TUFTED LOVEGRASS (*ERAGROSTIS PECTINACEA*) AND DOVEWEED

(*MURDANNIA NUDIFLORA*) CONTROL IN

WARM-SEASON TURFGRASSES

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TUFTED LOVEGRASS (*ERAGROSTIS PECTINACEA*) AND DOVEWEED (*MURDANNIA NUDIFLORA*) CONTROL IN WARM-SEASON TURFGRASSES

George H. Huckabay

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WARM-SEASON TURFGRASSES

George H. Huckabay

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VITA

George Houston Huckabay, son of Houston Keller and Georgia (Fillingham) Huckabay, was born February 23, 1981, in Monroe, Louisiana. He graduated from Fairhope High School in Fairhope, Alabama in May of 2000. He attended Faulkner State Community College, Bay Minnette, Alabama and transferred to Auburn University in the fall of 2002. He graduated with a Bachelor of Science degree in Agronomy and Soils August 2005. He entered the Graduate School of Auburn University August, 2005 and received a Master of Science Degree in Agronomy and Soils (Weed Science) in August, 2008. He married Ellen Knight from Wadley, Alabama and they live in Alexander City, Alabama.

THESIS ABSTRACT

TUFTED LOVEGRASS (*ERAGROSTIS PECTINACEA*) AND DOVWEED

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WARM-SEASON TURFGRASSES

George H. Huckabay

Master of Science, August 9, 2008
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Tufted lovegrass has been identified as a problem weed in sod production in Mississippi, Tennessee, Arkansas, Georgia and Alabama, particularly in zoysiagrass. The slow growth rate of zoysiagrass is suspected to be a contributing factor. In germination response to temperature and light studies it was determined that light was required and germination occurred over a wide temperature range. Conventional control recommendations require producers to spray reduced rates of glyphosate to control tufted lovegrass. However, producers are concerned with zoysiagrass injury, particularly to cultivars that have wider leaf blades. Preemergence-applied herbicide efficacy experiments were conducted in environmental growth chambers. Excellent control (>95%) was recorded from labeled rates of bensulide, dithiopyr, mesotrione (only 0.375 ppm concentration), metolachlor, oxidiazon, pendimethalin, and prodiamine. In small-plot, replicated experiments, mesotrione rates of 0.035, 0.072, 0.14, and 0.28 kg ai/ha

were applied two or three times to a recently harvested ‘Meyer’ zoysiagrass turf infested with tufted lovegrass. Applications were made in the summer of 2006 and 2007 to approximately 14-month-old zoysiagrass. A single application of 0.28 kg ai/ha provided complete control of lovegrass but turf injury was unacceptable (>30%). Three applications of 0.072 and 0.14 kg ai/ha provided 82 and 98% control, respectively, while turf injury averaged 11 and 15%, respectively. Zoysiagrass injury was in the form of foliar bleaching and slowed growth. These results indicate mesotrione has the potential to be a useful tool in managing tufted lovegrass in zoysiagrass turf.

In recent years doveweed has received increased interest due to occurrence in commercial turf and home lawns. One contributing factor is infestations found in container-grown ornamentals, further increasing its potential geographical distribution. Effective control of doveweed infestations in bermudagrass and zoysiagrass turf is lacking. Experiments were conducted in environmental growth chambers to determine optimum germination temperature. From these studies it was determined that optimum germination occurred at 32/23 C and doveweed seeds did not require light to germinate. Efficacy experiments with preemergence-applied herbicides were also conducted in the growth chambers to determine activity on scarified doveweed seeds. Labeled rates of atrazine, oxidiazon, dithiopyr, isoxaben, and metolachlor provided excellent control (>95%) while pendimethalin and prodiamine were ineffective. In field trials repeat applications (1.12 + 1.12 kg ae/ha) 21 days apart of MCPP-p-4; 2,4-D + 2,4-DP and MCPA amine provided excellent control of doveweed with minimal injury to zoysiagrass and bermudagrass turf.

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Style manual or journal used:

Weed Science, Weed Technology

Computer software used:

Microsoft Word and Excel 2003, SAS v8.0

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I. LITERATURE REVIEW

Tufted Lovegrass. Tufted lovegrass [*Eragrostis pectinacea* (Michx.) Nees ex Jedwabn.] has recently emerged as a troublesome weed in 'Meyer' zoysiagrass (*Zoysia japonica* Steud.) sod production. Two suggested reasons for this are: 1) tolerance to MSMA, and, 2) after the sod is harvested the soil surface remains bare for prolonged periods, creating an ideal environment for lovegrass seed to germinate (Boyd and Rodgers, 1999).

Tufted lovegrass is a native grass species that is found from southern Canada to Argentina (Zuloaga et al., 2003). It is commonly found in disturbed areas such as railroad embankments, roadsides, gardens, and cultivated fields (Boyd and Rodgers, 1999; Zuloaga et al., 2003). Tufted lovegrass is described as an annual that primarily reproduces by seed (Radford et al., 1968; Peterson, 2003). It has a tillering growth habit and forms short rhizomes (Peterson, 2003). There is a small tuft of hairs located on the collar from which tufted lovegrass derives its name (Peterson 2003). Tufted lovegrass is commonly confused with Indian lovegrass [*Eragrostis pilosa* (L) Beauv.] and is noted as being similar enough to be listed as the same plant description in the commonly referenced botany book *Flora of the Carolinas* (Radford et al., 1968). One characteristic that distinguishes tufted lovegrass from Indian lovegrass is that tufted lovegrass' lower glume is at least half as long as the adjacent lemma (0.5-1.5 mm), while Indian's lower glume is 0.3-0.6 mm long (Radford et al., 1968). Also tufted lovegrass' upper glumes are

usually broader than the lower glumes (1-1.7 mm) while Indian's are 0.7-1.2 mm (Peterson, 2003).

Germination Biology. There are no published studies investigating the germination response of tufted lovegrass to different temperatures, but there have been germination studies conducted on similar species. One such study found that Catalina boer lovegrass [*Eragrostis curvula* (Shrad) Nees var. *conferta* Stapf] and Lehamann lovegrass (*Eragrostis lehmanniana* Nees) germinated immediately when left uncovered on the soil surface. But when the seeds were covered with approximately 1 cm of soil no germination occurred. The researchers concluded that the seeds required light to germinate (Cox and Martin, 1984). A similar study investigated the response of woolybutt grass (*Eragrostis eriopoda* Benth) to constant temperatures and alternating temperatures and found that optimum germination occurred at 42 C under constant temperatures. Optimum germination occurred under alternating conditions at 30/22 C 12-hour day/12-hour night (Ross, 1976). Buckallew and Caddell, (2003) investigated reproduction of *Eragrostis* species and determined that the average flowering date of purple lovegrass [*Eragrostis spectabilis* (Pursh) Steud.] was approximately June-July. Another study on seed production determined that weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees] produced an average of 6,050 seeds per plant or 20,500 seeds/m^2 (Jones, 1967).

Response to Preemergence-applied (PRE) Herbicides. Although often reported as a problem, only one article presented data for control of tufted lovegrass with PRE herbicides. Boyd and Rodgers (1999) found that atrazine at 1.68 kg ai/ha applied in two applications 14 d apart provided excellent PRE control. Simazine at 1.68 kg ai/ha and

metolachlor at 1.12 kg ai/ha applied twice 14 d apart were ineffective as a PRE control (Boyd and Rodgers, 1999). Alternatively, there have been several articles published investigating stinkgrass [*Eragrostis cilinanesis* (All.) Vign. ex Janchen] control, which is a similar species to tufted lovegrass. One such article by Wehtje and Mosjidis in (2005) reported that imazethapyr applied at 0.142 and 0.213 kg ai/ha provided excellent (>95%) PRE control of stinkgrass 2 months after treatment. Similar results were reported with a single application of bensulide at 8.5 kg ai/ha, and oxadiazon at 4.5 kg ai/ha (Dernoeden et al., 1988). Several other herbicides were evaluated, but were ineffective for PRE control of stinkgrass which included napropamide, chlorthal-dimethyl (DCPA), pendimethalin, and prodiamine (Dernoeden et al. 1988).

Response to Postemergence-applied (POST) Herbicides. Analogous to PRE control studies, little has been done to evaluate POST control of tufted lovegrass. Tufted lovegrass control was evaluated using glyphosate at 0.34 kg ae/ha and glyphosate plus glufosinate at 0.34 kg ae/ha and 0.84 kg ae/ha respectively, and both provided 100% control 29 and 40 days after treatment (Boyd and Rodgers, 1999). Although glyphosate and glufosinate provided excellent control of the lovegrass, injury to the zoysiagrass was approximately 30% and 60%, respectively (Boyd and Rodgers, 1999). The amount of injury that is acceptable in zoysiagrass production is ≤ 30% (Personal communication, Walker). Other herbicides that were evaluated, but deemed ineffective, were fluazafop-butyl, clethodim, nicosulfuron, primsulfuron, atrazine, quinclorac, asulam, and pronamide (Boyd and Rodgers, 1999). Another study was conducted to evaluate POST herbicides that are less injurious to sensitive turf cultivars such as 'Meyer' zoysiagrass and centipedegrass [*Eremochloa ophiuroides* (Munro.) Hack.]. Treatments that showed

the greatest control were mesotrione at 0.14 kg ai/ha and mesotrione at 0.14 kg ai/ha plus atrazine at 0.14 kg ai/ha. Each provided excellent control (>98%) with minimal injury (<15%) (Huckabay and Walker unpublished data 2005). Mesotrione is a relatively new herbicide developed by Syngenta Crop Protection and is currently labeled for use on several turf species (Cornes, 2005. It is an analogue of the naturally occurring substance leptospermone, isolated from the roots of the 'bottle-brush' plant [*Callistemon citrinus* (Curtis) Skeels] (Cornes, 2005). Mesotrione is in the class of herbicides that inhibit 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD) (Cornes, 2005). The enzyme 4-HPPD is needed for carotenoid synthesis; inhibition of this enzyme prevents plants from producing necessary pigments. When plants are deficient of 4-HPPD the results are usually in the form of foliar bleaching which begins to show 7-14 days after treatment of susceptible plants (Vencill, 2002).

Doveweed. Doveweed [*Murdannia nudiflora* (L) Brenan.], an invasive species, is found as far north as Arkansas and North Carolina and as far west as the plains of Texas, but is most commonly found in and around coastal regions (Faden, 1982; Faden, 2000; Radford, et al. 1968). It is native to southern Asia and tropical Pacific regions but has been naturalized to North and tropical America (Wagner et al., 1999). Plants tolerate moist conditions and readily root at the nodes even after being cut (Holm et al., 1977). It is a troublesome weed species infesting home lawns, golf courses, and sod farms. Traditionally, doveweed has been found exclusively in managed turfgrass systems, but in recent years has emerged as a problem in row crops (Burton et al., 2003) and rice (*Oryza sativa* L.) production (Plaza, 1998; Thi Tan, 2000).

Doveweed is described as an annual in the temperate to sub-tropical southeast United States and Mexico where it has been naturalized. The leaves can be branched or unbranched and are spirally arranged. The leaf blades are linear, linear lanceolate, or lanceolate-oblong. Doveweed inflorescences are terminal or terminal and axillary. The cymes are few-flowered, solitary, or fascicled, pedunculate (Faden, 2005). Flowers are bisexual and slightly bilaterally symmetric; with pink to purple petals and seeds encapsulated (Faden, 2005).

Reasons for increased occurrence of doveweed are: 1) tolerance to glyphosate; 2) inadequate control from conventional POST-applied herbicides used in managed turfgrass systems; and 3) introduction through infested container-grown nursery stock into home landscapes (Culpepper et al, 2004, York 2006, Walker et al., 1998, Neal, 2005). The latter reason can be attributed as most common. Doveweed occurrence has dramatically increased due to the number of nursery plantings that are transplanted with infested media each year. These contaminated plants are transplanted into home landscapes for esthetics, introducing doveweed into the nearby lawns and eventually spreading throughout the entire lawn (Neal, 2005).

Seed Germination. A recent publication by Wilson et al. (2006) on doveweed found that when seeds were harvested, germination was immediate, but when seeds were allowed to dry they went into an induced dormancy that required mechanical scarification to break. The literature reported that the optimum constant germination temperature was 27.8 C after 14 days. Although doveweed germinated at constant temperature the highest germination (77%) occurred when seeds were treated with alternating day/night temperatures of 35/25 C. Experiments were conducted to determine if doveweed seeds

required light for germination and it was found that light was not required (Wilson et al. 2006). Recent studies have also been conducted on a similar taxa, tropical spiderwort (*Commelina benghalensis* L.), which has emerged as one of the most troublesome weeds in Georgia (Burton et al., 2003). Studies found that optimal temperature for vegetative growth and flower production of tropical spiderwort was between 30 and 35 C, but growth was recorded at a range of 20 to 40 C (Burton at al. 2003).

Preemergence-applied (PRE) Herbicides. Stamps and Chandler (1999) evaluated the efficacy of several PRE herbicides for doveweed control in container-grown nursery pots. The herbicides (kg ai/ha) included in the study were: flumioxazin, 0.42; oxyfluorfen, 0.24 + pendimethalin, 1.12; oxyfluorfen, 2.24 + oxadiazon, 1.12; oxyfluorfen, 2.24 + oryzalin, 1.12; trifluralin, 4.48 + isoxaben, 1.12; prodiamine, 1.68; flumioxazin, 0.42 + prodiamine, 1.68. Flumioxazin, oxyfluuorfen + oryzalin, and flumioxazin, + prodiamine, controlled doveweed completely at 0.42, 2.24 + 1.12, and 0.42 + 1.68 kg/ai ha, respectively. Oxyfluorfen + pendimethalin and trifluralin + isoxaben were effective but did allow some seedling emergence.

Postemergence-applied (POST) Herbicides. Several studies have been conducted evaluating POST control of doveweed. Walker et al. (1998) found that two applications of atrazine at 1.68 kg ai/ha 7 days apart provided excellent control (94%) of doveweed in St. Augustinegrass [*Stenotaphrum secundatum* (Waltz) Kuntze] and centipedegrass with both species being able to tolerate applications within the tolerable injury range (0-30%). Some other herbicides (kg ai/ha) that have been evaluated for POST control of doveweed are MCPP, 0.134 + 2,4-D, 0.149 + dicamba, 0.031; thifensulfuron methyl, 0.0134 + tribenuron, 0.00672 + metsulfuron, 0.00672; imazapic, 0.036; sulfometuron, 0.036;

triclopyr, 0.277 + clopyralid, 0.10; dicamba, 0.56; bentazon, 1.12 (Walker et al. 1998; Staples and Walker, 2001). Although earlier research focused on controlling doveweed in centipedegrass and St. Augustinegrass, there has been increased interest in doveweed control in zoysiagrass (*Zoysia* spp.) and hybrid bermudagrass [*Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burtt-Davy] species. Atrazine cannot be applied to actively growing zoysiagrass and bermudagrass due to the risk of injury.

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II. TUFTED LOVEGRASS (*ERAGROSTIS PECTINACEA*) GERMINATION BIOLOGY AND CONTROL IN WARM-SEASON TURFGRASSES

Abstract

Tufted lovegrass is a problem weed in sod production in the southeastern United States, and most severely in zoysiagrass. There have been several suggested reasons for the increased incidence in commercial turf. One such reason was the relative slow growth rate of zoysiagrass after the sod has been harvested. Germination response to temperature and light studies determined that light was required and germination occurred over a wide temperature range. Conventional control recommendations require producers to spray reduced rates of glyphosate to control tufted lovegrass. However, producers are concerned with zoysiagrass injury, particularly to cultivars that have wider leaf blades. Preemergence-applied herbicide efficacy experiments were conducted in environmental growth chambers. Excellent control (>95%) was recorded from for a range of rates of bensulide, dithiopyr, mesotrione (only 0.375 ppm concentration), metolachlor, oxidiazon, pendimethalin, and prodiamine. In small-plot, replicated experiments, mesotrione rates of 0.035, 0.072, 0.14, and 0.28 kg ai/ha were applied two or three times to a recently harvested 'Meyer' zoysiagrass turf infested with tufted lovegrass. Applications were made in the summer of 2006 and 2007 to approximately 14-month-old zoysiagrass. A single application of 0.28 kg ai/ha provided complete control of lovegrass but turf injury was unacceptable (>30%). Three applications of

0.072 and 0.14 kg ai/ha provided 82 and 98% control, respectively, while turf injury averaged 11 and 15%, respectively. Zoysiagrass injury was in the form of foliar bleaching and slowed growth. These results indicate mesotrione has the potential to be a useful tool in managing tufted lovegrass in zoysiagrass turf.

Introduction

Tufted Lovegrass [*Eragrostis pecticea* (Michx) Nees ex Jedwabn] is a troublesome weed that occurs in 'Meyer' zoysiagrass (*Zoysia japonica* Steud.) sod production and to a lesser extent in the production of hybrid bermudagrass [*Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burtt-Davy] (Boyd and Rodgers 1999). There are two suggested reasons for this emergence and they are: 1) a possible tolerance to MSMA, and, 2) a lengthened period of bare soil due to the slow growth rate of zoysiagrass between sod harvests, thus creating an ideal environment for lovegrass to germinate. (Boyd and Rodgers, 1999).

Tufted lovegrass is a native grass species that is found throughout North and South America (Zuloaga et al, 2003). It was commonly found in low maintenance disturbed areas such as railroad embankments, roadsides, gardens, and cultivated fields (Boyd et al. 1999, Zuloaga et al, 2003). Tufted lovegrass is commonly confused with Indian lovegrass [*Eragrostis pilosa* (L) Beauv.] and is noted as being similar enough to be listed as the same plant description in the commonly referenced botany book *Flora of the Carolinas* (Radford et al, 1968). One characteristic that distinguishes tufted lovegrass from Indian lovegrass is that tufted lovegrass' lower glumes is at least half as long as the adjacent lemma (0.5-1.5 mm), while Indian's lower glumes is 0.3-0.6 mm long (Radford et al. 1968). Also tufted lovegrass' upper glumes are usually broader than the lower glumes (1-1.7 mm) while Indian's are 0.7-1.2 mm (Peterson, 2003).

There is limited literature investigating the germination response of tufted lovegrass to different temperatures, even though there have been germination studies conducted on similar species. One such study found that Catalina boer lovegrass [*Eragrostis curvula* (Shrad) Nees var. *conferta* Stapf] and Lehamann lovegrass (*Eragrostis lehmanniana* Nees) when left exposed on the soil surface germinated at once, but when the seeds were covered with approximately 1 cm of soil germination did not occur (Cox and Martin, 1984). The researchers concluded that the seeds required light to germinate. A similar study investigated the response of woolybutt (*Eragrostis eriopoda* Benth) grass to constant and alternating temperatures and found that the optimum germination temperature occurred at 42 C under constant temperatures and 30/22 C 12-hour day/12-hour night under alternating temperatures (Ross, 1976). Limited research has been conducted investigating reproductive biology of *Eragrostis* species; one study found that the average flowering date of purple lovegrass [*Eragrostis spectabilis* (Pursh) Steud.] was approximately June-July (Buckallew and Caddell, 2003). Another study investigating plant reproduction of weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees] found that the average seed produced per plant was 6,050 seeds or 20,500 seeds/m^2 (Jones, 1967).

Even though tufted lovegrass has been reported as a problem, only one article presented data for control with PRE herbicides. Boyd and Rodgers (1999) found that atrazine at 1.68 kg ai/ha applied in two applications 14 d apart provided excellent PRE control. Simazine at 1.68 kg ai/ha and metolachlor at 1.12 kg ai/ha applied twice 14 d apart were ineffective as a PRE control. Alternatively, there have been several articles published investigating stinkgrass control, which is a similar species to tufted lovegrass. Wehtje and Mosjidis (2005) reported that imazethapyr applied at 0.142 and 0.213 kg

ai/ha provided excellent (>95%) PRE control of stinkgrass 2 months after treatment. Dernoeden et al. (1988), reported similar results with a single application of bensulide at 8.5 kg ai/ha, and oxadiazon at 4.5 kg ai/ha. Several other herbicides were evaluated, but were ineffective for PRE control of stinkgrass: napropamide, chlorthal-dimethyl (DCPA), pendimethalin, and prodiamine.

Similar to PRE control studies, little has been done to evaluate POST control of tufted lovegrass. Tufted lovegrass POST control was evaluated using glyphosate at 0.34 kg ae/ha and glyphosate plus glufosinate at 0.34 kg ae/ha and 0.84 kg ae/ha respectively, and provided 100% control 29 and 40 days after treatment (Boyd and Rodgers, 1999). Although glyphosate and glufosinate provided excellent control of the lovegrass, the injury to the zoysiagrass was approximately 30% and 60%, respectively (Boyd and Rodgers, 1999). The amount of injury that is acceptable is ≤ 30% (Personal communication, Walker). Other herbicides that were evaluated, but were ineffective, were fluazafop-butyl, clethodim, nicosulfuron, primsulfuron, atrazine, quinclorac, asulam, and pronamide (Boyd and Rodgers, 1999). Another study was conducted to evaluate POST herbicides that are less injurious to sensitive turf cultivars such as 'Meyer' zoysiagrass and centipedegrass [*Eremochloa ophiuroides* (Munro.) Hack.]. The treatments that produced the greatest control were mesotrione at 0.14 kg ai/ha, mesotrione at 0.14 kg ai/ha plus atrazine at 0.14 kg ai/ha. Each provided excellent control (>98%) with minimal injury (<15%) (Huckabay and Walker unpublished data 2005). Mesotrione is a relatively new herbicide developed by Syngenta Crop Protection and is currently labeled for use on several turf species. It is an analogue of the naturally occurring substance leptospermone, isolated from the roots of the 'bottle-brush' plant

[*Callistemon citrinus* (Curtis) Skeels] (Cornes, 2005). Mesotrione is in the class of herbicides that inhibit 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD), needed for caratenoid synthesis (Cornes, 2005). A lack of 4-HPPD prevents plants from producing necessary pigment. Bleaching symptoms begin to show 7-14 days after treatment on susceptible plants (Vencill et al., 2002). The objectives for this study were: 1) to determine the germination response of tufted lovegrass to alternating temperature regimes and alternating light cycles; 2) to determine the response of tufted lovegrass to preemergence-and postemergence-applied herbicides.

Materials and Methods

Germination Response. Tufted lovegrass plants were harvested and transplanted from natural infestations located around Auburn University in August 2005. Transplanted plants were allowed to grow for 2 months before seed heads were harvested in November 2005. Seeds were then separated from glumes by hand and allowed to dry for 5 days at 25 C and then stored at 7 C until used in experiments. Before seeds were used they were sieved with a no. 20 (0.84 mm) sieve to remove excess plant and inert matter. Germination studies were conducted in environmental growth chambers with a light intensity of 255 μmol $m^{-2}s^{-1}$. Experiments utilized 5 mg Terra-Sorb GB acrylamide copolymer[1] dissolved in 1 ml tap water as a growth medium (McElroy, 2003). Six-cell tissue culture trays[2] were filled to capacity with the gel. Each cell had capacity of 17

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[1]Fisher Scientific, Pittsburgh, PA 15275-9952.

[2]Industrial Services International, Inc., Bradenton, FL 34205.

mL. In all studies, 10 lovegrass seeds were placed into each of the six cells within a tray. Germinated seeds were counted for each cell and one cell was considered a replicate. Each study consisted of four trays, two covered and two uncovered to simulate buried seeds. Germination was first determined in covered trays when percent germinated in the uncovered trays was ≥ 70% or 14 days after initiation. Each study was repeated twice. Seed germination was recorded at 3, 7, and 14 days after initiation. A seed was considered germinated when cotyledon and radicle had visually emerged from the seed coat. All studies utilized a completely randomized design and there were 12 replications. Germination counts were converted to percentages for presentation purposes. Seed germination response was evaluated at three alternating temperature regimes: 18/7, 27/16, and 32/23 C and a constant 12-h light/12-h dark photoperiod. These temperature regimes were used because they reflected the average high/low for central Alabama for March, May, and July. Only seed that was stored at 7 C for at least 4 weeks was used. Data was analyzed with ANOVA and standard errors of the means were used to separate treatment means.

Laboratory Evaluation of Preemergence-applied (PRE) Herbicides. Laboratory studies were conducted in the fall and winter of 2005 and 2006 to determine PRE herbicide activity on tufted lovegrass seeds. Herbicide rates were calculated using the assumption that PRE herbicides remain in the top 7.62 centimeters of soil. The top 7.62 centimeters of soil in a hectare weighs approximately 1,120,000 kilograms, and this was used in determining parts per million (PPM) rates. Herbicide and rates (PPM) applied were: atrazine, 1, 1.5, and 2; prodiamine, 0.5, 0.75, and 1; oxidiazon, 1, 2, and 3; mesotrione, 0.0625, 0.125, 0.25, 0.375; dithiopyr, 0.375, 0.5, 0.75; pendimethalin, 1, 2,

and 3; metolachlor, 1, 1.25, and 1.5; and bensulide, 6, 9, and 12. Six-cell tissue culture trays containing 5 mg Terra-Sorb GB acrylamide copolymer per 1 ml herbicide solution were utilized as the growth medium (McElroy, 2003). Tissue culture trays were placed in the growth chambers using the 32/23 C and a constant 12-h light/12-h dark photoperiod. All studies utilized a completely randomized design and each cell was considered an experimental unit with six replicates and tests were repeated twice.

Field Evaluation of Postemergence-applied (POST) Herbicides. Field experiments were conducted in 2006 and 2007 to evaluate the response of tufted lovegrass to POST herbicides. Two experiments were conducted at Beck's Turf Inc. located approximately 10 miles southwest of Auburn, Alabama. Experiments were established on a Lurverne sandy loam soil (fine mixed semiactive thermic typic Hapludults) with a pH of 6.1 and 1.3% organic matter. Plots were 1.52 m wide by 4.57 m long. Each plot had a uniform stand of lovegrass with an average plant density of 100 - 150 plants m^2. Herbicide treatments were applied on 15 June 2006 and 15 May 2007 to lovegrass plants that were approximately 4-weeks old with 6-8 leaves. To each spray mixture, non-ionic surfactant was added at 0.25% v/v. Plants were mowed every 7 days to a height of 2.8 cm prior to herbicide applications and then mowed 1 week prior to each application.

Mesotrione was applied at four rates (kg ai/ha): 0.036, 0.072, 0.14, and 0.28. These four treatments were applied either two or three times. Treatments with two applications were applied 8 weeks apart, and those with three applications were applied 4 weeks apart. The experiments consisted of a factorial arrangement of four herbicides and two applications (two or three) and an untreated check, yielding nine treatments. First applications were applied 15 June 2006 and 15 May 2007, for the first and second study,

respectively. Second applications were applied 15 July 2006 and 15 June 2007; and the third application was made on 15 August 2006 and 15 July 2007 respectively. The treatments were applied with a CO_2 backpack sprayer calibrated to deliver a volume of 281 L/ha. Percent control was rated for each species on a scale of 0 no control to 100 complete control. Turf injury was rated for zoysiagrass on a scale of 0 no injury to 100 severely injured. Visual ratings of control were taken 2 weeks after initial treatments (WAIT) and 2 weeks after each additional treatment.

All data was subjected to arcsine transformation in order to meet the assumptions for analysis of variance (ANOVA). Violation of these assumptions can at times alter the standard errors falsifying results. Therefore transformations were used to make standard error as small as possible. Means were subjected to ANOVA and were separated using the standard errors.

Results and Discussion

Germination Response. Main effects of germination studies were significant therefore treatment means for temperature regimes will be presented. These results are displayed in (Table II, 1). Germination did occur at all temperature regimes after 3 days but was greatest at the highest temperature regime (32/23 C) at 99%. Seven days after planting (DAP) germination was 55% and 70% at 18/7 and 27/16 C, respectively. Final percent germination was recorded 14 DAP, the 18/7 C regime only had 65% and the 27/16 C was 74%. The 32/23C regime recorded the peak germination at 100% 3 DAP. Treatment means of lovegrass response to light were not significantly different, thus treatment means of covered and uncovered treatments means will be presented. Lovegrass response to light studies revealed greater germination in uncovered cells versus covered

cells (Table II, 2). Thus,we can conclude that light was required for tufted lovegrass seed to germinate.

Laboratory Evaluation of Preemergence-applied (PRE) Herbicides. Treatment means were significant and will be presented in Table II, 3. Excellent PRE control of tufted lovegrass seeds was obtained with all rates (PPM) of metolachlor, prodiamine, oxidiazon, bensulide, dithiopyr, and pendimethalin. Also providing excellent control was mesotrione at 0.375 and atrazine at 2. The remaining lower rates of mesotrione (0.0625, 0.125, and 0.25) and atrazine (1 and 1.5) provided unacceptable control.

Field Evaluation of Post-Emergence-applied (POST) Herbicides. Two or three applications of mesotrione at 0.035 kg ai/ha did not adequately control tufted lovegrass (Table II, 4.), but zoysiagrass injury was acceptable (<30%) (Table II, 5.). Two applications made 8 weeks apart of 0.28 kg ai/ha provided excellent (>95%) control, with acceptable zoysiagrass injury of 15%. Three applications of mesotrione made 4 weeks apart at 0.28 kg ai/ha yielded 85 % control, and zoysiagrass injury was undetectable. Mesotrione applied twice at 0.071 and 0.14 kg ai/ha provided 82 and 98 percent control with 0 and 11 percent injury to zoysiagrass turf 12/4 weeks after treatment, respectively. When the same rates of mesotrione were applied three times lovegrass control decreased to 21 and 62 % respectively, but there was no detectable injury to the zoysiagrass turf. Sequential applications of mesotrione at 0.14 kg ai/ha 8 weeks apart did provide adequate control of tufted lovegrass but minimal Meyer zoysiagrass injury.

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Table II, 1. Germination of tufted lovegrass seeds as influenced by three temperature regimes[1].

	Temperature regimes[2]			
Days after planting	18/7C	27/16C	32/23C	SE[3]
	----------%----------			
3	5	65	99	7
7	55	70	99	9
14	65	74	100	5

[1]Regimes had12-h light/12-h dark with light intensity of 255 µmols / $m^{-2}s^{-1}$.

[2] Data averaged over two repeated experiments.

[3] SE = Standard error; used for comparing within days after planting.

Table II, 2. Germination of tufted lovegrass as influenced by two light/dark regimes[1].

	----------Light/Dark----------		
Days after planting	12-h/12-h	0-h/24-h[2]	*p*-value
3	91	2	<0.0001
7	98	89	<0.0001
14	100	100	0.16

[1]Light intensity = 255 μmol / m^{-2} s^{-1}.

[2]Foil covers removed at 3-day counting and were not replaced.

Table II, 3. Tufted lovegrass control under laboratory conditions as affected by preemergence-applied herbicides and concentrations[1].

Treatment	Concentration	% Control			
		1 WAT[2]		2 WAT	
Herbicide	PPM[4]	Mean	SE[3]	Mean	SE
Non-treated	0	0	0	0	0
Atrazine	1	19	7.3	58	9.2
	1.5	28	11.1	78	8.0
	2	12	4.9	90	4.1
Bensulide	6	88	4.1	100	0.0
	9	100	0.0	100	0.0
	12	100	0.0	100	0.0
Dithiopyr	0.375	91	2.6	98	1.1
	0.5	99	0.8	100	0.0
	0.75	100	0.0	100	0.0
Mesotrione	0.0625	2	1.1	2	1.1
	0.125	11	2.6	28	10.4
	0.25	9	2.6	26	10.8
	0.375	100	0.0	100	0.0
Metolachlor	1	85	5.2	100	0.0
	1.25	19	4.2	100	0.0
	1.5	66	9.7	100	0.0
Oxidiazon	1	91	5.1	100	0.0
	2	100	0.0	100	0.0
	3	100	0.0	100	0.0
Pendimethalin	1	98	1.3	100	0.0
	2	100	0.0	100	0.0
	3	99	0.8	100	0.0
Prodiamine	0.5	100	0.0	100	0.0
	0.75	99	0.8	100	0.0
	1	99	0.8	100	0.0

[1]Data pooled over studies 1 and 2 in 2005 and 2006.
[2]WAT = weeks after treatment.
[3]SE = standard error applies to the mean of the rates within treatments.
[4]Parts-per-million %w/v.

Table II, 4. Tufted lovegrass control 4, 8, and 12 weeks after initial treatment (WAIT) under field conditions as influenced by mesotrione rates and number of applications.

Rate	Applications	Days between applications	4 WAIT[1]	8 WAIT	12 WAIT
kg ai/A			----------%----------		
0.035	2	56	45	60	15
0.071	2	56	51	87	82
0.14	2	56	73	100	98
0.28	2	56	96	100	100
0.035	3	28	53	58	12
0.071	3	28	56	86	21
0.14	3	28	75	100	62
0.28	3	28	96	100	95
SE[2]			0.96	1.25	1.29

[1]WAIT = Weeks after initial treatment.

[2]SE = Standard error applies to treatments within a WAIT.

Table II, 5. Meyer zoysiagrass injury 4,8, and 12 weeks after initial treatment (WAIT) under field conditions as influenced by mesotrione rates and number of applications.

Rate	Number of applications	Days between applications	4 WAIT	8 WAIT	12 WAIT
kg ai/ha			----------%----------		
0.035	2	56	13	7	0
0.071	2	56	18	9	0
0.14	2	56	32	24	11
0.28	2	56	53	32	15
0.035	3	28	11	0	0
0.071	3	28	16	0	0
0.14	3	28	23	17	0
0.28	3	28	61	25	0
SE[1]			1.3	1	0.4

[1]SE = Standard error applies to means within a specific WAIT column.

III. DOVEWEED GERMINATION BIOLOGY AND CONTROL IN WARM-SEASON TURFGRASSES

Abstract

In recent years doveweed has received increased interest due to occurrence in commercial turf and home lawns. One contributing factor is infestations found in container-grown ornamentals, further increasing its potential geographical distribution. Good to excellent control with atrazine is well documented. However, this treatment is limited to centipedegrass and St. Augustinegrass. Effective control of doveweed infestations in bermudagrass [*Cynodon dactylon* (L.) x *C. transvalensis* Burtt-Davy] and zoysiagrass (*Zoysia japonica* Steud.) turf is lacking. Experiments were conducted in environmental growth chambers to determine optimum doveweed germination temperature. From these studies it was determined that optimum germination occurred at 32/23C and doveweed seeds do not require light to germinate. Efficacy experiments with preemergence-applied herbicides were also conducted in the growth chambers to determine activity on scarified doveweed seeds. Labeled rates of atrazine, oxidiazon, dithiopyr, isoxaben, and metolachlor provided excellent control (>95%) while pendimethalin and prodiamine were ineffective. In field trials repeat applications (1.12 + 1.12 kg ae/ha) 21 days apart of MCPP-p-4, 2,4-D + 2,4-DP and MCPA amine provided excellent control of doveweed with minimal injury to zoysiagrass and bermudagrass turf.

Introduction

Doveweed has emerged as a problem in commercial turf and to lesser extent in home lawns and is spread primarily through seed propagules. It is a well-documented problem in container-grown ornamentals further increasing its potential geographical distribution. Traditionally doveweed has been a weed that was exclusive to managed turfgrass systems but in recent years has emerged as problem in row crops (Burton et al., 2006) and rice production (Plaza, 1998; Thi Tan, 2000).

Doveweed is described as an invasive species, it is found as far north as Arkansas and North Carolina and as far west as the plains of Texas, but is most commonly found in and around the coastal regions (Faden 2005; Radford et al., 1968). It is indigenous to southern Asia and tropical Pacific regions but has been naturalized to North and tropical America (Wagner et al., 1999). The plants can tolerate moist conditions and readily root at the nodes even after being cut (Holm et al., 1977). Doveweed is categorized as an annual in the temperate to sub-tropical southeast United States and Mexico where it has been naturalized. The leaves can be branched or unbranched and are spirally arranged. The leaf blades are linear, linear lanceolate, or lanceolate-oblong. Doveweed inflorescences are terminal or terminal and axillary. The cymes are few-flowered, solitary, or fascicled, pedunculate. Flowers are bisexual and slightly bilaterally symmetric; with pink to purple petals and seeds encapsulated. (Faden, 2005).

Atrazine is commonly used to control doveweed, however this treatment is limited to centipedegrass and St. Augustinegrass. Effectively controlling doveweed infestations in bermudagrass and zoysiagrass turfs is lacking. Research at Auburn has shown that herbicides containing MCPA ester provided acceptable levels of control (87%) (Staples

and Walker, 2001). Some suggested reasons for increased occurrence of doveweed are: 1) increased tolerance to glyphosate, 2) inadequate control from conventional postemegence-applied herbicides used in managed turfgrass systems, and, 3) introduction through infested container-grown nursery stock into home landscapes (York, 2006, Walker et al., 1998, Neal, 2005). The latter reason can be attributed as most common. These contaminated plants are transplanted into ornamental beds and the introduced doveweed produces seeds, which eventually spread to the adjacent lawn areas (Neal, 2005).

Seed Germination. A recent publication by Wilson et al. (2006) on doveweed germination found that when seeds were harvested germination was immediate, but when seeds were allowed to dry they went into an induced dormancy that required mechanical scarification to break. The literature reported that the optimum constant germination temperature was 27.8 C after 14 days. Doveweed germination occurred at both alternating and continuous temperature regimes, the 32 / 25 C alternating regime yielded the greatest germination with 77%. Experiments were conducted to determine if doveweed seeds required light for germination and found that light was not required (Wilson et al., 2006). Temperature studies were also conducted on a similar taxa, tropical spiderwort (*Commelina bengalis* L.), which according to researchers, has emerged as one of the worst weeds in Georgia agriculture (Burton et al., 2005). Studies found that optimal temperature for vegetative growth and flower production was between 30 and 35 C, but growth was recorded over a range of 20 to 40 C (Burton at al,. 2006).

Preemergence-applied (PRE) Herbicides. Stamps (2005) evaluated the efficacy of several PRE herbicides for doveweed control in container-grown nursery crops. The

herbicides (kg ai/ha) included in the study were: flumioxazin, 0.42; oxyfluorfen, 0.24 + pendimethalin, 1.12; oxyfluuorfen, 2.24 + oxadiazon, 1.12; oxyfluorfen, 2.24 + oryzalin, 1.12; trifluralin, 4.48 + isoxaben, 1.12; prodiamine, 1.68; flumioxazin, 0.42 + prodiamine, 1.68. Flumioxazin, oxyfluorfen + oryzalin, and flumioxazin, + prodiamine controlled doveweed completely at 0.42, 2.24 + 1.12, and 0.42 + 1.68 kg/ai ha, respectively. Oxyfluorfen + pendimethalin and trifluralin + isoxaben were effective but did allow some seedling emergence.

Postemergence-applied (POST) Herbicides. Several studies have been conducted evaluating POST control of doveweed. Walker et al., (1998) found that two applications of atrazine at 1.68 kg ai/ha 7 days apart provided excellent control (94%) of doveweed in St. Augustinegrass and centipedegrass with both species tolerant of herbicide applications within the tolerable injury range (0-30%). Other herbicides (kg ai/ha) that have been evaluated for POST control of doveweed are MCPP, 0.134 + 2,4-D, 0.149 + dicamba, 0.031; thifensulfuron methyl, 0.0134 + tribenuron, 0.00672 + metsulfuron, 0.00672; imazapic, 0.036; sulfometuron, 0.036; triclopyr, 0.277 + clopyralid, 0.10; dicamba, 0.56; bentazon, 1.12 (Walker et al., 1998; Staples and Walker, 2001). Although earlier research focused on controlling doveweed in centipedegrass and St. Augustinegrass, there has been increased interest in doveweed control in zoysiagrass and hybrid bermudagrass species. Atrazine cannot be applied to actively growing zoysiagrass and bermudagrass due to the risk of injury. The objectives for this study were: 1) to determine the response of doveweed seeds to three alternating temperature regimes and alternating light cycles, 2) determine the response of doveweed seeds to preemergence-applied herbicides, and 3)

determine the response of doveweed to repeat applications of postemergence-applied herbicides.

Materials and Methods

Germination Response. Doveweed plants were harvested and transplanted from natural infestations at the Auburn University Turfgrass Research unit in October 2005. Transplanted plants were allowed to grow for 1 month before capsules were harvested in November 2005. Seeds were then separated from plant material by hand and allowed to dry for 5 days at 25 C and then stored at 7 C until used in experiments. Before seeds were used they were sieved with a no. 20 (0.84 mm) sieve to remove excess plant and inert matter. Prior to germination initiation seeds were scarified for 30 seconds using a mechanical drum scarifier. Germination studies were conducted in environmental growth chambers with a light intensity of 255 μmol $m^{-2}s^{-1}$. Experiments utilized 5 mg Terra-Sorb GB acrylamide copolymer[1] dissolved in 1 ml tap water as a growth medium (McElroy et al., 2003). Six-cell tissue culture trays[2] were filled to capacity with this hydrated gel. Each cell has a liquid capacity of 17 mL. In all studies, 10 doveweed seeds were placed into each of the six cells within a tray. Germination was counted on each cell and one cell was considered a replicate. Each study consisted of four trays, two covered and two uncovered to simulate buried seeds lacking sunlight. The covers were removed when percent germinated in the uncovered trays was ≥ 70% or 14 days after initiation. Each study was repeated twice. Seed germination was recorded at 5.

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[1]Fisher Scientific, Pittsburgh, PA 15275-9952

[2]Industrial Services International, Inc., Bradenton, FL 34205.

7, 14, and 21 days after initiation. A seed was considered germinated when cotyledon and radical had visually emerged from the seed coat. All studies utilized a completely randomized design. Seed germination was evaluated at three temperature regimes: 32/23, 27/16, and 18/7 C and a constant 12-h light/12-h dark photoperiod. Only seed that was stored 7 C for at least 4 weeks was used.

Laboratory Evaluation of Preemergence-applied (PRE) Herbicides. Laboratory studies were conducted in the fall and winter of 2005 and 2006 to determine PRE herbicide activity on doveweed. Herbicide rates were calculated using the assumption that PRE herbicides remain in the top 7.62 centimeters of soil. The top 7.62 centimeters of soil in a hectare weighs approximately 1,120,000 kilograms, and this was used in determining [parts per million (PPM)] rates. Herbicide and concentrations applied were: atrazine, 1, 1.5, and 2; prodiamine, 0.5, 0.75, and 1; oxidiazon, 1, 2, and 3; dithiopyr, 0.375, 0.5, 0.75; pendimethalin, 1, 2, and 3; metolachlor, 1, 1.25, and 1.5; and isoxaben 2, 3, and 4. Six-cell tissue culture trays containing 5 mg Terra-Sorb GB acrylamide copolymer per 1 ml herbicide solution was utilized as the growth medium. Each cell had a capacity of 17 mL. Tissue culture trays were placed in the growth chambers using the 32/23 C and an alternating 12-h light/12-h dark photoperiod. All studies utilized a completely randomized design. Each cell was considered an experimental unit with six replicates and tests were repeated once.

Greenhouse Evaluation of Postemergence-applied (POST) Herbicides. Greenhouse experiments were established in fall 2006 and winter 2007 to evaluate activity of POST herbicides on doveweed. Actively growing doveweed seedlings were transplanted into 500-ml styrofoam cups and filled with Kalmia sandy loam soil (fine loamy over sandy or

sandy skeletal siliceous semi-active thermic Typic Hapludults) with a pH of 5.7. Plants were fertilized bi-weekly with MiracleGro®[1] 36-6-6 (N-P-K) fertilizer solution. One month old doveweed plants were clipped to height of 2.47 cm 1 week prior to herbicide applications. Herbicides were applied in a volume of 281 L/ha. Herbicide treatments and visual ratings were the same as for the field study. All plants received artificial lighting to a minimum of 12h light per day. Experimental design was a completely random design in which six herbicides and three rates per herbicide yielding a 6 x 3 factorial arrangement. Atrazine was included for comparisons purposes. A single cell represented a replication.

Field Evaluation of Postemergence-applied (POST) Herbicides. Field experiments were conducted in 2006 and 2007 to evaluate the response of doveweed to POST herbicides. Experiments were conducted at two locations: the first one was located at the Auburn University Turfgrass Research Unit and the second experiment at Beck's Turf Inc[2]. The experiments were established on a Marvyn loamy sand soil (fine-loamy kaolinitic thermic Typic Kanhapludults) with a pH 6.0 1.2% organic matter at the Auburn location and on a Lurverne sandy loam soil (fine mixed semiactive thermic typic Hapludults) with a pH of 6.1 and 1.3% organic matter at the Beck's Turf Inc. location. Plots were 1.52 m wide by 4.57 m long. In February 2006 scarified doveweed seeds were planted in plastic cones filled wirh a mixture of 30% sedge peat plus 70% medium-sized sand. The plants were allowed to grow for 2 months and then transplanted at

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[1]Scotts-Miracle Gro® Inc., Maryville, OH 43041.

[2] Becks Turf, Inc. 2858 County Road 53, Tuskegee, AL 36083.

the Auburn Turfgrass Research Unit to four plants per plot. Transplanted plants were allowed to grow until treatments were applied in July 2006. Herbicide treatments were applied on 28 June 2006 and 21 June 2007, respectively

Each herbicide mixes received 0.25% v/v non-ionic surfactant. Plots received irrigation three times per week or as needed and were maintained at a mowing height of 2.8 cm.

Common name and trade name along with treatments are presented in Table III, 1. Treatments were repeated 21 day after initial treatment. The experiments consisted of a factorial arrangement of six herbicides applied twice and a untreated check, yielding 12 treatments. First applications were applied 3 August 2006 and 28 June 2007, respectively. Second applications were applied 24 August 2006 and 19 July 2007, respectively. The treatments were applied with a CO_2 backpack sprayer calibrated to deliver a volume of 281 L/ha. Percent control was rated for each species on a scale of 0 (no control) to 100 (complete control). Visual ratings of control were taken 2 weeks after initial treatments (WAIT) and 2 weeks after each additional treatment. Data was transformed using the arcsine transformation in order to meet the assumptions for ANOVA.

Results and Discussion

Germination Response to Temperature and Light. Statistical analysis indicated that interactions by run were not significant and thus were pooled by treatment. Doveweed germination was observed 3 days after planting (DAP) at all three temperature regimes (Table III, 2). Although germination did occur in all three temperature regimes, the two higher regimes 27/16 and 32/23C had higher cumulative germination 21 DAP at 100% and 100%, respectively. The lowest regime 18/7C had a final germination of 62% at 21

DAP. Main effects of doveweed germination response to light were not significant; therefore germination was pooled as light or dark (Table III, 3). Three DAP germination was 30% in uncovered cells and not recorded until 7 DAP in covered cells. Seven DAP germination was 93% in uncovered and 58% in covered cells. Although these were significantly different from each other, germination did occur in the covered trays, which led us to conclude that doveweed seeds do not require light to germinate as previously reported by Wilson (2006).

Response to Preemergence-applied (PRE) Herbicides. All herbicide by concentration interactions were significant, thus data is presented by herbicides and concentrations. Although as a group the higher concentrations were more effective in inhibiting germination, the lower rates of atrazine, dithiopyr, isoxaben, metolachlor, and oxidiazon were just as effective (Table III, 4). Pendimethalin and prodiamine were ineffective at controlling doveweed PRE.

Response to Postemergence-applied (POST) Herbicides. In both greenhouse and field studies main effects of herbicide by concentration were significant so treatment means are presented. Treatments evaluated in greenhouse and field studies were identical except diflufenzopyr + dicamba was not included in field studies due to space limitations.

Greenhouse. Final ratings were taken 5 weeks after the second application (Table, 5). Treatments totaling 4.48 kg ae/ha (2.24 kg + 2.24 kg) of, MCPP-p 4 Amine, MCPA ester, and MCPA amine provided 99, 99, 98, 93 and 75% control, respectively. Rates totaling 2.24 kg ae/ha (1.12 kg + 1.12 kg) of, MCPA + triclopyr + dicamba, MCPA ester, MCPP-p-4 Amine, and MCPA amine provided 89, 88, 80, 72, and 23% control, respectively. Atrazine applied twice at 1.68 kg ai/ha provided 99% control.

Field. Final control ratings and injury ratings were taken 5 weeks after the second application (Table III, 6). Treatments totaling 2.24 kg ae/ha (1.12 kg + 1.12 kg) of MCPP-p 4 amine, 2,4-D + dichloroprop-p, MCPA amine, MCPA + triclopyr + dicamba, and MCPA ester provided 100, 99, 96, 92, and 83% control, respectively. The results were similar to greenhouse studies except MCPA amine performed better in field trials than in greenhouse trials. Treatments totaling 1.0 kg ae/ha (0.56 kg + 0.56 kg) of MCPA + triclopyr + dicamba, 2,4-D + dichoroprop-p, MCPP-p-4 Amine, MCPA ester, and MCPA amine provided 96, 95, 78, 48, and 44% control, respectively. Atrazine applied twice at 1.5 lb ai/A provided 100% control. All treatments produced minimal injury to both turf species. Repeat applications of MCPP-p 4 Amine, 2,4-D + dichloroprop, and MCPA amine at (1.12 kg + 1 kg) respectively, provide excellent control of doveweed in bermudagrass and zoysiagrass turf (Table III,7).

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Table III, 1. Common and trade names for products used in greenhouse and field studies for control of doveweed.

Common name	Trade name	Rate (kg ae/ha)
MCPP-p 4 amine	Riverdale® MCPP-p 4 Amine	0.56
		1.12
		2.24
MCPA ester	Nufarm® Rhonox	0.56
		1.12
		2.24
MCPA amine	Nufarm® Rhomene	0.56
		1.12
		2.24
2,4-D + dichloroprop-p	Nufarm® Turf Weed and Brush	0.56
		1.12
		2.24
MCPA + triclopyr + Dicamba	Nufarm® Horsepower	0.56
		1.12
		2.24
Dicamba + diflufenzopyr[1]	Distinct®	0.14
		0.28
		0.42
Atrazine	Atrazine® 4L	1.68[2]

[1]Dicamba + diflufenzopyr omitted in field studies due to space limitations.

[2]Rate in kg ai/ha not kg ae/ha.

Table III, 2. Germination of doveweed seeds as influenced by three temperature regimes[1].

	Temperature Regimes			
Days after planting	18/7C	27/16C	32/23C	SE[2]
	----------%----------			
3	16	65	65	5
7	39	92	93	5
14	56	98	100	3
21	62	100	100	2

[1]Regimes had12-h light/12-h dark with light intensity of 255 μmols $m^{-2}s^{-1}$.

[2]SE = Standard error; used for comparing within days after planting.

Table III, 3. Germination of doveweed seeds as influenced by two light/dark regimes[1].

	----------Light/Dark----------		
DAP[2]	12-h/12-h	0-h/24-h	*p*-value[3]
3	30	NA	0.13
7	93	58	<0.0001
14	99	79	<0.0001
21	100	100	0.23

[1]Light intensity = 255 μmol $m^{-2}s^{-1}$

[2]DAP = days after planting, foil covers removed at 7-day counting.

[3]NS = not significant when $p \leq 0.05$.

Table III, 4. Doveweed control as influenced by preemergence-applied herbicides and PPM concentrations.

Herbicide	PPM Concentration	1 WAIT[1]	2 WAIT	3 WAIT
		----------%----------		
Atrazine	0.5	48	83	57
	1	58	97	95
	2	53	100	96
Dithiopyr	0.375	27	94	55
	0.5	33	99	69
	0.75	38	100	95
Isoxaben	2	20	95	94
	3	49	100	97
	4	73	100	100
Metolachlor	1	30	98	82
	1.25	48	99	87
	1.5	53	100	100
Oxidiazon	1	98	96	98
	2	100	100	99
	3	100	100	100
Pendimethalin	1	5	44	58
	2	17	62	70
	3	26	67	70
Prodiamine	0.5	14	65	25
	0.75	26	78	50
	1	40	92	63
Standard Error[2]		8	4	4

[1]WAIT = weeks after initial treatment.

[2]SE = standard error; applies to all treatments within a rating period.

Table III, 5. Percent doveweed control 4 and 8 weeks after initial treatment (WAIT) under greenhouse conditions as influenced by repeat applications of herbicides.

Herbicide		4 WAIT		8 WAIT	
	kg ae/ha	%	SE[1]	%	SE
MCPP-p-4	0.56	23	10	8	10
	1.12	76	19	72	19
	2.24	98	10	98	10
MCPA ester	0.56	12	10	11	10
	1.12	67	10	80	10
	2.24	83	19	93	19
MCPA amine	0.56	7	9	12	9
	1.12	16	10	23	10
	2.24	73	10	75	10
2,4-D+ dichloroprop-p	0.56	4	10	51	10
	1.12	55	19	89	19
	2.24	91	19	99	19
MCPA + triclopyr + dicamba	0.56	32	10	53	10
	1.12	47	19	88	19
	2.24	99	10	99	10
dicamba + diflufenzopyr	0.14	20	19	81	19
	0.28	22	19	83	19
	0.42	31	10	85	10
Atrazine	1.68	100	10	100	10

[1]SE = standard error for comparing within treatment means within WAIT

Table III, 6. Percent doveweed control 4 and 8 WAIT under field conditions as influenced by repeat applications of herbicides.

		----------% Control----------			
Herbicide		4 WAIT[1]		8 WAIT	
	kg ae/ha	%	SE[2]	%	SE
MCPP-p-4	0.56	83	5	78	4
MCPP-p-4	1.12	99	4	100	3
MCPA ester	0.56	49	8	47	8
MCPA ester	1.12	78	8	83	8
MCPA amine	0.56	47	8	44	8
MCPA amine	1.12	90	5	96	4
2,4-D + dichloroprop-p	0.56	85	5	95	4
2,4-D + dichloroprop-p	1.12	97	4	100	3
MCPA + triclopyr + dicamba	0.56	91	5	96	4
MCPA + triclopyr + dicamba	1.12	92	5	92	4
Atrazine (kg ai/ha)	1.68	100	0	100	0

[1]WAIT = weeks after initial treatment.

[2]SE = standard error for comparing treatment means within WAIT.

Table III, 7. Meyer zoysiagrass and Tifway hybrid bermudagrass injury under field conditions as influenced by repeat applications of herbicides 4 and 8 weeks after initial treatement (WAIT)

Herbicide	Rate	Zoysiagrass	Bermudagrass
	kg ae/ha	----------% injury[1]----------	
MCPP-p-4	0.56	0	2
MCPP-p-4	1.12	12	2
MCPA ester	0.56	9	6
MCPA ester	1.12	16	9
MCPA amine	0.56	4	2
MCPA amine	1.12	0	2
2,4-D + 2,4-DP	0.56	12	6
2,4-D + 2,4-DP	1.12	14	10
MCPA + triclopyr + dicamba	0.56	11	6
MCPA + triclopyr + dicamba	1.12	14	9
Atrazine (kg ai/ha)	1.68	19	10
SE[2]		1	1

[1]Percent injury that is acceptable is ≤ 30%.

[2]SE = standard error used for comparing treatment means within WAIT