Chapter 1. INTRODUCTION

Any grass plant that can survive regular mowing at a reasonably low height may be considered to be a turfgrass. For the turfgrass plant to fulfill its mission of forming a dense, dark, green turf, it must be furnished adequate growing conditions. Nearly all commonly used turfgrass plants are perennial, living more than two growing seasons. Turfgrasses are divided into two main groupings: warm-season turfgrasses such as centipede, bermudagrass and zoysiagrass and cool-season turfgrasses such as tall fescue, Kentucky bluegrass and perennial ryegrass. These two groups of turfgrasses are very different in how they react to variations in soil moisture, sunlight and temperatures as represented in Table 1.1 (1).

Cool-season turfgrasses, because of their lower optimum temperature requirements, have a period of rapid growth in the spring and fall. Warm-season turfgrasses have a peak growth period in the summer, when cool-season grasses have reduced growth. When one group of turfgrasses is at its peak growth the other is in a period of temperature stress. Other than weedy invasions of one turf into another, it is rare to find mixtures of cool- and warm-season turfgrasses (i.e. winter overseeding of warm season turf). On one hand it seems beneficial to maintain a mixed stand of turf, thereby providing a dense green turf cover year round. However, a smooth transition would always be difficult in intensively managed turf and poor visual quality would be exhibited by the vast contrasts between the two turfgrasses in terms of leaf texture and color.

From discussions with golf course superintendents, lawn care specialists, students and university professors, encroachment and contamination of bermudagrass in other bermudagrass cultivars and/or cool-season turfgrasses is becoming more and more of a problem (4, 5, 7, 12, 17, 31, 32). Bermudagrass, with an extensive rhizome and stolon system, has tremendous reproductive potential. This characteristic, and its ability to survive in diverse environments, makes this weed very difficult to control in turf.

Great progress has been made in the ability to control most broadleaf and annual grass weeds in turf, thereby reducing the competition placed on vigorous growing summer weeds such as bermudagrass (5, 20). During the summer, bermudagrass will fill voids in cool-season turf caused by turf stress or eradication of other plants in the turf stand. Bermudagrass maintains the ability to constantly develop and reproduce from rhizomes located at various soil depths (11, 22, 31). Thus, bermudagrass can take rapid advantage of any open space in turf stands.

A formulation known as Horizon 2000, containing fenoxaprop and fluazifop, has provided at least some success in previous research for bermudagrass shoot suppression in tall fescue. This research will be focused on the use of fenoxaprop and fluazifop to suppress bermudagrass rhizomes and stolons as well as shoots.

1.1. LITERATURE REVIEW

Bermudagrass (*Cynodon dactylon* (L.) *Pers.*) is considered to be one of the most difficult to control grass weeds in turf in the U.S. Recent breeding efforts, however, have produced bermudagrass cultivars that are adequate as a turfgrass (19, 31). Over the past few years, many cultivars of bermudagrass have been produced which have a high degree of resistance to diseases and insects, good color, excellent heat and drought tolerance, a vigorous low growing dense turf, good traffic tolerance and cold tolerance (4, 12, 17, 19). Ironically, an increasing use of bermudagrass caused an even greater problem to the turf manager (5, 21). Bermudagrass contamination either by encroachment into another turfgrass or into other hybrids of bermudagrass frequently occurs and induces dramatic differences in texture and color (12, 22).

Bermudagrass is a desirable turfgrass species when grown in a monostand. When mixed with a cool-season turfgrass or another cultivar of bermudagrass it may be considered a serious weed. Bermudagrass is the number one pasture grass in the southeastern U.S.; however, bermudagrass is also considered to be the second worst grass weed in the world (22). A mixed stand of bermudagrass and virtually any cool-season turfgrass is an undesirable ground cover in high maintenance turf areas, with the sole exception being the overseeding of warm-season turfgrasses in the winter (17, 31). One of the most difficult problems facing a turf specialist is the attempt to selectively control a warm season perennial grass in a stand of cool-season turfgrass. Appearance and quality of the turfgrass cover is reduced because of great differences in leaf texture and color. In addition, bermudagrass will become dormant and brown in the late fall while the cool-season turfgrass is still actively growing, thereby creating a very poor quality turf area.

In warmer areas of the United States, bermudagrass growth is greater than that of other turfgrasses due to ideal climatic and edaphic conditions prevalent during the growing season and the physiological advantage of being a C_4 plant (11,16, 31). Preferably a herbicide should either control or should suppress bermudagrass enough for the desired grass to compete and gradually replace the bermudagrass (7). However, in order to be effective, a herbicide must suppress bermudagrass without injuring the desired turfgrass species.

Holm et. al.(22) reported that bermudagrass produces rhizomes that are quite superficial and/or very deep, ranging in soil depth from a few centimeters to a meter or more. They believe this adaptation may be the primary factor in its ability to survive in extreme climates and inhabit several different soil types. This biological advantage allows for a great variation in shoot emergence. Bermudagrass control for an extended period of time requires toxic amounts of foliar applied herbicide to reach the reproductive portions of the plant. The chemical must be translocated basipetally through the rhizome system. While non-translocated herbicides often provide good initial control of perennial weeds, a late season shoot regrowth from rhizomes or other parts occurs (8, 12, 16, 20).

Summer annual and perennial grass weed competition can limit successful spring and summer establishment of cool-season grasses (11). Therefore, vigorous summer weeds must be suppressed enough to allow for adequate establishment of the cool-season turfgrass. Bermudagrass is a particularly invasive species in cool-season lawns because of its vigorous growth rate and rhizomatous and stoloniferous habit. Bermudagrass is widely distributed in lawns, recreational facilities, highway rights-of-way and pasturelands throughout the warmer areas of the country (1). In fact, bermudagrass has been cited as being the most common desirable turfgrass in the world (22).

Bermudagrass is difficult to control. Frequently, the repeated application of herbicides which are ineffective against bermudagrass cause a greater problem by allowing for a heavier infestation and establishment of this persistent weed (4, 31). In mixed stands with bermudagrass, conditions should favor the growth of the desired turfgrass, enabling it to compete with chemically weakened bermudagrass. When integrated properly along with chemical suppression, cultural control methods such as manipulations of mowing height, soil fertility, and irrigation practices are far more advantageous to the turf manager than chemical control alone (7). Furthermore, modern molecular biology techniques are also establishing new avenues in weed control. Research is currently underway to develop glyphosate resistant tall fescue, bentgrass and perennial ryegrass and significant progress is being made toward this goal (18). Practices such as this would allow for the use of otherwise nonselective herbicides to achieve bermudagrass control.

Tall fescue (*Festuca arudinacea Schreb.*) is a cool-season, bunch type species, which originated in Europe and is now common to much of the U.S. It is adapted to a wide range of soil and climatic conditions and forms a turf of low shoot density (1). It is a long-lived perennial when grown in the transition zone. Desirable characteristics of tall fescue include low fertility requirement, rapid establishment from seed, adaptation to a wide range of soil types and good drought tolerance as roots penetrate to a great depth in the soil. Tall fescue has an upright bunch type growth habit and is characterized by slow summer growth (24). During summer, vigorous weeds such as bermudagrass and goosegrass (*Eleusine indica)* often invade areas where tall fescue is the desired turfgrass due its lack of growth and susceptibility to disease (7, 28).

Tall fescue retains green color year round, thereby increasing its popularity throughout the southeast for residential and commercial lawns where bermudagrass previously existed. Thereby, volunteer bermudagrass has becomes a serious weed and presently there are no consistently reliable herbicides to control bermudagrass without injuring tall fescue (7, 12). A major contrast in these two turfgrasses is year round color. The tall fescue remains green without a winter dormancy period while bermudagrass turns brown during its dormancy. Conversely, tall fescue can turn brown during periods of summer heat and drought stress.

Herbicides evaluated previously for control of bermudagrass in cool-season turfgrass have proven to offer only temporary or minimal reductions in bermudagrass infestations. Research has been conducted using chemicals including siduron [1-2-methylcyclohexyl)-3-phenylurea], oxadiazon [3-[2,4-dichloro-5- (1-methylethoxy) phenyl]-5-(1,1-dimethyl-1, 3,4-oxadizol)-2(3H)-one], fenoxaprop [2-[4-(6-chloro-2-benzoxazobyl] oxy] phenoxy] propanoate], fluazifop [2-[4-(5- trifluromethyl-2-pyridinyl) oxy] phenoxy] propionate], sethoxydim [2-[1-(ethoxyimino) butyl-5- {2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one], haloxyfop [2-(4-((3-chloro-5-trifluromethyl)-2-pyridinyl)oxy) phenoxy) propionate] and MSMA (monosodium acid methanearsonate) (4, 7, 9, 12, 21, 23, 24, 26, 28, 33, 34). In the past the only effective method of bermudagrass control was complete renovation of the site, using nonselective herbicides or fumigation. This method is very time consuming and expensive.

An abundant amount of research has been performed regarding fenoxaprop and fluazifop for bermudagrass control and also with regard to tall fescue tolerance (8, 9, 12, 13, 14, 16, 17, 20, 23, 24, 32, 36). Both fenoxaprop and fluazifop are aryl-propanoic-acids for selective control of annual and perennial grasses in broadleaf crops and turf. Fenoxaprop is partially systemic with no residual soil activity (35). Fluazifop is a systemic herbicide that exhibits at least marginal soil activity (35). Research has demonstrated that both compounds are effective in suppressing bermudagrass shoot growth (2, 3, 5, 9, 10, 12, 16, 17, 20, 21, 25, 26). Fenoxaprop alone is not as effective for bermudagrass control as fluazifop (31, 36). Moreover, tall fescue tolerance to fenoxaprop is much higher than to fluazifop (14, 23, 27).

Research has demonstrated inconsistent tolerance of tall fescue to fluazifop at rates ranging from 1.12-3.36 kg ai/ha. Different cultivars of tall fescue and different growth stages of the same cultivar vary in tolerance (3, 27). With fluazifop, a strong linear response in terms of both bermudagrass control and tall fescue injury is exhibited in response to increasing herbicide rates (8, 20). Perhaps even more important than the relationship between rate and control is the relationship between number and timing of applications and control. Bermudagrass has a very wide shoot emergence period due to its reproductive capabilities from rhizomes. Therefore sequential applications of systemic herbicides spaced approximately thirty days apart are the most effective means of suppression by reducing the number of viable rhizomes for shoot regrowth. A three-year study conducted in 1991-94 concluded that a synergistic reaction between fenoxaprop and sethoxydim existed in terms of common bermudagrass control when compared to sequential applications of each of these herbicides individually (24). An antagonistic reaction was observed with Tifway bermudagrass control with the same mixture (24). Therefore, a need exists for multiple applications of fenoxaprop and fluazifop to achieve adequate rhizome control through shoot absorption and translocation (24, 31).

The mode of action of fenoxaprop and fluazifop is inhibition of lipid biosynthesis, which prevents the formation of fatty acids (15, 30, 35). The primary symptom of aryloxyphenoxypropionates is cessation of plant growth due to a depletion of necessary fatty acids (15, 35). Secondary symptoms include chlorosis and necrosis of plant tissue followed by overall plant death. These symptoms are slow to develop (7 to 14 days) and appear first on new growth. Older tissues show symptoms more slowly due to the fact that they have a pool of fatty acids accumulated which must first be depleted before deleterious effects will be visible. The herbicide is taken up by the foilage and translocated in the phloem to the roots and rhizomes which allows control of perennial plants (15, 35).

The method by which aryloxyphenoxypropionates inhibit lipid biosynthesis is through the inhibition of a specific plant enzyme Acetyl-CoA Carboxylase (ACCase) (6, 8, 14, 15, 29, 30). ACCase is a complex enzyme that catalyzes the conversion of Acetyl CoA + HCO_3 Malonyl CoA + ADP+Pi. This reaction is required for fatty acid synthesis and occurs primarily in the chloroplast. Aryl-propanoic-acids are commonly known for another aspect of their physiological effects on plant tissue. Fenoxaprop and fluazifop have been repeatedly described as antagonists of auxin effects (15, 35). The antagonism between these two classes of herbicides is most likely due to an increased rate of aryl propanoic herbicide detoxification or conjugation (15). For this reason these herbicides cannot be used in combination with phenoxy broadleaf herbicides or others which mimic plant auxin effects.

The tolerance of tall fescue to fenoxaprop and fluazifop appears to be primarily based on metabolism and herbicide sequestration (26, 29). Research studies have demonstrated the sensitivity of ACCase in many tolerant plants. A temporary growth inhibition prior to a return to normal growth in tolerant plants following foliar application suggests herbicide metabolism and /or conjugation as a means of herbicide tolerance and /or resistance (29, 30). Tolerance of fine fescue appears to be based on the insensitivity of ACCase to these herbicides, which is similar to the tolerance mechanism of dicotyledonous species (26, 29).

In newer herbicide formulations, the fenoxaprop active ingredient is different from the one found in previous formulations. The fenoxaprop in the newer formulations is enriched in the R(+) isomer isolated from other isomers and these formulations are about twice as effective as the racemate predecessors containing both the R(+) and S(-) isomers (32). Muehler (29) reported that the S(-) isomer somehow must disrupt or reduce the activity of the R(+) isomer. This was hypothesized by Muehler in regards to sequential applications of each isomer separately to the same plant in which control being accomplished by the R+ isomer was negated following application of the S- isomer (29). The fenoxaprop R(+) enriched formulations not only have an increased activity in terms of weed control but also have a much lower crop tolerance level, supporting the hypothesis regarding the increased activity of this isolated isomer.

To date, no studies have been published on absorption and translocation of the mixture containing fenoxaprop(R+ isomer only) and fluazifop in the bermudagrass or tall fescue. However, research has shown that fenoxaprop and fluazifop individually are at least partially effective for suppression of bermudagrass in cool season turfgrasses (12, 24).

1.2. OBJECTIVES

The objectives of this research were three-fold. First, field tests were performed to determine the efficacy of the premix fenoxaprop plus fluazifop for control of various bermudagrass cultivars in tall fescue. Secondly, field tests were performed to determine if any differences existed among bermudagrass cultivars in tolerance to fenoxaprop and fluazifop. Thirdly, greenhouse tests were performed to evaluate interactions involved between fenoxaprop and fluazifop with regard to bermudagrass responses.

Table 1.1. Temperature Differences (1).

	Warm-Season	Cool-Season
Ideal Shoot Growth	80-95 °F	60-75 °F
Ideal Root Growth	75-85 °F	50-65 °F
Upper Limit-Shoot Growth	120 °F	90 °F
Upper Limit-Root Growth	110 °F	77 °F
Lower Limit- Shoot Growth	65 °F	40 °F
Lower Limit- Root Growth	50 °F	33 °F

Table 1.2. Turfgrasses evaluated in studies.

Botanical Name	
Cynodon dactylon	'Tifgreen I' 328
Cynodon dactylon	'Tifway I" 419
Cynodon dactylon	'Vamont'
Cynodon dactylon	'Brute'
Cynodon dactylon	'Navy Blue'
Cynodon dactylon	'Midiron'
Festuca arundinaceae	'Confederate'
Festuca arundinaceae	'Rebel Jr.'
Festuca arundinaceae	'Kentucky 31'

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