IMPROVING PRODUCTION PRACTICES OF ALABAMA CHRISTMAS TREES

by

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Abstract

A series of trials were conducted to provide updated recommendations regarding cultural practices for fertility and weed control for Alabama Christmas tree growers. Three trials were conducted to determine the effects of nitrogen (N) rate on newly planted Leyland cypress (x *Cuprocyparis leylandii*). The rates of N differed between trials due to the production practices associated with collaborating farms. Two trials were also conducted to evaluate plant safety in response to four popular preemergent herbicides. In Trial 1 the high N rate, 135 kg N ha^{-1} in year 1 and 67 kg N ha^{-1} in year 2 ($135_{Y1}/67_{Y2}$) had 25% greater growth when compared to the $0_{Y1}/34_{Y2}$ kg N ha^{-1} rate; however, the $67_{Y1}/34_{Y2}$ rate was similar to both $135_{Y1}/67_{Y2}$ and $0_{Y1}/34_{Y2}$. In Trial 2 the lowest rate of N (90 kg N ha^{-1}) produced the greatest increase in plant height when compared to the medium (135 kg N ha^{-1}) and high rate (180 kg N ha^{-1}) representing an increase of 14% and 5%, respectively. Similar to Trial 2, Trial 3 did not show growth benefit when applying N over 90 kg N ha^{-1}, when compared to the low rate. Soil type likely impacted the utilization of N as Trial 1 was conducted on a sandy soil and Trials 2 and 3 took place in a location with a higher CEC. Trial 4 and 5 were conducted to evaluate plant safety in response to four preemergent herbicides on Leyland cypress and Green Giant Arborvitae (*Thuja plicata*) with over-the-top applications. These included *indaziflam*, *dimenthenamid-P*, *flumioxazin* and a combination product of *prodiamine* and *isoxaben* all of which were compared to an untreated control. Trial 4 evaluated rates of 1x and 2x the label rate for each product and Trial 5 focused on the amount of time before a rain/irrigation event (1 hr. and 24 hr. post treatment for each product). Very little damage and reduction in growth was seen across both trials. Rate was not significant in Trial 4 and irrigation delay was not significant in Trial 5. Generally, across both

studies, indaziflam had the greatest level of phytotoxicity and impact on growth; however, the damage was not extensive enough to be of horticultural significance.

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N	Nitrogen
WAT	Weeks after treatment
RCBD	Randomized complete block design

I. Literature Review

Section 1

Fertility of Leyland Cypress

Proper fertilization can improve tree growth, quality, and tree color. Applying the optimal fertilizer rate can reduce nutrient waste and environmental impacts (Galloway et al, 2017).

Rideout and Overstreet (2004) reported a wide range of fertility practices from a survey of North Carolina Christmas tree growers. The common species grown were Virginia pine (*Pinus virginiana*, Philip Miller), eastern white pine (*Pinus strobus*, L), red cedar (*Juniperus virginiana*, L.), and Leyland cypress (x *Cuprocyparis leylandii*). Rideout and Overstreet (2004) concluded that there was no standard fertility program among Christmas tree growers. Growers applied fertilizer based on broad soil sample recommendations or grower preferences. Of the 23 respondents, five growers reported not using any fertilizer on their trees (Rideout and Overstreet, 2004).

The 2017 Census of Ag reported Alabama having a moderate number of Christmas tree growers with 12 operations generating $636,000 in sales (USDA, 2017). There has been a surge of Christmas tree operations in the last several years. The current number of growers has increased nearly two fold to roughly 30 growers (Personal communication with Jeremy Pickens, 2020).

Currently, the predominant Christmas tree species grown in Alabama is Leyland cypress; however, for many years the industry standard was Virginia pine. While still produced, Virginia pine has lost its dominance to Leyland cypress. Growers began planting Leyland cypress in the early 1990s due to its fast growth, optimum shape, and the lack of major pest when compared to Virginia pine (Stegelin, 2006).

A common recommendation for Christmas tree N fertilization is to begin applying following the first year after transplant. A New Jersey Agriculture Experiment Station bulletin (Heckman and Vodak, 2012) reported that no N fertilization was needed for Christmas trees grown following a clover crop. If N fertilizer is desired to be applied, NJAES recommends rates of 7.09 to 14.17 g (0.25 to 0.5 ounces) N/tree for year 2 and 3 following transplant.

Nutrient recommendations published by the Soil, Forage, and Water Testing Laboratory at Auburn University for Alabama grown Christmas trees lists that N is not needed at planting the first year; however, after the first year up to 34 kg N ha^{-1} (30 lbs·A N) should be applied as needed to give desired growth (Mitchel and Huluka, 2012). Nutrient and lime rates associated with the Alabama recommendations are not segregated by species but instead suggests nutrient and lime recommendations for a broad range of Christmas tree species: Eastern red cedar (*Juniperus virginiana*), Virginia pine (*Pinus virginiana*), pines in general, Leyland cypress (x *Cuprocyparis leylandii*), and Arizona cypress (*Cupressus arizonica*)) (Mitchel and Huluka, 2012). The recommended low N rate in addition to pH recommendations of 5.0 to 5.5 are more conducive to recommendations associated with pine tree culture. The use of N on pines has been reported to provide little or no economic benefit in terms of growth response (Peer, 2015). Virginia pine has been shown to perform well in areas with poor soil quality due to its ability to mine nutrients efficiently even in low fertility sites (Moorhead, 1998). Considering the lack of N response among some pine species, it is possible that Alabama's recommendations for Christmas trees are based off of Virginia pine and multiple species were lumped together due to lack of research when recommendations were published.

North Carolina has lime and N recommendations specific for individual tree species (McKinley et al., 2019). North Carolina recommends N rates of 28.3 g (1 oz) of actual N per tree based on a 1.5 x 1.5 m (5 x 5 ft.) tree spacing for Leyland cypress, recommended as a split-application, broken up into two 14.2 g (0.5 oz) in the spring for the first two years of establishment and then following the third year into full maturity, 14.2 g (0.5 oz) in the spring and 14.2 g (0.5 oz) in the fall. Additionally, a soil pH of 6.0 is recommended for Leyland cypress (NCDACS, 2012).

Applying fertilizer is an added production expense in terms of materials but it is also labor intensive, as many growers apply fertilizer by hand on a per tree basis. Over fertilization can have environmental and economic repercussions, and has also been shown to reduce growth on some species, (Adkins, 2009; Wright and Hale, 1983). For many horticulture crops increased N usually results in an economic benefit associated with increased growth. Research on the benefits of N on Christmas trees has had varied results.

Research conducted on Leyland cypress in the landscape industry showed a response to high fertility levels. At 400 ppm N, increased growth was observed primarily in the second year of growth (Bilderback, 1985). A later study conducted in 2006 by Hinesley, examined the growth effects of fertilizer at various pH levels. In their containerized study, the units that received high fertility (2.4 kg/m^3-N) and high lime (2.28 g/kg-Lime) were 45% larger than the low treatments, (0.6 kg/m^3-N and 0.0 g/kg-Lime respectively). While a positive growth response to N fertilization was the response evaluated, studies have demonstrated that fall fertilized Leyland Cypress appeared to increase hardiness of the trees (Pellet and White 1969; DeHayes et al. 1989).

Other species such as firs (*Abies sp.*), which are grown in northern regions of the United States are very different in their fertility requirements when compared to Virginia pine. Research illustrated a positive response of firs to N fertilization that increased the growth rate among trees (Gessel and Walker, 1956). Not only has N fertilization shown to accelerate growth but fertilized trees have increased aesthetic qualities. Timing and level of treatment affected quality rates of trees (Turner, 1966). Furthermore, N trials with Douglas fir (*Pseudotsuga menziesii*) have shown a positive response to N fertilization, however this produced excessive growth. Varying levels of N treatments over a five-year period demonstrated no affect in leader growth or budding outcomes (Turner, 1966). An increase in bud frequency was only seen on the proximal portion of the leaders of the observed trees. Although there were no growth patterns in height amongst the different treatments, an increase in desirable color response was observed. Turner (1966) concluded that the major growth responses could be expected in the second year of growth following N applications.

In a study where various N rates were applied to field-grown shade trees, height and stem diameter were not affected by N rate or timing of application (Warren et al., 1993). Similarly, a study conducted with flowering dogwood (*Cornus florida L.*), N rates were evaluated for effects on growth and health of the trees. The study reported tree growth was not affected by the N treatments until year 3 and 4 (Hagan et al., 2008).

Studies have also shown positive effects of N fertilization. A more recent study on Frasier fir (*Abies fraseri*), evaluated varying N levels over a five-year period. Results reported no effect on growth responses in the distal portion of the trees but similar results in the proximal portion of the tree (Hinesley 2018) which was comparable to the study conducted on Douglas fir (Turner 1966). Overall, the N applications presented numerous responses that increased the retail value of the trees: increased fresh weight, length and surface area of needles, and overall appearance (Hinesley, 2018). In a study done on maples, when N fertilization was increased trunk diameter and shoot growth did not increase. On the contrary, the same study on dogwoods produced opposite results with trunk diameter and shoot growth increasing with increased nitrogen levels (Wright and Hale, 1983).

Research by Struve (2002) on fertilizer practices with shade tree production examined another important aspect of fertilizer practice. Not only is it important to consider the type of fertilizer and application method, but another important factor to investigate is timing of the application. When referring to timing it is important to consider current weather and season in which the application is being applied, and the growth cycle of the plants. For example, if the trees are dormant, pre-budbreak, budbreak, or post-budbreak. In Struve's study (2002), applying fertilizer after budbreak produced the most favorable results. Further research needs to be conducted to analyze potential responses among various tree species at different points of the growth cycle.

A common recommendation for Christmas trees seen throughout the literature is to not apply fertilizer until the second year after establishment. Day and Harris (2007) stated that the trees may not be responding due to insufficient fertilizer applied or due to the small, undeveloped root systems paired with the trees' physiological stage.

Our objective was to evaluate multiple N rates: 90, 135, and 180 kg N ha^{-1} (80, 120, and 160 lbs. /acre), on one-year old Leyland cypress Christmas trees utilizing a split application. Following the Alabama recommendations of no N the first year after transplant, we tested three N rates to look for any positive growth response in the first year of growth. Results were intended to generate fertilizer recommendations for Leyland cypress Christmas trees in Alabama.

Section 2

Herbicide Practices of Leyland Cypress

Christmas tree farms may benefit by maintaining weed-free areas within rows. Weeds can hinder tree growth at many points in the growth cycle. Various methods exist for weed control: mechanical mowing, mulching, herbicides, cover crops, and cultivation. Some utilize biological control through various insects or wild animals for grazing. While mowing and herbicide use are the most common methods of weed control for growers of tree crops, herbicides can result in unwanted damage to plants and repeated application of the same herbicide can create resistant weeds (Saha et al., 2020). Proper vegetation management around Leyland cypress has been shown to improve tree growth (Nesmith and Lindstrom, 1996). In addition to Christmas trees, the benefits of vegetation management has been seen by enhancing production in orchards, landscapes and tree nurseries (Atkinson et al., 1979; Neely 1984; Robbins and Boyd, 2006).

Yield increases in terms of growth were demonstrated in a field nursery setting by (Robbins and Boyd, 2006), where field-grown seedlings of red maple (*Acer rubrum*) with vegetation control were compared to no vegetation control. Final shoot length was 85% taller, mean trunk caliper readings 167% greater, and there was lower tree mortality in the plots with vegetation control. Neely (1984) demonstrated an increase in growth in several species when using a combination of glyphosate for weed control and N fertilization over N only and an untreated control. Atkinson et al., (1979) investigated Nitrogen-15 uptake in apple orchards within herbicide maintained strip, or grassed row middles. Nitrogen assimilation occurred primarily in the herbicide maintained strip within the row and N applied to the grass area appeared to be wasted.

The size of the area being maintained weed free around the tree has been shown to significantly affect the growth benefits, and is attributed to lower weed competition. In 1993 and 1994, Nesmith and Lindstrom, (1996) designed an experiment to evaluate the influence of the size of vegetative free area around Leyland cypress. Vegetation free areas around selected trees consisted of treatments of 0, 0.6, 0.9, and 1.5 meters. Over the two years of the experiment it was concluded that tree growth increased as the level of vegetation control increased. More specifically, Leyland cypress trees planted on 1.8 meter centers achieved maximum growth response with a vegetation-free strip along the row length ranging in 0.6 to 0.9 meters in width (Nesmith and Lindstrom, 1996).

Competition for available nutrients often overshadows considerations of weed controls influence on water availability. Proper moisture in the soil allows newly transplanted trees to have the highest chance of survival and growth. The first few years following transplant are the most important times to maintain weed free areas around trees to ensure proper establishment and high quality as quickly as possible (Lantagne and Melvin, 1986).

Brown et al., (1989) investigated the effect of herbicide application frequency on several northern Christmas tree species with varied results. Tree quality generally improved with increased herbicide application rates. Height increase associated with increased application frequency was observed to be more prevalent on drier sites where weed competition for soil moisture was greater (Brown et al., 1989). Sands and Nambiar (1984) observed seedlings of Monterey Pine (*Pinus radiata*) grown without weed competition were not water stressed when compared to seedlings with unmanaged vegetation.

In an unpublished survey across the Alabama, Louisiana and Mississippi, growers reported using chemical post emergent herbicides but few utilized preemergent products. Growers reported five to even eight applications of glyphosate per year (Personal communication, Jeremy Pickens). Growers are reluctant to utilize preemergent herbicides due to fear of plant damage, cost and a lack of understanding in how preemergents work. There is potential for significant reduction in chemical use, a reduction in glyphosate resistance, and a reduction in labor associated with spraying if more growers utilized preemergent products in a proper way.

Products with greater efficacy and residual have been introduced in recent years. Many of these are labeled for Christmas trees; however, few specifically list Leyland cypress on the label. Many of these products have been shown to be safe on northern Christmas tree species. A study done with preemergent herbicides on Canaan Fir (*Abies balsamea* var *phanerolepis*) reported no injury to trees from any products evaluated, specifically flumioxazin and indaziflam. Richardson and Zandstra (2009) found similar results on Frasier fir (*Abies fraseri*) with the same products. Both flumioxazin and indaziflam have excellent residual control and could significantly reduce the number of herbicide applications in Alabama farms.

Excessive weed competition and growth can have long term effects. When weeds are managed properly, tree growth and establishment are less inhibited from competition. An extension bulletin from Michigan State University (Zandstra and O’Donnell, 2018) states that when young trees are able to grow in an environment with minimal weed competition, they are able to develop strong root systems that prepare them to survive periods of drought and tough conditions later in the growth cycle. Growing sites with sandy soils are more susceptible to drought stress when weeds are present due to weeds using up the available moisture in the soil.

Excessive weed growth also inhibits proper maintenance of trees when pruning and spraying needs to take place (Zandstra and O’Donnell, 2018).

Improperly applied herbicide can cause plant injury, but a common overlooked reason for injury caused by herbicide is applying at the wrong time of the year if dealing with older chemistries with higher degrees of volatility. The most common time of the year for southern growers to apply herbicide is in the spring when the trees just breaking dormancy and the weeds begin to grow. For a grower not using an effective preemergent, their applications continue on past an early spring application and continue into the summer months. Research from the late 1970’s and early 1980’s examined the level of injury on conifers in general in regards to the time of year the application was made. Applications were applied monthly from April to October to evaluate which months resulted in the most damage. Results showed the most damage from herbicide applications was recorded in the hottest months: June, July, and August. The least amount of damage was recorded in applications made in April, May, and September (King and Radosevich, 1985). Additional research on timing of herbicide application has shown that conifers have the most tolerance to herbicide application in the early fall months (Radosevich et al., 1980). Many of the newer chemistries have a low degree of volatility and can be applied year-round.

Due to the fast-growing characteristics of many Christmas trees, spraying can become a difficult task due to the overhanging branches and wide bases of the trees. Many growers in the southeast utilize direct spray applications around the trees using hand-held equipment. Growers can spray some postemergence herbicides safely with over-the-top applications (Zandstra and O’Donnell, 2018). Before over the top applications are made, growers should ensure that the label states it can be done with the desired chemical and species it is being applied on to avoid damage to the trees.

A very similar study to our study on Leyland Cypress was done to Canaan Fir (*Abies balsamea* var. *phanerolepis*) to evaluate the efficacy of multiple preemergent herbicides and testing for phytotoxicity response in the trees. The chemistries studied included Lumax® (*Atrazine* + *mesotrione* + *S-metoachlor*), Sureguard® (*Flumioxazin*), Westar® (*Hexazinone*), Marengo® (*Indaziflam*), and Princep® 4L + Surflan® AS (*Simazine* + *oryzalin*). Over the two years the study was conducted, none of the treatments caused signs of phyto-response in the trees and growth seemed to be unaffected (Aulakh, 2020).

Our research will evaluate the safety of newer chemistries of preemergent herbicides for southern grown Christmas trees. Demonstration of the safety of these products could increase their use among Alabama growers.

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Chapter II

DEVELOPING FERTILITY RECOMMENDATIONS FOR LEYLAND CYPRESS

Abstract

A series of trials evaluating fertility requirements were conducted to provide updated recommendations to Alabama Christmas tree growers. Three trials were conducted to determine the effects of N rate on newly planted Leyland cypress. The rates of N differed between trials due to the production practices associated with each collaborating farm. In Trial 1 the high N rate, 67 kg N ha^{-1} in year 1 and 67 kg N ha^{-1} in year 2 for a total of 135 kg N ha^{-1} ($135_{Y1}/67_{Y2}$) produced trees with 25% greater increase in growth when compared to the $0_{Y1}/34_{Y2}$ kg N ha^{-1} rate; however the $67_{Y1}/34_{Y2}$ rate was similar to both $135_{Y1}/67_{Y2}$ and $0_{Y1}/34_{Y2.}$ In Trial 2 the lowest rate (90 kg N ha^{-1}) produced the greatest increase in plant height when compared to the medium (135 kg N ha^{-1}) and high rate (180 kg N ha^{-1}) representing an increase of 14% and 5%, respectively. In Trial 3, no benefit was evident from applying N over 90 kg N ha^{-1}, when compared to the low rate. Soil type likely had a major impact on the utilization of nitrogen.

Introduction

Currently, N recommendations for Christmas trees grown in Alabama state that N is not needed at planting the first year. After the first year up to 34 kg N ha^{-1} (30 lb·ac N) can be applied as needed to give desired growth (Mitchell and Huluka, 2012). Alabama recommendations are not segregated by species. General recommendations are made for the following species: Eastern red cedar (*Juniperus virginiana*), Virginia pine (*Pinus virginiana*), pines in general, Leyland cypress (x *Cuprocyparis leylandii*), and Arizona cypress (*Cupressus arizonica*) (Mitchell and Huluka, 2012).

Today the majority of Christmas trees grown in Alabama are Leyland cypress; however, prior to the 1990's, Virginia pine was the primary Christmas tree species (Stegelin, 2006). Alabama's recommended low N rate in addition to pH recommendations of 5.0 to 5.5 are more conducive to recommendations associated with pine tree culture. Nutrient applications on pines has shown little to no economic benefit in growth responses (Peer, 2015). Virginia pine has been shown to perform well in areas with poor soil quality due to its ability to effectively mine nutrients from the soil (Moorhead, 1998). Considering the lack of N response for some pine species, it is possible that Alabama's recommendations for Christmas trees are based off of Virginia pine and multiple species were lumped together due to lack of research when guidelines were published.

Research on N response for field-grown trees has produced various and sometimes contradicting results depending on the growing scenario and the species. Some Christmas tree species such as Frasier fir (*Abies fraseri*) or Douglas fir (*Pseudotsuga menziesii*) have been shown to respond to N fertilization (Gessel and Walker, 1956; Hinesley, 2018; Turner, 1966). Studies evaluating N response to shade trees in nursery settings has shown limited or no benefit of N in terms of growth in the first year (Hagan et al., 2008; Warren et al., 1993; Wright and Hale, 1983). Generally, several states in the Southeastern US field nursery recommendations suggest 7.09 g to 14.17 g (0.25 oz, 0.5 oz) of N side dress for first year plants. The second and third year rates are increased to 14.17 g to 28.35 g (0.5 oz, 1.0 oz) with two-thirds before bud break and the remaining in mid-June. For year three and subsequent years rates are increased to 28.35 to 56.70 g (1.0, 2.0 oz) per plant (Adkins et al., 2009).

Several studies have shown positive results with N applications in Leyland cypress (Bilderback, 1985; Hinesley, 2018); however, limited research is available in field growing scenarios. Fertilization in first year Leyland cypress trees could have a major impact on production cost as increased growth could lead to reduced growing time; however, if N fertilization is not beneficial then a considerable amount of labor in hand applications could be saved. The objective of the following studies was to evaluate the effectiveness in growth from N fertilization of first year field grown Leyland cypress.

Materials and Methods

Trial 1 (Mobile, AL)

In Spring of 2019 and 2020, three N rates and 3 target pH ranges were evaluated on field grown Leyland cypress (x *Cuprocyparis leylandii)* trees at the Ornamental Horticulture Research Center in Mobile, Alabama (Latitude 30.70192, Longitude -88.14557). The site was a Wadley loamy sand map unit (loamy, siliceous, subactive thermic Grossarenic Paleudults). Trees were previously planted on 29 March 2019 from container grown 3.8 liter transplants. Tree rows were oriented north to south with 2.7 m between trees and 2.7 m between rows. The study was a split-plot design with target pH levels as the main plot in a randomized block design and three N rates as subplots. Prior to planting the field was subdivided into nine areas of equal dimensions where composite soil samples were collected to adjust main plots to one of three target soil pH levels (5.5, 6.0, and 6.5) with ten main plots per level. Subplots consisted of three N rates. Nitrogen rates included a no N first year and 34 kg N ha^{-1} applied the second year (0_{Y1}, 34_{Y2}), 67 kg N ha^{-1} in the first year and 34 kg N ha^{-1} in the second year ($67_{Y1}/34_{Y2}$), and 135 kg N ha^{-1} in the first year and 67 kg N ha^{-1} in the second year ($135_{Y1}/67_{Y2}$). The N fertilizer being used was 33-0-0 with 10.5% ammoniacal nitrogen and 22.5% urea nitrogen with 12% sulfur (AGRI-AFC, LLC, Evergreen, AL). Only half of the data from the second year application was recorded due to the trial being destroyed by inclement weather. Nitrogen treatments were evenly divided between two application dates per year. First year applications were made on 24 April 2019 and 25 July 2019. Second year applications were made on 11 March 2020 and 21 July 2020. Before planting, all plots were brought up to concentrations of 135 kg per ha of P and K using triple super phosphate (0-46-0) (AGRI-AFC LLC, Evergreen, AL) and muriate of potash (0-0-60) (Piedmont Fertilizer Company Inc., Opelika, AL). Data collected included tree height in centimeters and tree stem diameter in millimeters. Initial tree height and stem dimeter measurements were taken on 17 April 2019. Subsequent measurements were taken 13 weeks after treatment 1 (WAT1), 33 WAT2, and 1 WAT4. The research plot of trees was destroyed by inclement weather before final readings could be taken.

Statistical analysis of interactions of target pH, N rate with time included to account for repeated measures through analysis of variance using JMP statistical software ($P < 0.05$, JMP Version 15.2 SAS Institute Inc., Cary, NC, 2019). Comparisons within main effects on increase in stem diameter and height were made using least square means and were separated using Tukey's test ($P < 0.05$, JMP Version 15.2 SAS Institute Inc., Cary, NC, 2019).

Trial 2 (Lanett, AL)

In Spring of 2020, three N rates were evaluated on field grown Leyland cypress (x *Cuprocyparis leylandii*) trees at Gilbert Christmas Tree farm in Lanett, Alabama (Latitude 32.9709, Longitude -85.2417). The site was a Lloyd gravely clay map unit (fine kaolinitic, thermic Rhodic Kanhapludults). Trees had previously been planted by the grower in mid-January 2020 from 1-gallon transplants. Trees were approximately 40 cm tall when planted and had 38 grams of 13-6-6 fertilizer added to each planting hole. Treatments were applied in a split application on 1 April 2020 and 20 June 2020 and included the equivalent annual application of 90, 135, and 180 kg of N per hectare. The N fertilizer being used was 33-0-0 with 10.5% ammoniacal nitrogen and 22.5% urea nitrogen with 12% sulfur (AGRI-AFC, LLC, Evergreen, AL). On 1 April, N treatments were applied based on volume in a 60 cm by 60 cm-meter area extending around the base of the tree. Prior to planting a soil analysis revealed that the field required 135 kg per ha phosphorus and 135 kg per ha potassium. The soil was amended with 24.8 kg of Triple Super Phosphate (0-46-0) (AGRI-AFC LLC, Evergreen, AL) and 19.1 kg of Muriate of Potash (0-0-60) (Piedmont Fertilizer Company Inc., Opelika, AL). Tree rows were oriented north to south and were planted 2.1 meters in the row and 2.1 meters between rows providing a plant density of 889 trees per acre. The study was arranged in a randomized complete block design (RCBD) with blocks oriented down the length of rows to accommodate any variability due to soil type and topography. Individual trees served as experimental units within the blocks. Each treatment was applied to three trees side by side in the block, however only the center tree served as an experimental unit and the outside trees served to buffer any contamination from other treatments. In all there were 18 blocks and 52 total experimental units. Data recorded included tree height in centimeters and tree stem diameter in millimeters. Initial stem diameter and tree height were recorded 1 April 2020. Measurements following treatments were 9 WAT1, 4 WAT2, and 17 WAT2.

Data was analyzed using analysis of variance (JMP) interaction N rate with time included to account for repeated measures ($P < 0.05$). The effects of N rate on growth measurements were compared using least square means of growth measurements and were separated were separated using Tukey's test ($P < 0.05$, JMP Version 15.2 SAS Institute Inc., Cary, NC, 2019).

Trial 3 (Wetumpka, AL)

In Spring of 2020, three N rates were evaluated on field-grown Leyland cypress (x *Cuprocyparis leylandii*) trees at Wadsworth Christmas Tree farm in Wetumpka, Alabama (Latitude 32.6481, Longitude -86.1809). The site was a Chesterfield (marvyn) sandy loam (fine loamy, kaolinitic, thermic Typic Kanhapludults). Trees were planted 15 February 2020 from 1-gallon transplants. Trees were approximately 40 cm tall when planted and had no fertilizer added to each planting hole. After planting, each treatment was applied in a split application on 14 May 2020 and 22 July 2020 and included the equivalent of 90, 135, and 180 kg N ha^{-1} The N fertilizer used was 33-0-0 with 10.5% ammoniacal nitrogen and 22.5% urea nitrogen with 12% sulfur (AGRI-AFC, LLC, Evergreen, AL). On 14 May, N treatments were applied based on volume in a 70 by 70 cm area extending around the base of the tree. Treatments were applied a second time on 22 July 2020. Prior to planting, a soil analysis revealed that the field required 67 kg per ha phosphorus and 45 kg per ha potassium. The soil was amended with 7.0 kg of Triple Super Phosphate (0-46-0) (AGRI-AFC LLC, Evergreen, AL) and 3.6 kg of Muriate of Potash (0-0-60) (Piedmont Fertilizer Company Inc., Opelika, AL) to bring soil concentrations up to the equivalent of 135 kg of P and K per ha. Tree rows were oriented north to south and were planted 2.1 meters in the row and 2.1 meters between rows providing a plant density of 889 trees per acre. The study was arranged in a randomized complete block design (RCBD) with blocks oriented down the length of rows to accommodate any variability due to soil type. Individual trees served as experimental units within the blocks. Each treatment was applied to three trees side by side in the block, however only the center tree served as an experimental unit and the outside trees served to buffer any contamination from other treatments. In all, there were 13 blocks and 53 total experimental units. Data recorded included tree height in centimeters and tree stem diameter in millimeters. Initial stem diameter and tree height were recorded 14 May 2020. Measurements following treatments were 11 WAT1, 1 WAT2, and 9 WAT2.

Stem diameter increase and increase in height were analyzed using analysis of variance (JMP) with the interactions of N rate and time included to account for repeated measures using repeated ($P < 0.05$). The effects of N rate on growth measurements were compared using least square means of growth measurements and nitrogen rates were compared to the untreated control using Dunnett's test. ($P < 0.05$, JMP Version 15.2 SAS Institute Inc., Cary, NC, 2019).

Results Trial 1

Analysis of variance indicated no interaction between the fixed effects target pH, N rate, and time (p = 0.9995). Differences were observed with increases in height and stem diameter over time (p= <.0001) but there were no interactions between time and N rate and target pH (Table 1.1). No differences were seen across target pH levels for increase in plant height or stem diameter (p = 0.3297 and 0.0784 respectively) (Table 1.1; Table 1.2). Increase in stem diameter was significant for N rate (p = 0.0111) but not increase in plant height (p = 0.1514). (Table 1.1; Table 1.3). Plant height was 25% greater for plants receiving 135 kg N ha^{-1} compared to plants receiving 0 kg N ha^{-1} in year 1 and 34 kg N ha^{-1}, representing a 0.9 cm increase in plant height. Plants receiving 67 kg N ha^{-1} in year one and 34 kg N ha^{-1} in year two were similar to plants receiving the highest rate and the zero N in year one. Despite a lack of significance in plant height due to increasing N rates, there was a visible trend with 135 kg N ha^{-1} having a greater increase throughout the study (Table 1.3 and Figure 1.1, 1.2).

Results Trial 2

No interaction was seen between the main effects rate and time (p = 0.784). Nitrogen rate was significant for increase in height and stem diameter (p = 0.0309 and 0.0298 respectively).

Both plant height and stem diameter were affected by time (p = <.0001 and <.0001 respectively) (Table 1.4). Fertilizer rate of 90 kg N ha^{-1} produced the greatest increase in plant height when compared to the medium and high rate. The lowest rate of 90 kg N ha^{-1} was 14% and 5% greater in height increase when compared to the 135 and 180 kg N ha^{-1} respectively. Similarly, the lowest rate of 90 kg N ha^{-1} was 12% greater in stem diameter increase when compared to the 135 kg N ha^{-1} rate; however the 180 kg N ha^{-1} rate was similar to the 90 and 135 kg N ha^{-1} rates (Table 1.5). Despite the increase in growth it is unlikely that this would be of any horticultural significance over this short of a period of time. However, if a positive growth occurred in subsequent years the cumulative effect might be significant.

Results Trial 3

Nitrogen rate was not significant (p = 0.0681) with regard to increase in height (Table 1.6). In an attempt to control for any effect initial plant quality had on growth rate, a ratio was calculated using growth over initial height. The result was an increase in significance of the rate of N (p=0.0421). There was no effect on stem diameter from N rate (p=0.0794). The 90 kg rate was significant when compared to the control in height and the ratio of growth: initial height (Table 1.7). An increase in N rates over 90 kg N ha^{-1} may not be beneficial to growers within such a short time frame. While statistically significant, this increase in growth represents a 19% increase in growth but may not be significant to growers. Stem diameter growth was significant when the 180 kg rate was used and compared to the control. This represented an 18% increase in stem diameter compared to the control (Table 1.7). Trends indicate that the 90 kg N ha^{-1} rate was had a slight increase compared to the other treatments throughout the study (Figure 1.7 and 1.8). An increase in N rates over 90 kg N ha^{-1} may not be beneficial to growers in a short term study, however it could become important cumulatively over a longer duration study.

Discussion

It is difficult to make accurate comparisons between all three trials based on inherent differences by site and on farm cultural practices. These differences were associated with the distinct growing techniques at the collaborating farms. The trial at the OHRC in Mobile took place in a very sandy soil in an area with high rainfall. This likely lead to increase leaching at the Mobile site. The Mobile study was carried out beyond two years. Trees grown in Lanett were treated at planting with 38 grams of 13-6-6 per each planting hole. No control was available at the Lanett location due to the grower not wanting to risk a reduction in growth to a percentage of the crop. The Wetumpka location provided an opportunity to have an untreated control as fertilization was not used on that farm.

Soil type could be a major factor in N response to Leyland cypress. Carter and Lyle (1966) demonstrated a positive effect of N on loblolly pines in the Coastal Plain regions of Alabama, where topsoil has a large fraction of sand. No economic benefit was observed on pines grown in the Piedmont soil locations that are associated with a large percentage of clay (Carter and Lyle, 1966). The lower rates of nitrogen performed well in Trials 2 and 3 where CEC was greater. Soil in Trial 1 was a sandy soil with lower CEC where higher nitrogen rates may be needed.

In Trial 2 in Lanett, AL, the grower amended each planting hole with 38 grams of 13-6-6 at planting. This represented a significant amount of N that was already present at the time of the experiments first treatment application, and might explain the increase in growth when comparing the low rate of 90 kg to the medium and high rates of 135 and 180 kg N ha^{-1}. The increase in salt index for the high rates could have damaged or inhibited root growth.

Little benefit in fertilization could be associated with an underdeveloped root system during the first year following transplant. Day and Harris (2007) stated that newly planted trees may not respond to added fertilizer due to insufficient exposure to undeveloped root systems. Container grown plants must transition between the nursery substrate and the surrounding field soil interface in addition to potential root morphological problems associated with container grown trees (Marshal and Gilman, 1998). Container grown Leyland cypress have been shown to perform poorer post-transplant when compared to bare-root trees, potentially indicating a sensitivity to root/soil interface issues (Harris and Gilman, 1991). Wright and Hale (1983) concluded that height difference in trees amongst different treatments was not seen until the second year following treatments in red maples. With a similar study on flowering dogwood, (*Cornus florida* L.), N rates were evaluated for effects on growth and health of the trees. The study reported tree growth was not affected by the N treatments until year 3 and 4 (Hagan et al., 2008). Turner (1966) reported improved color but not growth in the first year when comparing rates of N on Douglas-fir Christmas trees. Growth increase due to N applications was only seen in year two of the study (Turner, 1966).

In a survey conducted of North Carolina growers by Rideout and Overstreet (2004), a wide range of fertility practices were reported. Data from the survey resulted in no standard fertility program to be followed by any of the growers. Of the total 23 respondents to the survey, five growers reported no use of fertilizer (Rideout and Overstreet, 2004). Observations of Alabama growers' diversity in fertilizer use is similar to that of NC.

Nitrogen applications are an input intended to provide a return on investment in the form of increased growth and improved quality. Fertilizer cost in areas associated with these trials were \$3.6·kg N when using a 13(N)-13(P)-13(K) fertilizer. In some cases, growers will broadcast apply fertilizers at 135 kg per ha (120 lbs. per acre). In this case with smaller trees a ½ rate may be used resulting in 67 kg per ha (60 lbs. per acre) for first year trees would result in \$241·ha if broadcast and \$106·ha if banded. Modern fertilizer recommendations for field nurseries recommend 7.09 to 14.14 g (0.25, 0.5 oz) of N per tree for first year trees resulting in \$56 to \$113·ha. Many growers hand apply fertilizer around each tree, which requires about 2.5 labor hours per ha. The fertilizer and the labor associated with its application are not a significant cost in production; however, an opportunity cost of time is of concern as many growers are owner/operators and have other means of full-time employment. Time/labor may be worth more than a monetary value.

These trials suggest a benefit of N over no fertilizer for first year trees; however, results on optimum rate and the usefulness of this benefit are inconclusive. Where a benefit of N was observed in first year trees, more work is needed to determine optimum rates in accordance with what gain would be of value to the grower. Future studies should consider longer production times as a factor to determine how first year fertilization impacts 2^{nd} year growth. Additionally, future studies should include quality measurements that may not be captured in growth data. Height trends may not be affected greatly, but a way to measure fullness, shape, color, or lateral branching may prove beneficial to future studies (Turner, 1966).

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Tables and Figures

Table 1.1. Trial One: Fixed effects on growth parameters on first year Leyland Cypress (x *Cuprocyparis leylandii*) Christmas trees grown with various nitrogen rates.

	Increase in Plant Height P-value[Z]	Increase in Stem Diameter P-value
Lime	0.3927	0.0784
Fert	0.1514	0.0111
Time	<0.0001	<0.0001
Lime*Fert	0.8747	0.8171
Lime*Time	0.6176	0.8012
Fert*Time	0.6176	0.6215
Lime*Fert*Time	0.9995	0.9997

[Z]Model was analyzed using a mixed model repeated measures analaysis.

Table 1.2. Trial One: Comparisons of various of target pH levels on Leyland Cypress (x *Cuprocyparis leylandii*) Christmas trees .

Target pH[Z]	Increase in Plant Height (cm)	Increase in Stem Diameter (mm)
5.5	3.6 A[X]	3.0 A
6.0	4.2 A	3.6 A
6.5	4.1 A	3.5 A

[Z]Adjustments to pH were based off of soil analysis prior to planting.

[Y]Plants were destroyed due to storm before final measurements were made.

[X]Treatments were compared using Tukey's multiple range test ($\alpha = 0.05$). levels not connected by the same level are significanlty different.

Table 1.3. Trial One: Comparisons of various nitrogen rates on Leyland Cypress (x *Cuprocyparis leylandii*) Christmas trees .

Rate (kg N ha^{-1})[Z]		Increase in	Increase in
Year 1	Year 2[Y]	Plant Height	Stem Diameter
0	33.7	2.9 A[X]	3.5 B
68	33.7	3.2 A	4.0 AB
135	67.3	3.7 A	4.4 A

[Z]Nitrogen rates represent yearly total following a split application using 33-0-0. Year one nitrogen April 24, 2019 and July 25. 2019. Year 2 nitrogen was applied on April 28, 2020 and July 21, 2020.

[Y]Plants only received half of treatment before last measurement 69 weeks after planting. Plants were destroyed due to storm before final measurements were made.

[X]Treatments were compared using Tukey's multiple range test ($\alpha = 0.05$). levels not connected by the same level are significanlty different.

Table 1.4. Trial Two: Fixed effects on growth parameters on first year Leyland Cypress (x *Cuprocyparis leylandii)* Christmas trees grown with various nitrogen rates.

	Increase in Plant Height P-value[z]	Increase in Stem Diameter P-value
Rate	0.0309	0.0298
Time	<0.0001	<0.0001
Rate x Time	0.784	0.7656

[z]Model was analyzed using a mixed model repeated measures analaysis.

Table 1.5. Trial Two: Comparisons of various nitrogen rates on Leyland Cypress (x *Cuprocyparis leylandii*) Christmas trees .

Rate (kg N ha^{-1})[Z]	Increase in Plant Height (cm)	Increase in Stem Diameter (mm)
90	19.08 A[Y]	8.28 A
135	16.75 B	7.38 B
180	18.24 B	7.94 AB

[Z]Nitrogen rates represent yearly total following a split application using 33-0-0: April 1, 2020 and June 20, 2020.

[Y]Treatments were compared using Tukey's multiple range test ($\alpha = 0.05$). levels not connected by the same level are significanlty different.

Table 1.6. Trial Three: Fixed effects on growth parameters on first year Leyland Cypress (x *Cuprocyparis leylandii)* Christmas trees grown with various nitrogen rates. .

	Height Growth P-value[Z]	Height Growth: Original Height (cm) P-value	Diameter Growth P-value
Nitrogen Rate	0.0681	0.0421	0.0794
Date	<0.0001	<0.0001	<0.0001
Nitrogen Rate * Time	0.9423	0.9419	0.4888

[Z]Model was analyzed using a mixed model repeated measures analaysis with replicant as a random effect with rate, date, and date*time.

Table 1.7. Trial Three: Effects of nitrogen rates on growth of first year Leyland Cypress (x *Cuprocyparis leylandii)* Christmas trees grown.

Rate (kg N ha^{-1})	Height Growth (cm)	P-value[Z]	Height Growth: Original Height (cm)	P-value	Diameter Growth (mm)	P-value
180	2.8	0.5345	0.08	0.8537	4.5	0.0406
135	2.8	0.6447	0.08	0.9986	4.0	0.644
90	3.1	0.0234	0.09	0.0313	3.9	0.9427
Untreated	2.6	-	0.07	-	3.8	-

[Z]Level of significance when compared to control based on Dunnett's multiple comparison test. Model was analyzed using a mixed model repeated measures analaysis with replicant as a random effect with rate, date, and date*time.

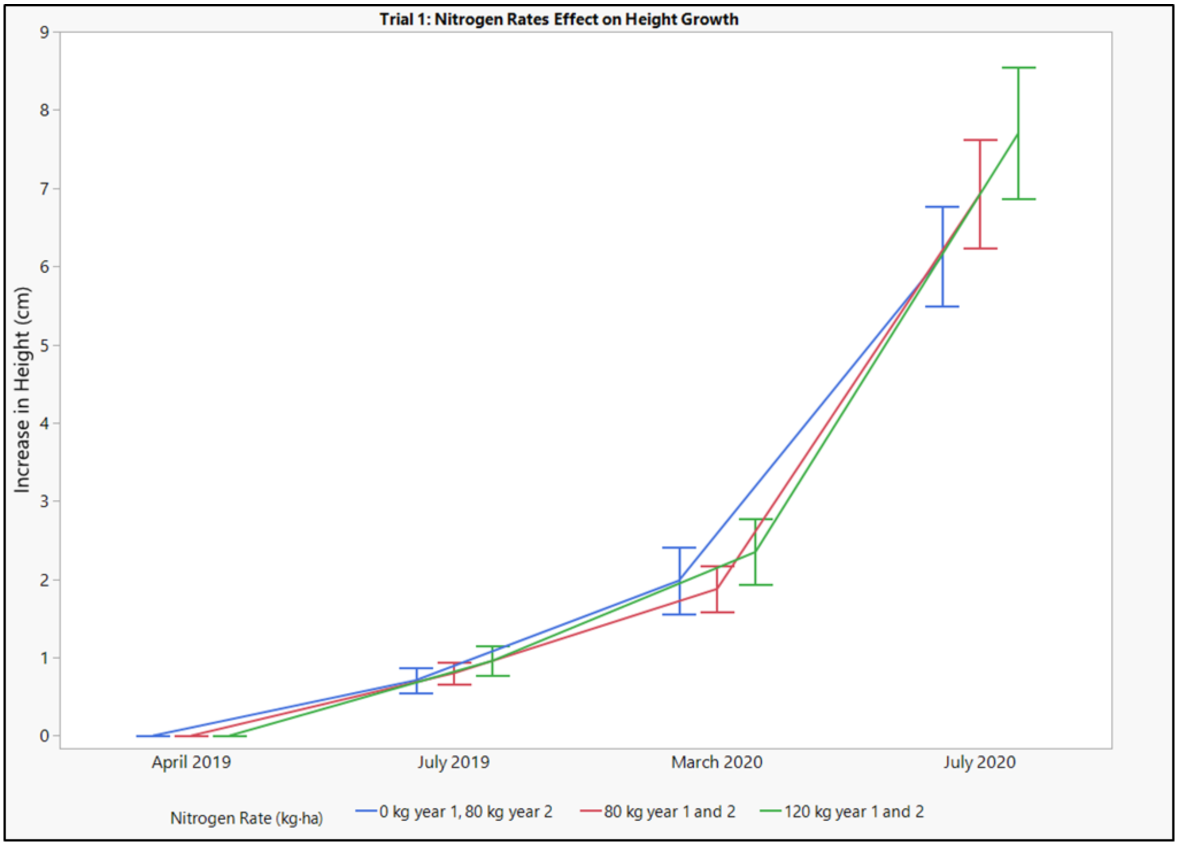

Figure 1.1: Trial 1: Nitrogen Rates Effect on Height Growth

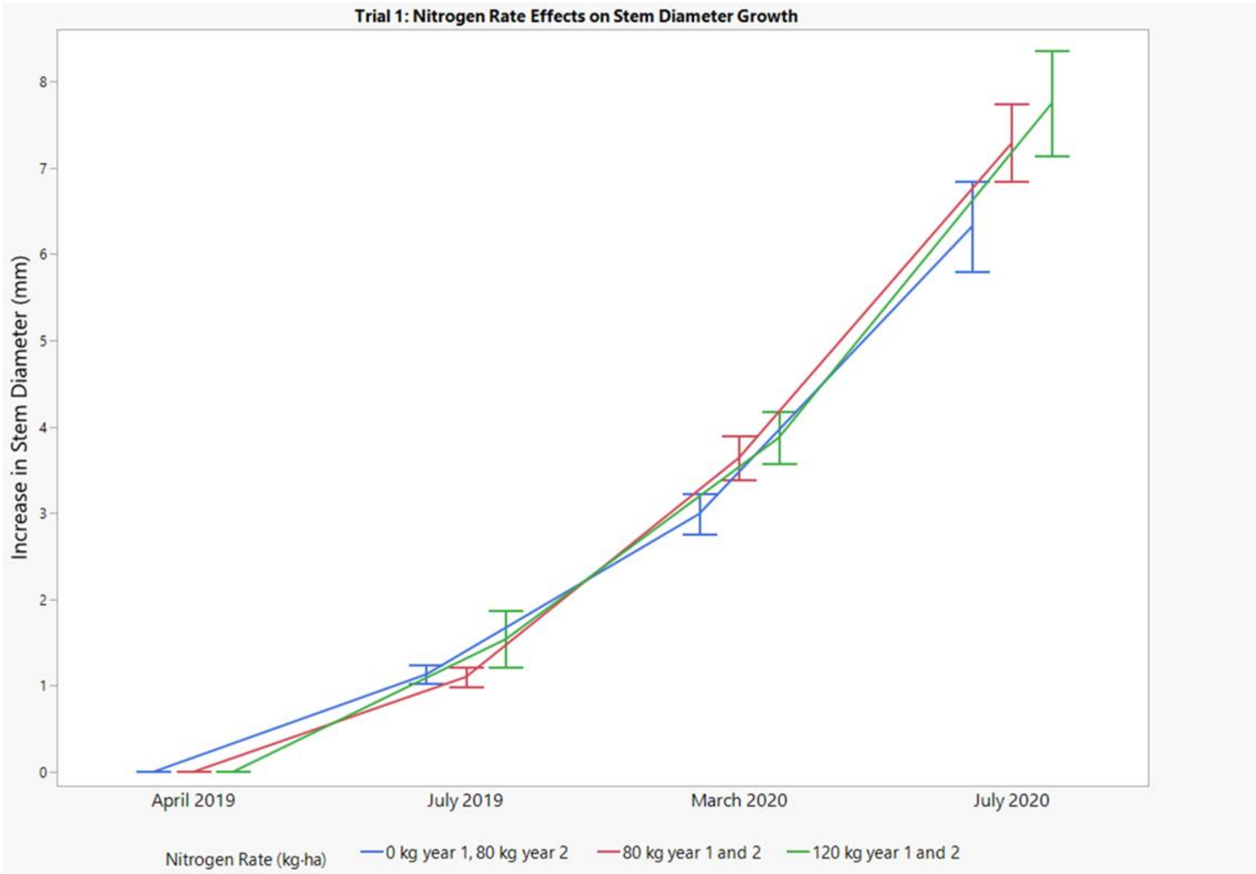

Figure 1.2: Trial 1: Nitrogen Rates Effect on Stem Diameter

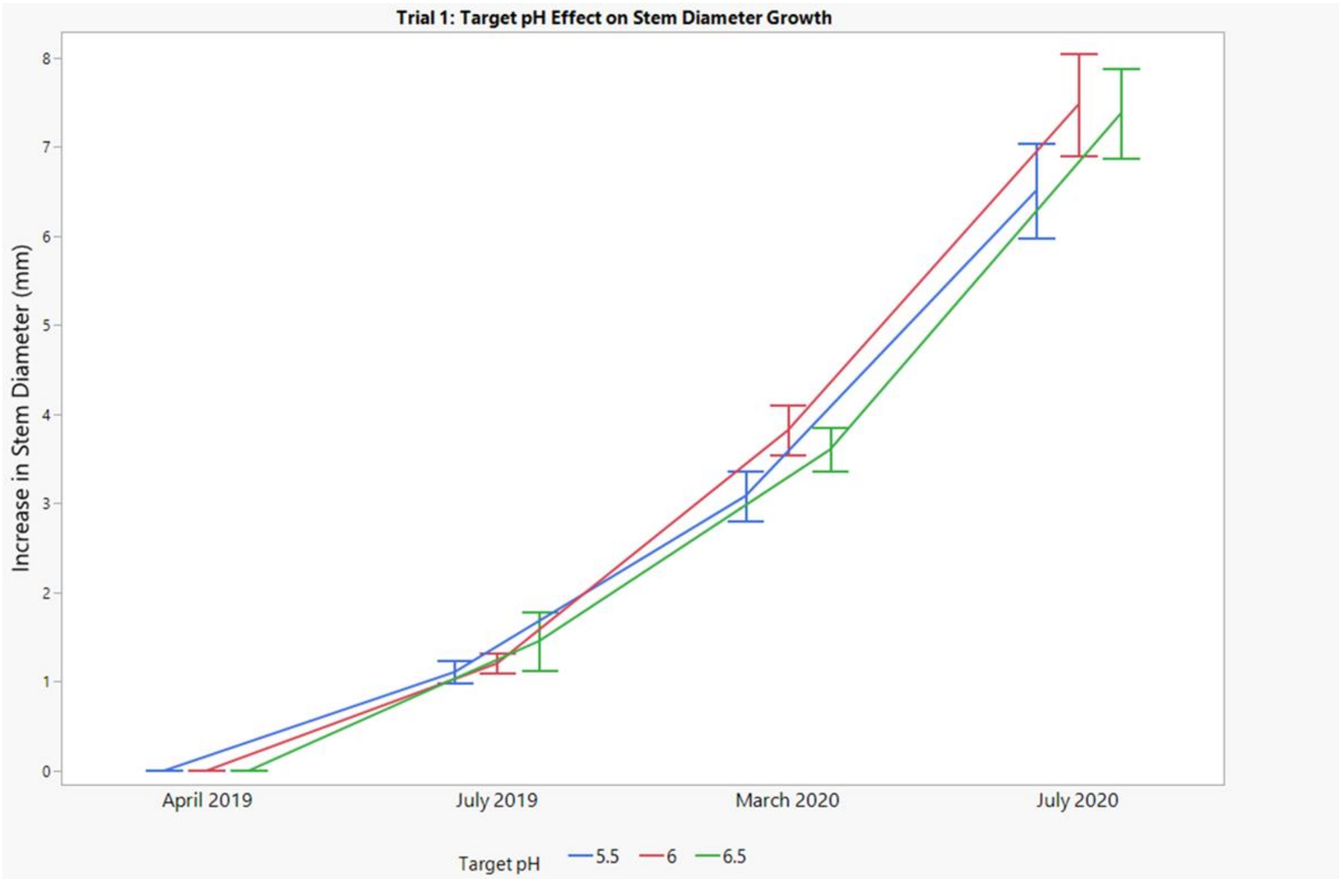

Figure 1.3: Trial 1: Target pH effect on Stem Diameter Growth

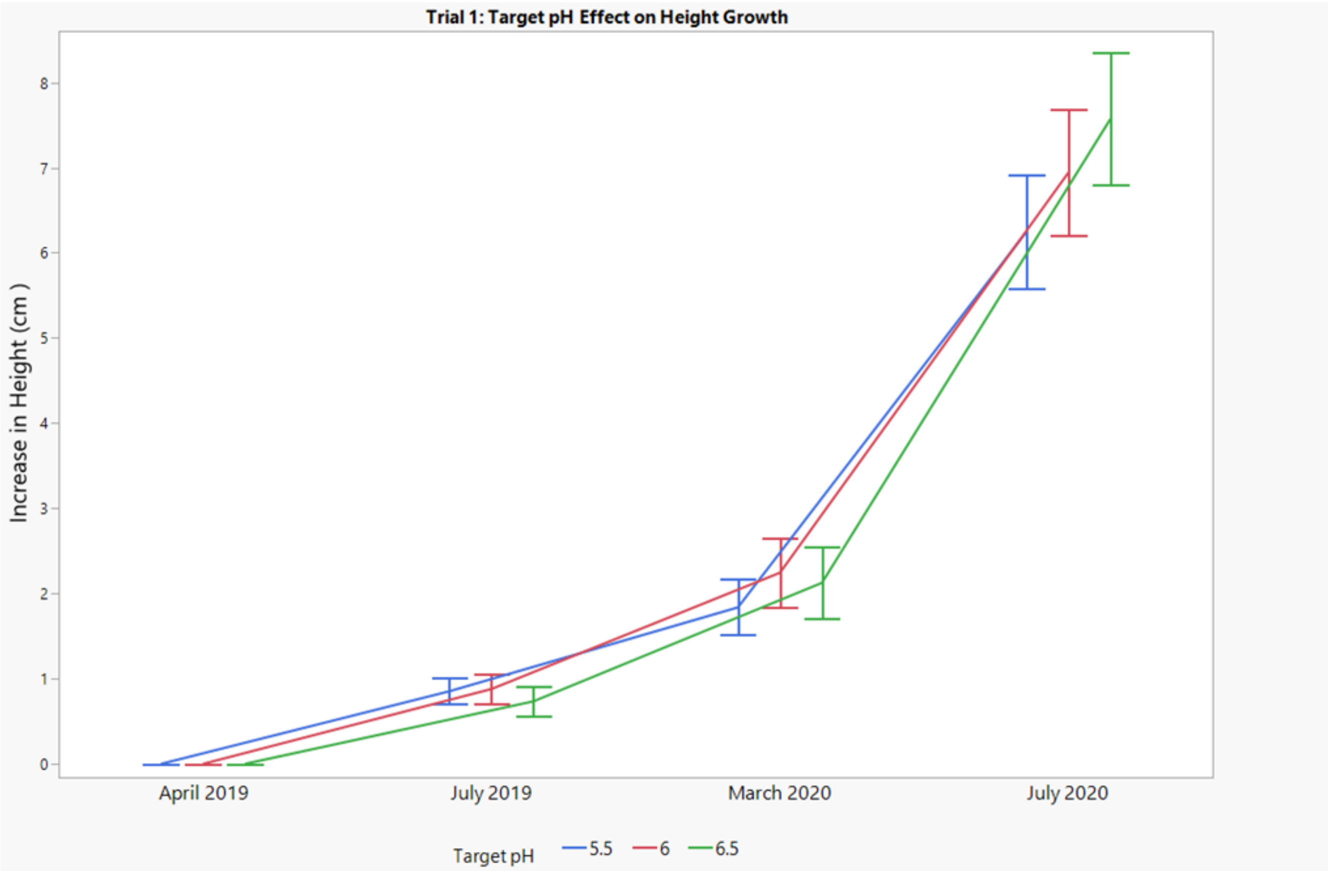

Figure 1.4: Trial 1: Target pH effect on Height Growth

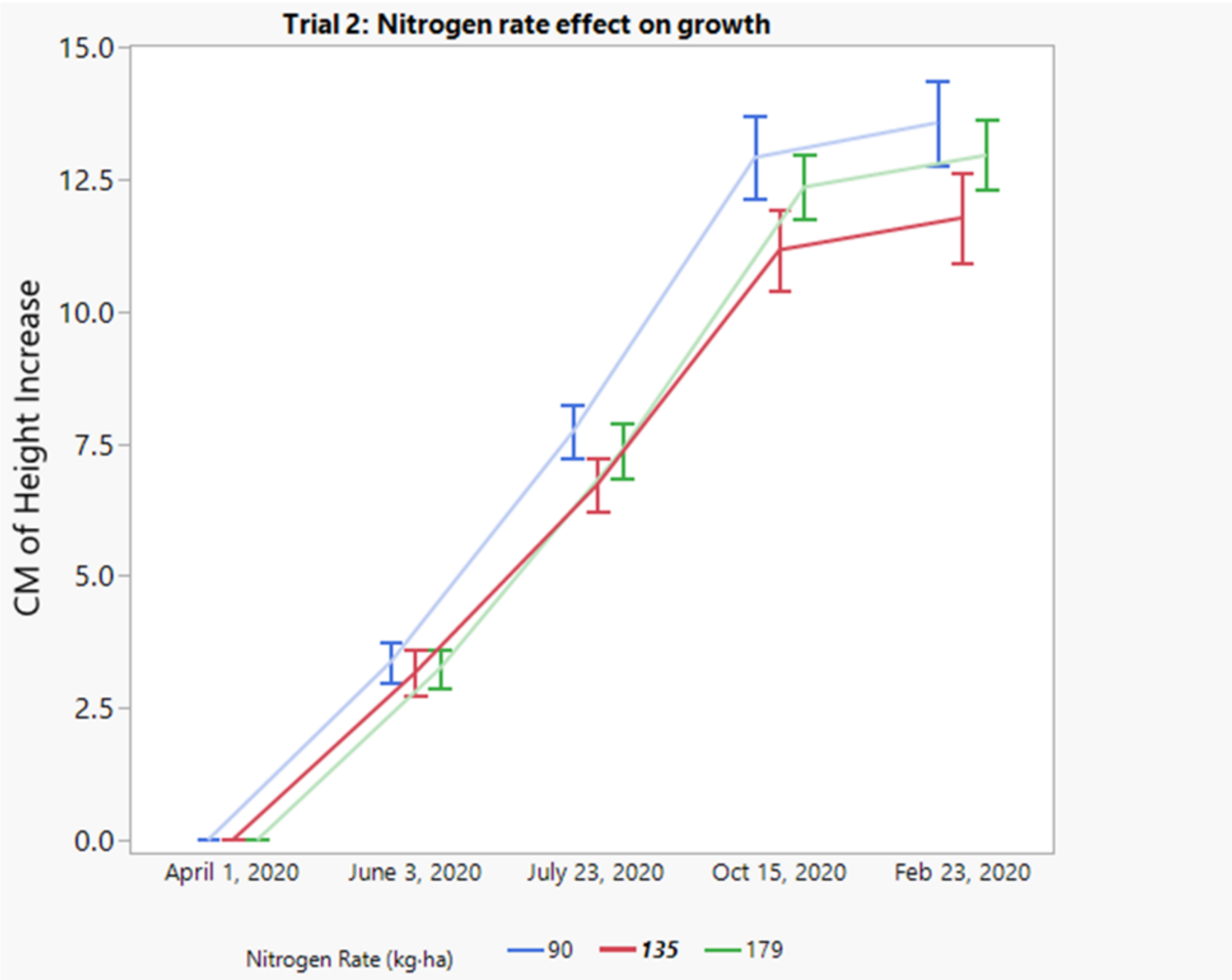

Figure 1.5: Trial 2: Nitrogen rate effect on Height Growth

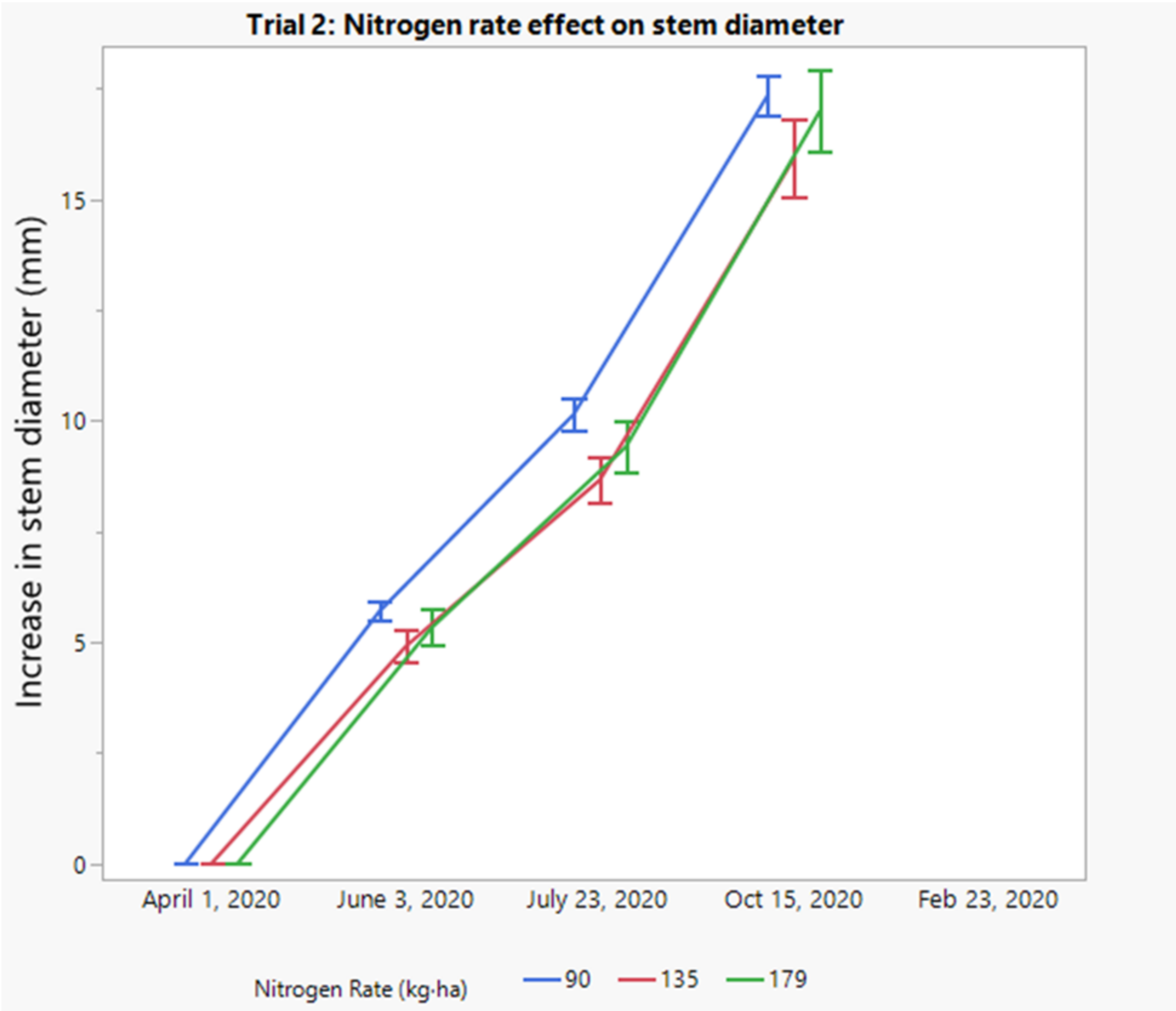

Figure 1.6: Trial 2: Nitrogen rate effect on Stem Diameter

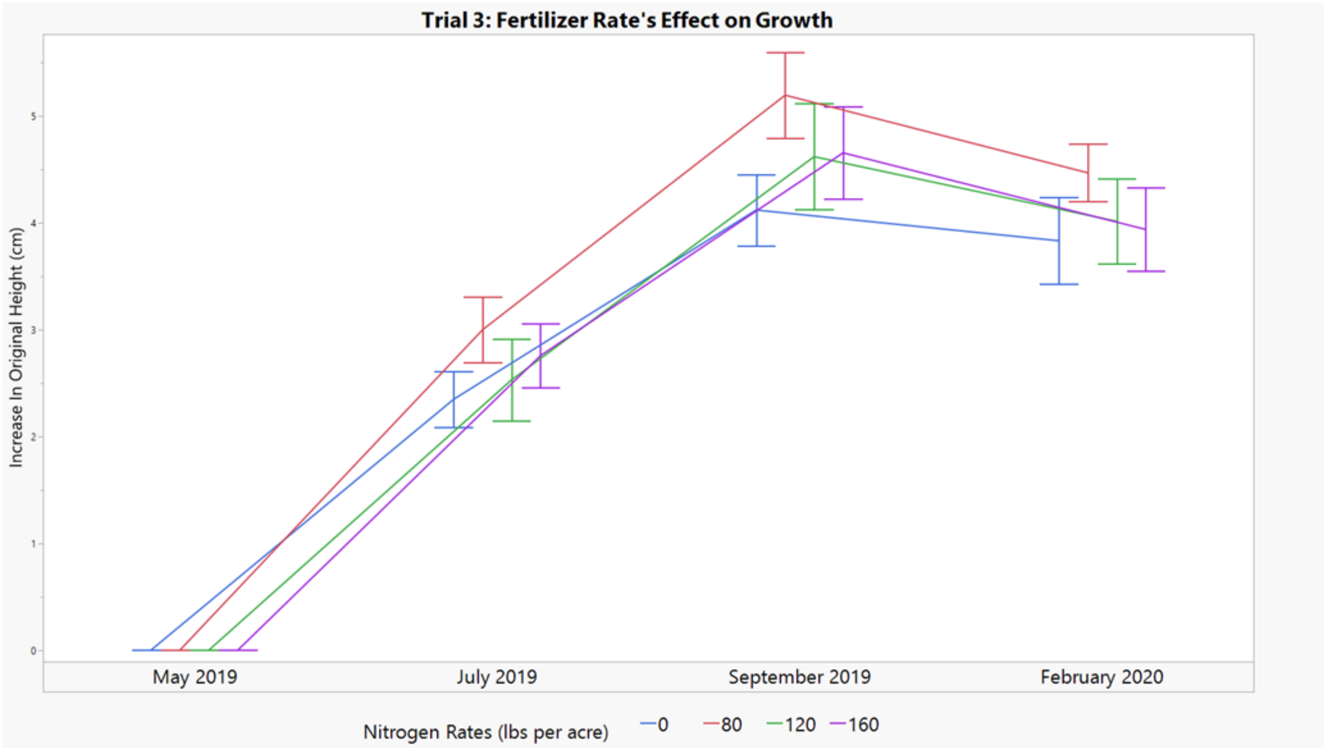

Figure 1.7: Trial 3: Fertilizer Rate's Effect on Growth

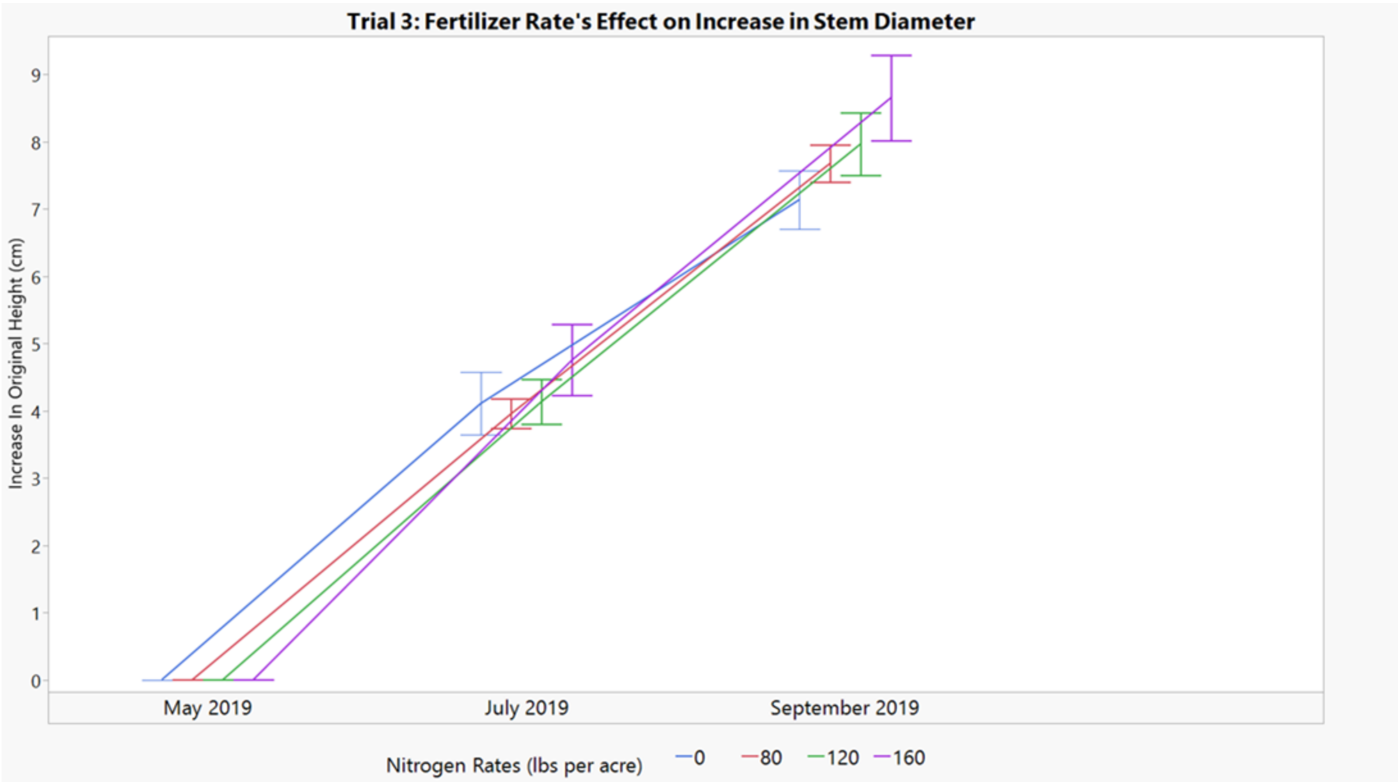

Figure 1.8: Trial 3: Fertilizer Rate's Effect on Increase in Stem Diameter

Chapter III

EVALUATING SAFETY OF HERBICIDES ON LEYLAND CYPRESS AND THUJA GREEN GIANT ARBOVITAE

Abstract

Two trials were conducted to evaluate four preemergent active ingredients on plant safety and growth effects for Leyland cypress (x *Cuprocyparis leylandii*). These included *indaziflam*, *dimenthenamid-P*, *flumioxazin* and a combination product of *prodiamine* and *isoxaben* which were compared to an untreated control. Trial 1 evaluated rates of 1x and 2x the label rate and Trial 2 focused on the amount of time before a rain/irrigation event (1 hr. and 24 hr.). Very little damage or reduction in growth was seen across both trials. Herbicide rate was not significant in Trial 1 and irrigation delay was not significant in Trial 2. Generally, across both studies, indaziflam had the greatest level of phytotoxicity and growth reduction; however not enough damage to be of horticultural significance.

Introduction

Paired with proper fertility regimens, good weed control practices are imperative to maintain tree health and maximize growth potential. In a study conducted on Red Maple (*Acer rubrum*), vegetation control was compared to no vegetation control. Data of the seedlings grown with vegetation control compared to no vegetation control illustrated final shoots 85% taller, mean trunk caliper readings 167% larger, and lower tree mortality when vegetation was controlled (Robbins and Boyd, 2006).

Weeds are a major concern for all Christmas tree growers. Weeds can hinder tree growth at many points in the growth cycle. Various methods exist for weed control: mechanical mowing, mulching, herbicides, cover crops, and cultivation. While mowing and herbicide use are the most common methods of weed control for growers of tree crops, herbicides can result in unwanted damage to plants and repeated application of the same herbicide can create weed resistance (Saha et al., 2020).

Weed control is not only an aesthetic issue, but also imperative for tree health. Excessive weed competition and growth can have long-term effects. When weeds are managed properly, tree growth and establishment are less inhibited from growth hindrances. An extension bulletin from Michigan State University (Zandstra and O'Donnell, 2018) states that when young trees are able to grow in an environment with minimal weed competition, they are able to develop strong root systems that prepare them to survive periods of drought and tough conditions later in the growth cycle. Furthermore, in cut your own Christmas tree operations a weed free growing environment is more pleasing for customers.

When trees are planted in a weed free field, the available moisture to trees is higher than areas with weeds competing for moisture. Proper moisture in the soil allows newly transplanted trees to have the highest chance of survival and growth. The first few years following transplant are the most important times to maintain weed free areas around trees to ensure proper establishment and high quality as quickly as possible (Lantagne, 1986).

Proper vegetation management around Leyland cypress was shown to improve tree growth (Nesmith and Lindstrom, 1996). It is important to analyze what degree and method of vegetation management provides the most desirable results. Research done on vegetation management has been done for many years. In 1993 and 1994 (Nesmith and Lindstrom, 1996) designed an experiment evaluating different levels of vegetation management in a plot of Leyland cypress and Haggerston Grey trees. Vegetation free areas were created around selected trees consisting of treatments of 0, 0.61, 0.91, and 1.52 m (0, 2, 3, and 5 feet). Over the two years of the experiment it was concluded that tree growth increased as the level of vegetation control increased. More specifically, Leyland cypress trees planted on 1.83 m (6 ft) centers achieved maximum growth response with a vegetation-free strip along the row length ranging in 0.61 to 0.91 m (2 to 3 ft) in width (Nesmith and Lindstrom, 1996).

The objective of this research was to evaluate the potential safety of five preemergent active ingredients used across 4 products by evaluating plant safety and growth in relation to rate of application and timing of application in the event of potential delays in a rain or irrigation event. Most growers utilize directed sprays around the base of plants and would prefer to include the preemergent product with the post emergent product through the same application. These trials utilized an over-the-top application to demonstrate a worst-case scenario.

Materials and Methods

Trial 1 (Auburn)

On 6 March 2020, at the Paterson Greenhouse Research Facility in Auburn, AL (32.597030, -85.487855), rooted liners of Murray Cypress (x *Cuprocyparis leylandii*) and Thuja Green Giant (*T. plicita* × *T. standishii*) were transplanted into 6.0 L (2 gallon) containers. The rooted liners were obtained from Ralph Rushing Nursery in Semmes, AL. Liners were transplanted into a 100% pine bark substrate that was amended with a controlled release fertilizer (18-6-8, 2-Stage) (Florican CRF with Nutricote, Sarasota, FL) at 10.09 $kg{\cdot}m^3$ (17 $lb{\cdot}yd^3$). Following transplant, all plants were watered-in, then moved to a full-sun nursery pad where they received overhead irrigation as needed. On 12 June 2020 all plants were treated with herbicides with an over the top application using a CO_2 backpack sprayer calibrated to deliver 42 GPA. Prior to treatment plants were 164.5 cm in height. Plants were split into 9 treatment groups with 12 experimental units per group per each species, Murray Cypress and Thuja Green Giant. Plants were randomly selected and a corresponding label with treatment group and experimental unit was labeled with a paint marker on each pot. Each treatment group was placed in a secluded area of the Paterson Greenhouse Facility to eliminate any possibility for spray drift. Herbicides being evaluated were indaziflam (Marengo®, Bayer Environmental Science, Research Triangle Park, NC) at 9 and 18 fl oz per A, dimenthenamid-P (Tower®, BASF, Research Triangle Park, NC) at 32 and 64 fl oz per A, flumioxazin (SureGuard®, Valent U.S.A. Corporation, Walnut Creek, CA) at 12 and 24 fl oz per A, and prodiamine, isoxaben (Gemini® 3.7 SC, Everris NA, Inc., Dublin, OH) at 43.5 and 87 fl oz per A. A non-treated control was included along with the treatments for phytotoxicity comparison.

The two herbicide rates being used for each herbicide represent the high recommended rate and twice the high recommended rate. These treatment levels were selected to evaluate the level of phytotoxicity tolerance for each species to simulate a grower making an improper application due to not calibrating a sprayer properly or an error in calculation of active ingredient to be mixed. All plants were irrigated one hour after treatment. Following treatment, all plants were returned to the nursery pad described above and received normal irrigation for the following two weeks. Exactly two weeks after treatments were applied, ratings were taken to assess for any visible signs of phytotoxicity when comparing plants to the non-treated control group.

This experiment was a completely randomized design consisting of 9 total groups and 12 plants per group for each of the two species. Species were kept separate among groups, but each species received the same treatments and methods. Prior to treatment growth indices were recorded for each plant. Following treatment, injury ratings were taken visually using a 0 to 10 scale, 0 representing 0% injury and 10 representing 100% injury. Ratings were taken on new growth and the entire plant. The first rating was taken 2 weeks after treatment (2WAT1) Approximately 9 WAT1, ratings were retaken, and the treatments were applied a second time on 26 August 2020. Treatments were rated again 3 WAT2. Growth indexes [(height + tree widest width + tree width perpendicular) ÷ 3] were taken prior to any treatment on 11 June 2020 then subsequently after treatments as following: 10 WAT1 and 16 WAT2.

Trial 2 (Mobile)

On 4 March 2020, at the Ornamental Horticulture Research Center (OHRC) in Mobile, AL, fully rooted liners of Murray Cypress (x *Cuprocyparis leylandii*) and Thuja Green Giant (*T. plicita* × *T. standishii*) were transplanted into 6.0 L (2 gallon) containers. The rooted liners were obtained from Ralph Rushing Nursery in Semmes, AL. Liners were transplanted into a 100% pine bark substrate amended with a controlled release fertilizer (18-6-8, 2-Stage) (Florican CRF with Nutricote, Sarasota, FL) at 10.09 kg·m^3 (17 lb·yd^3). Following transplant, all plants were watered-in, then moved to a full-sun nursery pad where they received overhead irrigation as needed. All trees remained on this pad and were irrigated following the above schedule and were routinely hand weeded each week. On 1 July 2020 all plants were treated with herbicides with an over-the-top application using a CO_2 backpack sprayer calibrated to deliver 40 GPA. Prior to treatment, plants were split into 9 treatment groups with 12 experimental units per group per each species, Murray Cypress and Thuja Green Giant. Plants were randomly selected and a corresponding label with treatment group and experimental unit was labeled with a paint marker on each pot. Each treatment group was placed in a secluded area of OHRC to eliminate any possibility for spray drift. Herbicides evaluated were *indaziflam* (Marengo®, Bayer Environmental Science, Research Triangle Park, NC) at 9 oz per A with irrigation following treatment immediately and 24 hours post treatment, *dimenthenamid-P* (Tower®, BASF, Research Triangle Park, NC) at 32 fl oz per A with irrigation following treatment immediately and 24 hours post treatment, *flumioxazin* (SureGuard®, Valent U.S.A. Corporation, Walnut Creek, CA) at 12 fl oz per A with irrigation following treatment immediately and 24 hours post treatment, and *prodiamine, isoxaben* (Gemini® 3.7 SC, Everris NA, Inc., Dublin, OH) at 43.5 oz per A with irrigation following treatment immediately and 24 hours post treatment. A non-treated control was included along with the treatments for phytotoxicity comparison. The herbicide rate being used for each treatment was the highest recommended rate.

Corresponding plants were irrigated 1 hour or 24 hours post treatment to simulate a rain shower following application as labels recommends an irrigation event to activate products. Irrigation or rain events timed immediately after an over-the-top application may reduce phytoxicity. Following treatment, all plants were returned to the nursery pad described above and received normal irrigation for the following three weeks. Three weeks after treatments were applied, ratings were taken to assess for any visible signs of phytotoxicity when comparing plants to the control group.

This experiment was a completely randomized design consisting of 9 total groups and 12 plants per group for each of the two species. Species were kept separate among groups. Following treatment, injury ratings were taken visually using a 0 to 10 scale, 0 representing 0% injury and 10 representing 100% injury. Ratings were taken on new growth and the entire plant.

The first rating was taken 3 and 10 WAT1. Treatments were applied a second time at 10 WAT1. Growth index [(height + tree widest width + tree width perpendicular) ÷ 3] was taken 2 days prior to treatment and 1 WAT1 and 3 WAT2.

Data Analysis

In Trial 1, the effects of rate and product on growth data was analyzed using analysis of variance using JMP statistical software ($P < 0.05$, JMP Version 15.2 SAS Institute Inc., Cary, NC, 2019). Least square means of herbicide treatments were compared to the untreated control using Dunnett's test using JMP statistical software. Nonparametric procedures were used on all phytotoxicity ratings with Kruskal-Wallis nonparametric test for the entire model (JMP). Steel Dwass with control was used to compare ratings for each herbicide treatment to the untreated control (JMP).

Results

Trial 1

The main effects and potential interactions between rate and herbicide were tested (Table 2.1). At 13 WAT there was an interaction between rate and herbicide of height increase when applied to both Leyland cypress and Arborvitae. At 21 WAT there were no differences associated with the main effects or their interactions on both species in increase in height; however, herbicide product was significant for Arborvitaes. Similar to height, an interaction between rate and herbicide products on both species at 13 WAT on growth index was observed at the 0.1 α level. A stronger interaction was observed at the 0.05 α level at 21 WAT on Leyland cypress. The interactions in growth indexes between rate and herbicide indicate that some herbicides may affect growth depending on the rate.

There were no differences in height increase in both species at 13 and 21 WAT between any of the products regardless of rate when compared to the control (Table 2.2, Table 2.3). At 13 and 21 WAT Leyland cypress and Arborvitae had no differences in growth index between any of the products when compared to the control except for Prodiamine and Isoxaben combination at 21 WAT on Arborvitae, resulting in a lower growth index by 16.6% (Table 2.3).

Damage was not observed on Arborvitaes at the 1x or 2x rate by any herbicide or rate when compared to the control throughout the entire study. No significance in damage was observed 2 weeks or 10 weeks on Leyland cypress associated with new growth or damage over the entire plant when compared to the untreated control. Damage was observed on new growth and across the entire plant at three weeks after the second treatment on both rates of Indaziflam (Table 2.4, Table 2.5). This however only represented a small fraction of damage that would be considered acceptable in a Christmas tree operation depending on the time of year and the age of the tree. This damage would not be acceptable in a nursery situation where any damage would be considered unacceptable.

Trial 2.

No interaction was observed between irrigation delay and product for either species in regard to increase in height or growth index. This indicates that the irrigation delay was not a contributing factor to growth across all products. No differences were observed in height increase or growth index between the untreated control and any products and irrigation delays times were seen on Arborvitae throughout the study (Table 2.6). No differences were seen in height increase in Leyland cypress at 13 WAT1 and 13 WAT2. Both Indaziflam irrigation delay times were significantly lower in growth index when compared to the control at 13WAT1; however, the one-hour delay was significantly lower at 13 WAT2. Flumioxizin was also significantly smaller than the control at this time (Table 2.7).

Damage was observed with indaziflam to new growth on Arborvitae at the 24 hour delay at 3 WAT when compared to the untreated control. Damage was also observed to the entire plant by ndaziflam at the one-hour delay 13 WAT and by the 24 hour delay 13 WAT and 21 WAT when compared to the untreated control. No other significant damage was seen on any product at either delay on arborvitae when compared to the control (Table 2.9). Damage to new growth was observed on Leyland cypress at the 24-hour delay on both indaziflam and dimethenamid-P. No other significant damage was observed on any of the other new growth on the other products at both delay times. Generally, indaziflam had minor damage throughout the study at both irrigation delay times. Some damage was observed with dimethenamid-P, however plants grew out of this damage after treatment 2 (Table 2.10). Damage was of little horticultural significance and would be considered acceptable in a Christmas tree farm scenario.

Discussion

Generally, across both studies very little damage was observed across all the products tested on both species (Table 2.11). Considering no effect was seen between the 1x and 2x rate, growers can consider these products considerably safe regarding phytotoxicity and plant growth. Generally, while not significant, growth was more impacted by the 1-hour irrigation delay than the 24-irrigation delay. This cannot be explained through these results and may be due to some environmental condition associated with how the plants were handled and not associated with the irrigation delay.

Aulakh (2020), did not record any injury from flumioxazin on Canaan fir (*Abies balsamea* var *phanerolepis*) when testing for efficacy, which coincides with data for both species in our trial. The products Marengo® and Sureguard® were used for the active ingredients, indaziflam and flumioxazin respectively. Both products are labeled for over-the-top application on arborvitae and many other conifer species; however, they are not labeled for over-the-top application of Leyland cypress. The Sureguard® (indaziflam) label indicates that it should be used before budbreak or after conifer species have sufficiently hardened off. Injury was not observed when using flumioxazin. Similarly, Aulakh (2020), did not record any injury from flumioxazin on Canaan fir (*Abies balsamea* var *phanerolepis*) when testing for efficacy. The Tower® (dimenathamid-P) label restricts over-the-top applications until trees have been established for one or more years in the field. The results from our screening suggest that Tower® could be used at the label rate during the first year of establishment. These trials validate the label recommendation of Gemini® where both arborvitae and Leyland cypress are indicated as a species "not likely to be injured" when over-the-top applications are made.

When surveyed many Christmas tree growers in Alabama, Louisiana, and Mississippi did not use pre-emergent herbicides (personal communication, Jeremy Pickens, 2018). These active ingredients represent products that are fairly new to the industry. Costs associated with one application of these pre-emergent products made on an acre are Marengo® (indaziflam) $72.99/acre, Tower® (dimetheneamid-P) $31.20/acre, Sureguard® (flumioxazin) $50.40/acre, and Gemini® (prodiamine + isoxaben) $51.39/acre. Growers reported making anywhere from 4 to 8 applications of glyphosate per year. This represents cost associated with the chemical; however, the savings in labor costs associated with reduced spraying would be of greater interest to growers (Table 2.12).

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Tables and Figures

Table 2.1. Trial 1: Effects of growth associated with product and rate when applied over the top of (x *Cuprocyparis leylandii*) 'Murray' and (*Thuja plicata* x *standishi*) 'Green Giant'.

		Leyland Cypress	Arborvitatae
Increase in Height		Significance of treatment factors[X]	
13 WAT[Z]	Rate (R)[Y]	0.6239	0.6374
	Herbicide (H)	0.3638	0.2649
	R by H	0.0193	0.0090
21 WAT	Rate (R)	0.8558	0.982
	Herbicide (H)	0.4122	0.0045
	R by H	0.2031	0.4413
		Leyland Cypress	Arborvitatae
Increase in Growth Index		Significance of treatment factors	
13 WAT	Rate (R)	0.1293	0.8473
	Herbicide (H)	0.0021	0.6428
	R by H	0.0502	0.0833
21 WAT	Rate (R)	0.1217	0.2133
	Herbicide (H)	0.1631	0.1712
	R by H	0.0051	0.0250

[Z]WAT = weeks after treatment. Initial treatment was applied on July 1, 2020 and second treatment was applied 13 WAT one.

[Y]Herbicides were applied at 1x or 2x the labled rate.

Table 2.2. Trial 1: Growth effects of preemergent herbicide application on 'Green Giant' arborvitae (*Thuja plicata x standishi*) when applied over the top at two rates.

	Rate[Z]		Rate[Y]	Increase Height[X]		Increase Growth Index	
Herbicide	kg·ai·ha^{-1}	lb·ai·A^{-1}	(hr)	8 WAT1[X]	15 WAT2	8 WAT1	15 WAT2
Indaziflam	0.05	0.04	1x	34.00 NS[W]	54.60 NS	21.20 NS	30.60 NS
Indaziflam	0.10	0.09	2x	30.00 NS	50.80 NS	17.90 NS	27.00 NS
Dimethenamid-P	1.68	1.50	1x	31.70 NS	49.50 NS	18.20 NS	27.10 NS
Dimethenamid-P	3.40	3.00	2x	34.20 NS	53.30 NS	20.50 NS	29.20 NS
Flumioxazin	0.42	0.38	1x	30.90 NS	51.60 NS	17.30 NS	26.80 NS
Flumioxazin	0.80	1.70	2x	33.80 NS	56.90 NS	18.80 NS	27.50 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	1x	36.00 NS	57.00 NS	20.50 NS	28.10 NS
Prodiamine, Isoxaben	1.7;1.14	1.5;1.02	2x	32.70 NS	51.40 NS	17.30 NS	25.00 *
Control	-	-	-	31.90 -	53.80 -	19.50 -	30.00 -

[Z]Rate is expressed in kg of active ingredient per hectare and all treatments were applied at 392 liters per hectare (42 gallons per A).

[Y]Irrigation delay represents the time in between application and the first irrigatino application.

[X]WAT = weeks after treatment.First applications was made on June 12., 2020 and the second application was made on August 26, 2020 (12 weeks after treatment one).

[W]Difference between control and individual treatment means are indicated by an asterisk (Dunnett's test)at α = 0.5 (*), 0.01 (**), or 0.001 (***).

Table 2.3. Trail 1: Growth effects of preemergent herbicide application on Murray Crypress (x *Cuprocyparis leylandii)* 'Murray' when applied over the top.

	Rate[Z]		Rate[Y]	Increase Height (cm)[X]		Increase Growth Index	
Herbicide	kg·ai·ha^{-1}	lb·ai·A^{-1}	(hr)	8 WAT1[X]	.5 WAT.	8 WAT1	15 WAT2
Indaziflam	0.05	0.04	1x	24.7 NS[W]	42 NS	10.5 NS	16.8 NS
Indaziflam	0.10	0.09	2x	23.2 NS	38.8 NS	13.0 NS	22.3 NS
Dimethenamid-P	1.68	1.50	1x	19.7 NS	33.7 NS	9.8 NS	14.8 NS
Dimethenamid-P	3.40	3.00	2x	28.4 NS	45.7 NS	13.1 NS	22.5 NS
Flumioxazin	0.42	0.38	1x	23.9 NS	43.4 NS	11.6 NS	20.7 NS
Flumioxazin	0.80	1.70	2x	25.8 NS	43.6 NS	14.8 NS	21.4 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	1x	30.5 NS	49.8 NS	17.8 NS	25.4 NS
Prodiamine, Isoxaben	1.7;1.14	1.5;1.02	2x	24.7 NS	43.4 NS	14.6 NS	21.4 NS
Control	-	-	-	23.2 -	40.6 -	12.33 -	20.8 -

[Z]Rate is expressed in kg of active ingredient per hectare and all treatments were applied at 392 liters per hectare (42 gallons per A).

[Y]Irrigation delay represents the time in between application and the first irrigatino application.

[X]WAT = weeks after treatment.First applications was made on June 12., 2020 and the second application was made on August 26, 2020 (12 weeks after treatment one).

[W]Difference between control and individual treatment means are indicated by an asterisk (Dunnett's test)at $\alpha = 0.5$ (*), 0.01 (**), or 0.001 (***).

Table 2.4. Trial 1: Comparisons of phytotoxicity ratings (*Thuja plicata* x *standishi)* 'Green Giant'select preemergent herbicides when compared to an untreated control.

	Rate[Z]		Rate[Y]	New growth with damage [X]			Entire plant with damage [X]		
Herbicide	$kg{\cdot}ai{\cdot}ha^{-1}$	$lb{\cdot}ai{\cdot}A^{-1}$	(hr)	2 WAT1[X]	10WAT1	3 WAT2	2 WAT1	10WAT1	3 WAT2
Indaziflam	0.05	0.04	1x	0 NS[W]	0 NS	0 NS	0 NS	0 NS	0 NS
Indaziflam	0.10	0.09	2x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Dimethenamid-P	1.68	1.50	1x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Dimethenamid-P	3.40	3.00	2x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Flumioxazin	0.42	0.38	1x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Flumioxazin	0.80	1.70	2x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	1x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Prodiamine, Isoxaben	1.7;1.14	1.5;1.02	2x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Control	-	-	-	0 -	0 -	0 -	0 -	0 -	0 -

[Z]Rate is expressed in kg of active ingredient per hectare and all treatments were applied at 392 liters per hectare (42 gallons per acre).

[Y]Inidicates 1x and 2x times the labled rate.

[X]WAT = weeks after treatment. Thefirst applications was made on June 12, 2020 and the second application was made on August26, 2020 (13 weeks after treatment one).

[W]Difference between control and individual treatment means are indicated by an asterisk (Steel-Dwass with control) at α = 0.5 (*), 0.01 (**), or 0.001 (***).

Table 2.5. Trial 2: Comparisons of phytotoxicity ratings (x *Cuprocyparis leylandii)* 'Murray' select preemergent herbicides when compared to an untreated control.

	Rate[Z]		Rate[Y]	New growth with damage [X]			Entire plant with damage [X]		
Herbicide	$kg{\cdot}ai{\cdot}ha^{-1}$	$lb{\cdot}ai{\cdot}A^{-1}$	(hr)	2 WAT1[X]	10WAT1	3 WAT2	2 WAT1	10WAT1	3 WAT2
Indaziflam	0.05	0.04	1x	0 NS[W]	0 NS	0.91 *	0 NS[W]	0 NS	0.58 *
Indaziflam	0.10	0.09	2x	0 NS	0 NS	0.16 *	0 NS	0 NS	0.16 *
Dimethenamid-P	1.68	1.50	1x	0 NS	0.08 NS	0 NS	0 NS	0 NS	0 NS
Dimethenamid-P	3.40	3.00	2x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Flumioxazin	0.42	0.38	1x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Flumioxazin	0.80	1.70	2x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	1x	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Prodiamine, Isoxaben	1.7;1.14	1.5;1.02	2x	0 NS	0 NS	0 NS	0 NS	0 NS	0.33 NS
Control	-	-	-	0 -	0 -	0 -	0 -	0 -	0 -

[Z]Rate is expressed in kg of active ingredient per hectare and all treatments were applied at 392 liters per hectare (42 gallons per acre).

[Y]Inidicates 1x and 2x times the labled rate.

[X]WAT = weeks after treatment. Thefirst applications was made on June 12, 2020 and the second application was made on August26, 2020 (13 weeks after treatment one).

[W]Difference between control and individual treatment means are indicated by an asterisk (Steel-Dwass with control) at $\alpha = 0.5$ (*), 0.01 (**), or 0.001 (***).

Table 2.6. Effects of growth associated with time between preemergent herbicide application and first irrigation event on (x *Cuprocyparis leylandii*) 'Murray' and (*Thuja plicata* x *standishi*) 'Green Giant'.

		Leyland Cypress	Arborvitatae
Increase in Height		Significance of treatment factors[X]	
13 WAT[Z]	Irrigation delay (ID)[Y]	0.1726	0.3587
	Herbicide (H)	0.7073	0.0696
	ID by H	0.2932	0.4412
21 WAT	Irrigation delay (ID)	0.0738	0.982
	Herbicide (H)	0.0881	0.0045
	ID by H	0.3616	0.4413
		Leyland Cypress	Arborvitatae
Increase in Growth Index		Significance of treatment factors	
13 WAT	Irrigation delay (ID)	0.0625	0.6516
	Herbicide (H)	0.0156	0.3469
	ID by H	0.0811	0.9085
21 WAT	Irrigation delay (ID)	0.0025	0.6973
	Herbicide (H)	0.0641	0.0262
	ID by H	0.7229	0.6082

[Z]WAT = weeks after treatment. Initial treatment was applied on July 1, 2020 and second treatment was applied 13 WAT one.

[Y]Irrigation delay represents the time in between application and the first irrigation application.

Table 2.7. Trial 2: Growth effects of preemergent herbicide application on (x *Cuprocyparis leylandii)* 'Murray' when applied over the top.

	Rate[Z]		Delay[Y]	Increase Height[X]		Increase Growth Index	
Herbicide	$kg{\cdot}ai{\cdot}ha^{-1}$	$lb{\cdot}ai{\cdot}A^{-1}$	(hr)	13 WAT1[X]	13 WAT2	13 WAT1	13 WAT2
Indaziflam	0.05	0.04	1	11.8 NS[W]	16.2 NS	5.3 *	6.7 ***
Indaziflam	0.05	0.04	24	11.2 NS	15.8 NS	4.4 **	10.7 NS
Dimethenamid-P	1.68	1.50	1	11.3 NS	14.2 NS	6.1 NS	10.5 NS
Dimethenamid-P	1.68	1.50	24	14.2 NS	19.8 NS	8.9 NS	12.8 NS
Flumioxazin	0.42	0.38	1	12.6 NS	17.1 NS	8.3 NS	10.9 ***
Flumioxazin	0.42	0.38	24	12.2 NS	17.8 NS	6.5 NS	12.6 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	1	14.3 NS	15.2 NS	6.9 NS	9.5 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	24	14.8 NS	19.3 NS	8.1 NS	12.5 NS
Control	-	-	-	14.3 -	19.3 -	9.5 -	15.1 -

[Z]Rate is expressed in kg of active ingredient per hectare and all treatments were applied at 392 liters per hectare (42 gallons per acre).

[Y]Irrigation delay represents the time in between application and the first irrigatino application.

[X]First applications was made on July 1, 2020 and the second application was made on October 2, 2020 (13 weeks after treatment one).

[X]WAT = weeks after treatment

[W]Difference between control and individual treatment means are indicated by an asterisk (Dunnett's test)at $\alpha = 0.5$ (*), 0.01 (**), or 0.001 (***).

Table 2.8. Trial 2: Growth effects of preemergent herbicide application on 'Green Giant' arborvitae (*Thuja plicata x standishi*) when applied over the top.

	Rate[Z]		Delay[Y]	Increase Height[X]		Increase Growth Index	
Herbicide	kg·ai·ha^{-1}	lb·ai·A^{-1}	(hr)	13 WAT[X]	21 WAT	13 WAT	21 WAT
Indaziflam	0.05	0.04	1	18.1 NS[W]	20.2 NS	9.0 NS	13.7 NS
Indaziflam	0.05	0.04	24	16.3 NS	20.6 NS	9.0 NS	14.8 NS
Dimethenamid-P	1.68	1.50	1	14.8 NS	17.5 NS	7.6 NS	12.5 NS
Dimethenamid-P	1.68	1.50	24	12.3 NS	16.3 NS	8.9 NS	12.1 NS
Flumioxazin	0.42	0.38	1	14.4 NS	17.9 NS	8.9 NS	14.1 NS
Flumioxazin	0.42	0.38	24	16.6 NS	21 NS	8.9 NS	15.5 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	1	18.9 NS	23.3 NS	9.9 NS	15.8 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	24	16.5 NS	21 NS	9.9 NS	14.8 NS
Control	-	-	-	14.3 -	16.2 -	9.0 -	12.8 -

[Z]Rate is expressed in kg of active ingredient per hectare and all treatments were applied at 392 liters per hectare (42 gallons per acre).

[Y]Irrigation delay represents the time in between application and the first irrigation application.

[X]First application was made on July 1, 2020 and the second application was made on October 2, 2020 (13 weeks after treatment one).

[X]WAT = weeks after treatment

[W]Difference between control and individual treatment means are indicated by an asterisk (Dunnett's test) at $\alpha = 0.5$ (*), 0.01 (**), or 0.001 (***).

Table 2.9. Trial 2: Comparisons of phytotoxicity ratings (*Thuja plicata x standishi)* 'Green Giant'select preemergent herbicides when compared to an untreated control.

	Rate[Z]		Irrigation Delay	New growth with damage [X]			Entire plant with damage [X]		
Herbicide	kg·ai·ha^{-1}	lb·ai·A^{-1}	(hr)[Y]	3 WAT1[X]	13 WAT1	8 WAT2	3 WAT1	13 WAT1	8 WAT2
Indaziflam	0.05	0.04	1	0 NS[W]	0 NS	0 NS	0.4 NS[W]	1 ***	0 NS
Indaziflam	0.05	0.04	24	0.6 *	0 NS	0 NS	0.6 NS	1 ***	0 **
Dimethenamid-P	1.68	1.50	1	1.08 NS	0 NS	0 NS	0 NS	0.2 NS	0 NS
Dimethenamid-P	1.68	1.50	24	0 NS	0 NS	0 NS	0 NS	0.3 NS	0 NS
Flumioxazin	0.42	0.38	1	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Flumioxazin	0.42	0.38	24	0 NS	0 NS	0 NS	0 NS	0.1 NS	0 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	1	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	24	0 NS	0 NS	0 NS	0 NS	0 NS	0 NS
Control	-	-	-	0 -	0 -	0 -	0 -	0 -	0 -

[Z]Rate is expressed in kg of active ingredient per hectare and all treatments were applied at 392 liters per hectare (42 gallons per acre).

[Y]Irrigation delay represents the time in between application and the first irrigatino application.

[X]First applications was made on July 1, 2020 and the second application was made on October 2, 2020 (13 weeks after treatment one).

[X]WAT = weeks after planting

[W]Difference between control and individual treatment means are indicated by an asterisk (Steel-Dwass with control) at α = 0.5 (*), 0.01 (**), or 0.001 (***).

Table 2.10. Trial 2: Comparisons of phytotoxicity ratings (x *Cuprocyparis leylandii)* 'Murray' select preemergent herbicides when compared to an untreated control.

	Rate[Z]		Irrigation Delay	New growth with damage [X]			Entire plant with damage [X]		
Herbicide	kg·ai·ha^{-1}	lb·ai·A^{-1}	(hr)[Y]	3 WAT1	13 WAT1	8 WAT2	3 WAT1	13 WAT1	8 WAT2
Indaziflam	0.05	0.04	1	2 **[W]	0 NS	0 NS	1.0 ***[W]	0.6 ***	1 *
Indaziflam	0.05	0.04	24	1.75 ***	0 NS	0 NS	1.0 ***	0.9 ***	0 NS
Dimethenamid-P	1.68	1.50	1	0.1 NS	0 NS	0 NS	0.0 NS	0.6 *	0 NS
Dimethenamid-P	1.68	1.50	24	0.6 *	0 NS	0 NS	0.6 *	0.8 **	0 NS
Flumioxazin	0.42	0.38	1	0 NS	0 NS	0 NS	0.0 NS	0.0 NS	0 NS
Flumioxazin	0.42	0.38	24	0 NS	0 NS	0 NS	0.0 NS	0.1 NS	0 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	1	0 NS	0 NS	0 NS	0.0 NS	0.0 NS	0 NS
Prodiamine, Isoxaben	0.84; 0.57	0.75; 0.51	24	0 NS	0 NS	0 NS	0.0 NS	0.0 NS	0 NS
Control	-	-	-	0 -	0 -	0 -	0.0 -	0.0 -	0 -

[Z]Rate is expressed in kg of active ingredient per hectare and all treatments were applied at 392 liters per hectare (42 gallons per acre).

[Y]Irrigation delay represents the time in between application and the first irrigatino application.

[X]First applications was made on July 1, 2020 and the second application was made on October 2, 2020 (13 weeks after treatment one).

[X]WAT = weeks after planting

[W]Difference between control and individual treatment means are indicated by an asterisk (Steel-Dwas with control) at $\alpha = 0.5$ (*), 0.01 (**), or 0.001 (***).

Table 2.11: Preemergent Herbicide damage description from over-the-top applications on Arborvitae (*Thuja plicita* x *standishi*) and Leyland cypress (x *Cuprocyparis leylandii*)[z]

Active Ingredient	Trade Name	REI (hours)	Arborvitae Damage	Leyland Cypress Damage
Indaziflam	Marengo®	12	No damage or reduction in growth	Necrotic yellowing of tips on new growth
Dimetheneamid-P	Tower®	12	No damage or reduction in growth	No damage or reduction in growth
Flumioxazin	SureGuard®	12	No damage or reduction in growth	No damage or reduction in growth
Prodiamine + Isoxaben	Gemini®	12	No damage, but 16.6% reduction in growth	No damage or reduction in growth

[Z] A study conducted on Leyland cypress and Arborvitae in 2020

Table 2.12: Costs of applying preemergent herbicides in Christmas tree farms compared to glyphosate

Active Ingredient	Trade Name	[Z]Cost/Hectare ($)	Cost/Acre ($)	Applications per year	[Y]Time to Treat 1 acre (hours)	Cost/hour ($)	Total Cost/year/acre ($)
Indaziflam	Marengo®	180.67	72.99	4	1	25	391.96
Dimetheneamid-P	Tower®	77.23	31.20	4	1	25	224.80
Flumioxazin	SureGuard®	124.75	50.40	4	1	25	301.60
Prodiamine + Isoxaben	Gemini®	127.2	51.39	4	1	25	305.56
Glyphosate	RoundUp®	25.74	10.40	8	1	25	283.20

[Z]Based off of 1.8 m between rows with 0.91 m herbicide band application down the length of rows with 2200 tree density/ha

[Y]Time reported by local grower to treat one acre of Christmas trees