ABSTRACT

GANNON, TRAVIS WILLIAM. Establishment and Allelopathic Potential of Centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.) In Utility Turf Areas.

Field and greenhouse experiments were conducted to 1) evaluate the safety and effectiveness of weed control treatments while establishing seeded centipedegrass and 2) determine the allelopathic potential of centipedegrass. Centipedegrass tolerance to treatments applied at seeding and early postemergent was evaluated. Atrazine, simazine, or low rates of imazapic did not reduce centipedegrass ground cover compared to the control while select rates of sulfometuron and all rates of metsulfuron were injurious to centipedegrass when applied at seeding. All rates of imazapic, sulfometuron, atrazine, or simazine applied 6 weeks after seeding (WAS) (one-leaf to one-tiller growth stage) caused less than 15% phytotoxicity, while chlorsulfuron + mefluidide, or metsulfuron caused 16 to 83% phytotoxicity 56 DAT. When large crabgrass and centipedegrass were seeded together, large crabgrass emergence was reduced (48%) by atrazine applied at seeding compared to the control (89%). In atrazine treated flats, centipedegrass tiller production and cover were greater due to reduced interspecific competition from large crabgrass. These data indicate that where large crabgrass is present, centipedegrass can be established more quickly if appropriate herbicides are used at seeding or shortly thereafter.

Germination and growth of indicator species were evaluated in response to treatment with soil leachates, leaf debris, and aqueous leaf extracts of centipedegrass. Incorporated centipedegrass leaf debris did not reduce lettuce germination, shoot weight, or root weight as compared to the control. However, shoot and root dry weight of radish were reduced with increasing rates of centipedegrass leaf debris. These data do not conclusively demonstrate centipedegrass has widespread allelopathic activity; however significant reductions in shoot and root dry weight of radish with increasing debris rate demonstrates a pattern of inhibition of one species against another fulfilling a requirement of allelopathic interactions.

ESTABLISHMENT AND ALLELOPATHIC POTENTIAL OF CENTIPEDEGRASS (*Eremochloa ophiuroides* (Munro) Hack.) IN UTILITY TURF AREAS.

by

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A thesis submitted to the Graduate Faculty of
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APPROVED BY:

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Dr. Fred H. Yelverton
Chair of Advisory Committee

DEDICATION

This thesis is dedicated in memory of my sister and
in honor of my mother, father, and wife.

Without each of their love and support, none of
my accomplishments thus far would have been possible.

Allison Lea Gannon

Cecelia Gannon

David Gannon

Daniele Neese Gannon

BIOGRAPHY

I was born and raised in Julian, a small community south of Greensboro, North Carolina. I have always been interested in the outdoors and growing up next to a golf course interested me in turfgrass management. I was employed seasonally at Walnut Wood Golf Course during high school and continued during my first two years of college.

I began my collegiate career in the Fall of 1995 at North Carolina State University and completed a B.S. degree in 1999 with honors in agronomy with a concentration in turfgrass management. During my undergraduate career, I received the Carolinas Golf Course Superintendents Association undergraduate scholarship in 1996-97, 97-98, and 98-99. I also participated in the USGA Green Section Student Internship Program during the Summer of 1998 and became a member of the Golden Key National Honor Society. Upon graduating in 1999, I began working under the direction of Dr. Fred Yelverton investigating weed control and plant growth regulator use in turfgrass systems. I ultimately pursued an M.S. degree at North Carolina State University under the direction of Dr. Fred Yelverton while working as a Research Associate. This experience has exposed me to all levels of turfgrass systems and rights-of-way maintenance. While in graduate studies, I was awarded second place in the oral poster contest at the 2002 Southern Weed Science Society annual meeting.

ACKNOWLEDGMENTS

There are a number of individuals for which I would like to recognize for their contribution to my development and success. First and foremost, I would like to thank my parents, David and Cecelia Gannon for their unconditional love and support they have lent for many years. None of the success I am able to celebrate would be possible without the values they have instilled in me. Next, I would like to extend gratitude to my wife, Daniele Neese Gannon, whose support and caring nature have made many things possible including this graduate degree. I would also like to thank Mitch Clendenin and Danny Neese, among others who have helped me in various ways, but mainly for the friendship.

Professionally, I would like to thank Dr. Fred H. Yelverton who extended the opportunity and offered guidance throughout my graduate studies. I would also like to thank Drs. Bowman, Bruneau, and Neal for their guidance and support.

I would also like to acknowledge the friendship and assistance from other graduate students and technicians including Keith Burnell, Hennen Cummings, Matt Fagerness, Jason Hinton, Scott McElroy, and Leon Warren.

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CHAPTER 1

Establishment of Seeded Centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.) in Utility Turf Areas.[1]

TRAVIS W. GANNON, FRED H. YELVERTON, HENNEN D. CUMMINGS, AND J. SCOTT McELROY[2]

Abstract: Experiments were conducted to evaluate the safety and effectiveness of weed control treatments during establishment of seeded centipedegrass. Centipedegrass tolerance to treatments was evaluated at seeding and early postemergent. Imazapic at 105 g ai/ha, sulfometuron at 53 g/ha, or metsulfuron at 21 or 42 g/ha applied at seeding reduced centipedegrass ground cover. Imazapic at 18 or 35 g/ha, or atrazine or simazine each at 1100 or 2200 g/ha applied at seeding did not reduce centipedegrass ground cover compared to the control. Applications of chlorsulfuron + mefluidide (7 + 140 g/ha), or metsulfuron at 21 or 42 g/ha applied 6 weeks after seeding (WAS) centipedegrass (one-leaf to one-tiller growth stage) caused 20, 16, and 83% phytotoxicity, respectively, 56 days after treatment (DAT). Imazapic at rates up to 105 g/ha, sulfometuron at 26 or 53 g/ha, or atrazine or simazine, each applied at 1100 or 2200 g/ha applied 6 WAS caused less than 15% phytotoxicity 56 DAT. When large crabgrass and centipedegrass were seeded together, large crabgrass emergence was reduced by 41% when atrazine (1100 g/ha) was applied at seeding compared to the control. Centipedegrass tiller production was reduced with increasing amounts of crabgrass.

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However, centipedegrass tiller production and cover were higher when atrazine was applied due to reduced interspecific competition from large crabgrass. These data indicate centipedegrass can be established more quickly if appropriate herbicides are used at seeding or shortly thereafter.

Nomenclature: large crabgrass, *Digitaria sanguinalis* (L.) Scop. #[3]DIGSA; centipedegrass, *Eremochloa ophiuroides* (Munro) Hack.

Additional index words: Competition, herbicide tolerance, PGR tolerance, atrazine, chlorsulfuron, imazapic, mefluidide, metsulfuron, simazine, *Digitaria sanguinalis*, DIGSA.

Abbreviations: DAS, days after seeding; DAT, days after treatment; PGR, plant growth regulator; WAS, weeks after seeding.

INTRODUCTION

Centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.) is a warm-season turfgrass species introduced to the United States from China in 1916 (Duble 1996). Centipedegrass is a minimal input turf species requiring no more than 50 kg N/ha/yr and infrequent mowing. It is adapted to a wide range of soil conditions, but grows best in sandy, acidic soils with optimum pH ranging from 4.0 to 6.1 (Waddington 1992). Centipedegrass can be propagated from seed, plugs, or sod. It spreads slowly by stolons and has poor recuperative ability (Emmons 1995). Centipedegrass is ideal for use in low-traffic, utility turf areas and roadsides because of reduced foliar growth and inconspicuous seedheads. These traits could potentially eliminate the need for routine mowing in low-maintenance areas (Lewis and DiPaola 1986).

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[3]Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

Centipedegrass is increasingly used in many areas of the southeastern United States. According to the North Carolina Turfgrass Survey (1995 and 2001), centipedegrass acreage increased from 189,000 in 1994 to 231,000 in 1999 accounting for 11.4 and 16.3%, respectively, of the maintained turf in North Carolina. Throughout the coastal plain and piedmont region of North Carolina, centipedegrass is used in many turfgrass areas including home lawns, commercial properties, schools, and roadsides.

Several herbicides are registered for use on centipedegrass. Established centipedegrass is tolerant of sethoxydim and clethodim which provide control of select annual and perennial grasses (Cox et al. 1999; Johnson 1987; McCarty et al. 1986). Broadleaf weeds in established centipedegrass can be controlled with common broadleaf herbicides not containing 2,4-D (McCarty et al. 2001).

Research has identified the safety of herbicides applied to recently sprigged centipedegrass. Applied immediately after sprigging, single applications of atrazine or simazine at 1100 g ai/ha controlled large crabgrass (*Digitaria sanguinalis* (L.) Scop.) and goosegrass (*Eleusine indica* (L.) Gaertn.) and increased percent ground cover of centipedegrass (Johnson 1973). However, Coats (1975) reported 2200 g/ha atrazine or simazine applied at sprigging reduced survival and growth of centipedegrass. Also, Johnson (1973 and 1976) reported centipedegrass establishment was as good or better in single treated plots with atrazine, simazine, or oxadiazon compared to those with repeat applications; however, repeat applications of atrazine, simazine, or oxadiazon increased large crabgrass and goosegrass control.

Although herbicide weed control options exist in established centipedegrass, no herbicide is registered for application during establishment of centipedegrass from seed (Porter 1996). This is a significant problem since most weeds will outcompete centipedegrass and delay establishment. This grow-in delay is exacerbated with centipedegrass because of its slow growth habit. Control of weeds during turf establishment permit uniform establishment, and

in the case of warm-season turfgrass species, improved winter survival (Bingham and Shaver 1981). However, Smith and Callahan (1968), recommended when implementing weed control programs, it is important to utilize compounds that balance turfgrass safety and weed control.

In North Carolina, centipedegrass is often seeded into tall fescue (*Festuca arundinacea* Schreb.) or bahiagrass (*Paspalum notatum* Fluegge.) previously treated with plant growth regulators (PGR) or herbicides where residuals could threaten newly seeded centipedegrass. Chlorsulfuron + mefluidide or imazapic are commonly used for tall fescue or bahiagrass growth regulation and the residual effect of these compounds on newly seeded centipedegrass is unknown. Metsulfuron and sulfometuron are commonly used for annual grass and broadleaf weed control in established centipedegrass, while atrazine and simazine have proven to be safe for treatment of vegetatively propagated centipedegrass (Johnson 1973). Thus, the objectives of this research were to determine 1) the tolerance of newly seeded centipedegrass to treatments applied at seeding or early after seeding and 2) the effect of atrazine applied at seeding while establishing centipedegrass in the presence of large crabgrass seed.

MATERIALS AND METHODS

Herbicides and PGRs Applied at Seeding. Experiments were conducted to determine effects of plant growth regulators (PGR) or herbicides applied at seeding on the establishment of seeded centipedegrass. Field experiments were initiated near Greensboro, NC on 02 June 2000 and 09 May 2001 in areas previously maintained as tall fescue. Six weeks prior to trial initiation, areas were treated with 2200 g/ha glyphosate. At trial initiation, areas were mown to remove debris and rotary tilled to a 20 cm depth. Soil was a Mecklenburg clay loam (fine, mixed, active, thermic Hapludalfs) with 1.3% organic matter and pH 5.8.

Diammonium phosphate (18-46-0) was applied at 336 kg/ha and incorporated to 20 cm

with a rotary tiller prior to leveling the seed bed. Treatments were applied and allowed to air-dry before broadcast seeding centipedegrass at a rate of 29.3 kg/ha. Immediately after seeding, a cultipacker was utilized in two directions to ensure optimum soil to seed contact and 0.6 cm irrigation was applied. At 8 and 12 weeks after seeding (WAS), 280 kg/ha of a complete fertilizer (10-10-10) was applied.

Treatments applied at seeding included chlorsulfuron[4] + mefluidide[5], at 7 + 140 g/ha, respectively, imazapic[6] at 18, 35, 70, or 105 g/ha, sulfometuron[7] at 26 or 53 g/ha, metsulfuron[8] at 21 or 42 g/ha, atrazine[9] at 1100 or 2200 g/ha, and simazine[10] at 1100 or 2200 g/ha. Imazapic treatments included a methylated seed oil[11] at 1.8 L/ha while sulfometuron, metsulfuron, atrazine, and simazine treatments included a non-ionic surfactant[12] at 0.25% v/v. Treatments were applied with a CO_2 pressurized hand-held spray boom equipped with four VS8003XR[13] flat fan nozzles on 38 cm spacings calibrated to deliver 304 L/ha.

Visual estimates of centipedegrass ground cover were recorded at 12 and 16 WAS in 2000 and 12, 16, and 20 WAS in 2001, utilizing a 0 (no ground cover) to 100% (complete ground

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[4]Telar 75DF. E.I. du Pont de Nemours and Company, Wilmington, DE 19898.

[5]Embark 2L. PBI/Gordon Corporation, 1217 West 12th Street, Kansas City, MO 64101.

[6]Plateau 2L. BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

[7]Oust 75DG. E.I. du Pont de Nemours and Company, Wilmington, DE 19898.

[8]Escort 60DF. E.I. du Pont de Nemours and Company, Wilmington, DE 19898.

[9]AAtrex 4L. Syngenta Crop Protection, Greensboro, NC 27409.

[10]Princep 4L. Syngenta Crop Protection, Greensboro, NC 27409.

[11]Dyne-Amic, 100% blend of methylated seed oils. Helena Chemical Company, 225 Schilling Boulevard, Collierville, TN 38017.

[12]X-77, 90% nonionic surfactant. Loveland Industries, P.O. Box 1289, Greeley, CO 80632.

[13]Teejet Spraying Systems Company, North Avenue, Wheaton, IL 60189-7900.

cover) scale. Four replicates were included in both experiments and plots (1.8 by 4.3m) were arranged in a randomized complete block design. Data were arcsine square root transformed to increase homogeneity of variance (Zar 1999), subjected to ANOVA (P = 0.05), and means were separated according to Fisher s Protected LSD. Nontransformed means are presented for clarity. A treatment by year interaction prevented pooling data across years; thus data are presented separately.

Herbicides and PGRs Applied Early Postemergent. Greenhouse experiments were conducted to determine the effect of PGR and herbicide applications to newly seeded centipedegrass. Centipedegrass was surface seeded (29.3 kg/ha) in 600 ml pots containing a 1:1 (v/v) ratio of sand plus Norfolk loamy fine sand (thermic Typic Kandiudults, pH of 6.1 and 0.3% humic matter). Plants were grown with 30/15 C day/night temperatures and lightly irrigated three times daily with overhead irrigation. Natural lighting was supplemented with metal halide lamps with a photon flux density of 300 µmol/m^2/s set on a 12-h photoperiod. Plants were fertilized with 25 kg N/ha from a commercial greenhouse fertilizer[14] solution 28 d after seeding (DAS). Treatments were applied 6 WAS at which time the centipedegrass was in the one-leaf to one-tiller growth stage.

PGR and herbicide treatments were identical to treatments applied at seeding in the previous field experiment. Treatments were applied with a CO_2 pressurized spray chamber equipped with one VS8001E[13] flat fan nozzle calibrated to deliver 187 L/ha. Visual estimates of centipedegrass phytotoxicity utilizing a 0 (no injury) to 100% (complete death) scale were recorded at 28 and 56 DAT.

Experiments were conducted twice, each containing four replicates. Treatments were arranged in a completely randomized design. Data were subjected to ANOVA (P = 0.05) and

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[14]Peters Professional All Purpose 20-20-20, Scotts-Sierra Horticultural Products Co., 14111 Scottslawn Road, Marysville, OH 43041.

means were separated according to Fisher s Protected LSD. A non-significant (P>0.05) treatment by experimental run interaction permitted pooling of data across experimental runs.

Establishment with Large Crabgrass. Greenhouse experiments were initiated in July and August 2002 to determine the effects of weed control when establishing centipedegrass from seed in the presence of large crabgrass. Large crabgrass was selected because *Digitaria* spp. are ranked second and fourth on the most common and most troublesome weed composites, respectively, in turfgrass areas in North Carolina (Reynolds 2000). A 1:1 (v/v) ratio of sand plus Norfolk loamy fine sand (thermic Typic Kandiudults, pH of 6.1 and 0.3% humic matter) was placed in 8.2 L flats and seeded with either centipedegrass, large crabgrass, or a mixture of centipedegrass and large crabgrass.

A seeding rate of 12.2 kg/ha or 0.158 g/flat for centipedegrass and large crabgrass was equivalent to 100% of the total seed mix weight for five seed mixes of 1) 100:0, 2) 75:25, 3) 50:50, 4) 25:75, and 5) 0:100 centipedegrass:large crabgrass. The seed mix composites based on seed numbers are presented in Table 1.

Weed control treatments were 1100 g/ha atrazine applied at seeding and no herbicide. Atrazine was applied to soil and allowed to air-dry prior to surface seeding the seed mixture. All flats received 25 kg N/ha from a commercial greenhouse fertilizer[14] solution 28 DAS.

Dependent variables measured included percent emergence of centipedegrass and large crabgrass, average number of tillers/plant, and average foliar height. Percent emergence was calculated based on number of plants divided by the total number that were seeded in the respective flat. Average number of tillers/plant and average foliar height were based on ten randomly selected plants. Total number of centipedegrass stolons and stolon lengths were also recorded. Stolon lengths were divided by the number of stolons present to determine average stolon length. The aforementioned parameters were measured at 4 and 8 WAS, except for seedling emergence which was measured only at 4 WAS. Also, at 8 WAS, percent centipedegrass covering the soil surface of the flat was visually estimated utilizing a 0 (no

ground cover) to 100% (complete centipedegrass ground cover) scale.

The experimental design was completely randomized with a factorial arrangement of treatments and four replicates. Factorial levels included five seed mixes and two weed control options. Data were subjected to ANOVA (P=0.05) and precedence was given to significant seed mix by weed control option interactions over main effects. The sums of squares for seed mixes were partitioned into linear, quadratic, and cubic effects to evaluate the establishment of centipedegrass with increasing amounts of large crabgrass seed. Significant main effects for weed control options were separated using Fisher s Protected LSD (P=0.05). A non-significant (P>0.05) seed mix by weed control option by experimental run interaction permitted the pooling of data across experimental runs. This experiment was repeated once.

RESULTS AND DISCUSSION

Herbicides and PGRs Applied at Seeding. The treatment by year interaction was likely due to reduced rainfall in 2001 as compared to 2000. Cumulative rainfall in 2000 and 2001 for the 16 WAS was 46 and 30 cm, respectively (Tables A1 and A2). Rainfall differences reduced the growth of centipedegrass as noted in the control. In 2000, 66% centipedegrass ground cover was observed in the control 12 WAS, while in 2001, only 31% centipedegrass ground cover was observed (Table 2). At 16 WAS, 87% centipedegrass ground cover was observed in 2000 while in 2001, only 68% centipedegrass ground cover was present in the control. Although the plots were irrigated immediately after seeding, the rainfall deficit in 2001 likely had a significant effect reducing centipedegrass ground cover. Further, an early May seeding date may be too early for centipedegrass due to daylength, irradiance, or other environmental factors which may affect centipedegrass grow-in.

Imazapic (18 or 35 g/ha), atrazine (1100 or 2200 g/ha), or simazine (1100 or 2200 g/ha) applied at seeding had no effect on centipedegrass ground cover at any observation date in

2000 or 2001 compared to the control (Table 2). However, imazapic applied at 105 g/ha reduced centipedegrass ground cover compared to the control at all observation dates. Additionally, imazapic applied at 70 g/ha reduced centipedegrass ground cover at 12 WAS in 2000 and 16 WAS in 2001. These data indicate that centipedegrass is tolerant to atrazine, simazine, or lower rates of imazapic applied at seeding. Further, these data indicate imazapic rates at seeding should not exceed 35 g/ha unless the possibility of grow-in delay is acceptable. Turner et al. (1990) reported that centipedegrass was tolerant of atrazine and simazine (2200 and 3400 g/ha) while Adcock et al. (1998) reported only slight centipedegrass injury with imazapic (35 to 140 g/ha); however, each were applied to established centipedegrass.

Sulfometuron at 53 g/ha and metsulfuron at 21 or 42 g/ha reduced centipedegrass ground cover compared to the control at each rating date in 2000 and 2001. Chlorsulfuron + mefluidide reduced centipedegrass ground cover at 12 and 16 WAS in 2000, but no reduction was observed in 2001. Also in 2000, sulfometuron at 26 g/ha did not reduce centipedegrass ground cover compared to the control; however, centipedegrass ground cover was reduced at 12, 16, and 20 WAS in 2001. It is likely that sulfometuron was more persistent and caused additional grow-in delay in 2001 due to less rainfall as compared to 2000.

Sulfometuron applications at seeding caused less injury than metsulfuron, likely due to a difference in metabolism of sulfometuron and metsulfuron by centipedegrass (Baird et al. 1989). Label recommendations for sulfometuron[7] permit its application up to 106 g/ha for centipedegrass release in industrial areas; however, these data suggest sulfometuron is injurious at seeding. Further, these data do not suggest the use of metsulfuron on immature centipedegrass which is consistent with label recommendations for metsulfuron[13] that allow the application of 11 to 21 g/ha on centipedegrass greater than one year old.

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[13]Manor 60DF. Riverdale Company, Burr Ridge, IL.

Herbicides and PGRs Applied Early Postemergent. Imazapic at 18, 35, 70, or 105 g/ha, sulfometuron at 26 or 53 g/ha, atrazine at 1100 or 2200 g/ha, or simazine at 1100 or 2200 g/ha applied to centipedegrass 6 WAS (one-leaf to one-tiller growth stage) caused < 15% phytotoxicity at 28 and 56 DAT (Table 3). These data demonstrate the safety of these compounds applied to centipedegrass that has emerged and is actively growing, compared to applications at seeding. Similarly, established or newly sprigged centipedegrass has exhibited tolerance to atrazine, imazapic, or simazine applications (Johnson 1973 and 1976; Adcock et al. 1998). Further, imazapic applications are effective for bahiagrass (Yelverton et al. 1997) and tall fescue growth regulation (Yelverton et al. unpublished data). However, because immature centipedegrass is tolerant to low rates of imazapic, it is possible that imazapic could aid in converting existing bahiagrass and tall fescue utility areas to centipedegrass.

At 28 and 56 DAT, chlorsulfuron + mefluidide, or metsulfuron at 21 g/ha applied 6 WAS caused 16 to 27% centipedegrass phytotoxicity (Table 3). Metsulfuron at 42 g/ha was detrimental to centipedegrass resulting in 88 and 83% phytotoxicity at 28 and 56 DAT, respectively. With the compounds evaluated, PGR and herbicide tolerance in seedling centipedegrass appears to be similar to established centipedegrass. Newly seeded centipedegrass tolerance to sulfometuron is likely due to centipedegrass readily metabolizing sulfometuron (Baird et al. 1989). From this research, sulfometuron can be applied after centipedegrass has emerged and is actively growing; however, applications at seeding should be avoided.

Establishment with Large Crabgrass. Large crabgrass emergence data are presented at 4 WAS, as all emergence had occurred (Table 4). Large crabgrass emergence was reduced (48%) when atrazine (1100 g/ha) was applied at seeding compared to when it was not applied (89%), averaged over seed mixes. Johnson (1973) reported 57% control of large crabgrass and goosegrass with atrazine applied at sprigging of centipedegrass. However, large

crabgrass tiller production and height were not affected by seed mix or weed control (data not shown) indicating that large crabgrass plants, once emerged were not affected by atrazine applied at seeding.

Centipedegrass tiller production, foliar height, and percent ground cover are presented at 8 WAS, while emergence is presented at 4 WAS. Centipedegrass emergence was unaffected by seed mix or weed control with germination $\geq$ 80% (Table 5). However, centipedegrass tiller production, percent cover, and foliar height decreased linearly with increasing amounts of large crabgrass (Table 5). Centipedegrass tiller production was reduced from six tillers to one tiller when large crabgrass increased from 0 to 75% of the seed mix. However, tillers/plant only decreased to three tillers/plant with 75% large crabgrass seed mix when atrazine (1100 g/ha) was applied at seeding. Similarly, centipedegrass ground cover decreased to less than 50% when large crabgrass increased to 25% of the seed mix and no atrazine was applied. However, when atrazine was applied, centipedegrass ground cover did not decrease below 50% until large crabgrass comprised 75% of the seed mix. These data are similar to reports from Walker et al. (1998) reporting bermudagrass forage production was reduced between 59 and 67% when grown in the presence of large crabgrass and no weed control was applied as compared to a monoculture. In the absence of large crabgrass, there was no effect of atrazine on centipedegrass ground cover. These data indicate the use of atrazine at seeding can hasten the establishment of centipedegrass from seed by reducing the interspecific competition caused by large crabgrass.

No difference was observed for centipedegrass foliar height in response to atrazine application; however, centipedegrass foliar height decreased from 82 mm to 58 mm when large crabgrass increased to 75% of the seed mix. This further validates the need for large crabgrass control to hasten centipedegrass establishment.

Stolon production ($P<0.0001$) and stolon length decreased linearly ($P<0.0001$) with seed mixes containing increasing amounts of large crabgrass indicating a negative effect of

interspecific competition on centipedegrass establishment (Table 6). Further, stolon production and stolon length were significantly increased when atrazine was applied at seeding (Table 7). Only 7 stolons averaging 68 mm in length were produced when atrazine was not applied, compared to 13 stolons averaging 142 mm in length when atrazine was applied at seeding. Again, this reduction in stolon production and length was due to atrazine providing greater than 40% reduction in large crabgrass emergence, thus reducing interspecific competition.

Regardless of atrazine application, centipedegrass cover was less with increasing amounts of large crabgrass seed; however, the centipedegrass seeding rate was decreasing as well with a slow to establish species. Also, the 100:0 mix, is equivalent to 12.2 kg/ha, and seeding below this rate often results in grow-in delay in field environments regardless of weed pressure. Furthermore, these data suggest seeded centipedegrass grow-in can be increased with atrazine or other herbicide programs that combine turfgrass safety and weed control. However, atrazine only provides about 30 d of residual large crabgrass control (Boyd 1998); therefore, repeat applications or postemergent applications of other herbicides are required for acceptable weed control when establishing centipedegrass from seed.

In conclusion, these data indicate that seeded centipedegrass is tolerant to select rates of atrazine, imazapic, or simazine; therefore, they can be utilized for weed control during centipedegrass establishment. Sulfometuron applications at seeding should be avoided, but once centipedegrass is emerged and actively growing, sulfometuron can be applied. Metsulfuron resulted in unacceptable injury regardless of application time; therefore, applications to centipedegrass should be avoided.

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Table 1. Seed mix composition.

Seed mix	EREOP	DIGSA	Total
— EREOP:DIGSA[a] —	———— No. seed ————		
100:0	140	0	140
75:25	105	30	135
50:50	70	59	129
25:75	35	89	124
0:100	0	118	118

[a] EREOP, centipedegrass; DIGSA, large crabgrass; seed mixture is based on a weight:weight ratio.

Table 2. Effect of PGR and herbicide applications at seeding on centipedegrass ground cover[a].

		Centipedegrass ground cover [b]				
		12 WAS		16 WAS		20 WAS
Treatment	Rate	2000	2001	2000	2001	2001
	g/ha	%				
Chlorsulfuron + mefluidide	7 + 140	24 ef	44 abc	54 de	71 ab	86 a
Imazapic	18	68 ab	56 a	88 ab	78 a	88 a
Imazapic	35	68 ab	20 cde	84 ab	59 abc	68 abc
Imazapic	70	49 cd	13 def	74 bc	29 cde	50 bcd
Imazapic	105	36 de	5 efg	61 cd	9 ef	20 def
Sulfometuron	26	51 bcd	14 efg	76 abc	28 de	36 cde
Sulfometuron	53	24 ef	0 g	46 de	0 f	5 f
Metsulfuron	21	15 f	0 g	35 ef	8 ef	6 ef
Metsulfuron	42	11 f	0 g	21 f	0 f	0 f
Atrazine	1100	60 abc	48 ab	89 ab	84 a	88 a
Atrazine	2200	55 abc	24 b-e	83 ab	43 bcd	60 abc
Simazine	1100	65 ab	31 a-d	86 ab	69 ab	85 a
Simazine	2200	70 a	16 cde	90 a	48 bcd	45 bcd
Control	-	66 ab	31 a-d	87 ab	68 ab	74 ab

[a] Means within a column followed by the same letters are not significantly different according to Fisher s Protected LSD test at P = 0.05. PGR, plant growth regulator. WAS, weeks after seeding.

[b] Treatment by year interaction ($P<0.05$) prevented pooling data across years. Percent cover based on visual estimates of centipedegrass ground cover utilizing a 0 (no ground cover) to 100% (complete ground cover) scale.

Table 3. Effect of PGR and herbicide applications applied 6 WAS to centipedegrass[a].

Treatment	Rate	Centipedegrass phytotoxicity[b]	
		28 DAT	56 DAT
	g/ha	%	
Chlorsulfuron + mefluidide	7 + 140	22 bc	20 b
Imazapic	18	0 d	0 d
Imazapic	35	0 d	0 d
Imazapic	70	0 d	0 d
Imazapic	105	0 d	3 d
Sulfometuron	26	11 bcd	7 cd
Sulfometuron	53	9 cd	11 bcd
Metsulfuron	21	27 b	16 bc
Metsulfuron	42	88 a	83 a
Atrazine	1100	3 d	0 d
Atrazine	2200	4 d	5 cd
Simazine	1100	3 d	3 d
Simazine	2200	3 d	3 d
Control	-	0 d	0 d

[a] Means within a column followed by the same letters are not significantly different according to Fisher s Protected LSD test at P =0.05, centipedegrass was one-leaf to one-tiller development

stage at application. DAT, days after treatment. PGR, plant growth regulator. WAS, weeks after seeding.

[b] Phytotoxicity was based on visual estimates utilizing a 0% (no injury) to 100% (complete death) scale.

Table 4. Effect of atrazine on large crabgrass emergence 4 WAS[a]

Treatment	DIGSA[b]
	Emergence
	%
Control	89
Atrazine (1100 g ai/ha)[c]	48
LSD (0.05)[d]	10

[a] Data pooled over seed mixes.

[b] DIGSA, large crabgrass.

[c] Atrazine applied at seeding.

[d] Values indicate significant means separation, based on standard F tests at =0.05.

Table 5. Effect of seeding mix and atrazine on centipedegrass emergence, height, tiller production, and ground cover.

	EREOP					
			No atrazine		Atrazine[a]	
EREOP:DIGSA[b]	Emergence[c]	Height[d]	Tillers[e]	Cover[f]	Tillers	Cover
	— % —	—— mm ——	—— No. ——	—— % ——	—— No. ——	—— % ——
100:0	84	82	6	89	6	89
75:25	83	67	4	44	5	76
50:50	84	63	2	14	5	51
25:75	80	58	1	6	3	13
P-value[g]	NS	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[a] Atrazine applied at seeding at a rate of 1100 g/ha.

[b] EREOP, centipedegrass; DIGSA, large crabgrass. Seed mixture is based on a weight:weight ratio.

[c] Emergence of centipedegrass measured at 4 WAS (weeks after seeding), averaged over weed control option.

[d] Average foliar height calculated by measurement of ten randomly selected centipedegrass plants at 8 WAS, averaged over weed control option.

[e] Average tillers present calculated by measurement of ten randomly selected centipedegrass plants at 8 WAS.

[f] Visual estimate of % centipedegrass ground cover utilizing a 0 (no ground cover) to 100% (complete ground cover) scale at 8 WAS.

[g] P-value for rate linear contrast, NS indicates P>0.05.

Table 6. Effect of seed mix on centipedegrass stolon production 8 WAS.[a]

	Stolon	
EREOP:DIGSA[b]	Count[c]	Length[d]
	——— No. ———	——— mm ———
100:0	28	220
75:25	7	100
50:50	4	67
25:75	1	28
P-value[e]	<0.0001	<0.0001

[a] Data pooled over weed control options.

[b] EREOP, centipedegrass; DIGSA, large crabgrass. Seed mixture is based on a weight:weight ratio.

[c] Total number of centipedegrass stolons present per flat.

[d] Average centipedegrass stolon length.

[e] P-value for rate linear contrast.

Table 7. Effect of atrazine on centipedegrass stolon production 8 WAS.[a]

Treatment	Stolon	
	Count[b]	Length[c]
	No.	mm
Control	7	68
Atrazine (1100 g ai/ha)[d]	13	142
LSD (0.05)[e]	4	29

[a] Data pooled over seed mixes.

[b] Total number of centipedegrass stolons present per flat.

[c] Average centipedegrass stolon length.

[d] Atrazine applied at seeding.

[e] Values indicate significant means separation, based on standard F tests at =0.05.

CHAPTER 2

Gannon et al.: Centipedegrass allelopathy

Allelopathic Potential of Centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.)[1]

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Abstract. Laboratory and greenhouse experiments were conducted to determine the allelopathic potential of centipedegrass. Germination and growth of indicator species were evaluated in soil leachates, leaf debris, and aqueous leaf extracts of centipedegrass. Centipedegrass soil leachates did not inhibit annual bluegrass, goosegrass, henbit, large crabgrass, or perennial ryegrass germination compared to the nonfertilized control. Incorporated centipedegrass leaf debris did not reduce lettuce germination, shoot weight, or root weight as compared to the control. However, shoot and root dry weight of radish were significantly reduced with increasing rates of centipedegrass leaf debris. Six and nine mg debris per g of soil reduced radish shoot weight by 49 and 64%, respectively, as compared to the control. Aqueous leaf extracts of centipedegrass reduced lettuce germination, however, radicle and hypocotyl length were similar to the control. These data do not conclusively suggest that centipedegrass has widespread allelopathic activity; however, significant reductions in shoot and root weight of radish with increasing debris rate demonstrates a pattern of inhibition of one species against another which fulfills a requirement of allelopathic interactions.

Nomenclature: annual bluegrass, *Poa annua* L. POAAN; goosegrass, *Eleusine indica* (L.) Gaertn. ELEIN; henbit, *Lamium amplexicaule* L. LAMAM; large crabgrass, *Digitaria sanguinalis* (L.) Scop. DIGSA; bahiagrass, *Paspalum notatum* Fluegge; bermudagrass, *Cynodon dactylon* (L.) Pers.; centipedegrass, *Eremochloa ophiuroides* (Munro) Hack.; lettuce, *Lactuca sativa*; perennial ryegrass, *Lolium perenne* L.; radish, *Raphanus sativus*; tall fescue, *Festuca arundinacea* Schreb.

Key words: aqueous leaf extract, leaf debris, root leachate, seed germination, soil leachate, turfgrass, weeds**.**

Rice (1984) defined allelopathy as inhibitory or stimulatory biochemical interactions between all types of plants including microorganisms . Allelopathic cover crops have proven beneficial, especially in no-till crop systems, by reducing weed populations (Blum et al. 2002). Future implications of allelopathy could use germplasms of allelopathic plants to select for improved cultivars providing season-long weed suppression ultimately requiring fewer herbicide applications (Weston 1996). With environmental fate of pesticides atop public concern, allelopathy will likely gain additional attention in the future.

Allelopathic screenings have been conducted on many plants including small grain cover crops which have repeatedly demonstrated allelopathic interactions. Small grain mulches including wheat (*Triticum aestivum* L.), rye (*Secale cereale* L.), oats (*Avena sativa* L.), and barley (*Hordeum vulgare* L.) have been shown to reduce certain weed densities and growth (Liebl 1983). Further, lettuce (*Lactuca sativa*) and proso millet (*Panicum miliaceum*) emergence were reduced by 58 and 35%, respectively, with rye residues present in simulated no-till conditions (Barnes and Putnam 1986).

Allelopathic effects of turfgrass species have been explored to lesser extent. Red fescue (*Festuca rubra* L.) releases significant quantities of allelopathic growth inhibitors into the rooting environment; however, the allelopathic properties are cultivar dependent (Bertin et al. 2002). Allelopathic properties of tall fescue (*Festuca arundinacea* Schreb.) have also been reported and include the inhibition of seed germination or reduction in seedling growth (Chung and Miller 1995; Luu et al. 1989; Pederson 1986; Peters and Zam 1981; Smith and Martin 1994). Indicator species that have been negatively affected by tall fescue include alfalfa (*Medicago sativa* L.), birdsfoot trefoil (*Lotus corniculatus* L.), and white clover (*Trifolium repens* L.). Lickfeldt et al. (2001) investigated the allelopathic potential of tall fescue, hard fescue, Kentucky bluegrass (*Poa pratensis* L.), perennial ryegrass (*Lolium perenne* L.), and annual bluegrass (*Poa annua* L.) but concluded all were equally inhibitory

in the bioassays tested and expressed uncertainty regarding previous studies that declared tall fescue allelopathic. Other turfgrass species suggested to possess allelopathic properties include bahiagrass (*Paspalum notatum* Fluegge) (Martin and Smith 1994) and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) (Wu et al. 2002).

Centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.) is a warm-season turfgrass species introduced to the United States from China in 1916 (Duble 1996). No published research has assessed the allelopathic potential of centipedegrass. However, weed scientists in the southeastern US have observed the lack of weed populations in established stands of centipedegrass, possibly indicating some type of interference mechanism.

Several requirements to establish a negative allelopathic interaction include a pattern of inhibition of one species or plant on another, the putative aggressor plant must produce a toxin or a potential toxin, there must be a mode of toxin release from the plant into the environment, there must be a mode of toxin transport and/or accumulation in the environment, the afflicted plant must have some means of toxin contact and/or uptake, the afflicted plant must be sensitive to the toxin, and the pattern of inhibition cannot be explained solely by physical factors or other biotic factors especially competition, herbivory, or disease (Willis 1985) .

Although it is difficult to convincingly demonstrate allelopathic interactions, several approaches are commonly used to investigate one component within a system. General methods to determine the allelopathic potential of a species include experiments monitoring indicator species germination and growth in the presence of leachates, extracts, or debris of potential allelopathic agents (Inderjit and Keating 1999). The objectives of this research were to evaluate the germination and growth response of various indicator species to soil leachates, leaf debris, and aqueous leaf extracts of centipedegrass to determine if a pattern of inhibition exists.

Materials and Methods

Soil Leachate. Experiments were conducted to determine if soil leachate collected from centipedegrass affected germination of various indicator species. Bermudagrass (*Cynodon dactylon* (L.) Pers. Sahara), centipedegrass, and tall fescue (*Festuca arundinacea* Schreb Confederate) plugs (11 cm diameter and 18 cm height) were collected from the Sandhills Research Station, Jackson Springs, NC using a standard golf cup cutter and returned to the North Carolina State University Greenhouses, Raleigh, NC in Fall, 2000. Bahiagrass plugs were collected from a home lawn in Wake County, NC. All plugs were collected from sites that had not been treated with pesticides for at least 36 months. Plugs were placed in 5.5 L lysimeters and backfilled with river bottom sand. All plugs were grown with 30/15 C day/night temperatures, irrigated three times daily with overhead irrigation, and clipped weekly to a 4 cm height, removing clippings. Natural lighting was supplemented with metal halide lamps with a photon flux density of 300 µmol m^{-2} s^{-1} set on a 12-h photoperiod. Lysimeters were allowed to acclimate for 60 d. All turfgrass and fertilized control lysimeters received 25 kg N ha^{-1} from a commercial fertilizer[1] solution every 14 d.

After the acclimation period, a plastic container was placed under lysimeters to capture soil leachate. From this point, overhead irrigation was continued; however, fertilization was discontinued. The leachate captured in the containers was recycled every second d by reapplying it to the lysimeter. The lysimeters were maintained with soil leachate recycling for 30 d, after which the soil leachate from each of the lysimeters was collected. Leachate treatments included eight lysimeters of each bahiagrass, bermudagrass, centipedegrass, tall fescue, fertilized control, and nonfertilized control. Leachates from each lysimeter comprising a turf species or control were combined, filter sterilized with a 0.2 micron (µm) disposable filter unit[2] and stored at room temperature.

Five indicator species were germinated in turfgrass soil leachates and control soil leachates

to determine if germination was affected. Indicator species included annual bluegrass, goosegrass (*Eleusine indica* (L.) Gaertn.), henbit (*Lamium amplexicaule* L.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.), and perennial ryegrass (*Lolium perenne* L. Charger II). Annual bluegrass and large crabgrass were purchased as weed seed from California[3]. Goosegrass and henbit were collected from naturally infested sites in Wake County, NC.

Thirty seed of the specified indicator species were placed in a petri dish with two pieces of blotter paper and eight ml of the corresponding solution was placed on the blotter paper. Petri dishes were then covered, enclosed in a plastic bag to minimize evaporation, and placed in an incubation chamber. Annual bluegrass, henbit, and perennial ryegrass were germinated at a constant temperature of 15 C, while goosegrass and large crabgrass were germinated at 35/20 C day/night temperature. Each chamber received a 16/8 h day/night photoperiod (30 µmol m^{-2} s^{-1}) from fluorescent bulbs. Three ml of the corresponding solution was placed in the petri dish at 7 and 14 days after initiation (DAI) to replenish moisture. Germination was recorded at 7, 14, and 21 DAI. Seedlings were considered germinated if radicle emergence exceeded 2 mm and germinated seedlings were removed from the petri dish after counting.

Three replicates were included in the experiment. The experimental design was completely randomized, with a factorial arrangement of treatments. Factorial levels included the leachate treatment and the indicator species. Due to differences in germination of indicator species, a main effect of indicator species was not evaluated in the ANOVA. Instead, indicator species were analyzed separately in ANOVA using SAS and means were separated according to Fisher s Protected LSD (P=0.05).

Leaf Debris. Greenhouse experiments were conducted to evaluate the effect of centipedegrass leaf debris on the germination and growth of lettuce and radish (*Raphanus sativus*). Centipedegrass leaf material was collected from New Hanover County, NC from a site that had not been treated with pesticides for at least 36 months. A walk-behind rotary

mower with bagger was used to collect leaf material by mowing the area at 3.8 cm. Centipedegrass leaf material was placed on ice and returned to Raleigh, NC, after which leaf material was cleaned free of debris, freeze dried, and stored intact at room temperature to minimize oxidation (Inderjit et al. 1999).

Soil medium was a 1:1 (v/v) ratio of river bottom sand and Norfolk loamy fine sand (thermic Typic Kandiudults, pH of 6.1 and 0.3% humic matter). Leaf material was ground, weighed, and immediately incorporated thoroughly into the soil at a rate of 0, 3, 6, and 9 mg centipedegrass leaf debris per g of soil. Soil plus debris substrate was then placed in 600 ml pots before seeding either three lettuce[4] or radish[5] seeds on the soil surface. Plants were grown with 30/15 C day/night temperatures. Lighting, irrigation, and fertilization were similar to the previous greenhouse environment. Seedling germination was recorded weekly for 28 d. Shoots and roots were harvested at 28 DAI, roots were washed, both shoots and roots were oven dried at 60 C for 96 h, 0% relative humidity, and dry weights were recorded.

The experiment was conducted four times with each containing four replicates. The experimental design was completely randomized, with a factorial arrangement of treatments. Factorial levels included the amount of leaf debris and the indicator species. Due to differences in germination and growth of indicator species, a main effect of indicator species was not evaluated in the ANOVA. Instead, indicator species were analyzed separately using rate linear contrasts (P=0.05).

Leaf Extract. Laboratory experiments were conducted to evaluate the effect of aqueous leaf extracts of bermudagrass and centipedegrass on large crabgrass, goosegrass, lettuce, and radish germination and growth. Centipedegrass and bermudagrass leaves were harvested from New Hanover County and Johnston County, NC, respectively, from sites that had not been treated with pesticides for at least 36 months. Clippings were collected as in the previous experiment. Clippings were placed on ice and returned to Raleigh, NC, after which

plant material was oven dried at 60 C for 72 h. Clippings were then stored at -6 C until extractions were performed.

Centipedegrass and bermudagrass leaf clippings were ground to a powder using a standard coffee grinder. Two and one-half g of either centipedegrass or bermudagrass leaf clippings were extracted with 50 ml deionized water for 48 h at 200 rpm with a G2 Gyratory Shaker[6] at room temperature (25 C). Extracts were then filtered through filter paper[7] followed by three 25 ml rinses with deionized water. Several extracts were performed and combined to provide an adequate amount of solution.

Four seeded indicator species were germinated in centipedegrass extract, bermudagrass extract, or control (tap water). Thirty seed of large crabgrass, goosegrass, radish, or lettuce were counted and placed in a petri dish with two pieces of blotter paper. Eight ml of the corresponding extract solution or control was placed in the petri dish. The petri dishes were then covered, enclosed in a plastic bag to minimize evaporation, and placed in an incubation chamber with a 35/20 C day/night temperature and 16/8 h day/night photoperiod. The chambers contained two fluorescent bulbs (30 µmol m^{-2} s^{-1}) for supplemental lighting. Germination was recorded at 7 DAI. At 14 DAI, germination, radicle length, and hypocotyl length were measured and recorded.

The experiment was conducted twice with four replicates in each experiment. The experimental design was completely randomized, with a factorial arrangement of treatments. Factorial levels included the extract species and the indicator species. Due to differences in germination and growth of indicator species, a main effect of indicator species was not evaluated in the ANOVA. Instead, indicator species were analyzed separately in ANOVA using SAS and means were separated according to Fisher s Protected LSD (P=0.05).

Results and Discussion

Soil Leachate. Annual bluegrass, henbit, large crabgrass, and perennial ryegrass germination in soil leachate collected from bahiagrass, bermudagrass, centipedegrass, or tall fescue was similar to germination in the fertilized control and the nonfertilized control (Table 1). Goosegrass germination in centipedegrass leachate was less than in bahiagrass, bermudagrass, tall fescue, and the fertilized control. However, goosegrass germination was not significantly reduced as compared to the nonfertilized control. Goosegrass germination in bahiagrass, bermudagrass, and tall fescue soil leachate was similar to the fertilized control. Chemicals that stimulate germination such as potassium nitrate (Andersen 1968) may be present in soil leachates from bahiagrass, bermudagrass, and tall fescue similarly to the fertilized control; however, it is possible they are not present in soil leachates collected from centipedegrass and the nonfertilized control. Henbit germination was minimal, possibly due to dormancy mechanisms with freshly harvested seed (Andersen 1968).

These data agree with Rice (1974), roots generally contain fewer and less potent inhibitors than leaves. Lickfeldt et al. (2001) evaluated several cool-season turfgrass species and concluded no significant inhibition of germination or growth with leachates. Further, if allelochemicals are only produced in leaf tissue, the system utilized in this experiment would not suffice since clippings were removed upon mowing.

Leaf Debris. Three and six mg centipedegrass leaf debris did not significantly reduce lettuce germination, shoot, or root dry weight (Table 2). Similar trends are common with incorporated debris experiments with stimulatory effects at lower rates, and inhibitory effects at higher rates (Inderjit and Keating 1999).

Barnes and Putnam (1986) indicated lettuce germination was significantly reduced by rye residues in a simulated no-till system. However, in these experiments lettuce germination or growth was not significantly affected by centipedegrass leaf debris.

Radish germination was not affected by centipedegrass leaf debris (Table 2). However, radish shoot and root dry weight were reduced linearly with increasing rates of centipedegrass leaf debris. Six and nine mg of debris per g of soil produced only 193 and 138 mg shoot material, respectively, as compared to 380 mg produced by the control (Table 2). This represents a 49 and 64% reduction in shoot dry weight with six and nine mg, respectively, as compared to the control. These data are consistent with Rice (1974), suggesting leaves are the most consistent source of inhibitors. White et al. (1989) reported similar results, with morningglory growth continually declining with increasing amounts of incorporated hairy vetch or crimson clover debris.

Mechanisms of action of inhibitory compounds include inhibition of cell division and elongation, inhibition of gibberellin or indoleacetic acid induced growth, effect on mineral uptake, retardation of photosynthesis, inhibition or stimulation or respiration, among others (Rice 1974). Germination was not inhibited with incorporated centipedegrass leaf debris; however, significant reductions in radish shoot and root dry weight were observed with incorporated centipedegrass leaf debris. This is significant because size and weight, which are directly related to plant cell growth, are main criteria in determining the relative effect of allelopathic agents on test organisms (Inderjit and Keating 1999; Rice 1974).

Leaf Extract. Aqueous extracts of centipedegrass or bermudagrass leaves did not affect germination of large crabgrass or radish seed (Table 3). Goosegrass seed did not germinate in the experiment. Centipedegrass extracts reduced lettuce germination (28%) compared to the control (40%). Bermudagrass extracts reduced lettuce germination (14%) more than both centipedegrass and the control.

Centipedegrass and bermudagrass leaf extracts did not reduce radicle and hypocotyl length of large crabgrass compared to the control (Table 4). Furthermore, centipedegrass extract did not affect radicle and hypocotyl length of radish. However, bermudagrass extract

significantly reduced radicle and hypocotyl length of radish seedlings as compared to both centipedegrass and the control.

Centipedegrass increased lettuce radicle length (10 mm) compared to bermudagrass (7 mm) and the control (7 mm). No treatment differences were detected for lettuce hypocotyl lengths. Although indicator seed germination and growth in aqueous leaf extracts have proven to support allelopathic interactions with forage and turfgrass species (Chung and Miller 1995; Martin and Smith 1994; Luu et al. 1989; Pederson 1986), aqueous leaf extract of centipedegrass did not inhibit seed germination or initial development in a similar manner.

Within the experiments conducted, allelopathic properties were not widespread. However, significant reductions in radish shoot and root dry weight with increasing amounts of incorporated centipedegrass leaf debris is important and fulfills a requirement of proven allelopathic interactions, thus demonstrating a pattern of inhibition or reduction of one species on another (Willis 1985).

Allelopathic interactions must be studied at least in part in laboratory and greenhouse environments to separate and more definitively study a variable; however, they are not representative of a field environment and possibly constitute differences that are important when investigating allelopathic interactions. Soil microorganisms are largely responsible for the decomposition and decay of plant residues and other organic matter and therefore many allelopathic cases involve microbial activity (Radosevich et al. 1997). Microorganisms are capable of changing nontoxic compounds to toxic ones (Rice 1984); however, in the laboratory, once solutions and soils are sterilized, microbial populations are not present and therefore field conditions are not simulated.

Also, perennial turfgrass environments are unique in several ways. Tillage is not included in cultural practices as compared to conventional agriculture. Perennial turfgrass environments also possess a microbial rich thatch layer. These factors possibly promote the

accumulation of allelochemicals over time in turfgrass systems. Also, with turfgrass systems, the decomposition rate of leaf debris, which is continually deposited through mowing, is difficult to simulate in laboratory and greenhouse environments.

Although established centipedegrass stands frequently exhibit less weeds, centipedegrass did not inhibit selected indicator species germination as demonstrated with other allelopathic plants. However, significant reductions in shoot and root dry weight of radish with increasing rates of centipedegrass leaf debris demonstrate a pattern of inhibition of one species against another which fulfills a requirement of allelopathic interactions.

Sources of Materials

[1] Peters Professional All Purpose 20-20-20, Scotts-Sierra Horticultural Products Co., 14111 Scottslawn Road, Marysville, OH 43041.

[2] Nalgene 115 ml 0.2 micron disposable filter unit, Fisher Scientific Co., 3970 Johns Creek Court Suite 500, Suwanee, GA 30024.

[3] Valley Seed Service, P.O. Box 9335, Fresno, CA 93791.

[4] Green oak leaf lettuce seed, Wyatt-Quarles Seed Company Wholesale, 730 West US 70, Garner, NC 27529.

[5] Early scarlet turnip white radish seed, Wyatt-Quarles Seed Company Wholesale, 730 West US 70, Garner, NC 27529.

[6] G2 gyratory shaker, New Brunswick Scientific Co., Inc. 44 Talmadge Road, Edison, NJ 08818.

[7] 934AH glass fiber filter paper, H. Reeve Angel & Co., Inc., 9 Bridewell Place, Clifton, NJ 07015.

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Table 1. Effect of turfgrass soil leachates on indicator species germination[a].

Soil leachate	POAAN	ELEIN	LAMAM	DIGSA	LOLPE
	%				
Bahiagrass	93 a	69 a	4 a	33 a	97 a
Bermudagrass	97 a	66 a	9 a	29 a	99 a
Centipedegrass	93 a	40 c	10 a	33 a	97 a
Tall fescue	89 a	60 ab	4 a	27 a	94 a
Fertilized control	88 a	62 a	7 a	22 a	97 a
Nonfertilized control	93 a	47 bc	8 a	23 a	96 a

[a] Means within a column followed by the same letters are not significantly different according to Fisher s Protected LSD test at P = 0.05. POAAN, annual bluegrass; ELEIN, goosegrass; LAMAM, henbit; DIGSA, large crabgrass; LOLPE, perennial ryegrass.

Table 2. Effect of incorporated centipedegrass leaf debris on lettuce and radish germination, shoot dry weight, and root dry weight.

	Germination		Shoot dry weight		Root dry weight	
Rate (mg debris/g soil)	LACSA	RAPSA	LACSA	RAPSA	LACSA	RAPSA
	%		mg			
0	44	85	21	380	4	228
3	52	88	16	296	2	192
6	60	90	10	193	2	142
9	33	90	9	138	3	102
Probability > F[a]	NS	NS	NS	0.0005	NS	0.0422

[a] Probability values for rate linear contrast (NS indicates P>0.05). LACSA, lettuce; RAPSA, radish.

Table 3. Effect of aqueous leaf extracts on indicator species germination[a].

Extract species	DIGSA	ELEIN	RAPSA	LACSA
	%			
Centipedegrass	58 a	0 a	100 a	28 b
Bermudagrass	64 a	0 a	87 a	14 c
Control (tap water)	59 a	0 a	99 a	40 a

[a] Means within a column followed by the same letters are not significantly different according to Fisher s Protected LSD test at P = 0.05. DIGSA, large crabgrass; ELEIN, goosegrass; RAPSA, radish; LACSA, lettuce.

Table 4. Effect of aqueous leaf extracts on indicator species radicle and hypocotyl length.[a]

	DIGSA		RAPSA		LACSA	
Extract species	Radicle	Hypocotyl	Radicle	Hypocotyl	Radicle	Hypocotyl
	mm					
Centipedegrass	17 a	20 a	19 a	18 a	10 a	11 a
Bermudagrass	20 a	19 a	11 b	10 b	7 b	7 a
Control (tap water)	17 a	18 a	17 a	15 a	7 b	12 a

[a] Means within a column followed by the same letters are not significantly different according to Fisher s Protected LSD test at P = 0.05. DIGSA, large crabgrass; RAPSA, radish; LACSA, lettuce.

Table A1. Rainfall records for 2000.

Date	June	July	August	September
	cm			
1	-	-	0.1	0.9
2	-	-	0.3	0.8
3	-	-	0.8	0.1
4	-	-	0.8	2.5
5	-	0.1	0.8	1.1
6	0.6	0.5	-	-
7	-	-	-	-
8	-	-	-	-
9	-	-	-	-
10	-	-	2.2	-
11	-	-	0.4	-
12	-	0.1	-	-
13	-	-	-	-
14	-	2.5	-	-
15	0.1	0.1	-	0.6
16	2.4	0.1	-	-
17	-	-	-	-
18	-	-	-	-
19	-	-	3.0	1.3
20	2.4	-	-	-
21	-	-	-	-
22	-	-	-	0.9
23	-	0.2	-	1.4
24	-	-	-	0.8
25	-	5.1	-	-

Table A1, continued.

26	-	0.2	-	2.5
27	-	-	0.6	-
28	1.7	-	5.2	-
29	1.3	-	-	-
30	0.3	-	-	-
31	-	0.1	0.6	-
Total	8.8	9.0	14.8	12.9

Table A2. Rainfall records for 2001.

Day	May	June	July	August	September
	cm				
1	-	-	-	-	0.5
2	-	2.2	-	-	0.6
3	-	-	-	-	-
4	-	0.1	-	-	1.3
5	-	-	3.9	-	-
6	-	-	-	-	-
7	-	0.2	-	-	-
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	-	0.1
11	-	-	-	-	-
12	-	-	-	0.6	-
13	2.0	-	-	-	-
14	-	-	-	-	-
15	-	0.5	-	-	-
16	2.9	-	-	-	-
17	1.0	-	-	1.2	-
18	-	-	1.6	-	-
19	-	-	-	-	-
20	-	-	-	-	0.2
21	-	-	-	-	3.5
22	0.4	-	-	-	-
23	1.0	2.1	-	-	-
24	-	0.1	0.7	0.5	-
25	-	-	-	-	3.1

Table A2, continued.

26	-	-	-	-	-
27	0.4	-	2.7	-	-
28	-	-	0.7	-	-
29	0.6	-	0.3	-	-
30	-	-	0.9	-	-
31	-	-	-	1.0	-
Total	8.3	5.2	10.8	3.3	9.3