d]
Comparisons among main effects:					
		g ai ha^{-1}	no.	kg ha^{-1}	%
Pre-crimp			8.6 ns[b]	12020 ns	68.7
Post-crimp			9.9	10050	41.2
	Ethalfluralin	1470	6.0 b[c]	8800 b	23.6
	Fomesafen	180	11.7 a	17330 a	143.4
	Halosulfuron	39	10.1 a	6980 b	-2.1
Comparisons among individual treatments:					
Pre-crimp	Ethalfluralin	1470	6.0 bc	11940 a	67.7
	Fomesafen	180	10.5 ab	16500 a	131.7
	Halosulfuron	39	9.4 abc	7610 b	6.8
Post-crimp	Ethalfluralin	1470	6.0 bc	5660 b	-20.5
	Fomesafen	180	12.9 a	18160 a	155.1
	Halosulfuron	39	10.8 ab	6340 b	-10.9
-	Nontreated	-	5.4 c	7120 b	-

[a] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[b] Abbreviations: WAT = weeks after treatment; ns = not significant

[c] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

[d] Yield increase compared to the nontreated. Negative values indicate a decrease in yield.

Table 6. Total weed coverage as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Plant Breeding Unit in Tallassee, AL. Data for 2016 and 2017 are pooled.

Treatment			Total weed coverage			
Timing[a]	Herbicide	Rate	2 WAT[b]	4 WAT	6 WAT	8 WAT
Comparisons among main effects:						
		g ai ha^{-1}	——————————————%——————————————			
Pre-crimp			0.9 b	1.8 b	3.9 b	14.1 ns
Post-crimp			1.8 a	2.3 a	8.8 a	14.0
	Ethalfluralin	1470	1.7 a	2.3 ns	5.0 ns	15.5 ns
	Fomesafen	180	1.7 a	2.5	9.3	17.3
	Halosulfuron	39	0.7 b	1.3	4.7	12.2
Comparisons among individual treatments:						
Pre-crimp	Ethalfluralin	1470	1.0 ns	2.4 ns	4.5 b	19.9 ns
	Fomesafen	180	1.3	2.0	3.1 b	12.9
	Halosulfuron	39	0.5	1.1	4.1 b	9.4
Post-crimp	Ethalfluralin	1470	2.3	2.3	5.5 ab	11.6
	Fomesafen	180	2.1	3.1	15.4 a	15.5
	Halosulfuron	39	0.9	1.4	5.4 ab	15.0
-	Nontreated	-	2.1	2.8	7.9 ab	20.1

[a] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[b] Abbreviations: WAT = weeks after treatment; ns = not significant

[c] Means followed by the same letter do not differ according to the Shaffer-Simulated test ($\alpha = 0.10$).

Table 7. Broadleaf weed density[a] as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Plant Breeding Unit in Tallassee, AL. Data for 2016 and 2017 are pooled.

Treatment			Broadleaf weed density			
Timing[b]	Herbicide	Rate	2 WAT[c]	4 WAT	6 WAT	8 WAT
Comparisons among main effects:						
		g ai ha^{-1}	no. m^{-2}			
Pre-crimp			0.1 ns	0.5 ns	0.9 ns	4.4 a
Post-crimp			0.2	0.4	0.8	2.1 b
	Ethalfluralin	1470	0.3 ns	0.5 ns	1.2 ns	4.2 a
	Fomesafen	180	0.2	0.3	0.7	1.4 b
	Halosulfuron	39	0.0	0.5	0.5	4.1 a
Comparisons among individual treatments:						
Pre-crimp	Ethalfluralin	1470	0.3 ns	0.5 ns	1.0 ns	3.9 a
	Fomesafen	180	0.1	0.3	1.0	2.5 ab
	Halosulfuron	39	0.0	0.8	0.6	6.8 a
Post-crimp	Ethalfluralin	1470	0.4	0.5	1.5	4.5 a
	Fomesafen	180	0.3	0.4	0.5	0.4 b
	Halosulfuron	39	0.0	0.3	0.5	1.5 ab
-	Nontreated	-	0.5	0.6	0.7	2.5 ab

[a] Broadleaf weed species present at this site included: *Amaranthus palmerii* ; *Ipomea* spp., and *Senna obtusifolia* .

[b] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[c] Abbreviations: WAT = weeks after treatment; ns = not significant

[d] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

Table 8. Grass weed density[a] as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Plant Breeding Unit in Tallassee, AL. Data for 2016 and 2017 are pooled.

Treatment			Grass weed density			
Timing[b]	Herbicide	Rate	2 WAT[c]	4 WAT	6 WAT	8 WAT
Comparisons among main effects:						
		g ai ha^{-1}	----------------	---------------- %	----------------	----------------
Pre-crimp			0.2 ns	0.8 ns	2.0 ns	8.4 a
Post-crimp			0.3	0.7	1.9	5.8 b
	Ethalfluralin	1470	0.5 ns	0.8 ns	2.0 ns	8.3 a
	Fomesafen	180	0.1	0.6	1.8	3.1 b
	Halosulfuron	39	0.2	0.7	2.1	9.8 a
Comparisons among individual treatments:						
Pre-crimp	Ethalfluralin	1470	0.5 ns	0.9 ns	1.8 ns	12.5 ab
	Fomesafen	180	0.1	0.9	2.1	4.5 bc
	Halosulfuron	39	0.1	0.6	2.1	8.2 ab
Post-crimp	Ethalfluralin	1470	0.5	0.8	2.1	4.2 bc
	Fomesafen	180	0.1	0.3	1.5	1.7 c
	Halosulfuron	39	0.3	0.9	2.2	11.5 ab
-	Nontreated	-	0.5	1.3	2.6	15.0 a

[a] Grass weed species present at this site included: *Digitaria* spp., *Eleusine indica* and *Urochloa platyphylla* .

[b] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[c] Abbreviations: WAT = weeks after treatment; ns = not significant

[d] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

Table 9. Nutsedge[a] density as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Plant Breeding Unit in Tallassee, AL. Data for 2016 and 2017 are pooled.

Treatment			Nutsedge weed density		
Timing[b]	Herbicide	Rate	4 WAT[c]	6 WAT	8 WAT
Comparisons among main effects:					
		g ai ha^{-1}	no. m^{-2}		
Pre-crimp			11.1 ns[c]	25.0 ns	58.1 ns
Post-crimp			18.5	37.5	47.8
	Ethalfluralin	1470	14.8 a[d]	29.7 ab	57.2 a
	Fomesafen	180	25.1 a	47.3 a	71.5 a
	Halosulfuron	39	4.6 b	16.7 b	30.2 b
Comparisons among individual treatments:					
Pre-crimp	Ethalfluralin	1470	11.9 abc	24.9 ab	73.0 ab
	Fomesafen	180	15.1 ab	31.5 ab	61.3 ab
	Halosulfuron	39	6.4 bc	18.7 b	40.1 ab
Post-crimp	Ethalfluralin	1470	17.6 ab	34.5 ab	41.5 ab
	Fomesafen	180	35.1 a	63.1 a	81.7 a
	Halosulfuron	39	2.8 c	14.8 b	20.3 b
-	Nontreated	-	9.0 abc	17.2 b	23.0 ab

[a] Nutsedge species measured included: *Cyperus esculentus* and *Cyperus rotundus*.

[b] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[c] Abbreviations: WAT = weeks after treatment; ns = not significant

[d] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

Table 10. Watermelon yield as influenced by herbicide and application timing in watermelon planted into a rye cover crop at the Plant Breeding Unit in Tallassee, AL. Data for 2016 and 2017 are pooled.

Treatment			Watermelon yield		
Timing[a]	Herbicide	Rate	Count	Weight	Yield increase[d]
Comparisons among main effects:					
		g ai ha^{-1}	no.	kg ha^{-1}	%
Pre-crimp			13.4 ns	11073 ns	23.2
Post-crimp			10.3	9331	3.8
	Ethalfluralin	1470	12.6 ns	10224 ns	13.7
	Fomesafen	180	12.4	10191	13.4
	Halosulfuron	39	10.5	10192	13.3
Comparisons among individual treatments:					
Pre-crimp	Ethalfluralin	1470	12.8 ns	10471 ns	16.5
	Fomesafen	180	13.8	11632	29.4
	Halosulfuron	39	13.6	11116	23.6
Post-crimp	Ethalfluralin	1470	12.4	9976	11.0
	Fomesafen	180	11.1	8751	-2.6
	Halosulfuron	39	7.5	9267	3.1
-	Nontreated	-	11.3	8987	-

[a] Timing: Pre-crimp = herbicide treatments were applied either prior to rolling and crimping the rye cover crop; Post-crimp = herbicide treatments were applied after rolling and crimping the rye cover crop.

[b] Abbreviations: WAT = weeks after treatment; ns = not significant

[c] Means followed by the same letter do not differ according to the Shaffer-Simulated test (α = 0.10).

[d] Yield increase compared to the nontreated. Negative values indicate a decrease in yield.

Chapter III

Final Discussion

Cover crops are a vital to the implementation of a conservation tillage system. They provide many benefits, one of which is early season weed control. However, research has shown that weed control is improved when the use of a cover crop is combined with a preemergence herbicide. This provides residual weed control well into the season, depending on the herbicide. Although cover crops provide many benefits, research has demonstrated that they can interfere with the efficacy of preemergence herbicides. This elicits a need for a more effective herbicide application method when implementing a cover crop system. Preliminary research has shown that applying certain preemergence herbicides while the cover crop is still standing can provide greater weed control, inevitably leading to greater yield. Adequate preemergence weed control is extremely important to vegetable production due to the limited number of postemergence herbicides labeled in vegetable crops. Therefore, the need exists to research ways to extend preemergence weed control to reach critical weed free periods and maximize yields in vegetables.

In chapter II, field studies were conducted to evaluate preemergence herbicides applied pre- and post-crimp for broadleaf weed control in watermelons. The trial consisted of an augmented factorial arrangement with 3 levels of preemergence herbicides and two levels of application timings. Application timings were pre-crimp (applied prior to crimping and rolling of the cover crop) and post-crimp (applied after crimping and rolling of the cover crop). Preemergence herbicide options were ethalfluralin (1,470 g ai·ha^{-1}), fomesafen (180 g ai·ha^{-1}), and halosulfuron (39 g ai·ha^{-1}). A nontreated cover crop only treatment was also included yielding a total of 7 treatments. In this study, it was revealed that application timing had no effect on weed control, and ultimately yield. This could be due to many factors. One potential issue is that when applying the pre-crimp treatments, the spray pattern was disturbed due to the cereal rye stems, resulting in non-uniform spray coverage. Further research should be conducted to evaluate more effective application methods. Although application timing had no effect on yield, herbicide alone did. At the Old Agronomy Farm in Auburn, AL, it was demonstrated that both ethalfluralin and fomesafen increased yield compared to the nontreated control. While at PBU in Tallassee, AL, all three herbicides provided similar yield increases.

Results from this study suggest that further research should be conducted. Application methods should be evaluated to determine if there is a more effective way for the herbicide to reach the soil surface and limit sorption to the cover crop residue. Although this study focused on single preemergence herbicides, studies should be conducted using preemergence herbicide tank-mixes. This is desirable for multiple reasons: one, to control a broader weed spectrum, and two, to prevent herbicide resistance. Along with this, it would be beneficial to research preemergence weed control in vegetables using strip tillage in a cover crop system. This would expose the soil where the crop will be planted, meaning that the herbicide could potentially have better control due to increased soil contact. Additionally, it leaves the cover crop mulch between the rows, providing early season broadleaf weed control. When these studies are conducted, herbicide concentration in the soil solution should be measured to determine if the cover crop is intercepting the herbicide before it reaches the soil surface, thus reducing its efficacy.