Evaluation of Pine Bark Mulch-Herbicide Combinations for Weed Control in Nursery Containers

by

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Abstract

Weed control is a continuing challenge for greenhouse, field, and container nursery growers across the United States. Weed control techniques in container grown ornamentals include hand pulling, herbicide applications, and utilizing mulches. The practices each bring a unique challenge including labor costs associated with hand pulling, herbicide non-target loss, herbicide resistant weeds, and improper calibration of sprayers and spreaders.

Research has shown that wood-based mulches can successfully control weeds both with and without addition of preemergence herbicides (Bartley et al., 2014). The research presented addresses the effects of utilizing mulches in combination with preemergence herbicides. By identifying preemergence herbicides that work effectively with pine bark mini-nugget mulch, growers may be able to increase weed control effectiveness and longevity in container grown nursery stock. The research presented also addresses the effect of preemergence herbicide application timing to pine bark-based mulches on weed control. The objective of this research is to evaluate the weed control efficacy of three preemergence herbicides, formulations of those herbicides, and herbicide application timing in conjunction with 5 cm (2 in.) of a commercially available pine bark mini-nugget mulch for control on long stalk phyllanthus (*Phyllanthus tenellus*), spotted spurge (*Chamaesyce maculata*), or eclipta (*Eclipta prostrata*).

On 14 May, all containers were treated with the appropriate herbicide recommended label rate either below or above 5 cm (2 in.) of a pine bark mini-nugget mulch (Hood Landscaping Products, Adel, GA). Liquid herbicide treatments included dimethenamid-P (Tower®; BASF Corp., Research Triangle Park, NC) + pendimethalin (Pendulum® Aquacap™; BASF, Corp.) (1.7 kg/ha, 12.2 kg/ha) (1.5 lbs ai/A, 3.3 lbs ai/A), indaziflam (Marengo® SC, Bayer Crop Science, Research Triangle Park, NC) (0.08 kg/ha) (0.07 lbs ai/A), and flumioxazin (SureGuard®; Valent Corp., Walnut Creek, CA) (0.43 kg/ha) (0.38 lbs ai/A) and were applied using a CO_2 pressure backpack sprayer at 30 gallons per acre. Granular herbicide treatments also included dimethenamid-P + pendimethalin (Freehand®; BASF, Corp.) (1.7 kg/ha, 2.2 kg/ha) (1.5 lbs ai/A, 2lbs ai/A), indaziflam (Marengo® G, Bayer Crop Science) (0.08 kg/ha) (0.07 lbs ai/A), and flumioxazin (Broadstar™; Valent, Corp.) (0.42 kg/ha) (0.38 lbs ai/A) and were applied using a handheld shaker.

For all three weed species, weed count and fresh weight means were not different when any herbicide was treated below or above an application of mulch. Generally, shoot fresh weight and weed count were similar between all herbicide-mulch combinations and mulch alone containers. For most fresh weights and weed counts of different placements or herbicides linear or quadratic trends increase up to 30-60 DAT then steadily declined at 90, 120, and 150 DAT. This is thought to be caused by shortened day length and the continuing depletion of available controlled released fertilizer throughout the year. Indaziflam, liquid or granular, and liquid flumioxazin consistently provided smaller shoot fresh weight and weed count that either formulation of flumioxazin.

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First off I would like to thank my major professor, Dr. Charles Gilliam, for allowing me to work for him the last two years. I'd also like to thank my committee members Dr. Adam Newby, Dr. Glenn Wehtje, and Dr. Christopher Marble for all their time and commitment to my research. The entire horticulture department has supported me in my academic efforts and I could not be more grateful for my time at Auburn.

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I would never have gotten to where I am today without the Marine Corp. It made me the man I am today. I'd also like to thank my best friend and fellow marine Evan Beaule for reminding me that no matter how difficult grad school got, we have made it through worse.

For God, Country, and the Corp—War Eagle!

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CHAPTER I

Introduction and Literature Review

Weed control is a continuing challenge for greenhouse, field, and container nursery growers across the United States. Weed control techniques in container grown ornamentals include hand pulling, herbicide applications, and utilizing mulches. Research has shown that weeds can suppress plant growth in containers, which increases the length of time from planting to an acceptable selling size (Berchillie-Robertson et al., 1990). Most growers apply 2-3 herbicide applications a year, and some growers also use expensive labor for hand pulling (Gilliam et al., 1990). Herbicide and labor costs for controlling weeds are a significant cost to growers (Mathers, 2003). Research has shown that wood-based mulches can successfully control weeds both with and without addition of preemergence herbicides (Bartley et al., 2014). The research presented addresses the effects of utilizing mulches in combination with preemergence herbicides. By identifying preemergence herbicides that work effectively with pine bark mini-nugget mulch, growers may be able to increase weed control effectiveness and longevity in container grown nursery stock. The research presented also addresses the effect of preemergence herbicide application timing to pine bark-based mulches on weed control.

Common Control Practices

Some literature before 1900 mentions the use of mechanical devices and inorganic herbicides used for weed control (Timmons, 2005). Research on inorganic chemicals as herbicides began in Europe in the 1890's and continued to increase until the 1940's. Research into biological and mechanical control of weeds continued to grow during this same time as well. However, weed control has changed significantly since the 1970's with the introduction of new herbicides, identification of herbicide resistant weeds, the introduction of herbicide resistant crops, and changes in federal laws (Appleby, 2005). By 1996, there were over 140 herbicides registered for weed control across all crops (Case et al., 2005). However, this number is greatly reduced for the ornamental industry because of the wide variety of plants grown and the limited resources that are available to test the safety on all species. Herbicides used in ornamental plant nurseries must cause little to no phytotoxcity to the ornamental crop and be highly active on the target weed.

A weed can be any plant that is growing where it is not wanted (Mathers, 2003). Even though weed management problems and practices vary by nursery producing regions (Derr, 1994), to a nursery grower, a weed is any vegetation that competes for nutrients, light and/or water, interferes with harvesting, and marketability (Mathers, 2003). By competing for nutrients and water, some weed species can inhibit plant growth in containers with only a single weed per container (Berchielle-Robertson et al., 1990). Research has shown that one eclipta in a container can reduce crop shoot growth by 43% (Berchielle-Robertson et al., 1990).

Weed control is not specifically restricted to herbicide use, and many growers utilize both herbicide and hand pulling. Nurseries in the 1990's reported that annual labor costs for hand pulling weeds ranged from $246 – 567/acre (Gilliam et al., 1990). That was when hourly wages for the nurseries ranged from $3.53 – 3.97/hr. (Gilliam et al., 1990). Many years later, in 2003, nurseries estimated that they were spending $500-4000/acre (Mathers, 2003). That number is based on an hourly wage of $14.75, which is over a 200% increase in the cost over 13 years. Nurseries reported that the top weed species that are not controlled with preemergence herbicides were prostrate spurge (*Chamaesyce maculata*) (24%), oxalis (*Oxalis* spp.) (22%), nutsedge (*Cyperus* spp.) (18%), and eclipta (*Eclipta prostrata*) (13%) (Gilliam et al., 1990). Nurserymen also reported that the hardest weed species to control are nutsedge (27%), prostrate spurge (23%), oxalis (16%), and eclipta (12%) (Gilliam et al., 1990). Problem species are not limited just to these few listed above. Liverwort has become a problem in southeastern nurseries as well, and herbicide treatments have been successful in research trials (Newby et al., 2007). Eclipta and spurge have been controlled when using a combination of a single preemergence herbicide and organic mulches (Bartley et al., 2014). Growers are typically making three preemergence herbicide applications per year but are still having to utilize hand pulling for some harder to control weed species (Gilliam et al., 1990). Improper calibration, herbicide runoff, and multiple applications per year are several problems that are associated with herbicide use in container production (Mathers, 2003). Another issue is that many nurseries still utilize granular formulations even though research has suggested that liquid formulations are more effective (Wehtje et al., 2015). Gilliam et al. (1992) concluded that jamming 2.8 L (3 qt.) containers greatly reduced non-target loss when applying granular herbicides. Non-target herbicide loss was only 27%-30% for jammed containers, but when spacing was increased to 20 cm (8 in.) and 30 cm (12 in.), loss increased to 54%-55% and 79%-80%, respectively. Reducing herbicide runoff and non-target loss can be obtained by selecting herbicides that bind more tightly to organic matter, jamming containers during application, and staggering applications throughout the year (Gilliam et al., 1993).

As concern over the financial and environmental sustainability of pesticide use has increased, much research has been placed on finding ways to reduce herbicide use without sacrificing plant quality that consumers expect (Mathers, 2003). Field grown plants are often grown for several years, and container grown plants can spend 1 to 3 years in the same container before being moved into a larger container or sold (Derr, 1994). Therefore, a long-term solution to weed control is fundamental. Organic mulches offer another long-term weed control option.

Organic Mulches

Any material that is placed on the soil surface is considered a mulch (Crutchfield et al., 1986). Mulch type and availability vary between regions based on what resources are available (Marble, 2015). Mulches provide many benefits to crops including erosion control, water conservation, reduced temperature fluctuations, increase in soil organic matter, and weed suppression (Crutchfield et al., 1986). Some of these benefits, such as erosion control, are only realized in field nursery or landscape situations; however, most of the benefits mulch provides are application to container grown plants as well. Common mulch materials that are used for weed control include yard trimmings, straw, leaves, paper, plastic, films, and gravel (Marble, 2015). More recently waste materials have been used including tree barks, newspaper pellets, coconut coir, nut hulls, wood shavings, and seashells (Marble, 2015). Spurge germination can be suppressed with only 2.5 cm (1 in.) of recycled newspaper pellets 30 days after treatment (DAT) with seed sown either below or above the mulch (Smith et al., 1998). Some of these mulch materials have also been proven to work well as carriers for herbicides (Samtani et al., 2007). Rice hulls, landscape leaf-waste pellets, and pine bark that were impregnated with herbicides provided acceptable weed control 120 DAT. Several different wood mulch species (privet, sweetgum, cedar, pine, and pine bark) have been shown to provide weed control (Bartley et al., 2014). Two inches of a pine bark mini nugget mulch has been used to provide long-term weed control on spotted spurge, phyllanthus (*Phyllanthus tenellus*), and eclipta (Bartley et al., 2014), but mulching alone will not control all weeds, and as an organic mulch degrades it can become a growing medium for weeds (Derr, 1994).

Physical impedance and light exclusion are two factors that influence weed control efficacy of mulch. (Teasdale and Mohler, 2000). Pine bark mulches are also hydrophobic and dry quickly after rainfall/irrigation, which reduces water availability and hinders weed growth/germination (Richardson et al., 2008). When Tower® (dimethenamid-P; BASF Corp. Research Triangle Park, NC) preemergence herbicide was used in conjunction with mulch, it neither increased nor decreased weed control for 60 days after application (DAT) (Bartley et al., 2014). This could be due to the fact that herbicides behave differently when applied to different soil types and organic materials, with some being bound more tightly thus reducing herbicide longevity (Marble, 2015), or because of the half-life of the herbicide used. The residual effects of preemergence herbicides can be lengthened by simply increasing the rate at which the herbicide is applied (Derr, 1994). However, increased herbicide rates can also increase crop phytotoxicity, runoff, and non-target losses (Derr, 1994). Over-the-top (OTT) applications of preemergence herbicides have been shown to reduce shoot dry weights of spirea (*Spirea japonica* 'Little Princess') and root dry weight of roses (*Rosa* × *hybrid* 'Carefree Beauty') (Mathers and Case, 2010), but effects on crop growth vary between species. Herbicide treated mulches can also be utilized to increase weed control and reduce crop phytotoxicity when compared to OTT applications (Mathers and Case, 2010). Herbicide treated mulches moreover can reduce herbicide leaching, volatility, and degradation in container media which could in turn decrease environmental impacts and costs for the nursery (Mathers and Case, 2010).

Utilizing mulches as a weed control method may help with the control of herbicide resistant weeds and help to reduce the additional number of resistant weed species. One of the first herbicide resistant weed occurrences was recorded in common groundsel in 1968 (Ryan, 1970). This resistance was found at a nursery that only sprayed two applications of either simazine or atrazine per year. Results from this study proved that herbicide rotation is vital in lessening the possibility for resistance. Over the next several years, the amount of weed species developing herbicide resistance increased dramatically (Shaner, 2013). Forty-one cases of herbicide resistance were recorded in 1980, and that number drastically increased to 191 in 1995. However, it appears that many of the resistant weeds were most prevalent in major crops such as corn, wheat, and cotton. Weeds can adapt to new herbicides and exhibit herbicide resistance in a short period of time. Within 5 years after introduction, resistance had already been reported for aceytle CoA carboxylase (ACCase) and acetolactate synthase (ALS) inhibitors. One possible way to decrease the number of herbicide resistant weeds and the rate at which weeds become resistant is through diverse weed management practices such as the utilization of mulches either alone or in combination with preemergence herbicides (Shaner, 2013).

Organic Mulches Utilized in Landscaping

There is little research establishing the best time to apply herbicides in conjunction with mulch (before or after mulch addition) in nursery containers or the effects of herbicide application before or after the mulch is applied. Research suggests that efficient weed control can be obtained when using high mulch depths, but the interaction between mulch type and herbicide type becomes pronounced as mulch depth decreases (Marble, 2015). Landscape crews who utilize preemergence herbicides are typically applying a preemergence herbicide before laying mulch in landscape beds (Marble, 2015). This method provides a longer-term weed control and helps control a broader spectrum of weed species (Marble, 2015), but it is unclear if this technique will provide similar results in nursery containers. This technique is often used because it helps to reduce labor costs associated with hand pulling and also helps to reduce the application of postemergence herbicides later in the growing season (Marble, 2015). Billeaud and Zajicek (1989) concluded that organic mulches at a depth of 15 cm (6 in) provided excellent weed control in landscape beds. Conversely, nitrogen content was depleted whether mulching at 5, 10, or 15 cm (2, 4, or 6 in.), and soil pH was lower when using certain tree-derived mulches. Thus, there is a possibility that nitrogen content and pH levels could be affected in the soilless substrates used in container production. It is unclear if an increase in mulch depth, which provides excellent weed control, will have any long-term effects on crop health (Billeaud and Zajicek, 1989), and the outcome may vary from species to species.

The objective of this research is to evaluate the weed control efficacy of three preemergence herbicides, formulations of those herbicides, and herbicide application timing in conjunction with 5 cm (2 in.) of a commercially available pine bark mini-nugget mulch.

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CHAPTER II

Pine bark Mulch-Herbicide Combinations

Abstract

Weed control is a continuing challenge for greenhouse, field, and container nursery growers across the United States. Weed control techniques in container grown ornamentals include hand pulling, herbicide applications, and utilizing mulches. The practices each bring a unique challenge including labor costs associated with hand pulling, herbicide non-target loss, herbicide resistant weeds, and improper calibration of sprayers and spreaders.

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application timing in conjunction with 5 cm (2 in.) of a commercially available pine bark mini-nugget mulch for control on long stalk phyllanthus (*Phyllanthus tenellus*), spotted spurge (*Chamaesyce maculata*), or eclipta (*Eclipta prostrata*).

On 14 May, all containers were treated with the appropriate herbicide recommended label rate either below or above 5 cm (2 in.) of a pine bark mini-nugget mulch (Hood Landscaping Products, Adel, GA). Liquid herbicide treatments included dimethenamid-P (Tower®; BASF Corp., Research Triangle Park, NC) + pendimethalin (Pendulum® Aquacap™; BASF, Corp.) (1.7 kg/ha, 12.2 kg/ha) (1.5 lbs ai/A, 3.3 lbs ai/A), indaziflam (Marengo® SC, Bayer Crop Science, Research Triangle Park, NC) (0.08 kg/ha) (0.07 lbs ai/A), and flumioxazin (SureGuard®; Valent Corp., Walnut Creek, CA) (0.43 kg/ha) (0.38 lbs ai/A) and were applied using a CO_2 pressure backpack sprayer at 30 gallons per acre. Granular herbicide treatments also included dimethenamid-P + pendimethalin (Freehand®; BASF, Corp.) (1.7 kg/ha, 2.2 kg/ha) (1.5 lbs ai/A, 2lbs ai/A), indaziflam (Marengo® G, Bayer Crop Science) (0.08 kg/ha) (0.07 lbs ai/A), and flumioxazin (Broadstar™; Valent, Corp.) (0.42 kg/ha) (0.38 lbs ai/A) and were applied using a handheld shaker.

For all three weed species, weed count and fresh weight means were not different when any herbicide was treated below or above an application of mulch. Generally, shoot fresh weight and weed count were similar between all herbicide-mulch combinations and mulch alone containers. For most fresh weights and weed counts of different placements or herbicides linear or quadratic trends increase up to 30-60 DAT then steadily declined at 90, 120, and 150 DAT. This is thought to be caused by shortened day length and the continuing depletion of available controlled released fertilizer throughout the year. Indaziflam, liquid or granular, and liquid flumioxazin consistently provided smaller shoot fresh weight and weed count that either formulation of flumioxazin.

Introduction

All facets of the ornamental plant production industry whether it be field, container, or greenhouse production must strive and adapt to ever-changing weed control issues. The methods that are used have changed dramatically from the 1900's to present day (Appleby, 2005; Timmons, 2005). Vast amounts of research have been conducted to test what herbicides work best, as well as identifying alternative methods to control weeds (Bartley et al., 2014, Crutchfield et al., 1986, Mathers and Case, 2010, Richardson et al., 2008, Wehtje et al. 2015, Yang et al. 2012).

A weed can be any plant that is growing where it is not wanted (Mathers, 2003). Even though weed management problems and practices vary by nursery producing regions (Derr, 1994), to a nursery grower, a weed is any vegetation that competes for nutrients, light and/or water, interferes with harvesting, and marketability (Mathers, 2003). By competing for nutrients and water, some weed species can inhibit plant growth in containers with only a single weed per container (Berchielle-Robertson et al., 1990). Research has shown that one eclipta in a container can reduce crop shoot growth by 43% (Berchielle-Robertson et al., 1990).

Typically, producers will try to alleviate these detrimental effects on plants by utilizing herbicides, hand pulling, mulches, or some combination of these methods.

Weed control is not specifically restricted to herbicide use, and many growers utilize both herbicide and hand pulling. Nurseries in the 1990's reported that annual labor costs for hand pulling weeds ranged from $246 – 567/acre (Gilliam et al., 1990). That was when hourly wages for the nurseries ranged from $3.53 – 3.97/hr. (Gilliam et al., 1990). Many years later, in 2003, nurseries estimated that they were spending $500-4000/acre (Mathers, 2003). That number is based on an hourly wage of $14.75, which is over a 200% increase in the cost over 13 years.

Any material that is placed on the soil surface is considered a mulch (Crutchfield et al., 1986). Mulch type and availability vary between regions based on what resources are available (Marble, 2015). Mulches provide many benefits to crops including erosion control, water conservation, reduced temperature fluctuations, increase in soil organic matter, and weed suppression (Crutchfield et al., 1986). Common mulch materials that are used for weed control include yard trimmings, straw, leaves, paper, plastic, films, and gravel (Marble, 2015). More recently waste materials have been used including tree barks, newspaper pellets, coconut coir, nut hulls, wood shavings, and seashells (Marble, 2015). Physical impedance and light exclusion are two factors that influence weed control efficacy of mulch. (Teasdale and Mohler, 2000). Pine bark mulches are also hydrophobic and dry quickly after rainfall/irrigation, which reduces water availability and hinders weed growth/germination (Richardson et al., 2008). Several different wood mulch species (privet, sweetgum, cedar, pine, and pine bark) have been shown to provide weed control (Bartley et al., 2014). Two inches of a pine bark mini nugget mulch has been used to provide long-term weed control on spotted spurge, phyllanthus (*Phyllanthus tenellus*), and eclipta (Bartley et al., 2014), but mulching alone will not control all weeds, and as an organic mulch degrades it can become a growing medium for weeds (Derr, 1994).

There is little research establishing the best time to apply herbicides in conjunction with mulch (before or after mulch addition) in nursery containers or the effects of herbicide application before or after the mulch is applied. Research suggests that efficient weed control can be obtained when using high mulch depths, but the interaction between mulch type and herbicide type becomes pronounced as mulch depth decreases (Marble, 2015). Landscape crews who utilize preemergence herbicides are typically applying a preemergence herbicide before laying mulch in landscape beds (Marble, 2015). This method provides a longer-term weed control and helps control a broader spectrum of weed species (Marble, 2015), but it is unclear if this technique will provide similar results in nursery containers. This technique is often used because it helps to reduce labor costs associated with hand pulling and also helps to reduce the application of postemergence herbicides later in the growing season (Marble, 2015).

The objective of this research was to evaluate the weed control effect of three preemergence herbicide chemicals, formulations of those herbicides, and herbicide application timing in conjunction with 5 cm (2 in.) of a commercially available pine bark mini-nugget mulch.

Materials and Methods

On 12 May 2015, 360 11.4 L (3 gal.) #3 nursery containers were filled with a 6:1 (v:v) pine bark:sand substrate amended per cubic yard with 2.3 kg (5 lbs.) dolomitic lime, 6.4 kg (14 lbs.) of Polyon 18-6-12 (Pursell Technologies, Sylacauga, AL) and 0.7 kg (1.5 lbs.) MicroMax (Scotts Co., Maryville, OH). Containers were filled 5 cm (2 in.) from the top of the container to allow an application of 5 cm (2 in.) of pine bark mini-nugget mulch. Containers were then placed onto a black weed fabric pad at the Paterson greenhouse complex on the Auburn University campus. All twenty treatments were then organized according to the preemergence herbicide chemical and formulation to be applied. One inch (2.5 cm) of overhead irrigation was applied to settle the substrate. On 13 May, twenty-five long stalk phyllanthus (*Phyllanthus tenellus*), spotted spurge (*Chamaesyce maculata*), or eclipta (*Eclipta prostrata*) seed were distributed onto the substrate surface of 120 containers per weed species. Two inches (5 cm) of a pine bark mini nugget mulch (Hood Landscaping Products, Adel, GA) was then applied to the treatments that would have preemergence herbicide applied over the top of the mulch and the control treatment that received mulch but no herbicide. On 14 May, all containers were treated with the appropriate herbicide recommended label rate. Liquid herbicide treatments included dimethenamid-P (Tower®; BASF Corp., Research Triangle Park, NC) + pendimethalin (Pendulum® Aquacap™; BASF, Corp.) (1.7 kg/ha, 12.2 kg/ha) (1.5 lbs ai/A, 3.3 lbs ai/A), indaziflam (Marengo® SC, Bayer Crop Science, Research Triangle Park, NC) (0.08 kg/ha) (0.07 lbs ai/A), and flumioxazin (SureGuard®; Valent Corp., Walnut Creek, CA) (0.43 kg/ha) (0.38 lbs ai/A) and were applied using a CO_2 pressure backpack sprayer at 30 gallons per acre. Granular herbicide treatments included dimethenamid-P + pendimethalin (Freehand®; BASF, Corp.) (1.7 kg/ha, 2.2 kg/ha) (1.5 lbs ai/A, 2lbs ai/A), indaziflam (Marengo® G, Bayer Crop Science) (0.08 kg/ha) (0.07 lbs ai/A), and flumioxazin (Broadstar™; Valent, Corp.) (0.42 kg/ha) (0.38 lbs ai/A) and were applied using a handheld shaker. One inch (2.5 cm) of overhead irrigation was than applied to all treatments. Treatments were arranged in a randomized complete block design with six blocks and one replication per treatment per block for a total of 120 containers per weed species. Fourteen days after treatment (DAT), weeds were counted on all treatments to confirm adequate germination. Final weed counts and shoot fresh weights were taken 30 and 60 DAT for spotted spurge and long stalk phyllanthus once weeds had flowered and were close to seed dispersal. Eclipta weed count and shoot fresh weight was recorded 30 DAT. Weeds were harvested by clipping at the substrate level. Due to no germination, all eclipta containers were emptied and the project was restarted on 27 July and treated on 28 July following the aforementioned procedures. After each harvest, all treatments were treated with paraquat dichloride (Gramoxone Inteon®, Syngenta Crop Protection, Inc., Greensboro, NC) (13.4 kg/ha) (12 lbs ai/A) to kill any remaining weeds. Twenty-five additional weed seeds of the appropriate species were then over seeded on top of the mulch or substrate after an application of paraquat. Germination counts were recorded 14 days after over seeding, and final weed counts and shoot fresh weights were taken 30 days after over seeding.

Above procedures were repeated on 10 May 2016. Weed number and shoot fresh weight was recorded 30, 60, 90, 120, and 150 DAT.

An analysis of variance was performed on all responses using PROC GLIMMIX in SAS version 9.4 (SAS Institute, Cary, NC). The Gaussian probability distribution was used with all responses. The experimental design was a randomized complete block design with data recording date treated as repeated measures using a heterogeneous covariance structure. Experiment year and block was included in the model as random variables. The treatment design was a 3-way augmented factorial of herbicide by herbicide placement by data recording date. For the significant 2-way interactions, least squares means comparisons among herbicides and among herbicide placements simple effects were tested. Comparisons between the mulch, no herbicide or no mulch, no herbicide treatments and the remaining treatments were also tested. Linear and quadratic trends over data recording date were tested using orthogonal polynomials. All comparisons were adjusted for multiplicity using the simulated method and significances were at a family-wise error rate of $\alpha = 0.05$.

Results and Discussion

Year was included as a random variable, therefore data from the 2015 and 2016 experiments are combined.

Eclipta shoot fresh weight and weed count were significantly affected by the 2-way interactions of herbicide by herbicide placement ($p<0.0001$) and herbicide placement by data recording date ($p<0.0001$). In containers treated with either formulation of dimethenamid-P+pendimethalin there were similarly low weed shoot fresh weights and weed counts when treated either before or after the pine bark mini nugget mulch (Table 2.1). Eclipta weed counts were greater in containers treated with liquid or granular dimethenamid-P+pendimethalin or granular flumioxazin alone than in conjunction with mulch. However, weed number was similar for both formulations of indaziflam and liquid flumioxazin. Significantly higher shoot fresh weight and weed counts occurred in dimethenamid-P+pendimethalin treatments without mulch. There were no differences in shoot fresh weight or weed count between liquid or granular indaziflam or liquid flumioxazin treated before, after, or in the herbicide only treatments. There were no differences in shoot fresh weight or weed count among all six herbicides regardless of placement before or after mulching. However, liquid or granular indaziflam and liquid flumioxazin yielded lower shoot fresh weights than both formulations of dimethenamid-P+pendimethalin and the granular formulation of flumioxazin when no mulch was applied.

Both herbicide+mulch combinations had a similar shoot fresh weight 30 DAT, but at 60, 90, and 120 DAT containers treated with herbicide alone had a higher shoot fresh weight (Table 2.2). Weed counts were also higher when applying herbicide alone 30, 90, and 120 DAT. There were also quadratic trends among fresh weights for herbicide only and no mulch/no herbicide treatments with weed weight increasing up to 60 DAT but then decreasing 90, 120, and 150 DAT. There were linear trends among weed counts in herbicide only treatments with weed count increasing over time, and there was a quadratic trend in no mulch/no herbicide treatments with weed count increasing with data recording date to 120 DAT and decreasing by 150 DAT.

Phyllanthus shoot fresh weight was significantly affected by herbicide placement by time interaction ($p<0.0001$) and herbicide by data recording date ($p<0.0146$). Before and after treated mulches, herbicide only, and mulch only treatments all had smaller shoot fresh weights than no mulch/no herbicide treatments up to 120 DAT (Table 2.3). Herbicide only treatments had greater shoot fresh weights 120 DAT than below mulch, above mulch, or mulch only containers, and at 150 DAT there were no differences between all five herbicide placements. Quadratic trends were observed for herbicide only and no mulch/ no herbicide treatments with an increase in shoot fresh weight up to 60 DAT and then a steady decline at 90, 120, and 150 DAT. All herbicide placement treatments had similar shoot fresh weights 150 DAT.

Herbicide by herbicide placement ($p<0.0156$), herbicide by data recording date ($p<0.0001$), and herbicide placement by data recording date ($p<0.0001$) interactions significantly affected phyllanthus weed count . Below or above treated mulched containers as well as herbicide only containers had a significant linear increase in weed count from 30 to 150 DAT (Table 2.3). No herbicide/no mulch containers showed a quadratic trend with weed number decreasing 60 DAT. At 30, 60, 90, and 120 DAT no mulch/no herbicide containers had a greater weed counts than all other containers, but at 150 DAT mulch only and no mulch/no herbicide containers had similar weed counts. Total number of weeds was greater for containers treated with liquid dimethenamid-P+pendimethalin alone than below treated mulches (Table 2.4). Yet there were no differences in weed counts between all other remaining herbicides whether treated below or above the mulch or with the herbicide alone. Dimethenamid-P+pendimethalin performed worst at reducing shoot fresh weight than all other herbicides 120 DAT (Table 2.5).

Dimethenamid-P+pendimethalin in either form and granular flumioxazin had a linear increase in weed count from 30 to 150 DAT (Table 2.5). By 150 DAT, liquid indaziflam and flumioxazin had fewer weeds than either formulation of dimethenamid-P+pendimathalin. No mulch/no herbicide containers had a significant quadratic trend with weed count increasing from 30 DAT but then decreasing at 60, 90, 120, and 150 DAT. Over time, all herbicides had similar weed counts when compared to no herbicide containers up to 60 DAT. At 150 DAT liquid dimethenamid-P+pendimethalin had similar weed numbers with no herbicide containers.

Spurge shoot fresh weight was affected by the interaction of herbicide placement by data recording date ($p<0.0001$) (Table 2.6). No mulch/no herbicide treatment means were all significantly higher for shoot fresh weight than all other herbicide placements from 30 to 150 DAT. Also, herbicide placements below or above mulch, herbicide only, and mulch only treatments all had similar shoot fresh weight means 30, 60, 90, 120, and 150 DAT. The only quadratic trend was in the no herbicide/no mulch treatments where shoot fresh weight decreased rapidly between 30 and 120 DAT, but decreased less rapidly between 120 and 150 DAT.

Herbicide by herbicide placement ($p<0.0001$), herbicide by data recording date ($p<0.034$), and herbicide placement by data recording date ($p<0.0001$) significantly affected spurge weed count. Over date recording dates, herbicide placement below or above mulch and mulch only treatments showed no linear or quadratic trends on weed count from 30 to 150 DAT (Table 2.6). Herbicide alone had a linear trend and weed count increased up to 90 DAT then declining. No herbicide/no mulch had a significant linear trend as weed count decreased with data recording date. Herbicide placement below or above mulch, herbicide only, or mulch only had fewer weeds when compared to the no herbicide/no mulch containers across all data recording dates.

Liquid or granular applied dimethenamid-P+pendimethalin applied either below or above mulch contained fewer weeds than herbicide only with means of 0.23, 0.17, and 2.23 respectively (Table 2.7). Indaziflam, granular or liquid, and liquid flumioxazin resulted in similar weed count when used with or without mulch. Herbicide placement, above or below, did not have an effect on weed count regardless of the herbicide used. When herbicides were applied alone, formulation of the same chemical did not result in different weed counts. Either formulation of indaziflam and liquid flumioxazin provided better weed control and a reduced number of weeds then either formulation of dimethenamid-P+pendimethalin.

These results are similar to those of Bartley et al. where 5cm (2 in) of pine bark mini nugget mulch provided excellent weed control on spotted spurge, eclipta, and phyllanthus (2014). In the experiments described here, applying preemergence herbicides before an application of mulch did not improve weed control over mulch alone as reported by landscapers using this practice (Marble, 2015). Formulation of the same chemical yielded similar shoot fresh weight and weed count which is not consistent with other research that found liquid applied preemergence herbicides to be more effective than granular formulations (Wehtje, 2015).

Based on the results from this study, there does not seem to be any added benefit to using a combination of a preemergence herbicide and pine bark mini nugget mulch when using any of the herbicides listed. Three of the preemergence herbicides consistently performed equally as well as mulch alone or when applied with mulch. Although mulch alone provides excellent weed control, its application is more time consuming than herbicide applications. Thus, mulch application in place of herbicide application will usually result in higher costs. Applying preemergence herbicides is probably the most cost-effective weed control method for container sizes up to #15. Mulching may be as or more cost-effective for containers larger than #15 as crops in containers that size usually stay in that container for long periods of time, and the long term weed control potential of mulch would prevent the need for multiple herbicide applications.

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Table 2.1 Effect of herbicide by herbicide placement on shoot fresh weight[z] and weed count[y] of eclipta. Data combined from experiments treated on 28 July 2015 and 10 May 2016 and across all data recording dates.

		Herbicide Placement									
		Before[x]	After[w]	Herb. Only	Mulch Only[v]	No mulch/herb.	Before	After	Herb. Only	Mulch Only	No mulch/herb.
Herbicide (Chemical Name)	Herbicide (Trade Name)	Shoot Fresh Weight					Weed Count				
Dimethenamid-P+Pendimethalin (Liquid)	Tower® + Pendulum® Aquacap™ [u]	0nsB*[o,n]	0nsB*	52.11abA***			0nsB*	0nsB*	1.97aA***		
Dimethenamid-P+Pendimethalin (Granular)	Freehand® [t]	0B*	0.56B*	69.60aA***			0B*	0.17B*	1.72abA***		
Indaziflam (Liquid)	Marengo® SC [s]	0NS*	0*	0.06c*			0NS*	0*	0d*		
Indaziflam (Granular)	Marengo® G [r]	0NS*	0*	0.05c*			0NS*	0*	0.03d*		
Flumioxazin (Liquid)	SureGuard® [q]	0NS*	0*	4.66c*			0B*	0B*	0.73cdA*		
Flumioxazin (Granular)	Broadstar™ [p]	0NS*	0*	31.94b*			0B*	0B*	1.13bcA***		
No herbicide	No herbicide				0.01B	254.59A				0.03B	3.02A

[z]Shoot fresh weight = grams per container.

[y]Weed count = number of weeds per container.

[x]Herbicide applied before 2 in (5.0 cm) of pine bark mini nugget mulch applied.

[w]2.0 in (5.0 cm) of pine bark mini nugget mulch applied before herbicide.

[v]2.0 in (5.0 cm) of pine bark mini nugget mulch applied alone.

[u]Tower® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}); Pendulum® Aquacap™ applied at 3.3 lb aia (3.7 aia (1.7 kg ai • ha^{-1}).

[t]Freehand® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}) for Dimethanimid-P and 2.0 lb aia (2.2 kg ai • ha^{-1}).

[s]Marengo® SC applied at 0.07 lb aia (0.08 kg ai • ha^{-1}).

[r]Marengo® G applied at 0.07 lb aia (0.08 kg ai • ha^{-1}).

[q]SureGuard® applied at 0.38 lb aia (0.43 kg ai • ha^{-1}).

[p]Broadstar® applied at 0.38 lb aia (0.43 kg ai • ha^{-1}).

[o]Least squares means comparisons in columns (lower case letters) and rows (upper case letters) using the simulated method at $P < 0.05$. NS and ns = not significant.

[n]Least squares means comparisons of no mulch/herbicide (*) or mulch only (**) to the remaining treatments using the simulated method at $P < 0.05$.

Table 2.2 Effect of herbicide placement by time on shoot fresh weight[z] and weed count[y] of eclipta. Data combined from experiments treated on 28 July 2015 and 10 May 2016.

	Shoot Fresh Weight						Weed Count					
Placement	30 DAT[u]	60 DAT	90 DAT	120 DAT	150 DAT	Sign.[s]	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	Sign.
Below[x]	0b[t]	0c	0c	0c	0b	NS	0c	0c	0c	0c	0c	NS
Above[w]	0b	0c	0c	0.06c	0.4b	NS	0c	0c	0c	0.03c	0.11c	NS
Herb. Only	5.7b	54.07b	47.64b	15.34b	9.26b	Q***	0.33b	0.50c	0.67b	1.39b	1.78ab	L***
Mulch Only[v]	0b	0c	0c	0c	0.67b	NS	0c	0c	0c	0c	0.17bc	NS
No Mulch/Herb	230.00a	639.73a	255.12a	92.28a	57.86a	Q***	1.74a	3.00a	3.33a	4.17a	2.83a	Q**

[z]Shoot fresh weight= grams per container.

[y]Weed count= # of weeds per container.

[x]Herbicide applied before 2 in (5.0 cm) of pine bark mini nugget mulch applied.

[w]2.0 in (5.0 cm) of pine bark mini nugget mulch applied before herbicide.

[v]2.0 in (5.0 cm) of pine bark mini nugget mulch applied alone.

[u]DAT= Days after treatment.

[t]Least squares means comparisons in columns using the simulated method at $P < 0.05$. NS and ns = not significant.

[s]Not significant (NS) or significant (Sign.) linear (L) or quadratic (Q) trends using orthogonal contrasts at $P < 0.01$ (**) or 0.001 (***).

Table 2.3 Effect of herbicide placement by time on shoot fresh weight[z] and weed count[y] of phyllanthus. Data combined from experiments treated on 12 May 2015 and 10 May 2016.

	Shoot Fresh Weight						Weed Count					
Placement	30 DAT[u]	60 DAT	90 DAT	120 DAT	150 DAT	Sign.[s]	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	Sign.
Below[x]	0b[t]	0b	1.09b	2.20c	1.14ns	NS	0b	0b	0.11c	0.48b	1.04b	L**
Above[w]	0b	0b	0.58b	1.35c	2.56	NS	0b	0b	0.06c	0.26b	1.04b	L**
Herb. Only	0b	0.44b	18.57b	7.16b	1.98	NS	0b	0.08b	0.65b	0.87b	1.07b	L***
Mulch Only[v]	0b	3.56b	6.50b	5.05bc	6.73	NS	0b	0.08b	0.25bc	0.62b	1.46ab	NS
No Mulch/Herb	143.22a	188.68a	187.66a	40.7a	7.4	Q***	12.68a	10.25a	3.50a	4.62a	3.46a	Q***

[z]Shoot fresh weight= grams per container.

[y]Weed count= # of weeds per container.

[x]Herbicide applied before 2 in (5.0 cm) of pine bark mini nugget mulch applied.

[w]2.0 in (5.0 cm) of pine bark mini nugget mulch applied before herbicide.

[v]2.0 in (5.0 cm) of pine bark mini nugget mulch applied alone.

[u]DAT= Days after treatment.

[t]Least squares means comparisons in columns using the simulated method at P < 0.05. NS and ns = not significant.

[s]Not significant (NS) or significant (Sign.) linear (L) or quadratic (Q) trends using orthogonal contrasts at P < 0.05 (*), 0.01 (**) or 0.001 (***).

Table 2.4 Effect of herbicide by herbicide placement on weed count[z] of phyllanthus. Data combined from experiments treated on 12 May 2015 and 10 May 2016 and across all data recording dates.

		Herbicide Placement				
Herbicide (Chemical Name)	Herbicide (Trade Name)	Before[y]	After[x]	Herb. Only	Mulch Only[w]	No mulch/herb.
Dimethenamid-P+Pendimethalin (Liquid)	Tower® + Pendulum® Aquacap™ [v]	0.16nsB*[p,o]	0.57nsB*	1.43aA*		
Dimethenamid-P+Pendimethalin (Granular)	Freehand® [u]	1.03NS*	1.00*	1.4a*		
Indaziflam (Liquid)	Marengo® SC [t]	0NS*	0*	0b*		
Indaziflam (Granular)	Marengo® G [s]	0.27NS*	0*	0b*		
Flumioxazin (Liquid)	SureGuard® [r]	0.07NS*	0*	0b*		
Flumioxazin (Granular)	Broadstar™ [q]	0.63NS*	0.23*	0.57ab*		
No herbicide	No herbicide				0.57	7.43

[z]Weed count= # of weeds per container.

[y]Herbicide applied before 2 in (5.0 cm) of pine bark mini nugget mulch applied.

[x]2.0 in (5.0 cm) of pine bark mini nugget mulch applied before herbicide.

[w]2.0 in (5.0 cm) of pine bark mini nugget mulch applied alone.

[v]Tower® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}); Pendulum® Aquacap™ applied at 3.3 lb aia (3.7 aia (1.7 kg ai • ha^{-1}).

[u]Freehand® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}) for Dimethanimid-P and 2.0 lb aia (2.2 kg ai • ha^{-1}).

[t]Marengo® SC applied at 0.07 lb aia (0.08 kg ai • ha^{-1}).

[s]Marengo® G applied at 0.07 lb aia (0.08 kg ai • ha-1).

[r]SureGuard® applied at 0.38 lb aia (0.43 kg ai • ha-1).

[q]Broadstar® applied at 0.38 lb aia (0.43 kg ai • ha-1).

[p]Least squares means comparisons in columns (lower case letters) and rows (upper case) using the simulated method at $P < 0.05$. NS and ns = not significant.

[o]Least squares means comparisons of no mulch/herbicide (*) or mulch only (**) to the remaining treatments using the simulated method at $P < 0.05$.

Table 2.5 Effect of herbicide by time on shoot fresh weight[z] weed count[y] of phyllanthus. Data combined from experiments treated on 12 May 2015 and 10 May 2016.

Herbicide	Herbicide (Trade Name)	Shoot Fresh Weight					
		30 DAT[r]	60 DAT	90 DAT	120 DAT	150 DAT	Sign.[p]
Dimethenamid-P+Pendimethalin (Liquid)	Tower® + Pendulum® Aquacap™ [x]	0b[q]	0.03b	12.41b	5.09c	16.21ns	NS
Dimethenamid-P+Pendimethalin (Granular)	Freehand® [w]	0b	0.86b	19.67b	13.07b	3.6	NS
Indaziflam (Liquid)	Marengo® SC [v]	0b	0b	0b	0c	0	NS
Indaziflam (Granular)	Marengo® G [u]	0b	0b	0b	0.06c	0.11	NS
Flumioxazin (Liquid)	SureGuard® [t]	0b	0b	0b	0c	0.51	NS
Flumioxazin (Granular)	Broadstar™ [s]	0b	0b	8.42b	3.19c	2.97	NS
No herbicide	No herbicide	72.94a	96.13a	97.08a	22.88a	7.07	Q***

Herbicide	Herbicide (Trade Name)	Weed Count					
		30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	Sign.
Dimethenamid-P+Pendimethalin (Liquid)	Tower® + Pendulum® Aquacap™	0b	0b	0.39bc	0.73b	2.73a	L***
Dimethenamid-P+Pendimethalin (Granular)	Freehand®	0b	0b	1.06b	1.73b	2.51a	L***
Indaziflam (Liquid)	Marengo® SC	0b	0b	0c	0b	0b	NS
Indaziflam (Granular)	Marengo® G	0b	0b	0.06c	0.06b	0.22ab	NS
Flumioxazin (Liquid)	SureGuard®	0b	0b	0c	0b	0.07b	NS
Flumioxazin (Granular)	Broadstar™	0b	0b	0.19c	0.79b	1.29ab	L**
No herbicide	No herbicide	6.34a	5.17a	2.04a	2.62a	2.46a	Q***

[z]Shoot fresh weight= grams per container.

[y]Weed count= # of weeds per container.

[x]Tower® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}); Pendulum® Aquacap™ applied at 3.3 lb aia (3.7 aia (1.7 kg ai • ha^{-1}).

[w]Freehand® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}) for Dimethanimid-P and 2.0 lb aia (2.2 kg ai • ha^{-1}).

[v]Marengo® SC applied at 0.07 lb aia (0.08 kg ai • ha^{-1}).

[u]Marengo® G applied at 0.07 lb aia (0.08 kg ai • ha-1).

[t]SureGuard® applied at 0.38 lb aia (0.43 kg ai • ha-1).

[s]Broadstar® applied at 0.38 lb aia (0.43 kg ai • ha-1).

[r]DAT= Days after treatment.

[q]Least squares means comparisons in columns using the simulated method at $P < 0.05$. NS and ns = not significant.

[p]Not significant (NS) or significant (Sign.) linear (L) or quadratic (Q) trends using orthogonal contrasts at $P < 0.05$ (*), 0.01 (**) or 0.001 (***).

Table 2.6 Effect of herbicide placement by time on shoot fresh weight[z] and weed count[y] of spotted spurge. Data combined from experiments treated on 12 May 2015 and 10 May 2016.

Placement	Shoot Fresh Weight						Weed Count					
	30 DAT[x]	60 DAT	90 DAT	120 DAT	150 DAT	Sign.[s]	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	Sign.
Below[w]	0b[t]	1.46b	3.86b	1.20b	1.49b	NS	0b	0.22b	0.67c	0.25b	0.36bc	NS
Above[v]	0b	0.03b	0.41b	0.50b	1.55b	NS	0b	0.01b	0.15c	0.22b	0.28c	NS
Herb. Only	1.86b	10.59b	19.67b	3.97b	3.78b	NS	0b	0.90b	2.25b	0.97b	1.47b	Q***
Mulch Only[u]	0b	2.02b	3.63b	0.32b	1.38b	NS	0b	0.17b	0.58c	0.75b	0.75bc	NS
No Mulch/Herb	522.66a	345.98a	122.68a	57.32a	42.90a	Q***	13.78a	12.50a	9.17a	8.09a	4.75a	L***

[z]Shoot fresh weight = grams per container.

[y]Weed count = # of weeds per container.

[x]DAT= Days after treatment.

[w]Herbicide applied before 2 in (5.0 cm) of pine bark mini nugget mulch applied.

[v]2.0 in (5.0 cm) of pine bark mini nugget mulch applied before herbicide.

[u]2.0 in (5.0 cm) of pine bark mini nugget mulch applied alone.

[t]Least squares means comparisons in columns (lower case letters) and rows (upper case letters) using the simulated method at $P < 0.05$.

[s]Not significant (NS) or significant (Sign.) linear (L) or quadratic (Q) trends using orthogonal contrasts at $P < 0.001$ (***).

Table 2.7 Effect of herbicide by herbicide placement on weed count[z] of spotted spurge. Data combined from experiments treated on 12 May 2015 and 10 May 2016 and across all data recording dates.

		Herbicide Placement				
Herbicide	Herbicide (Trade Name)	Before	After	Herb. Only	Mulch Only	No mulch/herb.
Dimethenamid-P+Pendimethalin (Liquid)	Tower® + Pendulum® Aquacap™ [y]	0.23nsB*[s,r]	0.17nsB*	2.23aA***		
Dimethenamid-P+Pendimethalin (Granular)	Freehand® [x]	0.28B*	0.08B*	1.97aA***		
Indaziflam (Liquid)	Marengo® SC [w]	0.03NS*	0.03*	0.03c***		
Indaziflam (Granular)	Marengo® G [v]	0.13NS*	0.03*	0.25c*		
Flumioxazin (Liquid)	SureGuard® [u]	0.28NS*	0.03*	0.72bc*		
Flumioxazin (Granular)	Broadstar™ [t]	0.83AB*	0.45B*	1.53abA*		
No herbicide	No herbicide				0.45B	9.66A

[z]Weed count= # of weeds per container.

[y]Tower® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}); Pendulum® Aquacap™ applied at 3.3 lb aia (3.7 aia (1.7 kg ai • ha^{-1}).

[x]Freehand® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}) for Dimethanimid-P and 2.0 lb aia (2.2 kg ai • ha^{-1}).

[w]Marengo® SC applied at 0.07 lb aia (0.08 kg ai • ha^{-1}).

[v]Marengo® G applied at 0.07 lb aia (0.08 kg ai • ha-1).

[u]SureGuard® applied at 0.38 lb aia (0.43 kg ai • ha-1).

[t]Broadstar® applied at 0.38 lb aia (0.43 kg ai • ha-1).

[s]Least squares means comparisons in columns (lower case letters) and rows (upper case) using the simulated method at $P < 0.05$. NS and ns = not significant.

[r]Least squares means comparisons of no mulch/herbicide (*) or mulch only (**) to the remaining treatments using the simulated method at $P < 0.05$.

Table 2.8 Effect of herbicide by time on weed count[z] of spurge. Data combined from experiments treated on 12 May 2015 and 10 May 2016.

		Weed Count					
Herbicide (Chemical Name)	Herbicide (Trade Name)	30 DAT[y]	60 DAT	90 DAT	120 DAT	150 DAT	Sign.[q]
Dimethenamid-P+Pendimethalin (Liquid)	Tower® + Pendulum® Aquacap™ [x]	0b[r]	0.67	1.67bc	0.75b	2.86ns	L*
Dimethenamid-P+Pendimethalin (Granular)	Freehand® [w]	0b	0.56b	1.50bc	0.81b	1.03	NS
Indaziflam (Liquid)	Marengo® SC [v]	0b	0b	0c	0.09b	0.09	NS
Indaziflam (Granular)	Marengo® G [u]	0.3b	0.03b	0.19bc	0.14b	0.31	NS
Flumioxazin (Liquid)	SureGuard® [t]	0b	0.36b	0.92bc	0.09b	0.36	NS
Flumioxazin (Granular)	Broadstar™ [s]	0b	0.67b	1.86b	1.03b	1.14	L*
No herbicide	No herbicide	6.89a	6.33a	4.88a	4.42a	2.75	Q***

[z]Weed count= # of weeds per container.

[y]DAT= Days after treatment.

[x]Tower® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}); Pendulum® Aquacap™ applied at 3.3 lb aia (3.7 aia (1.7 kg ai • ha^{-1}).

[w]Freehand® applied at 1.5 lb aia (1.7 kg ai • ha^{-1}) for Dimethanimid-P and 2.0 lb aia (2.2 kg ai • ha^{-1}).

[v]Marengo® SC applied at 0.07 lb aia (0.08 kg ai • ha^{-1}).

[u]Marengo® G applied at 0.07 lb aia (0.08 kg ai • ha^{-1}).

[t]SureGuard® applied at 0.38 lb aia (0.43 kg ai • ha^{-1}).

[s]Broadstar® applied at 0.38 lb aia (0.43 kg ai • ha^{-1}).

[r]Least squares means comparisons in columns (lower case letters) and rows (upper case) using the simulated method at $P < 0.05$. NS and ns = not

[q]Not significant (NS) or significant (Sign.) linear (L) or quadratic (Q) trends using orthogonal contrasts at $P < 0.05$ (*), 0.01 (**) or 0.001 (***).

CHAPTER III

Final Discussion

Weed control is a continuing challenge for greenhouse, field, and container nursery growers across the United States. Weed control techniques in container grown ornamentals include hand pulling, herbicide applications, and utilizing mulches. Each practice has unique disadvantages that include labor costs associated with hand pulling, herbicide non-target loss, herbicide resistant weeds, and improper calibration of sprayers and spreaders. By identifying preemergence herbicides that work effectively with pine bark mini-nugget mulch, growers may be able to increase weed control effectiveness and longevity in container grown nursery stock.

On 14 May, all containers were treated with the appropriate herbicide recommended label rate either below or above 5 cm (2 in.) of a pine bark mini-nugget mulch (Hood Landscaping Products, Adel, GA). Liquid herbicide treatments included dimethenamid-P (Tower®; BASF Corp., Research Triangle Park, NC) + pendimethalin (Pendulum® Aquacap™; BASF, Corp.) (1.7 kg/ha, 12.2 kg/ha) (1.5 lbs ai/A, 3.3 lbs ai/A), indaziflam (Marengo® SC, Bayer Crop Science, Research Triangle Park, NC) (0.08 kg/ha) (0.07 lbs ai/A), and flumioxazin (SureGuard®; Valent Corp., Walnut Creek, CA) (0.43 kg/ha) (0.38 lbs ai/A) and were applied using a CO_2 pressure backpack sprayer at 30 gallons per acre. Granular herbicide treatments also included dimethenamid-P + pendimethalin (Freehand®; BASF, Corp.) (1.7 kg/ha, 2.2 kg/ha) (1.5 lbs ai/A, 2lbs ai/A), indaziflam (Marengo® G, Bayer Crop Science) (0.08 kg/ha) (0.07 lbs ai/A), and flumioxazin (Broadstar™; Valent, Corp.) (0.42 kg/ha) (0.38 lbs ai/A) and were applied using a handheld shaker.

For all three weed species, weed count and fresh weight means were not different when any herbicide was treated below or above an application of mulch. Generally, shoot fresh weight and weed count were similar between all herbicide-mulch combinations and mulch only containers. Weed shoot fresh weights and weed counts generally started higher 30 to 60 DAT and then steadily declined at 90, 120, and 150 DAT. The decline at later data recording dates is thought to be caused by shortened day length and the continuing depletion of available controlled released fertilizer throughout the year. Indaziflam, liquid or granular, and liquid flumioxazin consistently provided smaller shoot fresh weight and weed count that either formulation of flumioxazin.

Based on the results from this study, there does not seem to be any added benefit to using a combination of a preemergence herbicide and pine bark mini nugget mulch when using any of the herbicides listed. Three of the preemergence herbicides consistently performed equally as well as mulch alone or when applied with mulch. Although mulch alone provides excellent weed control, its application is more time consuming than herbicide applications. Thus mulch application in place of herbicide application will usually result in higher costs. Applying preemergence herbicides is probably the most cost-effective weed control method for container sizes up to #15. Mulching may be as or more cost-effective for containers larger than #15 as crops in containers that size usually stay in that container for long periods of time, and the long term weed control potential of mulch would prevent the need for multiple herbicide applications.