

USE OF MESOTRIONE FOR ANNUAL BLUEGRASS (*POA ANNUA* L.) AT COOL-
SEASON TURFGRASS ESTABLISHMENT

by

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ABSTRACT OF THE THESIS

USE OF MESOTRIONE AT COOL-SEASON TURFGRASS ESTABLISHMENT

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Annual bluegrass is a problematic weed in highly maintained turfgrass environments, and is difficult to control due to its adaptability to highly maintained turfgrass environments and lack of highly effective chemical control options. Mesotrione is a relatively new herbicide which has been found to show some level of control of annual bluegrass, and is safe to use at cool season turfgrass establishment. Thus, mesotrione has potential to be utilized for weed control in cultivated sod production. The objectives of this research were to evaluate mesotrione to determine: 1) tolerance of selected tall fescue cultivars, an important turfgrass species cultivated for sod, to applications of mesotrione; 2) the length of residual of mesotrione versus prodiamine, bensulide and dithiopyr for control of annual bluegrass; and 3) potential of mesotrione to control winter annual broadleaf weeds at Kentucky bluegrass establishment.

Tall fescue cultivars were found to be tolerant to mesotrione applications made preemergence and preemergence plus 4 weeks after emergence at higher rates than required for weed control. Significant cover reductions were only observed at the 1.12 kg ha⁻¹ application rate of mesotrione, which is four times the highest labeled rate for weed control. There was little difference in the response of the seven tall fescue cultivars

evaluated suggesting minor intraspecific variability between tall fescue cultivars to mesotrione.

When applied to bare ground, mesotrione provided 48% annual bluegrass control in the fall and annual bluegrass control decreasing to 20% in the following spring. Proflaminate, bensulide and dithiopyr provided much greater levels of annual bluegrass control and high levels of control were maintained into the following spring. These results suggest that although mesotrione has some activity on newly germinating annual bluegrass it is much lower relative to proflaminate, bensulide and dithiopyr.

Mesotrione was found to be more effective for winter annual broadleaf weed control when applied POST compared to PRE. For overall winter annual broadleaf weed control mesotrione should be applied PRE at rates of 0.21 kg ha⁻¹ or higher and POST at 0.14 kg ha⁻¹ or higher.

The results of these studies demonstrate that mesotrione is safe for use in newly seeded tall fescue and previous studies have shown similar findings with Kentucky bluegrass. The safety of mesotrione to these two economically important turfgrass species widely grown for cultivate sod combined with its ability to control winter annual broadleaf weeds and suppress annual bluegrass demonstrate that is a new and valuable component to an overall weed control program in cultivated sod production.

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CHAPTER 1: REVIEW OF THE LITERATURE

ANNUAL BLUEGRASS

Annual bluegrass (*Poa annua* L.) is a problematic weed in high maintenance turf areas such as golf courses, athletic fields and sod farms. A wide range of genetic variability exists within annual bluegrass that allow is it to thrive under various environmental conditions and turfgrass management practices. Physical characteristics of annual bluegrass can detract from the aesthetics and functionality of a turf area. Infestations of annual bluegrass in other turfgrass species can produce a mottled appearance due to its lighter green color (Beard et al. 1978; Beard 1973; Turgeon 1999; Vargas 1996). Annual bluegrass is a prolific seedhead producer even at low heights of cut which can disrupt the textural uniformity of a turf stand (Beard et al. 1978, Cattani 1999; Johnson et al. 1993). Annual bluegrass has a shallow root system which can result in the turf thinning under heavy traffic. Annual bluegrass is generally more susceptible to disease and insect damage than most cool-season turfgrasses. Anthracnose (*Colletotrichum graminicola* (Ces.) Wils.) is a major disease of annual bluegrass grown under stressful, highly maintained conditions (Danneberger et al. 1983; Smiley et al. 2005). Anthracnose grows best in warm, wet, and humid weather and the severity on annual bluegrass may be increased by low mowing heights, traffic and compacted soils (Danneberger et al. 1984; Inguagiato et al. 2005; Smiley et al. 2005). Annual bluegrass is also susceptible to bacterial wilt (*Xanthomonas campestris*) and other common turf diseases such as dollar spot (*Sclerotinia homeocarpa* F.T. Bennett), pythium (*Pythium* spp.), and summer patch (*Magnaporthe poae*) (Turgeon 1999; Smiley et al. 2005).

Annual bluegrass is also highly susceptible to damage by the annual bluegrass weevil (*Listronotus maculicollis* Dietz; Vittum 2005, 2006). Damage from annual bluegrass weevil larvae commonly damage annual bluegrass around collars and perimeters of golf greens leaving other turf species unharmed (Rothwell and Vittum 2003; Vittum 2006). Annual bluegrass sensitivity to disease, insects and environmental stress often requires more pesticide use than most turfgrasses for successful culture, and thus, controlling annual bluegrass is often desirable in mixed turfgrass stands. Cultivated sod infested with annual bluegrass may greatly reduce its value or even render the sod unsalable.

Annual bluegrass occurs as a clump-forming grass which is light green-yellow in color. Although both the annual and perennial types are clump forming, the perennial biotype tends to have a more prostrate growth habit. The leaves are smooth, with boat-shaped leaf tips and a line on either side of the midrib. The plant has a pointy, membraneous ligule that is roughly 1-2 mm in length. The leaf sheath is slightly compressed and keeled, with a folded vernation. The leaves can also demonstrate a rippled or wavy texture. Annual bluegrass seedheads are pyramidal panicles, which are open and greenish-white. The spikelets are normally between 4 and 6 mm long, and will produce 2 to 6 flowers each. Root systems are quite shallow and fibrous, and plants often enlarge through very aggressive tillering. Perennial biotypes will root at the base of each tiller (Turgeon 1999, Uva et al. 1997).

Annual bluegrass is a cool season grass, and a member of the *Poacea* family, subfamily *Festucoidea* and tribe *Festuceae* (Turgeon 1999). Members of the *Festucoidea* subfamily are often found in temperate and subarctic climates, where they require cooler temperatures in order to achieve optimal growth and development. Annual bluegrass is

thought to have evolved on the northern side of the Mediterranean Sea during the Interglacial or Late Glacial time periods (Tutin 1957). Annual bluegrass is a non-apomictic, allotetraploid ($2n=4x=28$) which is thought to have arisen from a cross between the annual diploid *P. infirma* and perennial diploid *P. supina* (Tutin 1957 and Koshy 1969).

This particular species has various weedy ecotypes, both perennial (*Poa annua* var. *reptans* (Hauskins) Timm.) and annual (*Poa annua* var. *annua*). Unsown annual and perennial biotypes of annual bluegrass coexist in field settings. Oftentimes, the annual biotypes tend to behave like winter annual weeds, which germinate in the late summer or fall and/or spring. They do not easily survive hot, dry summer conditions and may die out leaving voids in the turf, reducing the quality of the playing surface. Annual bluegrass requires intensive water and fertility management during the summer in order to survive. Despite these constraints, and the lack of highly effective chemical control options this plant is often looked at as one to be cultivated, not eradicated (Lush 1988). The fact that it is able to withstand close mowing, produces high numbers of tillers in a given unit of area, is of uniform height and when uniform, is aesthetically pleasing, gives annual bluegrass support for cultivation and maintenance on golf courses and other turf areas (Lush 1988).

Annual bluegrass can be used on putting green surfaces when it has out-competed creeping bentgrass, or in some situations, hybrid bermudagrass. This grass is able to tolerate extremely low heights of cut, approaching one eighth of an inch, and will even produce viable seed. It does, however, thrive in mixed stand environments. Annual bluegrass is capable of germinating year round, but it most commonly germinates

between September and December, with a small flush in the spring. Summer growth is slow and sensitive to stresses (Kaminski et al 2007). Germination of the grass can occur in low levels throughout the winter (Kaminski et al 2007).

Due to its shallow root system, annual bluegrass plants have higher sensitivities to stresses like heat and drought as well as overall problems with plant growth and stability (Uva et al 1997, Nam-Il et al 2001, Beard 1989). Water management for the cultivation of annual bluegrass is important, as the plants can enter into a period of heat stress no matter how much water is applied to the turf. Annual bluegrass has been found to have fair tolerance to heat, but exposure to 42 C temperatures for two hours has been shown to have lethal effects (Whener and Watschke 1981). The plants will turn unsightly yellow, indicating that they are under stress. This can be visually unappealing to the people utilizing the turf area for sports, golf, or production. Annual bluegrass has a higher evapotranspiration (ET) rate than other grasses, which can be detrimental during periods of water stress (Beard 1989). Although annual bluegrass has some desirable characteristics, such as its fast growth, it is still considered an undesirable, weedy species.

CHEMICAL CONTROL OF ANNUAL BLUEGRASS

Managing annual bluegrass in cultivated turfgrass has relied heavily on various herbicides and cultural practices, but no single compound has been identified as a cure all. New chemistries which have demonstrated activity on annual bluegrass have emerged in the past few decades. Commonly, turfgrass managers have relied on various pre-emergence (PRE) or post-emergence (POST) herbicides to control annual bluegrass in

established turfgrass swards. There are various chemicals which can be applied as preventative treatments to control newly germinated annual bluegrass, but these same herbicides are not effective for control of established annual bluegrass plants, nor can they be used on newly seeded or immature cool season turfgrass due to potential for injury (Johnson 1994).

Prodiamine, bensulide and dithiopyr are routinely utilized pre-emergence (PRE) in mature turfgrass swards for the control of weedy annual grasses (Landschoot et al 1993). These herbicides have a long soil persistence and demonstrate high activity on susceptible species, including annual bluegrass (Yelverton and McCarty 2001). When prodiamine, bensulide or dithiopyr is applied to juvenile or overseeded turf injury is prominent and the number of seedlings is significantly reduced (Fermanian et al 1994). Prodiamine functions within susceptible species by disruption of mitosis (Senseman et al 2007). Although prodiamine will control annual bluegrass in established turfgrass swards, and is recommended for use on tall fescue and Kentucky bluegrass, but has the potential to cause injury on perennial ryegrass (Yelverton and McCarty, 2001, Dernoeden 2000). Prodiamine was found to be the safest for use on tall fescue when compared to dithiopyr (Dernoeden 2000). Bensulide has been found control newly germinating annual bluegrass but will delay growth and injure desirable turfgrass seedlings when planting occurs soon after herbicide application due to its long soil residual of approximately 120 days (Smith and Callahan et al 1969, Goss 1964, Bingham et al 1969, Senseman et al 2007). Bensulide functions as a lipid and fatty acid biosynthesis inhibitor, but its specific mode of action is unknown (Senseman et al 2007). Dithiopyr functions by inhibiting mitosis in late prometaphase (Senseman et al 2007). It is labeled for use in cool-season

turfgrass to control crabgrass, but if applied sooner than 10-14 days after emergence (DAE) to Kentucky bluegrass, tall fescue or perennial ryegrass, stand reduction has been observed (Reicher et al 2000, Johnson and Bundschuh 1993). It was also observed that formulation of dithiopyr influences the length of seeding delay. Keely and Zhou (2005) found that if Kentucky bluegrass is to be overseeded, utilizing dithiopyr rather than prodiamine is appropriate for increased turfgrass germination.

There are few herbicides that have the potential to safely remove established annual bluegrass from cool-season turf grasses. These include: ethofumesate, bispyribac-sodium and primisulfuron. Ethofumesate is a member of the benzofuranes chemical family, and functions as a fatty acid and lipid biosynthesis inhibitor, but its specific mode of action is unknown (Senseman et al 2007). It is labeled for annual bluegrass control in perennial ryegrass, Kentucky bluegrass and creeping bentgrass (Anonymous 2001). Ethofumesate is absorbed into annual bluegrass in greater amounts than desirable species such as creeping bentgrass and perennial ryegrass (Kohler and Branham 2002). It has also been found that annual bluegrass control with ethofumesate can be highly depended on application rate, timing and turfgrass species. Undesirable injury can occur on Kentucky bluegrass with inconsistent control of annual bluegrass (Woosley et al 2003, Kohler and Branham 2002). There are concerns over injury, which is why application rates below the labeled rate are required for use in creeping bentgrass versus perennial ryegrass which can tolerate higher rates of ethofumesate (Yelverton and McCarty 2001; Dernoeden 1996). With these reduced rates, however, consistent control is difficult to achieve (Dernoeden 1996, Dernoeden and Turner 1998).

Bisbyribac-sodium is a class D plant growth regulator which inhibits the enzyme acetolactate synthase (ALS), resulting in stunted growth and subsequent plant death (Senseman et al 2007). When applied between June and August to creeping bentgrass or perennial ryegrass, bisbyribac-sodium has the potential to control annual bluegrass (Lycan and Hart 2006, McCullough and Hart 2006). Although this herbicide may control annual bluegrass, there is concern over injury to other cultivated cool-season turfgrass species, especially Kentucky bluegrass (Shortell et al. 2005). Unlike bisbyribac-sodium, primisulfuron has potential to be used safely on established Kentucky bluegrass (Hart and McCullough 2007). Primisulfuron is a sulfonylurea herbicide which, like bisbyribac-sodium, inhibits the the enzyme acetolactate synthase (Senseman et al. 2007). When applied to mature stands of Kentucky bluegrass, primisulfuron exhibited high levels of control and minimal turfgrass injury (Hart and McCullough 2007). However, this herbicide is only safe for use on established Kentucky bluegrass during the months of June to August.

4-HYDROXYPHYENYL PYRUVATE DIOXYGENASE INHIBITORS

Herbicides classified as 4-hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitors are important in the control of broadleaf weeds in both agricultural and turfgrass settings. HPPD functions to catalyze the conversion of p-hydroxyphenyl pyruvate (HPP) to homogentisate (HGA), which is an important precursor to a-tocopherol and plastoquinone (Meazza et al 2002). HPPD inhibitors act by disrupting the function of HPPD, reducing the amount of available of plastoquinones, which act as cofactors for phytoene desaturase. The bleaching of new growth is a result of the inhibition, however

indirect, of the synthesis of carotenoids. Other examples of herbicides characterized as HPPD inhibitors include: amides, anilidex, furanones, phenoxybutan-amides, pyridiazinones, pyridines, callistemones, isozaxoles, pyrazoles, and trikeones (Senseman et al, 2007).

Discovered in 1982 by scientists at Zeneca while working on a functional mimic of the acetyl-CoA carboxylase (ACC-ase) inhibiting herbicide sethoxydim, scientists obtained an unexpected result in the form of a benzoylcyclohexanedione, which functions as a HPPD inhibitor. This molecule acts as a competitive inhibitor of HPPD, interrupting the synthesis of plastoquinone and α -tocopherol (Mitchell et al 2001, Lee et al 1997). HPPD inhibiting herbicides have demonstrated activity on both broadleaf and grassy plants. Precursors to mesotrione and other HPPD inhibiting herbicides was discovered as an allelopathic compound originating from the bottlebrush plant (*Callistemon citrinus* Stapf.) in California (Lee et al 1997). The isolated chemical, leptospermone, demonstrated bleaching symptoms when applied to some broadleaf and grassy weeds at rates of 1000g/ha.

HPPD inhibiting herbicides are classified as “reduced risk pesticides” by the United States Environmental Protection Agency due to their favorable environmental and toxicological profiles (Lee et al 1997). For example, mesotrione, a calistemone HPPD-inhibiting compound, is a weak acid, with a pKa value of 3.1. As pH increases in solution, mesotrione dissociates into an anionic form (Dyson et al 2002, Mitchell et al 2001). Dyson et al (2002) also found that residues in 15 different soil locations declined over time, with half-lives calculated from 4.5 to 32 days. This can be attributed to pH

differences between the samples. This chemical also has little potential to leach through the soil profile (Dyson et al 2002).

MESOTRIONE

Mesotrione (2-[4-mesy]-2-nitrobenzoyl)cyclohexane-1,3-dione) is a member of the benzoylcyclohexanedione chemical family, and functions by inhibiting HPPD function, interrupting the biosynthesis of plastoquinone which is a cofactor of phytotene desaturase. Mesotrione was registered with the Environmental Protection Agency (EPA) in 2001. It was initially labeled for use in corn production, for control of problematic broadleaf and some grassy weeds. More recently, however, it has been labeled for use in turfgrass production. It has been found that mesotrione can be used to control many different weed species including: *Xanthoium strumarium* L., *Abutilon theophrasitis* (L.) Medic, *Ambrosia trifida* L., *Digitaria* spp., *Echinochloa* spp., *Chenopodium* spp., *Amaranthus* spp., and *Chenopodium* spp. (Anonymous. 2008a; Anonymous 2008b; Mitchell et al 2001).. Rates used to control weeds vary between crops. For broadleaf weed control in corn, 0.11 to 0.25 kg ha⁻¹ is recommended and in turfgrass, between 0.14 to 0.28 kg ha⁻¹ (Anonymous 2008a; Anonymous 2008b).

Mitchell et al (2001) also discovered that within 24 hours of application, between 55 and 99 percent of the mesotrione is absorbed into the plant tissues. Furthermore, it is also translocated both basipetally and acropetally, with 48 percent of C-14 found to have moved out of a single treated *Chenopodium album* L. leaf seven days after application. The parent mesotrione extracted from the plant constituted 42 percent of the original application. The same experiment was conducted in maize (*Zea mays*), and only 14

percent of the C-14 had moved out of the treated leaf, and none of the parent mesotrione was gathered from plant tissues upon analysis. This is due to the fact that corn rapidly metabolizes mesotrione soon after applications are made (Mitchell et al 2001).

Mesotrione is metabolized within plant tissues to two non-herbicidal compounds, 4-(methylsulfonyl)-2-nitrobenzoic acid (MNBA) and 2-amino-4-(methylsulfonyl)benzoic acid (AMBA). Broadleaf weed species demonstrated slower metabolism of the herbicide, which translates to greater translocation of the herbicide from the site of initial absorption (Mitchell et al 2001).

Mesotrione has been found to function synergistically with other PS II inhibiting herbicides such as atrazine in broadleaf weed species. Experiments were conducted to examine rates required for this synergism in redroot pigweed which is resistant to triazine herbicides (Hugie et al 2008). In triazine-resistant redroot pigweed, synergism between mesotrione and atrazine was found to be rate dependent for both herbicides. Mesotrione applied at rates between 10 and 56 g/ha when combine with 126 g/ha atrazine demonstrated synergism. The minimum threshold amount of mesotrione applied is 10 g/ha and as mesotrione rates increase relative to atrazine, the magnitude of synergism increases as well. In triazine-susceptible redroot pigweed, synergism was observed at 56 g/ha mesotrione and 126 g/ha atrazine (Hugie et al 2008). Similar experiments were conducted by Armel et al (2005) examining whether mesotrione alone or paired with low application rates of atrazine would adequately control Canada thistle. Mesotrione has demonstrated some degree of control over Canada thistle, but only when the plants are in the rosette stage. Bolting plants were less susceptible to herbicide application. Initially, when mesotrione was applied alone at 105 g/ha, 59% of Canada thistle was controlled at

1 WAT, and by 8 WAT, 74% was controlled. Increasing the rate of mesotrione to 210 g/ha increased control to 75 and 84%, respectively. Pairing mesotrione at 105 g/ha with atrazine at 280 g/ha demonstrated an increase in control over both rates of mesotrione, seen as 86 and 87% at 1 WAT and 8 WAT, respectively (Armel et al 2005).

Mesotrione was found to exhibit safety on newly seeded and established cool-season turfgrasses, with the exception of creeping bentgrass (Hart et al. 2007, Beam et al 2006). This turfgrass safety will allow for mesotrione to be utilized in sod production, home lawn care, and athletic fields. The safety of mesotrione at cool-season turfgrass establishment may allow for less frequent use of herbicides such as bensulide, dithiopyr, proflam, ethofumesate, primisulfuron and bispyribac sodium in cultivated sod production. Each of these herbicides have serious limitations for use at cool-season turfgrass establishment which as opposed to mesotrione (Reicher et al 2000, Johnson and Bundschuh 1993, Dernoeden 2000, Hart and McCullough 2007, Shortell et al 2005).

In turfgrass, Hart et al. (2007) found that mesotrione, applied PRE at 0.19 kg ha⁻¹ achieved nearly complete control of henbit and chickweed in newly seeded Kentucky bluegrass. In spring-seeded tall fescue, Willis et al. (2006) observed complete control of henbit at a rate of 0.28 kg ai ha⁻¹. Bhowmik and Sarkar (2009) observed that henbit and chickweed were controlled in newly seeded perennial ryegrass when mesotrione was applied at 0.18 and 0.28 kg ha⁻¹. Mesotrione applied at 0.21 kg ha⁻¹ POST provided high levels of control for both henbit and chickweed (Hart et al. 2009). Due to the safety of mesotrione on most cool-season turfgrass species, applications of this herbicide within label rates will quickly control winter annual broadleaf weeds while maintaining safety of the turfgrass sward, especially if the seed has recently germinated (Hart et al. 2009,

Willis et al. 2006, Bhowmik and Sarkar 2009). By reducing the pressure of winter annual broadleaf weeds, the turfgrass will not have to compete for light and nutrient resources during establishment in the fall (Gannon et al. 2004).

TALL FESCUE

Tall fescue (*Festuca arundinacea*) is a desirable turfgrass species used extensively in home lawns, athletic fields and sod production (Waddington et al 1992). Tall fescue is a cool season, perennial grass which is tolerant to traffic, heat and shady conditions.

Tall fescue is a cool season bunch-type grass, and a member of the *Poaceae* family, subfamily *Festucoidea* and tribe *Festuceae* (Turgeon 1996). Grasses in the *Festucoidea* subfamily persist in temperate and subarctic climates where they require cooler temperatures for growth. Cool season grasses often see optimal growth in spring and fall months, with dormancy occurring in summer and winter. Tall fescue is adapted to the transition zone in the United States, but is difficult to grow in the northernmost and southernmost states (Fribourg et al 2009). Tall fescue has coarse textured leaves, a pointed leaf tip and rolled vernation. It has prominent veins on the upper side of the leaf and lacks a midrib (Beard 1973). Even though tall fescue is classified as a bunch-type grass, it can often have short rhizomes, a trait which is being pursued by turfgrass breeders (Christians 2007). Tall fescue is unique in the respect that it often coexists with an endophyte, *Neotyphodium coenophialum*, or fungus which imparts natural control against insects and some diseases (Funk and Meyer 2001, Emmons 2007, Fribourg et al

2009). Turfgrass breeders have developed cultivars of tall fescue with finer leaves, greater shoot density, slower vertical growth and better tolerance to mowing, allowing this species to become popular for use in home lawns, athletic fields and in cultivate sod production (Funk and Meyer, 2001).

Despite its deep root system, tall fescue does not tolerate compaction from wear very well, even though the act of wearing the turfgrass is well tolerated. It is important to cultivate tall fescue fields which are heavily utilized for sports or other compaction inducing activities (Anderson and Agnew 1994).

KENTUCKY BLUEGRASS

Kentucky bluegrass (*Poa pratensis*) is a cool-season, rhizomatous turfgrass which is widely used in sod production, home lawns, commercial sites and athletic fields (Waddington et al, 1992). It is a member of the *Poaceae* family, subfamily *Festucoidea* and tribe *Festuceae* (Turgeon 1996). Kentucky bluegrass has a folded vernation, membraneous ligule, and a broad collar with no auricles. Its most distinguishing characteristic is the boat-shaped leaf tip, which is present on all Kentucky bluegrass cultivated varieties. Kentucky bluegrass cultivars vary widely in characteristics such as color, density, mowing tolerance and texture (Turgeon 1999, Emmons 2007, Brede 2000). Kentucky bluegrass cultivars can be divided into distinct groups based on origin, growth habit, color and other parameters. Recently, work by Honig et al (2010) was able to genetically distinguish each group using microsatellite markers.

Kentucky bluegrass tends to have a shallow root system, but it does tolerate drought conditions by going into a period of dormancy until water becomes available.

Many cultivars of this species are poorly adapted to shady conditions (Beard 1973). Kentucky bluegrass can encounter serious problems with weeds during establishment due to its slow germination and establishment times. Despite the fact that Kentucky bluegrass is slow to establish, it is relatively tolerant to wear due to its stoloniferous growth habit which leads to good regenerative capability (Beard 1973, Bonos et al 2001). Bonos et al (2001) found that Kentucky bluegrass is variably tolerant to wear, but that certain cultivars may behave differently depending on the environmental conditions.

OBJECTIVES

The objectives of this research were to evaluate mesotrione to determine: 1) tolerance of selected tall fescue cultivars, an important turfgrass species cultivated for sod, to applications of mesotrione; 2) the length of residual of mesotrione versus prodiamine, bensulide and dithiopyr for control of annual bluegrass; 3) potential of mesotrione to control winter annual broadleaf weeds at Kentucky bluegrass establishment.

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CHAPTER 2: LENGTH OF RESIDUAL ANNUAL BLUEGRASS (*POA ANNUA* L.)
CONTROL OF MESOTRIONE RELATIVE TO OTHER PREEMERGENT WEED
CONTROL PRODUCTS

ABSTRACT

Field studies were conducted in the fall of 2009 and 2010 to evaluate annual bluegrass (*Poa annua* L.) control with residual herbicides applied to bare soil. Soil type was a Holmdel sandy-loam with pH 6.7 and 2.0% organic matter. Herbicides evaluated were mesotrione at 0.28 and 0.43 kg ai/ha, dithiopyr at 0.28 and 0.43 kg ai/ha, prodiamine at 0.57 and 0.74 kg ai/ha, and bensulide (O,O-bis(1-methylethyl) S-[2-[(phenylsulfonyl)amino]ethyl]phosphorodithioate) at 9.4 and 11.9 kg ai/ha. At 8 weeks after treatment (WAT) and the following spring, trials were evaluated for annual bluegrass control were visually estimated relative to the untreated on a scale of 0 (no control) to 100 (complete control). Annual bluegrass control, combined across application rates, ranged from 76 to 79% with prodiamine, dithiopyr and bensulide but was only 48% with mesotrione at 8 WAT. The following spring annual bluegrass control decreased to 22% with mesotrione while bensulide, prodiamine and dithiopyr maintained high levels of control ranging from 84 to 91%. The results of these studies suggest that mesotrione does not have the potential to provide residual annual bluegrass control that is equivalent to prodiamine, bensulide and dithiopyr.

Nomenclature: Bensulide, O,O-bis(1-methylethyl) S-[2-[(phenylsulfonyl)amino]ethyl]phosphorodithioate; dithiopyr, S,S-dimethyl 2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-3,5-pyridinedicarbothioate; prodiamine, 2,4 dinitro-N³,N³-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine; mesotrione, 2-(4-mesyl-2-nitrobenzoyl)-3-hydroxycyclohex-2-enone; annual bluegrass, *Poa annua* L. POAAN.

Key Words: Annual bluegrass control, PRE herbicide residual, mesotrione efficacy, POAAN.

INTRODUCTION

Annual bluegrass is a problematic weed in cultivated turfgrass environments, due to its undesirable aesthetic qualities, and intensive management requirements (Beard et al 1978). Annual bluegrass can infest an area which has been disturbed through abiotic stress, poor management or deliberate cultivation such as aerification of a putting green or fairway (Youngner 1959). It can also invade voids left in turfgrass swards due to damage or poor establishment (Beard et al 1978). There are few herbicides available to control annual bluegrass in established, or newly established cool-season turf (McElroy et al 2011). There are various chemicals which can be applied as preventative treatments to control newly germinated annual bluegrass, but these same herbicides are not effective

for control of established annual bluegrass plants, nor can they be used on newly seeded or immature cool season turfgrass due to potential for injury (Johnson 1994).

Prodiamine, bensulide and dithiopyr are routinely utilized pre-emergence (PRE) in mature turfgrass swards for the control of weedy annual grasses (Landschoot et al 1993). These herbicides have a long soil persistence and demonstrate high activity on susceptible species (Yelverton and McCarty 2001). When applied to juvenile or overseeded turf injury is prominent and the number of seedlings is significantly reduced (Fermanian et al 1994). Bensulide has been found to control newly germinating annual bluegrass but, it will delay growth and injure desirable turfgrass seedlings when planting occurs soon after herbicide application due to its long soil residual (Smith and Callahan et al 1969, Goss 1964, Bingham et al 1969). Dithiopyr is labeled for use in cool-season turfgrass to control crabgrass, but if applied sooner than 10-14 days after emergence (DAE) to Kentucky bluegrass, tall fescue or perennial ryegrass, stand reduction has been observed (Reicher et al 2000, Johnson and Bundschuh 1993).

Mesotrione is a soil or foliar applied HPPD-inhibiting herbicide being investigated in newly seeded cool-season turfgrass for its potential to control annual bluegrass (Hart et al 2009). Unlike prodiamine, bensulide or dithiopyr, previous research has demonstrated that mesotrione can be safely applied to newly seeded cool-season turfgrasses including, perennial ryegrass, tall fescue and Kentucky bluegrass (Askew and

Beam 2002, McCurdy et al 2008). It cannot be applied safely to creeping bentgrass (Beam et al 2006, Jones and Christians 2007, Branham et al 2005). Mesotrione can also be safely applied POST to turfgrass that is newly emerged (Willis et al 2006, Hart et al 2007). Mesotrione applied PRE in the fall to newly seeded Kentucky bluegrass has potential to provide significant, but not complete levels of annual bluegrass control (Hart et al 2009). This suggests that mesotrione may not have the same level of residual activity on annual bluegrass relative to prodiamine, bensulide and dithiopyr. The objective of this study was to determine the level of annual bluegrass control with mesotrione applied PRE relative to prodiamine, bensulide and dithiopyr when applied to bare soil.

MATERIALS AND METHODS

Field studies were conducted in fall of 2009 and 2010 at the Rutgers Plant Science Research Center in Adelphia, New Jersey. Soil type was a Holmdel sandy-loam (fine-loamy, mixed, active mesic Aquic Hapludults) with a pH of 6.7 and 2.0% organic matter. The field was prepared by disking followed by two passes with a soil pulverizer¹. The site was irrigated to ensure weed germination and subsequent annual bluegrass growth.

Treatments consisted of an untreated check and mesotrione² at 0.28 and 0.43 kg ha⁻¹, dithiopyr³ at 0.28 and 0.43 kg ha⁻¹, prodiamine⁴ at 0.57 and 0.74 kg ha⁻¹, and

bensulide⁵ at 9.4 and 11.9 kg ha⁻¹ applied PRE to bare soil. Treatments were applied to 0.9 x 3 m plots with a single nozzle CO₂ backpack sprayer equipped with a 9504EVS nozzle tip⁶ calibrated to deliver 375 L ha⁻¹ at 220 kPa. Applications were made on September 3, 2009 and September 16, 2010. The trials were visually evaluated at 8 weeks after treatment (WAT) and the following spring for annual bluegrass control on a scale of 0 (no control) to 100 (complete control). Visual evaluations of annual bluegrass control were estimated relative to the amount of annual bluegrass present in the untreated plots.

Experiments were conducted in a randomized complete block design with four replications. Data was analyzed by analysis of variance procedures (ANOVA) and pooled across years when year by treatment interactions were not significant. An analysis of variance test was conducted as a two-factor (herbicide by herbicide rate) factorial. Means were separated utilizing Fishers Least Significant difference test at the 0.05 confidence level.

RESULTS AND DISCUSSION

ANOVA procedures revealed that visual estimates of annual bluegrass control at 8 WAT and the following spring did not vary significantly across years, therefore data was combined. Herbicide by rate interactions were not detected, therefore rates were combined across herbicides.

Annual bluegrass pressure was greater in 2010 relative to 2009. Untreated plots averaged 36 (± 2) and 21% (± 8) annual bluegrass cover in fall 2009 and 2010, respectively. Proflamone provided 79% annual bluegrass control relative to the untreated in November and 91% annual bluegrass control in April (Table 1). Dithiopyr provided 76% control in November and 84% control in the following April. Annual bluegrass control with bensulfide was 79% control in November and 86% control in April. Control ratings in the fall and spring were not significantly different across all rates of dithiopyr, bensulfide and proflamone.

Across all rating dates and treatments, mesotrione controlled less annual bluegrass than proflamone, bensulfide and dithiopyr. Increasing the rate of mesotrione from 0.28 to 0.43 kg ha⁻¹ did not significantly increase annual bluegrass control. In November, mesotrione provided 48% control, which was over 20% less relative to bensulfide, proflamone and dithiopyr. In April, annual bluegrass control with mesotrione decreased to 20% which was over 60% less than proflamone, bensulfide and dithiopyr. Although mesotrione exhibits some control of annual bluegrass when applied PRE, it lacks the residual control of bensulfide, proflamone and dithiopyr.

Proflamone, bensulfide and dithiopyr are commonly utilized in mature turfgrass for control of annual grasses, including annual bluegrass. The results of these studies confirm previous findings which showed that these herbicides are highly effective for

controlling newly germinating annual bluegrass. Bingham et al (1969) found that bensulide applied to freshly prepared soil gave selective control of annual bluegrass, and allowed annual ryegrass and red fescue to emerge when seeded one month after annual bluegrass treatment. Callahan and McDonald (1992) found that when bensulide is applied three times per year (August, January and March) at 11 kg ha^{-1} , controlled 97% annual bluegrass after five years. When applied in late August, prodiamine was found to reduce the population of annual bluegrass 12 to 14% over one year (Rossi 2001). In this same study, total annual bluegrass was reduced by 40% over three years. Bunnell et al (1999) found that dithiopyr, applied at $0.43 \text{ kg ai ha}^{-1}$, controlled between 80 and 90% annual bluegrass when applied 50 days before overseeding.

When the soil half-life of each herbicide is examined, the reasons for their levels of annual bluegrass control may be explained. Bensulide has a relatively long chemical half-life in the soil, lasting for roughly 120 days (Senseman et al 2007, Branham and Rieke 1986). Prodiamine, like bensulide, has a long soil residual, with a half-life of averaging 120 days (Senseman et al 2007). Dithiopyr has the shortest half-life of these PRE herbicides, which is approximately 17 days (Senseman et al 2007). Mesotrione is a weak acid, which is only active in the soil for a relatively short period of time with a half-

Table 1. Visual estimates relative to the untreated of percent annual bluegrass control with PRE herbicides applied to bare soil in experiments initiated in fall 2009 and 2010.

Herbicide ^A	Percent annual bluegrass control	
	Fall ^B	Spring ^C
Mesotrione	48 B ^D	20 B
Bensulide	79 A	86 A
Prodiamine	79 A	91 A
Dithiopyr	76 A	84 A

^A There was no significant application rate by herbicide interaction, therefore rate are combine across herbicides.

^B There was no significant year by treatment interaction.

^C Visual estimates of tall fescue cover evaluated in the spring of 2010 and 2011.

^D Means within a column with the same letter are not significantly different according to the Fisher's Protected LSD test at the 0.05 confidence level.

life between 4.5 and 32 days (Dyson et al 2002). Due to the relatively short half-life of mesotrione versus bensulide, prodiamine and dithiopyr, the decrease in annual bluegrass control with mesotrione from fall to spring may be explained.

The lack of soil residual of mesotrione versus bensulide, prodiamine and dithiopyr can impact turfgrass establishment, especially when slow to establish grasses such as Kentucky bluegrass are being seeded (Turgeon 1999). Mesotrione may provide some levels of annual bluegrass control, but it may vary considerably depending on environmental factors as well as annual bluegrass pressure. Since mesotrione can be safely used on newly seeded Kentucky bluegrass, it is a valuable component but not a complete solution for an overall annual bluegrass control program. By reducing the weed competition for light and nutrients, mesotrione can allow seedling turfgrass to more quickly emerge and establish. Annual bluegrass pressure may play a role in how effectively mesotrione controls annual bluegrass on bare ground, but further investigation is required.

SOURCES OF MATERIALS

¹ Rotodairon, Greer Bros. Inc, Salem OR, 97035

² Mesotrione, Tenacity 4 SC, Syngenta Crop Protection LLC, Greensboro NC, 27419-8300

³ Dithiopyr, Dimension 2 EW, Dow AgroSciences LLC, Indianapolis IN, 46268-1189

⁴ Prodiamine, Barricade 65 WG, Syngenta Crop Protection LLC, Greensboro NC, 27419-8300

⁵ Bensulide, Bensumec 4 LF, PBI Gordon Corporation, Kansas City, MI 64101

⁶ Spray Systems Co., Wheaton IL, 60189

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CHAPTER 3: USE OF MESOTRIONE FOR WINTER ANNUAL BROADLEAF
WEED CONTROL AT KENTUCKY BLUEGRASS ESTABLISHMENT

ABSTRACT

Field studies were initiated in the fall 2009 and fall 2010 to evaluate the control of henbit (*Laminum amplexicaule* L.) and common chickweed (*Stellaria media* (L.) Vill.) in newly seeded Kentucky bluegrass (*Poa pratensis*) with mesotrione applied at planting (PRE) or POST (4 weeks after turfgrass emergence (WAE)) at rates ranging from 0.04 to 0.21 kg ha⁻¹. In fall 2009, visual estimates of control relative to the untreated of henbit ranged from 65 to 85% across all rates and application timings. In fall 2010, henbit control ranged between 40 and 99%. In spring of both years, control decreased to between 48 and 96%. Chickweed control in fall 2009 ranged between 39 and 91% and in fall 2010 control ranged between 74 and 99%. In spring of both years, chickweed control was between 57 and 98% across all treatments. As the rate of mesotrione increased, so did the level of weed control. The results of this study suggest that in to provide 90% or more control of chickweed and henbit, mesotrione should be applied at 0.21 kg ha⁻¹ or higher PRE and 0.14 kg ha⁻¹ or higher POST.

Nomenclature: mesotrione, 2-(4-mesyloxy-2-nitrobenzyl)-3-hydroxycyclohex-2-enone; henbit, *Laminum amplexicaule* L. LAMAM; common chickweed, *Stellaria media* (L.) Vill. STEME; Kentucky bluegrass, *Poa pratensis* L. POAPR.

Key Words: Winter annual broadleaf weed control, LAMAM, STEME, mesotrione

INTRODUCTION

Kentucky bluegrass (*Poa pratensis*) is an economically important, cool-season turfgrass grown for sod in the United States. It has a rhizomatous growth habit and fine leaf texture, making it ideal for use in home lawns, golf courses, athletic fields and commercial properties (Beard 1973, Turgeon 1999). However, Kentucky bluegrass is slow to germinate and establish which can lead to problems with winter annual broadleaf weed infestations if seeded in the late summer or fall (Christians 2007, Emmons 2008). Henbit (*Laminum amplexicaule* L.) and common chickweed (*Stellaria media* (L.) Vill.) are common winter annual weeds which infest newly seeded turfgrass swards, and can compete for nutrients, water and light (Kowalewski et al. 2006).

Previously, henbit and chickweed have been commonly controlled by postemergence (POST) applications of dicamba, or MCPP (Neal et al. 1990). Even though these weeds can be potentially controlled by these POST herbicides, applications made in the fall to immature turf may cause significant injury. If applications are made in the spring however, the turfgrass is subject to competition from the weeds in the fall and winter months (Gannon et al., 2004).

Mesotrione is an HPPD-inhibiting herbicide which is labeled for preemergence (PRE) and POST control of winter annual broadleaf weeds in cool-season turfgrasses (Anonymous 2008). Previous research has demonstrated that mesotrione can be safely applied to newly seeded tall fescue (*Festuca arundinacea*), Kentucky bluegrass and perennial ryegrass (*Lolium perenne*) (Askew and Beam 2002, Kowalewski et al. 2006, McCurdy et al. 2008). Mesotrione can also be safely applied POST to turfgrass that is newly emerged (Willis et al. 2006, Hart et al. 2007). Previous research has showed that

mesotrione applied PRE at 0.56 kg ha^{-1} completely controls common chickweed and henbit (Hart et al. 2007, Bhowmik and Sarkar 2009). However, the lower rates of mesotrione, applied PRE or POST, for control of these weeds have not been extensively evaluated. The objective of this study was to determine the minimum rate, applied PRE or POST, required for control of winter annual broadleaf weeds in newly seeded Kentucky bluegrass turf.

MATERIALS AND METHODS

Field studies were conducted in fall of 2009 and 2010 at the Rutgers Plant Science Research Center in Adelphia, New Jersey. Soil type was a Holmdel sandy-loam (fine-loamy, mixed, active, Aquic Hapludults) with a pH of 6.7 and 2.2% organic matter. The field was prepared for planting by disking followed by two passes with a soil pulverizer¹. 'Midnight II' Kentucky bluegrass was surface seeded at 86 kg ha^{-1} with a drop spreader on September 3, 2009 and September 16, 2010. Test site was fertilized at planting with $178 \text{ kg pr ha}^{-1}$ 10-10-10, on October 1, 2009 and November 19, 2009. In 2010 $178 \text{ kg pr ha}^{-1}$ 10-10-10 was applied on September 16 and November 20. The test site was irrigated to ensure optimal germination and subsequent Kentucky bluegrass growth.

Treatments consisted of an untreated check and mesotrione² at 0.04, 0.07, 0.11, 0.14 and 0.21 kg ha^{-1} applied PRE or POST (4 weeks after turfgrass emergence). PRE treatments were applied on September 3, 2009 and September 16, 2010 immediately after seeding, and POST treatments were applied on October 8 in 2009 and 2010. POST treatments of mesotrione included a non-ionic surfactant at $0.25\% \text{ v/v}$ ³. All herbicide

treatments were applied to 0.9 x 3 m plots with a single nozzle CO₂ backpack sprayer equipped with a 9504EVS nozzle tip⁴ calibrated to deliver 375 L ha⁻¹ at 220 kPa.

Control of winter annual broadleaf weeds was visually evaluated at 8 weeks after Kentucky bluegrass emergence (WAE) and the following April. Percent cover of Kentucky bluegrass was also visually evaluated. Visual estimates of control relative to the untreated was 0 to 100%, with 0 representing no control of winter annual broadleaf weeds or turfgrass cover, and 100% representing complete control of winter annual broadleaf weeds or complete turfgrass cover.

The experimental design was a randomized complete block with four replications. Data was subjected to an analysis of variance procedure (ANOVA) and pooled across years when year by treatment interactions were not significant at the 0.05% probability level.

RESULTS AND DISCUSSION

ANOVA procedures determined that visual estimates of henbit and chickweed control in the fall varied significantly across years, therefore fall data is presented separately by year. However, ANOVA detected no significant year by treatment interaction for spring data, therefore results were combined over years.

Kentucky Bluegrass Cover: Visual estimates of Kentucky bluegrass cover in the fall and spring were similar to the untreated regardless of mesotrione application rate or timing (data not shown). These results are in agreement with previous findings that show mesotrione can be used safely at Kentucky bluegrass establishment (Hart et al. 2007, Askew et al. 2003, Kowalewski et al. 2006).

Henbit: Henbit control with mesotrione in the fall of 2009 ranged from 65 to 85% across all rates and timings (Table 1). In 2010, control ranged from 40 to 99%. In the spring of both years, henbit control ranged from 48 to 96% across all rates and timings.

Differences between PRE versus POST treatment timings were evident. In fall, 0.04 kg ha⁻¹ applied PRE controlled henbit 70% in 2009 as opposed to only 40% in 2010, while POST applications of 0.04 kg ha⁻¹ provided 65 and 97% henbit control in 2009 and 2010, respectively.

Henbit control the following spring was 48 and 59% when mesotrione was applied PRE or POST at 0.04 kg ha⁻¹, respectively. When applied at 0.14 kg ha⁻¹ PRE, control of henbit in fall 2009 was 73%, but 99% in the fall of 2010. Control extending into the spring of both years was 72%, suggesting additional flushes of henbit were not completely controlled. When applied POST at 0.14 kg ha⁻¹, control was 78 and 99% in fall 2009 and 2010, respectively, with 91% control extending into spring for both years. Control with 0.21 kg ha⁻¹ applied PRE was 70% in fall 2009 and 97% in 2010. Control extending into spring for PRE applications at 0.14 and 0.21 kg ha⁻¹ was 72 and 74, respectively, whereas POST applications at 0.14 and 0.21 kg ha⁻¹ controlled 91 and 96% henbit, respectively. Control of henbit in fall 2009 was 85% at 0.21 kg ha⁻¹ POST. However in fall of 2010 henbit control was 96% or greater at rates of 0.11 kg ha⁻¹ or greater PRE, and across all rates post. These data suggest that increasing the rate of mesotrione to 0.14 kg ha⁻¹ POST increases henbit control but further increases in application rates were not required for additional control. In contrast, PRE applications at the highest rate of 0.21 kg ha⁻¹ failed to provide complete henbit control in the spring of both years.

Table 1. Percent control of henbit and chickweed with PRE and POST applications of mesotrione in experiments initiated in the fall of 2009 and 2010.

Main Effect		Percent control of henbit and chickweed					
		2009		2010		2009-2010	
		Fall ^A		Fall		Spring (Combined) ^B	
Timing	Rate (kg ha ⁻¹)	Henbit	Chickweed	Henbit	Chickweed	Henbit	Chickweed
PRE	0.04	70 d ^C	39 d	40 c	74 b	48 f	57 d
	0.07	68 cd	61 c	72 b	87 ab	57 ef	79 bc
	0.11	68 cd	68 bc	96 a	99 a	64 cde	85 abc
	0.14	73 bcd	83 abc	99 a	99 a	72 bcd	88 abc
	0.21	70 bcd	74 abc	97 a	99 a	74 bc	86 abc
POST ^D	0.04	65 d	63 bc	97 a	99 a	59 def	75 c
	0.07	75 bc	84 ab	99 a	99 a	84 ab	90 ab
	0.11	74 bc	78 abc	99 a	99 a	89 a	90 ab
	0.14	78 ab	80 abc	99 a	99 a	91 a	94 a
	0.21	85 a	91 a	99 a	99 a	96 a	98 a

^A Due to significant year by treatment interactions, fall was separated by year. In spring, these interactions were not significant and years were combined.

^B Visual estimates of tall fescue cover evaluated in the spring of 2010 and 2011.

^C Values with same letters are not significantly different according to Fishers Protected LSD at the 0.05 confidence level.

^D POST applied with non-ionic surfactant

Chickweed: Chickweed control with mesotrione in the fall of 2009 ranged from 39 to 91% across all rates and timings (Table 1). In the fall of 2010 control ranged from 74 to 99%. In the spring of both years, chickweed control ranged from 57 to 98% across all rates and timings. Differences between PRE versus POST treatment timings were evident. In fall, 0.04 kg ha⁻¹ applied PRE controlled chickweed 39% in 2009 as opposed to 74% in 2010, while POST applications at 0.04 kg ha⁻¹ provided 63 and 99% chickweed control in 2009 and 2010, respectively.

Chickweed control the following spring was 57 and 75% when mesotrione was applied PRE or POST at 0.04 kg ha⁻¹, respectively. When applied at 0.14 kg ha⁻¹ PRE, control of chickweed in fall 2009 was 83%, but 99% in the fall of 2010. Control extending into the spring of both years was 88%. When applied POST at 0.14 kg ha⁻¹, control was 80 and 99% in fall 2009 and 2010, respectively, with 94% control extending into spring for both years. Control with 0.21 kg ha⁻¹ applied PRE was 74% in fall 2009 and 91% in 2010. Control extending into spring for PRE applications at 0.14 and 0.21 kg ha⁻¹ was 88 and 86%, respectively, whereas POST applications at 0.14 and 0.21 kg ha⁻¹ controlled 94 and 98% chickweed, respectively. However, in fall 2009, chickweed control was 61% or greater at 0.07 kg ha⁻¹ applied PRE, and in fall 2010, control was 87% or greater at the same rates. POST applications in fall 2009, exceeded 84% control at rates of 0.07 kg ha⁻¹ or higher, and in fall 2010 complete control was achieved across all rates. These data suggest that increasing the rate of mesotrione applied POST to 0.11 kg ha⁻¹ or higher does not increase chickweed control. In contrast, PRE applications at the highest rate of 0.21 kg ha⁻¹ failed to provide complete chickweed control in spring of both years.

Overall, POST applications of mesotrione provided the highest levels of control of henbit and chickweed in fall 2009 and 2010 and in spring compared to PRE applications. POST applications of mesotrione at 0.11 and 0.14 kg ha⁻¹ provided the highest levels of henbit and chickweed control extending into the spring. However, there was no difference in control between these rates in the spring. Post applications were more effective, but to achieve higher levels of control PRE, application rates would need to be increased to 0.11 to 0.14 kg ha⁻¹.

Henbit and chickweed control with mesotrione control decreased fall to spring, due to the short residual of the herbicide in the soil. Mesotrione has a half-life of 32 days, which may explain why weed control decreased over the winter months (Dyson et al. 2002). The differences in control with PRE versus POST applications may be due to the fact that PRE applications were applied at planting, and applications made POST were applied later in the fall, allowing the mesotrione to persist longer to control subsequent germination of both weed species. However, PRE applications at higher rates can be advantageous because it eliminates weed competition at the initiation of turfgrass establishment.

Hart et al. (2007) found that mesotrione, applied PRE at 0.19 kg ha⁻¹ achieved nearly complete control of henbit and chickweed. Willis et al. (2006) observed complete control of henbit at a rate of 0.28 kg ai ha⁻¹ in spring-seeded tall fescue. Bhowmik and Sarkar (2009) observed that henbit and chickweed were controlled when mesotrione was applied at 0.18 and 0.28 kg ha⁻¹ to newly seeded perennial ryegrass. Mesotrione applied at 0.21 kg ha⁻¹ POST provided high levels of control for both henbit and chickweed (Hart et al. 2009). The rates utilized in our studies are similar to rates applied in these

studies, which reinforces results that application rates of mesotrione below 0.56 kg ha⁻¹ will control henbit and chickweed. In order to provide high levels (over 90%) control of both henbit and chickweed with mesotrione, applications of 0.14 or 0.21 kg ha⁻¹ applied POST should be utilized. Control in excess of 90% at these rates will extend into the spring. Due to the safety of mesotrione on most cool-season turfgrass species these application rates will quickly control winter annual broadleaf weeds while maintaining safety of the turfgrass sward (Hart et al. 2009, Willis et al. 2006, Bhowmik and Sarkar 2009). Eliminating the winter annual broadleaf weeds will also benefit the turfgrass by reducing the competition for light and nutrient resources (Gannon et al. 2004).

Application rates of 0.2 to 0.28 kg ha⁻¹ of mesotrione are currently labeled for weed control at cool-season turfgrass establishment (Anonymous 2008). However, sod producers desiring control of winter annual broadleaf weeds may be able to utilize rates ranging from 0.14 to 0.21 kg ha⁻¹ applied PRE or POST. Not only to using lower application rates of mesotrione control winter annual broadleaf weeds, using less herbicide will save money for the sod producer in the future.

SOURCES OF MATERIALS

¹ Rotodairon, Greer Bros. Inc, Salem OR, 97035

² Tenacity 4 SC, Syngenta Crop Protection LLC, Greensboro NC, 27419-8300

³ Activator 90, Loveland Products, Greeley CO 80632-1286

⁴ Spray Systems Co., Wheaton IL, 60189

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CHAPTER 4: TOLERANCE OF TALL FESCUE CULTIVARS TO MESOTRIONE
APPLIED AT ESTABLISHMENT

ABSTRACT

Field studies were conducted in the fall of 2009 and 2010 to evaluate the response of seven newly seeded tall fescue cultivars to mesotrione applied at planting (PRE), and PRE followed by sequential treatment four weeks after turfgrass emergence (WAE) at rates ranging from 0.14 kg ha⁻¹ to 1.12 kg ha⁻¹. All applications were made with a single 9504EVS nozzle CO₂ pressured sprayer calibrated to deliver a total 178 L ha⁻¹ at 222 kPa. Experimental design was a split-split (tall fescue cultivar x mesotrione application regime) configuration with four replications. Tall fescue cultivars ‘Rebel Advance,’ ‘Cochise II,’ ‘Hounddog,’ ‘Bullseye,’ ‘3rd Millennium,’ ‘Faith,’ ‘Falcon V,’ and ‘Mustang IV’ were seeded on September 9, 2009 at a rate of 245 kg ha⁻¹ in 1.8 m wide rows using a drop spreader. PRE application was made on September 9, 2009 and PRE + 4 WAE on October 6, 2009. Tall fescue was visually evaluated for cover relative to the untreated 8 weeks after seeding and for injury 4 weeks after seeding, as well as in the springtime on a scale of 0 (no cover or injury) to 100% (complete cover or injury). As mesotrione application rate increased from 0.56 to 1.12 kg ha⁻¹, cover of all tall fescue cultivars was decreased in the fall with cover reductions relative to the untreated ranging from 6 to 16% in fall 2009 and 8 to 20% in fall 2010. Cover reductions observed in ‘Hounddog 5’ and ‘Rebel Advance’ were greater relative to the other cultivars in the fall of 2009. While, ‘Hounddog 5’ and ‘Faith’ had greater cover reductions relative to the other

cultivars in the fall of 2010. However, in the spring of 2010, only ‘Hounddog 5’ had greater cover reduction than the other cultivars. Therefore, the results of this study suggest that although differences in tolerance to mesotrione was observed in some cultivars, these differences were minor, suggesting that tall fescue cultivars should all respond similarly to mesotrione applications.

Nomenclature: mesotrione, 2-(4-mesy-2-nitrobenzyl)-3-hydrocyclohex-2-enone; tall fescue, *Festuca arundinacea* Shreb.

Key words: herbicide tolerance, cultivar tolerance, mesotrione, tall fescue

INTRODUCTION

Tall fescue is an economically important cool-season turfgrass species due to its good wear tolerance, fast growth and dark green color (Turgeon 1999; Shearman and Beard 1975). Tall fescue is more drought tolerant relative to Kentucky bluegrass due to its deep, extensive root system (Brede 2000, Carrow 1996). Tall fescue is a bunch-type grass that establishes quickly from seed and is a large component of seed mixes. Breeding work has reduced the size of the leaves to increase its potential use on athletic fields, golf courses, commercial site and home lawns, thus tall fescue has become an important species grown for cultivated sod. However, due to its bunch type growth habit, complete establishment may require several months and voids in the turfgrass sward can easily become infested with weeds if it is slow to establish.

Mesotrione is a p- hydroxyphenylpyruvate dioxegenase (HPPD) inhibiting herbicide, and a member of the triketone herbicide family. HPPD inhibitors function by

disrupting the function of HPPD, reducing the amount of available of plastoquinones, which act as cofactors for phytoene desaturase. The bleaching of new growth is a result of the inhibition, however indirect, of the synthesis of carotenoids. Mesotrione is labeled for the control of broadleaf weeds in grassy crops such as corn and turfgrass (Anonymous 2008a, Anonymous 2008b). Previous field studies have demonstrated that mesotrione, when applied at 0.28 and 0.56 kg ha⁻¹, are safe to apply at seeding to newly seeded Kentucky bluegrass, perennial ryegrass and tall fescue (Askew et al 2003; Gannon et al 2006; Kowalewski et al 2006). This has led to an interest in pursuing the use of mesotrione in cultivated sod production for control of not only broadleaf weeds, but for suppression of annual bluegrass (Hart 2009). Although tall fescue appears to be safe to mesotrione applied at establishment, comprehensive studies have not been conducted to evaluate the response of multiple tall fescue cultivars to mesotrione. Therefore, seven commercially available tall fescue cultivars were selected and evaluated to determine the extent of intraspecific variability among tall fescue cultivars to mesotrione applied at establishment in late summer or fall.

MATERIALS AND METHODS

Field studies were conducted in 2009 and 2010 at the Rutgers Horticultural Research Farm II, in New Brunswick, New Jersey to evaluate the response of seven tall fescue cultivars to mesotrione¹ applied at establishment. Soil type was Nixon loam (fine-loamy, mixed, semiactive, mesic Typic Haludults) with a pH of 5.9 and an organic matter content of 2.4%. Tall fescue cultivars: 'Rebel Advance,' 'Hounddog 5,' 'Bullseye,' '3rd Millennium,' 'Faith,' 'Falcon V,' and 'Mustang IV' were seeded on September 8, 2009

and August 30, 2010 at a rate of 245 kg ha⁻¹. Each cultivar was seeded in rows at a width of 1.8 m. Both years, the field was maintained at a mowing height of 4 cm, received applications of 10-10-10² at 178 kg pr ha⁻¹ at seeding and irrigated to insure optimum growth. Herbicide treatments consisted of an untreated check and mesotrione applied at 0.14, 0.28, 0.56 and 1.12 kg ha⁻¹ applied at planting (PRE) or PRE followed by a sequential application at 4 weeks after emergence (4 WAE). All mesotrione applications applied 4 WAE included non-ionic surfactant³ at 0.25% v/v. Treatments were applied to 0.9 m x 14.4 m plots with a single nozzle CO₂ backpack sprayer system equipped with a 9504EVS nozzle tip⁴ calibrated to deliver 178 L ha⁻¹ spray solution at 222 kPa. Treatments were applied on September 9 and October 6 in 2009, and August 30 and September 30 in 2010. Turfgrass cover and/or injury ratings were evaluated at eight weeks after initial treatment as well as the following spring on a scale of 0-100%, where 0 is equivalent to bare soil or no injury and 100% is complete cover or complete plant necrosis. Cover ratings were converted to percent of the untreated. Experimental design was a split-split (tall fescue cultivar x mesotrione application regime) configuration with four replications. Mesotrione application regime (PRE or PRE fb POST) was the main plot with mesotrione rate and cultivar as subplots. Data was analyzed by a 5 (mesotrione rate) x 2 (application regime) x 7 (tall fescue cultivar) factorial.

Data was subject to analysis of variance procedures and pooled across years when year by treatment interactions were not significant at the 0.05 probability level. Means were separated using Fisher's protected LSD at the 5% significance level using SAS statistical software.

RESULTS AND DISCUSSION

Due to significant year by treatment interactions, percent cover and percent injury data were separated by year ($P \leq 0.05$). Analysis of variance (ANOVA) detected significant main effects of regime and rate for all observation timings (Table 1). Main effects of cultivar were significant in the fall but not the spring of both years. ANOVA also detected significant interactions between mesotrione application regime and rate at all observation timings. But, there was no three way interaction between regime, rate, and cultivar. Therefore, visual estimates of tall fescue cover as affected by application regime or rate are combined across cultivars (Table 2). However, mesotrione application regime by tall fescue cultivar interactions were only significant in the spring of 2010 (data not shown). ANOVA also detected significant rate by cultivar interactions at all observation times except spring of 2011. Therefore, visual estimates of tall fescue cover as affected by mesotrione application rate, combined across treatment regimes are presented by individual cultivar (Table 3). There was no significant interactions between mesotrione application regime, rate and tall fescue cultivar. This ANOVA of reductions in tall fescue cover suggest that mesotrione application regime and rate had greater impact on cover reductions than specific tall fescue cultivars.

Cultivar alone was only significant in fall of 2009 and 2010, but not in spring 2010 or 2011, indicating that although differences between cultivars were observed in fall, those differences were no longer significant in spring. All tall fescue cultivars established rapidly in both years. Percent cover in the untreated plots ranged from 85 to 99% and 95 to 99% at 8 WAT, in 2009 and 2010, respectively. Overall observations indicated that tall fescue cover decreased as mesotrione application rate increased, but

this was only observed when mesotrione was applied PRE at the 1.12 kg ha⁻¹ application rate (Table 2). Mesotrione at 0.56 kg ha⁻¹ applied PRE and PRE + 4 WAE reduced tall fescue cover in the fall but not the spring of both years. However, tall fescue cover reductions were still evident in the spring of both years with the 1.12 kg ha⁻¹ rate applied PRE + 4 WAE. Applications of mesotrione applied PRE + 4 WAE did not increase tall fescue cover reductions relative to PRE applications except when mesotrione was applied at 1.12 kg ha⁻¹. Although tall fescue cover reductions were statistically significant at high application rates of mesotrione, they never exceeded 16%.

Mesotrione applied at 0.14, 0.28 or 0.56 kg ha⁻¹ PRE or PRE + 4 WAE did not reduce cover of tall fescue cultivars to less than 95 % relative to the untreated in either 2009 or 2010 (Table 3). ‘Rebel Advance’ cover was reduced when mesotrione rates were increased from 0.14 to 0.28 kg ha⁻¹ in fall 2009, and ‘Hounddog 5’ showed cover reduction when rates were increased from 0.28 to 0.56 kg ha⁻¹ in fall 2010. However, these reductions in cover were less than 4%. As mesotrione application rate increased from 0.56 to 1.12 kg ha⁻¹, cover of all tall fescue cultivars was decreased in the fall with cover reductions relative to the untreated ranging from 6 to 16% in fall 2009 and 8 to 20% in fall 2010. Cover reductions observed in ‘Hounddog 5’ and ‘Rebel Advance’ were greater relative to the other cultivars in the fall of 2009. While, ‘Hounddog 5’ and ‘Faith’ had greater cover reductions relative to the other cultivars in the fall of 2010. However, in the spring of 2010, only ‘Hounddog 5’ had greater cover reduction than the other cultivars. In spring of 2010, cover of all cultivars at 1.12 kg ha⁻¹ were still less than the untreated except ‘3rd Millennium.’ Although there were differences between the

cultivars examined, these differences were minor, suggesting there is little intraspecific variability to mesotrione within tall fescue as a species.

Foliar injury from mesotrione applied POST at 0.14 kg ha^{-1} was evident at 4 weeks after treatment (WAT) but did not exceed 11% (data not shown). At 1.12 kg ha^{-1} , percent injury ranged from 41 to 51% at 4 WAT in 2009 with 'Mustang IV' showing the least injury and 'Hounddog 5' showing the most. In 2010, percent injury at 1.12 kg ha^{-1} ranged from 73 to 85% 4 WAT, with 'Mustang IV' and 'Falcon V' showing the least injury and 'Hounddog 5' showing the most. Injury symptoms were typical of the carotenoid biosynthesis inhibitors, with bleaching of the turfgrass foliage. However, injury symptoms were transient and quickly diminished on all cultivars throughout the remaining fall and into the winter, and there was no evidence of bleaching injury on any cultivar in the spring of both years (data not shown). These observations suggest that although the extent of foliar injury from high application rates of mesotrione was severe, it had little to no detrimental effect on turfgrass cover the following spring.

Across nine separate field studies, McElroy and Breeden (2007) found that applications of mesotrione at 0.14 or 0.28 kg ha^{-1} applied to newly emerged tall fescue did not detrimentally impact establishment. At 70 DAE, cover ranged from 81 to 87%, including the untreated. These researchers also observed foliar injury in the form of bleaching that quickly dissipated. Overall, their results, as well as the data in this study clearly demonstrate that mesotrione is safe for use on tall fescue at seeding and during establishment.

Results of this study also suggest that tall fescue does not have high levels of intraspecific variability in its tolerance or susceptibility to applications of mesotrione

Table 1. Analysis of Variance (ANOVA) table for visual estimates of tall fescue cover relative to the untreated control as affected by regime, rate, and cultivar in experiments initiated in the fall of 2009 and 2010.

Main effect	Tall Fescue Cover			
	2009		2010	
	Fall	Spring ^A	Fall	Spring ^B
Regime	****	****	****	****
Rate	****	****	****	****
Cultivar	**	NS	**	NS
Regime x Rate	****	****	***	****
Regime x Cultivar	NS	***	NS	NS
Rate x Cultivar	****	*	****	NS
Regime x Rate x Cultivar	NS	NS	NS	NS

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

*** Significant at the 0.001 probability level.

**** Significant at the 0.0001 probability level.

^A Visual estimates of tall fescue cover evaluated in the spring of 2010.

^B Visual estimates of tall fescue cover evaluated in the spring of 2011.

Table 2. Visual estimates of tall fescue cover combined across cultivars as influenced by application regime and mesotrione rate for experiments initiated in the fall of 2009 and 2010 (Interaction of rate x regime combined across cultivars).^A

		Fall 2009	
		Regime	
		PRE	PRE + 4 WAE
Rate	0.14	98 Aa ^B	98 Aa
	0.28	98 Aa	98 Aa
	0.56	98 Aa	96 Bb
	1.12	93 Ab	87 Bc
		Spring 2010 ^C	
		Regime	
		PRE	PRE + 4 WAE
Rate	0.14	98 Aa	98 Aa
	0.28	98 Aa	98 Aa
	0.56	98 Aa	99 Aa
	1.12	95 Ab	89 Bb

^A Turfgrass cover rated on a scale of 0 to 100, where 0= bare soil and 100= complete turfgrass cover.

^B Means within a row of each evaluation timing followed by the same upper case letter and means within a column followed by the same lower case letter are not statistically different according to Fisher's protected LSD test (0.05).

^C Visual estimates of tall fescue cover evaluated in the spring of 2010.

Table 2...Cont'd. Visual estimates of tall fescue cover combined across cultivars as influenced by application regime and mesotrione rate for experiments initiated in the fall of 2009 and 2010 (Interaction of rate x regime combined across cultivars).^A

		Fall 2010	
		Regime	
		PRE	PRE + 4 WAE
Rate	0.14	98 Aa ^B	98 Aa
	0.28	98 Aa	98 Aa
	0.56	97 Aa	95 Ab
	1.12	90 Ab	84 Bc
		Spring 2011 ^C	
		Regime	
		PRE	PRE + 4 WAE
Rate	0.14	99 Aa	98 Aa
	0.28	99 Aa	98 Aa
	0.56	99 Aa	98 Aa
	1.12	97 Aa	87 Bb

^ATurfgrass cover rated on a scale of 0 to 100, where 0= bare soil and 100= complete turfgrass cover.

^B Means within a row of each evaluation timing followed by the same upper case letter and means within a column followed by the same lower case letter are not statistically different according to Fisher's protected LSD test (0.05).

^C Visual estimates of tall fescue cover evaluated in the spring of 2010.

Table 3. Visual estimates of tall fescue cover combined across application regimes as influenced by mesotrione rate in experiments initiated in the fall of 2009 and fall 2010.

Main Effect		Tall fescue cover (% of untreated) ^A						
		Fall 2009						
		Rebel Advance	Mustang IV	Hounddog 5	Falcon V	Faith	Bullseye	3 rd Millenium
Rate	0.14	99 Aa ^B	99 Aa	98 Aa	98 Aa	99 Aa	98 Aa	98 Aa
	0.28	96 Ab	99 Aa	97 Aa	98 Aa	98 Aa	98 Aa	98 Aa
	0.56	95 Bb	99 Aa	96 Aa	97 Aa	97 Aa	97 Aa	97 Aa
	1.12	84 Bc	94 Ab	82 Bb	89 Ab	92 Ab	91 Ab	92 Ab
Main Effect		Spring 2010 ^C						
		Rebel Advance	Mustang IV	Hounddog 5	Falcon V	Faith	Bullseye	3 rd Millenium
		Rate	0.14	98 Aa	98 Aa	97 Aa	97 Aa	98 Aa
0.28	97 Aa		98 Aa	97 Aa	98 Aa	99 Aa	99 Aa	98 Aa
0.56	96 Aa		99 Aa	97 Aa	96 Aa	98 Aa	98 Aa	97 Aa
1.12	91 Ab		94 Ab	85 Bb	90 Ab	92 Ab	95 Ab	94 Aa

^A Turfgrass cover rated on a scale of 0 to 100, where 0= bare soil and 100= complete turfgrass cover.

^B Means within a row of each evaluation timing followed by the same upper case letter and means within a column followed by the same lower case letter are not statistically different according to Fisher's protected LSD test (0.05).

^C Visual estimates of tall fescue cover evaluated in the spring of 2010.

Table 3...cont'd. Visual estimates of tall fescue cover combined across application regimes as influenced by mesotrione rate in experiments initiated in the fall of 2009 and fall 2010.

		Tall fescue cover (% cover relative to untreated) ^A						
		Fall 2010						
Main Effect		Cultivar						
		Rebel Advance	Mustang IV	Hounddog 5	Falcon V	Faith	Bullseye	3 rd Millenium
Rate	0.14	98 Aa ^B	97 Aa	99 Aa	99 Aa	97 Aa	98 Aa	99 Aa
	0.28	99 Aa	97 Aa	99 Aa	98 Aa	96 Aa	98 Aa	97 Aa
	0.56	97 Aa	95 Aa	95 Ab	97 Aa	95 Aa	95 Aa	96 Aa
	1.12	92 Ab	86 Ab	80 Bc	88 Ab	81 Bb	90 Ab	89 Ab

^ATurfgrass cover rated on a scale of 0 to 100, where 0= bare soil and 100= complete turfgrass cover.

^B Means within a row of each evaluation timing followed by the same upper case letter and means within a column followed by the same lower case letter are not statistically different according to Fisher's protected LSD test (0.05).

made PRE or PRE + 4 WAE. Previous research on different Kentucky bluegrass cultivars, Hart (2009) observed some level of intraspecific variability, but only when mesotrione rates approached 1.12 to 2.2 kg ha⁻¹.

SOURCES OF MATERIALS

¹ Mesotrione, Tenacity 4 SC, 40 g ai/L, Syngenta Crop Protection LLC, Greensboro NC, 27419-8300

² 10-10-10, Reed & Perrine Inc, Tennent NJ, 07763

³ Activator 90, Loveland Products, Greeley CO 80632-1286

⁴ Spray Systems Co., Wheaton IL, 60189

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PUBLICATIONS:

Venner, K. A., S. E. Hart and C. J. Mansue. 2010. Use of Mesotrione for Annual Bluegrass Control at Kentucky Bluegrass Establishment. Proc. NEWSS Ann. 64:16

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