2002

Control of two perennial grasses in southern turfgrasses

Ronald Eugene Strahan
Louisiana State University and Agricultural and Mechanical College, rstrahan@agctr.lsu.edu

CONTROL OF TWO PERENNIAL GRASSES IN SOUTHERN TURFGRASSES

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Horticulture

by
Ronald E. Strahan
B.S., Northeast Louisiana University, 1992
M.S., Louisiana State University, 1996
December 2002

ACKNOWLEDGEMENTS

First of all I would like to thank God for the most patient woman on earth, my wife Leslie. Leslie, you are truly the finest person that I have ever known and a blessing in my life. You will always be my best friend and a great joy in my heart. I look forward to spending the rest of our lives together. Thanks for always believing in me and not giving up.

To Dr. James N. McCrimmon, I can never tell you enough how much I appreciate your long hours getting me to this point in my career. You deserve so much more than the mere thanks that I offer you at this time.

I could not go any further without thanking my family. It has been difficult to be away from all of you for so long. My dear father, I long for the day when we can walk in your garden together again. I believe that God will heal you and we will have many years together. You have provided our family with so much more than just a roof over our heads. I wish I could express to you how much I love you. My sweet mother, I can't tell you how much you mean to me. So many nights I have called you with a sorrowful heart, lonesome for my family. You have always comforted me and shown great love for your family. To my sisters, Debbie and Kathy, thank you for the love and encouragement that you have given to me. I will treasure the many memories that we have.

This has been a long journey that hopefully is coming to an end. There has been so many wonderful people that have helped me through the years. To Dr. Dearl Sanders, Dr. Walter Morrison, and Dr. Reed Lencse, thank you for giving me the opportunity to gain valuable field experience. It has been a pleasure to work with each of you. You have taught me so much. To secretaries Becky, Jody, Peggy, and Trudy, thanks for all the laughs and good times. You made work so much fun.

A special thanks to my committee members, Dr. Paul Wilson, Dr. Clayton Hollier, Dr. Reed Lencse, Dr. Jeff Kuehny, and Dr. Gary Breitenbeck. Thanks for the advice and assistance that you have provided.

Thanks also to student workers Mark Vidrine and Ryan Yerby. Without your help, my graduation would not be possible. Your cooperation has been greatly appreciated. You are the unsung heroes here. Gentlemen, I salute you.

TABLE OF CONTENTS

ABSTRACT

Knotgrass (*Paspalum distichum* L.) and torpedograss (*Panicum repens* L.) are perennial grasses that are extremely difficult to remove in established turfgrass. Studies were conducted to determine the potential for controlling these troublesome perennial weeds.

Pot studies were conducted for two years to evaluate several herbicides with multiple modes of action for knotgrass control. In graminicides studies, 8 weeks after initial application (WAI) single or split applications of fluazifop or quizalofop provided excellent control (88 to 95%). In contrast, single or split applications of fenoxaprop at 0.21 kg ha^{-1} and single applications of diclofop at 0.84 kg ha^{-1} were no better than the untreated check. Single applications of sethoxydim at 0.62 kg ha^{-1} were similar (85%) to sequential applications at 0.31 kg ha^{-1} (90%). MSMA, the industry standard, provided less than 40% control knotgrass control.

In nonselective studies, glyphosate, glufosinate, and sulfosate were evaluated at equivalent rates (1.12, 2.24, or 4.48 kg ha^{-1}). At 7 WAT, knotgrass control was at 99% for glufosinate, regardless of rate applied. All rates glyphosate and glufosinate or sulfosate applied at 2.24 and 4.48 kg ha^{-1} were similar and provided at least 95% knotgrass control. However, sulfosate applied at 1.12 kg ha^{-1} only controlled knotgrass 79%.

In studies evaluating quinclorac, control was greater with the herbicide applied at the highest rate (2.24 kg ha^{-1}). Knotgrass was not satisfactorily controlled, however, as control never exceeded 34%.

Field and greenhouses studies were conducted to evaluate clethodim for torpedograss control in centipedegrass. Single or sequential applications of clethodim at 0.60 kg ha^{-1} and sequential applications at 0.30 kg ha^{-1} were more effective than sethoxydim applications. Torpedograss control with clethodim however, was not acceptable and did not exceed 79% throughout the study. Torpedograss control with sethoxydim was no greater than 55%. Although still commercially acceptable (< 30% injury), clethodim caused some moderate centipedegrass injury. In greenhouse studies, several spray adjuvants were evaluated to increase the efficacy of clethodim. Results indicated that herbicide rate is more critical than the adjuvant. Regardless of adjuvant, clethodim at 0.60 kg ha^{-1} controlled torpedograss better than the 0.30 kg ha^{-1} rate (62 vs 44%).

CHAPTER 1
INTRODUCTION

Creeping perennial grasses cause particularly serious weed control problems in turfgrasses because of their resistance to control methods. Knotgrass (*Paspalum distichum* L.) and torpedograss (*Panicum repens* L.) are two of the most troublesome creeping perennial weeds of turfgrasses in Louisiana.

KNOTGRASS

Knotgrass is a spreading, mat-forming perennial grass that has shallow rhizomes and creeping, extensively branched stolons with adventitious roots at nodes (Holm et al., 1997). The weed is native to South America and thrives throughout tropical and subtropical regions of the world.

Knotgrass is a major weed of tea and rice throughout the world and often invades cropland from irrigation canals and ditch banks (Holm et al., 1997). It is common in temperate climates such as Japan, Great Britain, and Washington in the United States (Good, 1964). It is used for levee bank stabilization in Australia (Duncan and Carrow, 2000). The species can be found throughout California at lower altitudes, occurring in wet pastures and along irrigation ditches (Huang et al., 1987). Knotgrass is listed as an invasive weed in turfgrass in the United States (McCarty et al., 2000; Karnok, 2000).

The key features that aid in identification of knotgrass are the dense mat of stolons and shallow rhizomes, membranous ligules, short internodes, and two rows of tightly packed spikelets on the underside of both racemes (Holm et al., 1997). The degree of plant pubescence in the plant increases from the Atlantic to the Pacific coast in the United States (Allred, 1982). Knotgrass is taxonomically similar to seashore paspalum

(*Paspalum vaginatum* O. Swartz) (Jovet and Guedes, 1972). Anatomical comparison of the leaves of both species revealed sufficient differences to justify their classification as separate species (Ellis, 1974). Seashore paspalum has a glabrous second glume, whereas, the second glume is hairy on knotgrass. There are differences in preferred habitat between the two species. Seashore paspalum colonizes saline ecosystems such as along seacoast and brackish sands, whereas, knotgrass can be found dispersed over a wider geographical area, but growing in freshwater, moist habitats (Silveus 1933).

Knotgrass propagates readily by means of seed and rhizomes (Manual and Mercado, 1977). Under optimum growing conditions, knotgrass is capable of producing 100 thousand seed m^{-2} (Okuma and Chikura, 1984). However, only 5 to 10% of the flowers produce viable seed, and seed germination rates do not exceed 40% when subjected to the optimum temperatures. Huang et al (1987) reported that knotgrass seed treated with H_2SO_4 increased germination 60-95%. Seed coverings including the hull and seed coat membranes are the main factors regulating germination.

Several researchers have suggested that, in addition to seeds and rhizomes, the capability of buds from stem segments to root represents a third mechanism that enhances the persistence of the weed (Manual and Mercado, 1977; Okuma and Chikura, 1984; Huang et al., 1987). Manual and Mercado (1977) suggested that the primary method of reproduction was sprouting from the nodes of aerial stem and that rhizomes and seeds have a reduced role in the spread of the weed. Aerial shoots (stolons) sprout faster than do the rhizomes, and contact with the soil helps to stimulate new shoot production (Okuma et al., 1983). Cut stolons can form new plants in only 36 hours

(Holm et al., 1997). The rate of sprouting and rooting increases when the soil temperatures are between 30 and 40^{o}C, and little growth occurs at 10^{o}C or less. However, plants growing in water survived the winter in Japan even when ice formed on the surface of the water (Shibayama and Miyahara, 1977).

Knotgrass roots are relatively shallow, and the root system is not too extensive (Holm et al., 1997). In Pakistan, maximum root depth was 37 cm, with 70% of all the root and rhizome biomass in the upper 8 cm and 90% in the upper 16 cm. Root surfaces often have orange-brown deposits, indicating that oxygen is escaping from the roots and reacting with iron to form iron oxides. Anatomical examination found large intercellular spaces in the leaves, the stems, and particularly the root cortexes. The proportion of corticular space increased as root depth increased. This adaptation allows oxygen to move from the aerial plant parts to the roots so that the plants can grow in saturated soils.

Invasive Weed of Turfgrass. Creeping perennial weeds such as knotgrass are particularly troublesome in southern turfgrasses because of their similar growth habit to that of the turfgrass. Knotgrass stolons contact the soil root and grow like stolons of other perennial grasses such as common bermudagrass (*Cynodon dactylon* L.) (Huang et al., 1987). Nodes located on the shoots have a very high sprouting rate, and the plant has the capacity to root rapidly in warm weather. Weeds that are most competitive have rapid seedling growth rates and a high growth rate compared to the crop in which they are competing with as a problem weed. Knotgrass has tremendous capability for both growth and regeneration, and stems can elongate up to 3.3 cm per day at 30^{o}C (Noda, 1969).

When compared with turfgrasses in the southern United States, knotgrass is second only to common bermudagrass in average daily growth rate (Busey and Myers, 1979). However, knotgrass is very sensitive to shade and growth is substantially reduced under decreased light (Manual et al., 1979).

Knotgrass is often found growing in golf course roughs, fairways, and greens and home lawns in southern Louisiana. Knotgrass superficially resembles torpedograss and is often misidentified as that weed. Knotgrass samples are sent to the Louisiana State Cooperative Extension Service for proper identification after control measures fail.

Knotgrass Control. Mowing is the most common cultural practice that manages the growth of desirable turfgrass and aids in the control and growth of undesirable weeds (Ross and Lembi, 1999). Only those plant species that are specially adapted to defoliation can survive as a weed in turfgrass situations (Christians, 1998). Knotgrass is uniquely adapted to tolerate mowing because injury to, or the shortening of knotgrass stems increases the rate of sprouting and rooting (Huang et al., 1987). Therefore, consistent mowing favors the persistence of this weed. In fields infested by knotgrass from either seeds or over-wintering rhizomes and shoots, cultivation may eradicate the seedlings but cutting shoots and rhizomes into small pieces may also help to propagate this weed species (Huang et al., 1987).

Unlike most weeds that infest turfgrass, knotgrass cannot be selectively removed by any currently labeled herbicides. Current control measures are limited to sequential applications of MSMA or spot applications of glyphosate; however, MSMA only provides limited suppression (McCarty et al., 2001). Since knotgrass has a superficial resemblance to torpedograss, golf superintendents mistakenly apply quinclorac, which has not been evaluated for knotgrass control. Knotgrass potentially could become a serious problem of turf throughout the Gulf Coast states. There are currently no cultural or single, selective chemical methods to control knotgrass adequately. The tremendous regenerative capacity and the lack of sufficient control methods favors the continued spread of knotgrass as a weed in turf.

Graminicides, members of the aryl-oxy-phenoxy and cyclohexinoide family, have no activity on broadleaved species or nongrass monocots (Ross and Lembi, 1985). These compounds are absorbed rapidly by the plant tissue and move in the symplast to the growing points, including those of underground perennial structures, where they inhibit meristematic activity. Several graminicides are useful for the control of grassy weeds in turfgrass (Anderson, 1996; McCarty et al., 1986). However, there is no documented research that has evaluated any graminicides for knotgrass control.

Nonselective herbicides have resulted in injury to the desired turfgrass species (Fleming et al., 1978; Burt, 1980). However, spot treating knotgrass with glyphosate is a recommended control practice in turfgrass (McCarty et al., 2001). Glufosinate (Liberty) is a nonselective postemergence herbicide used in orchards, vineyards, and glufosinate resistant crops (Ross and Lembi, 1999). Although glufosinate is considered nonselective, weed species vary considerably in sensitivity to this herbicide (Ridley and McNally, 1985; Steckel et al., 1997). Sulfosate (Touchdown) is a nonselective postemergence herbicide that is the sulfonium salt of glyphosate (Anderson, 1996). There are no documented studies that evaluate either glufosinate or sulfosate for knotgrass control. Therefore, very little information is available concerning the control of this troublesome weed.

TORPEDOGRASS

Torpedograss is a perennial, rhizomatous, C_4 plant that is a severe weed of 19 crops in 27 countries (Holm et al., 1977). It is a major weed in orchards, pastures, field crops, and noncropland areas in tropical climates of Africa, Europe (Holm et al., 1977), and Indonesia (Soerjani et al., 1987). Peng (1984) describes torpedograss as the major weed affecting sugarcane production in Taiwan. The first reported collection of the plant in North America was near Mobile, Alabama in 1876 (Tarver, 1979). In the United States, the weed is indigenous to the Gulf Coast region from Florida west into Texas (Murphy et al., 1992). The dispersal of the weed in the southern United States can be attributed to the distribution of the plant by the United States Department of Agriculture in the 1920's for planting as a livestock forage (Tarver, 1979). However, torpedograss is lower in protein than most improved forage grasses and may be more competitive than desirable forages (Holm, 1977). Ironically, it was later determined that torpedograss can be toxic to horses (Tarver, 1979). In Florida, torpedograss has been reported as a significant competitor in citrus groves (Baird et al., 1983).

Torpedograss primarily is found in moist, sandy soil in coastal areas. However, the weed can grow on heavy upland soils and has excellent drought tolerance (Holm et al., 1977). Torpedograss usually cannot survive under permanently flooded conditions but it can withstand occasional flooding, while acidic soils do not appear to negatively affect its growth (Wilcut et al., 1988).

Studies conducted by Wilcut et al. (1988) determined that growth is greater with day/night temperature regimes of 30/25^{o}C than with temperatures of 27/22^{o} or 24/18^{o} C. Rhizomes survived temperatures as low as -14^{o}C but failed to survive when temperatures were reduced to -28^{o}C. Results from these studies indicate that torpedograss rhizomes do not exhibit cold tolerance and therefore seems to be limited to areas where the winters are mild.

The plant mainly spreads by course, extensively creeping rhizomes which may extend as far as 7 m from the parent plant (Holm et al., 1977). Torpedograss does not appear to produce viable seed in the Southeastern United States (Wilcut et al., 1988) or Taiwan (Peng, 1984); however, viable seed production has been reported in Portugal (Moreira, 1978).

The extensive rhizome system of torpedograss contains high levels of carbohydrate reserves that provide the capacity for rapid regeneration of shoots and new rhizomes from small fragments (Manipura and Somaratine, 1974). Axillary buds produced along the entire length of the rhizomes can withstand burial depths of 8 - 16 cm (Wilcut et al., 1988). Growth is very rapid, and under favorable conditions, dense subterranean systems may be produced within a few months (Chandrasena, 1990).

Invasive Weed in Turfgrass. A weed is defined as any plant growing out of place. When weeds occur as part of a turfgrass community, the definition can be expanded to an undesirable plant because of its disruptive effect on the esthetic appearance, stabilizing capacity, or the overall utility of a turf stand (Turgeon, 1996). The most undesirable characteristic of weeds in turf is the disruption of the visual uniformity (McCarty, 1994).

Torpedograss has invaded fine turfgrasses throughout the Southern U.S. (McCarty et al., 1993). It has been estimated that as much as 90% of the golf courses in southern Mississippi have some degree of torpedograss infestation (Fleming et al., 1978). The weed has invaded golf courses and home lawns throughout south Louisiana. It is particularly troublesome in the New Orleans area where rhizome contaminated river silt from the Bonne Carre Spillway is used for lawn repair and construction (Koske[1], personal communication).

Intensively managed fine turfgrasses require frequent mowings and an ample quantity of nutrients for optimal growth. Weeds that are major problems in turfgrass are those that can withstand frequent close mowings (Ross and Lembi, 1985). Because of the tremendous regenerative capacity of torpedograss, frequent clippings do not suppress the growth (Manipura and Somaratine, 1974). As expected torpedograss growth and photosynthetic responses are enhanced by adequate nitrogen availability (Bowman, 1991). The weed is very competitive and can reduce common bermudagrass (*Cynodon dactylon* L.) yield by 37 % (Wilcut et al., 1988).

---

[1]Dr. Tom Koske, Professor, Department of Horticulture, Louisiana State University.

Torpedograss Control. Perennial grasses are the most difficult group of weeds to remove selectively from established turf (Ross and Lembi, 1985). Torpedograss has invaded fine turfgrasses in the southern United States because of its tolerance to most commonly used turfgrass herbicides (McCarty et al., 1993). The control of torpedograss requires the destruction of the underground rhizome system and rhizome buds, in addition to the destruction of top growth (Chandrasena, 1990). Moderate cultivation fails to control torpedo grass and may contribute to the spread of the weed (Kigel and Kollier, 1985). Torpedograss control has been limited to nonselective herbicides such as glyphosate (Manipura and Somaratine, 1974; Burt, 1980; Baird et al., 1983), paraquat (Manipura and Somaratine, 1974), and dalapon (Fleming et al., 1978). Glyphosate gives excellent control of torpedograss at rates of 2.24 kg ha^{-1} but inconsistent control at 1.12 kg ha^{-1} (Burt and Dudeck, 1975). Up to 4.48 kg ha^{-1} may be necessary for 100 % control of all rhizome buds in well-developed rhizome systems (Chandrasena, 1990). Applications in the fall may provide better control than spring applications (Baird et al., 1983). However, nonselective herbicides injure desired turfgrass species (Fleming et al., 1978; Burt, 1980), and individual turf species respond differently to various herbicides (Ross and Lembi, 1985). Bentgrass (*Agrostis* sp. L.) and St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze) are particularly susceptible to injury from turf herbicides. Asulam, labeled for grassy weed control in St. Augustinegrass, gives immediate control; however, torpedograss recovers very quickly (Fleming et al., 1978). MSMA, registered for use in bermudagrass, is not an effective herbicide for torpedograsss control (Fleming et al., 1978; McCarty et al., 1993).

Quinclorac was developed for annual grass and broadleaf weed control in rice (Street et al., 1988). Research has also shown that quinclorac can be an effective option for the selective removal of torpedograss in bermudagrass (McCarty, 1992; McCarty et al., 1993). Common and hybrid bermudagrass are the only southern turfgrasses that tolerate quinclorac (Drive[2]).

Singh and Tucker (1986) reported sethoxydim and fluazifop were effective herbicides for controlling torpedograss in citrus. Repeat applications of sethoxydim were necessary due to regrowth. Most southern turfgrass species, excluding zoysiagrass (*Zoysia* sp.) are intolerant to fluazifop (Fusilade II[2]), and the only southern turfgrass species tolerant to sethoxydim (Vantage[3]) is centipedegrass (*Eremochloa ophiuroides* [Munro.] Hack). Sethoxydim has not provided acceptable torpedograss control in centipedgrass (Lobb's Horticultural Spray[4], personal communication). Currently, there are no effective cultural

---

[2]Drive™ herbicide label, BASF Corporation, Research Triangle Park, NC 27709.

[3]Fusilade II™ herbicide label. Syngenta Turf and Ornamental Products. P. O. Box 18300, Greensboro, NC 27419.

[4]Vantage™ herbicide label. TopPro™ Specialties 530 Oak Court Drive, Suite 100. Memphis, TN 38117.

[5]Lobbs Horticultural Spray, Baton Rouge, LA 70821

practices or registered herbicides that provide selective removal of torpedograss in centipedegrass.

Centipedegrass is one the most commonly utilized turfgrass species for home lawns in Louisiana. The turf is popular because of its low fertility requirements and its resistance to disease and insects (Turgeon, 1996). Additionally, centipedegrass has excellent tolerance to the graminicide, sethoxydim (McCarty et al, 1986). Sethoxydim, a cyclohexanedione herbicide, is very effective in controlling annual and perennial grasses (Ross Lembi, 1985), and it kills susceptible grasses by inhibiting lipid biosynthesis (Anderson, 1996). However, torpedograss appears to tolerate sethoxydim rates that are not phytotoxic to centipedegrass (Lobbs Horticultural Spray, personal communication). Control is not achieved and continuous retreatment is necessary for weed suppression. Infestations are so severe in some lawns that total renovation is necessary.

Clethodim (Envoy), a graminicide, is excellent for the selective removal of bermudagrass in centipedegrass with minimal injury to the turfgrass (Cox et al., 1999). The herbicide mode of action is very similar to sethoxydim. To date, no documented research has been conducted to evaluate this herbicide for torpedograss control in centipedegrass.

Knotgrass and torpedograss are perennial grasses that are extremely difficult to remove in established turfgrass. There are currently no cultural or single, selective chemical methods to control knotgrass and torpedograss, adequately in all principal turfgrasses in the Southeast United States. The research herein will investigate the potential for controlling these troublesome creeping perennial grasses that invade fine turfgrasses in Louisiana.

LITERATURE CITED

Allred, K. 1982. *Paspalum distichum* L. var. *indutum* Shinners Poaceace. Great Basin Naturalist. 42:101-104.

Anderson W. P. 1996. Weed Science Principles and Application. West Publishing Co. p. 104.

Baird, D. D., V. M. Urrutia, and D. P. H. Tucker. 1983. Management systems with glyphosate on torpedograss in citrus. Proc. South. Weed Sci. 36:201.

Bowman, W. D. 1991. Effect of nitrogen nutrition on photosynthesis and growth in C_4 *Panicum* species. Plant, Cell and Environment. 14:295-301.

Burt, E. O. 1980. Glyphosate for torpedograss and bermudagrass control. p. 257-262 in J. B. Beard, ed. Prod. Int. Turfgrass Res. Conf., 3rd. Madison, WI.

Burt. E. O., and A. E. Dudeck. 1975. Glyphosate - Four years of results. Proc. South. Weed Soc. 28:152-153.

Busey, Philip and Barbara J. Myers. 1979. Growth rates of turfgrasses propagated vegetatively. Agr. J. 71:817-821.

Chandrasena, J. P. N. R. 1990. Torpedograss (*Panicum repens* L.) control with lower rates of glyphosate. Trop. Pest Management. 36(4)336-342.

Christians, N. 1998. Fundamentals of turfgrass management. Ann Arbor Press, Chelsea, Michigan.

Cox C. J., L. B. McCarty, and J. K. Higingbottom. Envoy (clethodim) for bermudagrass control and centipedegrass tolerance. Proc. South. Weed Sci. 52:68.

Duncan, R. R. and R. N. Carrow. 2000. In: Seashore Paspalum the Environmental Turfgrass. Ann Arbor Press, Chelsea, Michigan. p. 15.

Ellis, R. 1974. Comparative leaf anatomy of *Paspalum paspalodes* and *P. vaginatum.* Bothalia. 11:235-241.

Fleming, D. C., H. D. Palmertree, and D. W. Houston. 1978. Screening herbicides for torpedograss control in turf. Proc. South. Weed Sci. Soc. 30:136.

Good, R. 1964. The geography of flowering plants. Longmans, Green and Company., London. 518pp.

Holm, L., J. Doll, E. Holm, J. Pancho, and J. Herberger. 1997. World Weeds-Natural Histories and Distribution. 1129 pp.

Holm, L., G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. The Worlds Worst Weeds Distribution and Biology. Univ. Press of Hawaii Honolulu. 609 pp.

Huang W.Z., A.I Hsiao. and L. Jordan. 1987. Effects of temperature, light and certain growth regulating substances on sprouting, rooting and growth of single-node rhizome and shoot segments of Paspalum distichum L. Weed Res. 27:57-67.

Johnson, B. J. 1976. Renovation of turfgrass with herbicides. Weed Sci. 24:467-472.

Jovet, P. and M. Guedes. 1972. *Paspalum distichum* L. and *P. paspalodes* (Michx.) Scribn. Taxon. 21:546.

Karnok, K. J. Turfgrass Management Information Directory. 2000. Ann Arbor Press. Chelsea, Michigan. p. 256

Kigel, J. and D. Kollier. 1985. Asexual reproduction in weeds. Pages 65-100 in S. O. Duke, ed. Weed Physiology. Volume I. Reproduction and Ecophysiology. CRC Press, Boca Raton, FL.

Manipura, W. B. and A. Somaratine. 1974. Some of the effects of manual and chemical defoliation on the growth and carbohydrate reserves of *Panicum repens*. Weed Res. 14:167-172.

Manuel, J. S., and B. L. Mercado. 1977. Biology of Paspalum distichum. I. Pattern of growth and asexual reproduction. Philippine Agriculturist. 61:192-198.

Manuel, J. S., B. L. Mercado, and R. T. Lubigan. 1979. Approaches to the control of *Paspalum distichum* L. in lowland rice. Philippine Agricul. 62:255-261.

McCarty, L. B. 1992. Quinclorac evaluations in warm-season turfgrasses. Proc. South. Weed Sci. Soc. 45:136.

McCarty, L. B. 1994. Weed management. In: Best Management Practices for Florida Golf Courses. Univ. Florida, Gainsville p. 128-143.

McCarty, L. B., J. W. Everest, D. W. Hall, T. R. Murphy, and F. Yelverton. 2001. In: Color Atlas of Turfgrass Weeds. Ann Arbor Press. 298 pp.

McCarty, L. B., J. M. Higgins, and L. C. Miller, and T. Whitwell. 1986. Centipede tolerance to postemergence grass herbicides. HortSci. 21:1405-1407.

McCarty, L. B., J. M. Higgins, and D. L. Colvin. 1993. Selective torpedograss (*Panicum repens*) control in bermudagrass (*Cynodon* spp.) turf. Weed Tech. 7:911-915.

Moreira, I. 1978. Propagation of *Panicum repens* by seed. Weeds and herbicides in the Mediterranean Basin. Proc. Mediterr. Herb. Symp. Vol. 1:1-7.

Murphy, T. R., L. B. McCarty, D. Hall, D. L. Colvin, R. Dickens, and J. W. Everest. 1992. Weeds of Southern Turfgrasses. Fla. Coop. Ext. Serv., Gainsville, Fl. 208.

Noda, K. 1969. Specific hazardous weeds and their on paddy rice fields. 2nd Asian-Pacific Weed Sci. Soc. Conf. 97-111 pp.

Okuma M. and S. Chikura. 1984. Ecology and control of a subspecies of Paspalum distichum L. growing in creeks in the paddy area on the lower reaches of Chikugo River in Kyushu. Weed Res. Japan. 29:45-50.

Okuma M., S. Chikura, and Y. Moriyama. 1983. Ecology and control of a subspecies of Paspalum distichum L. growing in creeks in the paddy area on the lower reaches of Chikugo River in Kyushu. Weed Res. Japan. 28:31-34.

Peng, S. Y. 1984. The biology and control of weeds in sugarcane. Developments in Crop Science (4). New York: Elsevier Science.

Ridley, S. M. and S. F. McNally. 1985. Effects of phosphinothricin on the isoenzymes of glutamine synthetase isolated from plant species which variying degrees of susceptibility to the herbicide. Plant Sci. 39: 31-36.

Ross, M. A., and C. A. Lembi. 1999. Applied Weed Science. Macmillan Publishing Co. New York. p. 202.

Ross, M. A., and C. A. Lembi. 1985. Applied Weed Science. Macmillan Publishing Co. New York. p. 262.

Singh, M. and D. P. H. Tucker. 1986. Fluazifop-butyl and sethoxydim for grass control in citrus. Proc. South. Weed Sci. Soc. 39:184.

Silveus, W. A. 1933. Texas grasses. The Clegg Co., San Antonio, TX.

Shibayama, H. and M. Miyahara. 1977. Seasonal changes of growth of aquatic weeds and their control. Proc. 6th Asian-Pacific Weed Sci. Soc. Conf. 258-262.

Soerjani, M., A. J. G. H. Kostermans, and G. Tjitrosoepomo. 1987. Weeds of Rice in Indonesia.

Steckel, G. J., S. E. Hart, and L. M. Wax. 1997. Absorption and translocation of glufosinate on four weed species. Weed Sci. 45:378-381.

Street, J. E., M. E. Kurtz, and C. E. Snipes. 1988. Efficacy of BAS 51400H in rice. Abstr. Weed Sci. Soc. Am. No. 2.

Tarver, D. P. 1979. Torpedograss (*Panicum repens* L.). Aquatics 1:5-6.

Turgeon A. J. 1996. Turfgrass Managment. Prentice Hall, New Jersey. p. 234.

Wilcut John W., Roland R. Dute, Bryan Truelove, and Donald. E. Davis. 1988. Factors limiting the distribution of cogongrass (*Imperata cylindrica*) and torpedograss (*Panicum repens*). Weed Sci. 36:577-582.

CHAPTER 2

DIFFERENTIAL RESPONSE OF KNOTGRASS (*PASPALUM DISTICHUM* L.) TO HERBICIDES

INTRODUCTION

Knotgrass (*Paspalum distichum* L.) is a spreading, mat-forming perennial grass with shallow rhizomes and creeping, extensively branched stolons with adventitious roots at the nodes (Holm et al., 1997). Although the plant thrives in tropical and subtropical regions, the species is common in temperate climates such as Japan, Great Britain, and Washington in the United States (Good, 1964). Knotgrass can be seen throughout California at lower altitudes, occurring in wet pastures and along irrigation ditches (Huang et al., 1987).

Knotgrass is a weed of 20 crops in 61 countries (Holm et al., 1977). The plant is classified as an anchored, emergent aquatic weed but often invades upland crops from irrigation canals and ditch banks (Holm et al., 1997). Knotgrass is considered one of the most troublesome weeds of tea and rice throughout the world (Holm et al., 1977). The weed is utilized for levee bank stabilization in Australia (Duncan and Carrow, 2000). In the United States, the species is listed as an invasive weed of turfgrass (McCarty 2001; Karnok 2000).

The key features that aid in identification of knotgrass are the dense mat of stolons and shallow rhizomes, membranous ligules, short internodes, and two rows of tightly packed spikelets on the underside of both racemes (Holm et al., 1997). The degree of plant pubescence in the plant increases from the Atlantic to the Pacific coast in the United States (Allred, 1982). Knotgrass is taxonomically similar to seashore paspalum (*Paspalum vaginatum* O. Swartz) (Jovet and Guedes, 1972).

Anatomical comparison of the leaves of both species revealed sufficient differences to justify their classification as separate species (Ellis, 1974). Seashore paspalum has a glabrous second glume, whereas, the second glume is hairy on knotgrass. There are differences in preferred habitat between the two species. Seashore paspalum colonizes saline ecosystems such as along seacoast and brackish sands, whereas, knotgrass can be found dispersed over a wider geographical area, but growing in freshwater, moist habitats (Silveus, 1933).

Knotgrass propagates readily by means of seeds, and rhizomes (Manual and Mercado 1977). Okuma and Chikura (1984) reported that knotgrass is capable of producing 100 thousand seed m^{-2} under optimum growing conditions. Only 5 to 10% of the flowers produced form seeds and seeds mature 20 to 30 days after flowering (Okuma and Chikura, 1984). Seed germination rates do not exceed 40% when subjected to optimum temperatures. Huang et al (1987) reported that knotgrass seed treated with H_2SO_4 provided 60-95% germination. Seed coverings including the hull and seed coat membranes are the main factors regulating the germination.

Several researchers have suggested that in addition to seeds and rhizomes, the ability of buds from stem segments to root represents a third mechanism that favors the persistence of the weed (Manual and Mercado, 1977; Okuma and Chikura, 1984;). Manual and Mercado (1977) suggested that the primary method of reproduction was sprouting from the nodes of aerial stems while rhizomes and seeds play a lesser role in the distribution of the plant. In fact, aerial shoots (stolons) sprout faster than rhizomes and stolon contact with the soil stimulates new root production (Huang et al., 1987). Stolons that have been injured or cut can form new plants in only 36 hours (Holm et al., 1997). The rate of sprouting and rooting increases when temperatures are between 30 and 40°C and little growth occurs at 10°C or less. Plants growing in water survive winter in Japan even when ice forms on the water's surface (Shibayama and Miyahara, 1977).

Invasive Weed of Turfgrass. Creeping perennial weeds such as knotgrass are particularly troublesome in southern turfgrass because of shared growth habits. Knotgrass stolons that contact the soil root and behave like stolons of other perennial grasses such as common bermudagrass (*Cynodon dactylon* L.) (Huang et al., 1987) and has shown the capacity to root rapidly in warm weather. Weeds that are most competitive have rapid seedling growth and a high growth rate compared to the crop with which it is interfering. When compared with other turfgrasses in the southern United States, knotgrass was second only to common bermudagrass in average daily growth rate (Busey and Myers, 1979). Knotgrass has a tremendous capability for growth with reports of stem elongation up to 3.3 cm per day at 30°C Noda (1969).

The weed is often found growing in golf course roughs, fairways, and greens and home lawns in southern Louisiana. Highly managed turfgrass favors knotgrass growth because the plant is well adapted to wet soils and responds favorably to nitrogen fertilizer (Huang et al., 1987). Knotgrass superficially resembles torpedograss and is often misidentified.

Knotgrass Control. Mowing is the most common cultural practice that manages the growth of desirable turfgrass and aids in the control and growth of undesirable weeds. Only species that are specially adapted to defoliation can survive as a weed of turf (Christians, 1998). Knotgrass is uniquely adapted to tolerate mowing because injury to, or shortening of knotgrass stems increases the rate of sprouting and rooting (Huang et al., 1987). In fields being infested from seeds and over-wintering rhizomes and shoots, cultivation may eradicate seedlings, but cutting shoots and rhizomes into small pieces may only help to propagate this weed species (Huang et al., 1987).

Unlike most weeds that infest turfgrass, knotgrass cannot be selectively removed by currently labeled herbicides. Current control measures are limited to sequential applications of MSMA (McCarty et al., 2001) which only provide limited suppression. Because of its superficial resemblance to torpedograss, golf superintendents mistakenly apply quinclorac. Quinclorac controls torpedograss (*Panicum repens* L) in bermudagrass but has not been evaluated for knotgrass control (McCarty et al., 1993).

Graminicides, members of the aryl-oxy-phenoxy and cyclohexinoide family, have no activity on broadleaved species or nongrass monocots (Ross and Lembi, 1985). These compounds are absorbed rapidly by the plant tissue and move in the symplast to the growing points (including those of underground perennial structures), where they inhibit meristematic activity and lipid biosynthesis. Several graminicides are useful for the control of grassy weeds in turfgrass (Anderson, 1996). There is no documented research that has evaluated the efficacy of graminicides for the control of knotgrass.

Perennial grasses such as knotgrass are considered the most difficult weeds to remove selectively from established turf. They can be removed by hand or if they are in limited patches or as scattered plants by spot treating with effective symplastically translocating herbicides (Ross and Lembi, 1999). Glyphosate is translocated to rhizomes and provides control of perennial weeds (Claus and Behrens, 1976). Spot treating knotgrass with glyphosate is a recommended control practice in turfgrass (McCarty et al., 2001). Glufosinate (Liberty/Finale) is a nonselective postemergence herbicide used in orchards, vineyards, and glufosinate resistant crops. Although glufosinate is considered nonselective, weed species vary considerably in sensitivity to the herbicide (Ridley and McNally, 1985; Steckel et al., 1997). Sulfosate is a nonselective postemergence herbicide that is the sulfonium salt of glyphosate (Anderson, 1996). There are no documented studies that evaluate glufosinate or sulfosate for knotgrass control.

Knotgrass is very aggressive and potentially could become a serious problem of turf throughout the Gulf Coast. The weed's tremendous regenerative capacity and lack of sufficient control methods favors the continued spread as a weed.
The objective of this study is to determine control options for knotgrass.

MATERIALS AND METHODS

Perennial species most often occur in sporadic infestations that require large plots thus making the evaluations of results very difficult (Frans et al., 1986). Field plots usually need to be 6 to 20 m wide by 30 to 50 m long. Large field plots are usually not practical for turfgrass weed control research because of the space that is needed. Due to the sporadic occurrence of knotgrass in turfgrass, it is very difficult to evaluate several herbicides effectively under field conditions. Pot studies allow the opportunity to test several herbicides on uniform plants in a relatively small area.

Three separate pot experiments were conducted outdoors at the Burden Research Station in Baton Rouge, LA in 1998 and repeated in 1999 to evaluate herbicides for knotgrass control. Knotgrass control experiments conducted included a graminicide study, nonselective herbicide comparison, and evaluation of quinclorac.

Knotgrass plants were collected from the Louisiana State University Golf Course in Baton Rouge, LA. Selections were initially increased by planting stolons in flats containing Jiffy Mix Plus[1]. Prior to planting in pots, stolons were cut into one or two node sections and placed vertically in divided flats containing Jiffy Mix Plus for approximately 10 days. Rooted plants were transferred to 2.8 L nursery pots containing pine bark media for both the graminicide and nonselective studies or river silt for the quinclorac studies. Pine bark media was amended with 12-6-6 Stagreen[2] slow release fertilizer at 17 g pot^{-1} and the media pH was 5.3. Since quinclorac is absorbed through both the foliage and roots, river silt was used as the potting media for the quinclorac study (Stovicek and Penner, 1986). River silt was amended with 12-6-6 slow release fertilizer at 17 g pot^{-1}. Media pH for was 6.3. Daily overhead irrigation was applied at a rate of 0.64 cm.

---

[1]Jiffy-Mix Plus, potting media consisting of 50% sphagnum peat and 50% vermiculite. Jiffy Products Inc. Batavia, IL 60510.

[2]Stagreen 12-6-6, slow release fertilizer, Purcell Industries Inc., Birmingham, AL.

Knotgrass was allowed to establish for four weeks until 100 % coverage of the pot media surface area was achieved. Three days prior to herbicide applications, knotgrass stolons were trimmed back evenly with a rechargeable Black and Decker grass shear using the pot circumference as a guide. Plants were trimmed to provide a uniform plant height of 5.1 cm above the potting media surface. Herbicide applications were made to knotgrass with a hand boom equipped with two Teejet 8003 flat fan nozzles spaced 41 cm apart. Herbicides were mixed in water in 3 L containers and applied as a broadcast spray at a spray volume of 280 L ha^{-1} of water using a CO_2 pressurized backpack sprayer.

For the graminicide studies, studies were arranged in randomized complete block design (RCBD) with 25 total treatments. Graminicides evaluated were: fluazifop, sethoxydim, fenoxaprop, clethodim, quizlafop, and diclofop. MSMA, the most commonly applied herbicide for grassy weed control in bermudagrass turf, was included as the standard. Herbicide rates were low, high, and sequential (split) applications of low rate, 4 weeks after initial application (WAI).

The low and high rates applied for each herbicide were as follows: sethoxydim (0.31, 0.62 kg ha^{-1}), fluazifop (0.28, 0.56 kg ha^{-1}), clethodim (0.14, 0.28 kg ha^{-1}), quizalofop (0.09, 0.18 kg ha^{-1}), fenoxaprop (0.21, 0.42 kg ha^{-1}), diclofop (0.84, 1.70 kg ha^{-1}), and MSMA (1.70, 3.40 kg ha^{-1}). Agri-Dex[3], a crop oil concentrate, was

---

[3]Agri-Dex, paraffin-based petroleum oil and surfactant blend. Helena Chemical Co. Memphis, TN 38119.

added to the spray solution at a rate of 1% volume per volume (v/v) to all graminicides. MSMA[4] had a nonionic surfactant included in the formulation.

In 1998 (Table 2.1), initial herbicide applications occurred on June 8 followed by sequential applications on July 6. In 1999, initial herbicide applications were made on May 15 followed by sequential applications on June 12. Studies were concluded 56 days after the initial application (August 4, 1998 and July 11, 1999). Plant shoots and roots were harvested and separated and placed in a forced air draft oven at 60°C for 7 days. Knotgrass biomass for shoots and roots was taken.

Table 2.1. Herbicide application timings, and environmental information for graminicide studies conducted at the Burden Reseach Center, Baton Rouge LA in 1998 and 1999.

Year	Initial	Sequential	Conclusion	Average temps (°C)	Rainfall (cm)
1998	June 8	July 6	August 4	29	14.0
1999	May 15	June 12	July 11	26	24.1

In the nonselective studies, studies were arranged in a randomized complete block design (RCBD) with 10 total treatments and four replications. Herbicides tested were glyphosate, glufosinate, and sulfosate. All herbicides were evaluated at equivalent rates of 1.1, 2.2, and 4.5 kg ha^{-1}. Glyphosate (Roundup Pro[5]) and glufosinate (Liberty[6]) have a surfactant included in the formulation. Induce[7], a

---

[4]MSMA Turf herbicide label, UHS, Denver, CO.

[5]Roundup Pro herbicide label, Monsanto Co., St. Louis, MO.

[6]Liberty herbicide label, Aventis Enviromental Science, Montvale, NJ.

[7]Induce is a proprietary blend of Alkyl Aryl Polyoxylkane Ether Free Fatty Acids, Helena Chemical Co., Memphis, TN.

nonionic surfactant, was included with the sulfosate[8] applications. In 1998, herbicide were applied on June 8 (Table 2.2) and the study was concluded on July 29. In 1999, herbicides were applied on May 17 and the study was concluded on July 14.

Table 2.2. Herbicide application timings, and environmental information for nonselective studies conducted at the Burden Reseach Center, Baton Rouge LA in 1998 and 1999.

Year	Initial	Conclusion	Average temps (^{o}C)	Rainfall (cm)
1998	June 8	July 27	28	13.4
1999	May 17	July 14	27	24.1

Quinclorac studies were arranged in a randomized complete block design with four treatments and four replications and. Treatments were quinclorac applied at 0.56, 1.12, and 2.24 kg ha^{-1}. Agri-Dex was added to the spray solution at a rate of 1% v/v as recommended by the quinclorac (Drive[9]) manufacturer. In 1998, herbicides were applied on June 8 (Table 2.3) and study was concluded on July 27. In 1999, herbicide applications occurred on July 2 and study was concluded on August 22.

Table 2.3. Initial herbicide application timing and environmental information for quinclorac studies conducted at the Burden Reseach Center, Baton Rouge LA in 1998 and 1999.

Year	Initial	Conclusion	Average temps (^{o}C)	Rainfall (cm)
1998	June 8	July 27	29	14.0
1999	July 2	August 22	32	16.2

[8]Touchdown 5 herbicide label, Syngenta Turf and Ornamental, Greensboro, NC.

[9]Drive herbicide label, BASF, Research Triangle Park, NC 27709.

Data collection. For all three studies, knotgrass control was evaluated by weekly visual control ratings as described by Willard (1958). Control ratings are subjective visual ratings, where 0 = no control and 100 % = death of the plant. A control rating of 85% is considered to be acceptable. Shoots and roots were harvested and dry biomass weights were determined for the graminicide studies. All experiments were repeated over time and data were subjected to ANOVA using SAS (SAS, 1989). Means were separated by Fisher's protected LSD at the 5% level. If no interactions occurred, data were pooled over years. Several of the herbicides evaluated in these studies are used for weed control in southern turfgrass (Table 2.4).

Table 2.4. Herbicides evaluated for knotgrass control and the southern turfgrass for which they are labeled.

Common name	Trade name	Southern turfgrass
Sethoxydim	Vantage	Centipedegrass
Fluazifop	Fusilade	Zoysiagrass
Clethodim	Envoy	Centipedegrass
Quizalofop	Assure	None
Fenoxaprop	Acclaim	Zoysiagrass
Diclofop	Illoxan	Bermudagrass
MSMA	MSMA	Bermudagrass, zoysiagrass
Glyphosate	Roundup Pro	Nonselective
Glufosinate	Liberty/Finale	Nonselective
Sulfosate	Touchdown	Nonselective
Quinclorac	Drive	Bermudagrass

RESULTS AND DISCUSSION

Graminicide Study. A treatment by year interaction was not observed for knotgrass control (Table 2.5). Therefore, data were pooled over two years.

At the 1 week after initial application (WAI) observation, knotgrass control was similar for all rates of sethoxydim. However, fluazifop provided significantly greater control than sethoxydim, fenoxaprop, and MSMA. All rates of clethodim

Table 2.5. Knotgrass control as affected by graminicides applied in a single application or sequentially[a] at Burden Research Center, Baton Rouge, LA. Data pooled over two years.

		Knotgrass control							
		WAI[b]							
Herbicide	Rate	1	2	3	4	5	6	7	8
	(kg ha^{-1})								
		%							
Untreated		0	0	0	0	0	0	0	0
Sethoxydim	0.31	61	87	84	83	72	70	65	65
Sethoxydim	0.62	64	90	90	90	88	88	85	85
Sethoxydim	0.31 fb 0.31	66	85	86	91	92	89	83	90
Fluazifop	0.28	88	95	92	96	96	95	95	95
Fluazifop	0.56	88	95	92	96	96	98	95	95
Fluazifop	0.28 fb 0.28	80	89	90	94	93	94	93	94
Clethodim	0.14	80	91	86	86	81	82	75	75
Clethodim	0.28	79	88	86	93	91	89	86	86
Clethodim	0.14 fb 0.14	71	86	83	91	91	86	78	81
Quizalofop	0.09	74	94	90	92	91	88	88	88
Quizalofop	0.18	75	94	91	92	92	94	91	91
Quizalofop	0.09 fb 0.09	70	91	89	90	92	91	86	89
Fenoxaprop	0.21	20	35	12	10	9	8	10	10
Fenoxaprop	0.42	44	64	35	19	8	9	27	27
Fenoxaprop	0.21 fb 0.21	14	41	12	6	24	9	12	13
Diclofop	0.84	35	43	33	12	14	14	14	14
Diclofop	1.70	71	83	68	63	54	62	62	62
Diclofop	0.84 fb 0.84	49	56	34	23	21	36	31	27
MSMA	1.70	30	29	13	8	13	19	23	23
MSMA	3.40	36	41	14	26	26	31	31	31
MSMA	1.70 fb 1.70	30	38	15	16	28	43	36	39
$LSD_{0.05}$		12	16	13	13	13	13	16	14

[a]Seqential application applied 4 weeks after initial application.
[b]Abbreviation: WAI = Weeks after initial application.

and quizalofop provided similar knotgrass control (70 to 80%) which was greater than all rates of fenoxaprop or MSMA.

Maximum control with lipid biosynthesis inhibiting herbicides such as graminicides is observed 10-21 days after application (Ross and Lembi, 1999). Knotgrass control 2 WAI was similar for diclofop, sethoxydim, clethodim, quizalofop, fluazifop, and ranged from 83 to 95%, respectively. Poor control observed with MSMA applied at 1.7 or 3.4 kg ha^{-1} and fenoxaprop applied at 0.21 kg ha^{-1} (< 45%). At 3 WAI, knotgrass control with fenoxaprop at 0.21 kg ha^{-1} was no greater than 12% and similar to the untreated check. However, fenoxaprop applied at the high rate (0.42 kg ha^{-1}) was equivalent to diclofop applied at its low rate (0.84 kg ha^{-1}). As the diclofop rate increased to 1.70 kg/ha, significantly better knotgrass control was achieved compared to diclofop at its low rate. Seashore paspalum, a similar species to knotgrass, has also shown sensitivity to diclofop rates exceeding 1.1 kg ha^{-1} (Johnson and Duncan, 1998). For 2-4 WAI, good to excellent knotgrass control was achieved by sethoxydim, fluazifop, clethodim, and quizalofop, regardless of the application timing. Sequential treatments were applied 4 WAI and resulted in control similar to both the low and high rates of these herbicides.

At 5 WAI (1 week after sequential applications), single applications of sethoxydim at 0.31 kg ha^{-1} (72%) were less effective than sequential applications at 0.31 kg/ha (88%) or a single application at 0.62 kg/ha (92%). Control observed from single low rate applications of fluazifop and quizalofop were equivalent to their sequential and high rates. Knotgrass control with graminicides followed this trend 6 WAI.

Split applications of MSMA did not increase control when compared to single high rate applications, 7 or 8 WAI (4 weeks after sequential). Control was very poor overall with this herbicide (<40%). MSMA is a contact herbicide and repeat applications are usually necessary to achieve control of perennial weeds (Anderson, 1996). It is evident that multiple MSMA applications will be necessary to achieve knotgrass suppression.

Fenoxaprop and diclofop resulted in less than 40% control from 3 to 8 WAI. The exception was diclofop at the high rate, which resulted in 54 to 68% control. Final visual observations 8 WAI (4 weeks after sequential applications) indicated single or split applications of fluazifop or quizalofop provided excellent knotgrass control (88-95%). Both fluazifop and quizalofop are very effective on other creeping perennials such as common bermudagrass and johnsongrass (*Sorghum halepense* L.) (Ross and Lembi, 1999). All applications of fluazifop provided better knotgrass control than single low rate (0.30 kg ha^{-1}) applications of clethodim. Single or split applications of fenoxaprop at 0.21 kg/ha and single applications of diclofop at 0.84 kg/ha were no better than the untreated check. Single applications of sethoxydim at 0.62 kg ha^{-1} were similar (85%) to sequential applications at 0.31 kg ha^{-1} (90%). Applications of sethoxydim, fluazifop, clethodim, and quizalofop were more effective than MSMA applications. Fluazifop applied at the low rate (0.28 kg ha^{-1}) provided 56% greater knotgrass control than MSMA.

Knotgrass biomass. Data for knotgrass shoot weight (Table 2.6) are pooled over years. A treatment by year interaction was observed for knotgrass root biomass, therefore, data are presented separately for 1998 and 1999.

Averaged across the two years, knotgrass shoot weights were reduced by all herbicide applications when compared to the untreated check. Regardless of the rate or the sequential application, shoot weights were reduced by sethoxydim,

Table 2.6. Knotgrass biomass for shoots and roots as influenced by herbicide applications in 1998 and 1999 at the Burden Research Center, Baton Rouge, LA.

Herbicide	Rate	Shoots[a]	Roots	
			1998	1999
	kg/ha	—— g ——	———— g ————	
Untreated		14.09	6.62	3.50
Sethoxydim	0.31	1.03	1.07	1.28
Sethoxydim	0.62	0.64	1.04	1.44
Sethoxydim	0.31 fb 0.31	0.59	1.31	0.59
Fluazifop	0.28	0.34	1.07	0.67
Fluazifop	0.56	0.24	0.93	0.28
Fluazifop	0.28 fb 0.28	0.35	0.86	0.51
Clethodim	0.14	1.40	1.91	1.49
Clethodim	0.28	0.63	1.36	0.48
Clethodim	0.14 fb 0.14	0.77	1.30	0.68
Quizalofop	0.09	0.25	1.03	0.65
Quizalofop	0.18	0.37	1.26	0.59
Quizalofop	0.09 fb 0.09	0.56	1.18	0.64
Fenoxaprop	0.21	7.38	4.53	3.41
Fenoxaprop	0.42	4.55	2.74	2.14
Fenoxaprop	0.21 fb 0.21	7.54	5.17	2.71
Diclofop	0.84	6.77	2.54	1.85
Diclofop	1.70	1.52	1.06	0.88
Diclofop	0.84 fb 0.84	2.57	2.21	1.05
MSMA	1.70	6.53	2.49	1.65
MSMA	3.40	4.22	2.46	1.22
MSMA	1.70 fb 1.70	2.92	2.07	1.56
$LSD_{0.05}$		1.98	1.23	1.00

[a]Data pooled over 1998 and 1999.

fluazifop, clethodim, and quizalofop (0.24 to 1.40 g). This is not unexpected since knotgrass control was the greatest for these herbicides. Single fenoxaprop applications at 0.42 kg ha^{-1} reduced shoot weight 38% when compared to single applications of fenoxaprop at 0.21 kg ha^{-1} (4.55 vs 7.54 g). MSMA applied sequentially reduced knotgrass shoot weights more than single high or low rates of MSMA.

In 1998, root weights were reduced by all herbicide applications when compared to the untreated check. As with shoot weights, regardless of the rate or the sequential application, roots weights were most reduced by sethoxydim, fluazifop, clethodim, and quizalofop (0.86 to 1.91 g) and equivalent to diclofop (1.06 g) applied at 1.70 kg ha^{-1}. No significant differences in root weight were observed among MSMA applications. For 1999, knotgrass root weights were not significantly reduced by single or split applications of fenoxaprop at 0.21 kg ha^{-1} when compared to the untreated check. In contrast to 1998, root weights for MSMA split treatments were equivalent to root weights for fluazifop, quizalofop, clethodim, sethoxydim, and diclofop (sequential and high rates). However, contact herbicides such as MSMA applied sequentially can deplete underground reserves and vegetative buds (Ross and Lembi, 1999). Single high rate applications of fluazifop (0.56 kg ha^{-1}) caused lower root weights than single high (0.62 kg ha^{-1}) or low (0.31 kg ha^{-1}) sethoxydim rates (0.28 vs 1.28 and 1.44 g). Root weights were similar for all fluazifop and quizalofop treatments (0.28 to 0.79 g).

Nonselective Study. Nonselective herbicides were evaluated at equal rates in 1998 and 1999 (Table 2.7). A treatment by year interaction was not observed for knotgrass control in the nonselective study and data were pooled across both years.

Glufosinate is a contact herbicide and foliage necrosis usually appears 1 to 2 weeks after application (Ross and Lembi, 1999). At 1 WAT (week after treatment), all rates of glufosinate controlled knotgrass 80%. Glyphosate and sulfosate controlled knotgrass < 20%. The symptom observed most often in plants treated with glyphosate or sulfosate in the 1 WAT evaluation was chlorosis on new growth. By 2 WAT, excellent control was observed with glufosinate (92%) regardless of rate applied. Glyphosate and sulfosate at 1.12 kg ha^{-1} controlled 68 and 61% of knotgrass, respectively. However, glyphosate applied at 4.48 kg ha^{-1} controlled knotgrass better than sulfosate at 1.12 kg ha^{-1}. At 3 WAT, glyphosate and sulfosate

Table 2.7. Knotgrass control as affected by nonselective herbicide at Burden Research Center, Baton Rouge, LA. Data pooled for 1998 and 1999.

		Knotgrass control						
		WAT[a]						
Herbicide	Rate kg ha^{-1}	1	2	3	4	5	6	7
		%						
Untreated		0	0	0	0	0	0	0
Glyphosate	1.12	14	68	91	94	95	96	95
Glyphosate	2.24	16	82	97	97	98	97	97
Glyphosate	4.48	18	86	96	97	97	97	98
Glufosinate	1.12	80	92	98	98	98	99	99
Glufosinate	2.24	80	92	98	98	99	99	99
Glufosinate	4.48	80	92	97	97	98	99	99
Sulfosate[b]	1.12	14	61	79	79	79	83	79
Sulfosate	2.24	14	74	94	94	96	96	96
Sulfosate	4.48	18	78	95	95	96	98	98
$LSD_{0.05}$		9	10	6	6	4	4	7

[a]Abbreviation: WAT = weeks after treatment.
[b]All sulfosate treatments applied with Induce, a nonionic surfactant at 0.25% v/v.

at 2.24 and 4.48 kg ha^{-1} controlled knotgrass similar to glufosinate. Glyphosate at 1.12 kg/ha was more effective than sulfosate at 1.12 kg/ha (91 vs 79%).

By 4 WAT, all rates of glyphosate were as effective as glufosinate. Sulfosate at 2.24 and 4.48 kg/ha was equivalent to glyphosate and glufosinate. However, sulfosate at 1.12 kg/ha was the least effective herbicide treatment (< 80%) and significantly lower control resulted compared to all other treatments. The same trend observed 4 WAT continued until the experiment was concluded at 7 WAT.

By 7 WAT, knotgrass control was at 99% for glufosinate treatments, regardless of rate applied. Glufosinate translocation is limited and it mostly kills the aboveground portions of the plant (Ross and Lembi, 1999). Ultimately, regrowth of the plant from underground structures is expected. Onsando et al. (1990) reported kikuyugrass (*Pennisetum clandestinum* Chiov.) control with glufosinate was as effective as glyphosate for 5 weeks after treatment. However, kikuyugrass treated with glufosinate eventually had regrowth six weeks after treatment. In the present study, knotgrass regrowth was not observed for plants treated with glufosinate, 7 WAT. As expected, glyphosate provided excellent knotgrass control at all rates. Glyphosate is very effective on most creeping perennials grasses. DeDatta et al. (1979) reported similar knotgrass control results for glyphosate at 2 kg ha^{-1} as reported in the present study.

Quniclorac Study. A treatment by year interaction was not observed for knotgrass control, therefore, data were pooled over years (Table 2.5). At 1 WAT, there were no differences among treatments. For 2-7 WAT, knotgrass control was greater with quinclorac at its highest rate (2.24 kg ha^{-1}) than all other herbicide treatments. Knotgrass was not satisfactorily controlled, however, as control never exceeded 35%. Quinclorac has been effective in controlling torpedograss (McCarty et al., 1993), a creeping perennial grass similar to knotgrass. However, single quinclorac applications did not control kikuyugrass (Cudney et al., 1993). Likewise, quinclorac even at high rates provides only limited control of knotgrass.

Table 2.8 Knotgrass control as influenced by quinclorac [a] rate at Burden Research Center, Baton Rouge, LA. Data pooled over two years.

	Knotgrass Control						
	WAT[b]						
Rate	1	2	3	4	5	6	7
kg/ha	%						
Untreated	0	0	0	0	0	0	0
0.56	3	5	6	9	9	11	6
1.12	4	8	9	13	11	11	12
2.24	4	12	18	26	31	34	29
$LSD_{0.05}$	NS	5	8	9	7	9	10

[a]Herbicide mixtures included Agri-Dex at 1% v/v.
[b]Abbreviation: WAT = Weeks after treatment

Results of the knotgrass control studies indicate that control is possible with many of the herbicides that are labeled for use in Southern turfgrasses. Clethodim (Envoy) and sethoxydim (Vantage), labeled for grassy weed control in centipedegrass, are very effective herbicides for knotgrass control. Knotgrass infestations in zoysiagrass can be managed with fluazifop (Fusilade II). However, diclofop (Illoxan), quinclorac (Drive), and MSMA, registered for use in bermudagrass, did not provide acceptable control. Sporadic infestations may be removed effectively with nonselective herbicides glyphosate and glufosinate.

LITERATURE CITED

Allred, K. 1982. *Paspalum distichum* L. var. *indutum* Shinners Poaceace. Great Basin Naturalist. 42:101-104.

Anderson W. P. 1996. Weed Science Principles and Application. West Publishing Co. p. 104.

Busey, Philip and Barbara J. Myers. 1979. Growth rates of turfgrasses propagated vegetatively. Agr. J. 71:817-821.

Christians, N. 1998. Fundamentals of turfgrass management. Ann Arbor Press, Chelsea, Michigan. p. 201.

Claus, J. S. and R. Behrens. 1976. Glyphosate translocation and quackgrass rhizome bud kill. Weed Sci. 24:149-152.

Cudney, D. W., J. A. Downer, V. A. Gibeault, J. M. Henry, and J. S. Reints. Kikuyugrass (*Pennisetum clandestinum*) Management in Turf. Weed Tech. 7: 180-184.

De Datta, S. K., F. R. Bolton, and W. L. Lin. 1979. Prospects for using minimum and zero tillage in tropical lowland rice. Weed Res. 19:9-15.

Duncan, R. R. and R. N. Carrow. 2000. In: Seashore Paspalum the Environmental Turfgrass. Ann Arbor Press, Chelsea, Michigan. p. 15.

Ellis, R. 1974. Comparative leaf anatomy of *Paspalum paspalodes* and *P. vaginatum.* Bothalia. 11:235-241.

Frans, R. R. Talbert, D. Marx, and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. In: Research Methods in Weed Science.

Good, R. 1964. The geography of flowering plants. Longmans, Green and Company., London. 518pp.

Holm, L., J. Doll, E. Holm, J. Pancho, and J. Herberger. 1997. World Weeds-Natural Histories and Distribution. 1129 pp.

Holm, L., G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. The Worlds Worst Weeds Distribution and Biology. Univ. Press of Hawaii Honolulu. 609 pp.

Huang W.Z., A.I Hsiao. and L. Jordan. 1987. Effects of temperature, light and certain growth regulating substances on sprouting, rooting and growth of single-node rhizome and shoot segments of Paspalum distichum L. Weed Res. 27:57-67.

Johnson, B. J. and R. Duncan. 1998. J. Environ. Hort. Influence of herbicides on establishment of eight seashore paspalum cultivars. 16(2):79-81.

Jovet, P. and M. Guedes. 1972. *Paspalum distichum* L. and *P. paspalodes* (Michx.) Scribn. Taxon. 21:546.

Karnok, K. J. Turfgrass Management Information Directory. 2000. Ann Arbor Press. Chelsea, Michigan. p. 256

Manipura, W. B. and A. Somaratine. 1974. Some of the effects of manual and chemical defoliation on the growth and carbohydrate reserves of *Panicum repens*. Weed Res. 14:167-172.

Manuel, J. S., and B. L. Mercado. 1977. Biology of Paspalum distichum. I. Pattern of growth and asexual reproduction. Philippine Agriculturist. 61:192-198.

McCarty, L. B. 1992. Quinclorac evaluations in warm-season turfgrasses. Proc. South. Weed Sci. Soc. 45:136.

McCarty, L. B., J. W. Everest, D. W. Hall, T. R. Murphy, and F. Yelverton. 2001. In: Color Atlas of Turfgrass Weeds. Ann Arbor Press

McCarty, L. B., J. M. Higgins, and D. L. Colvin. 1993. Selective torpedograss (*Panicum repens*) control in bermudagrass (*Cynodon* spp.) turf. Weed Tech. 7:911-915.

Noda, K. 1969. Specific hazardous weeds and their on paddy rice fields. 2nd Asian-Pacific Weed Sci. Soc. Conf. 97-111 pp.

Okuma M. and S. Chikura. 1984. Ecology and control of a subspecies of Paspalum distichum L. growing in creeks in the paddy area on the lower reaches of Chikugo River in Kyushu. Weed Res. Japan. 29:45-50.

Okuma M., S. Chikura, and Y. Moriyama. 1983. Ecology and control of a subspecies of Paspalum distichum L. growing in creeks in the paddy area on the lower reaches of Chikugo River in Kyushu. Weed Res. Japan. 28:31-34.

Osando, J. M., M. J. S. Magambo, and J. G. Omolo. 1990. Trop. Pest. Manag. 36(4): 346-348.

Ridley, S. M. and S. F. McNally. 1985. Effects of phosphinothricin on the isoenzymes of glutamine synthetase isolated from plant species which variying degrees of susceptibility to the herbicide. Plant Sci. 39: 31-36.

Ross, M. A., and C. A. Lembi. 1999. Applied Weed Science. Macmillan Publishing Co. New York. p. 289.

Ross, M. A., and C. A. Lembi. 1985. Applied Weed Science. Macmillan Publishing Co. New York. p. 262.

[SAS] Statistical Analysis Systems. 1989. Version 6, 4th ed, Volume 2. Cary, NC: Statistical Analysis Systems Institute. 846 p.

Shibayama, H. and M. Miyahara. 1977. Seasonal changes of growth of aquatic weeds and their control. Proc. 6th Asian-Pacific Weed Sci. Soc. Conf. 258-262.

Steckel, G. J., S. E. Hart, and L. M. Wax. 1997. Absorption and translocation of glufosinate on four weed species. Weed Sci. 45:378-381.

Stovicek, R. F. and K. Penner. 1986. Absorption of BAS 514. Proc. North Cent. Weed Control Conf. 41:94-95.

CHAPTER 3

TORPEDOGRASS (*PANICUM REPENS* L.) CONTROL IN CENTIPEDEGRASS (*EREMOCHLOA OPHIUROIDES* [MUNRO] HACK.)

INTRODUCTION

Torpedograss (*Panicum repens* L.) is a perennial, rhizomatous, C_4 plant that is a severe weed of 19 crops in 27 countries (Holm et al., 1977). It is a major weed of orchards, pasture, field crops, and noncropland areas in tropical climates of Africa, Europe (Holm et al., 1977), and Indonesia (Soerjani et al., 1987). Peng (1984) describes torpedograss as the major weed affecting sugarcane production in Taiwan.

The first reported collection of the plant in North America was near Mobile, Alabama in 1876 (Tarver, 1979). In the United States, the weed is indigenous to the Gulf Coast region from Florida west into Texas (Murphy et al., 1992). The dispersal of the weed in the southern United States can be attributed to the distribution of the plant by United States Department of Agriculture in the 1920's for planting as a livestock forage (Tarver, 1979). Torpedograss, however, is lower in protein than most improved grasses and may be more competitive than desirable forages (Holm, 1977). The weed has also been reported as a significant competitor in citrus groves in Florida (Baird et al., 1983).

Torpedograss prefers moist, sandy, coastal soils, however, it can grow on heavy upland soils and has excellent drought tolerance (Holm et al., 1977). The weed usually cannot survive under permanently flooded conditions but can withstand some occasional flooding. Acidic soils do not appear to negatively affect its growth (Wilcut et al., 1988).

Wilcut et al. (1988) reported growth was greater with day/night temperature regimes of 30/25°C than with temperatures of 27/22 or 24/18°C. Rhizomes survived temperatures as low as -14°C, but failed to survive when temperatures were reduced to -28°C. Results from these studies indicate that torpedograss rhizomes do not exhibit cold tolerance and seems to be limited to areas where winters are mild.

The plant spreads mainly by course, extensively creeping rhizomes which may extend as far as 7 m from the parent plant (Holm et al., 1977). Torpedograss does not appear to produce viable seed in the southeastern United States (Wilcut et al., 1988) or Taiwan (Peng, 1984). Yet, viable seed production has been reported in Portugal (Moreira, 1978). Torpedograss contains an extensive rhizome system that has high levels of carbohydrate reserves that provide the capacity for rapid shoot growth and the generation of new rhizomes from small fragments (Manipura and Somaratine, 1974). Axillary buds produced along the entire length of the rhizomes can withstand burial depths of 8 - 16 cm (Wilcut et al., 1988). Weed growth is very rapid and, under favorable conditions, dense subterranean systems may be produced within a few months (Chandrasena 1990).

Invasive Weed in Turfgrass. A weed is defined as any plant growing out of place. When weeds occur as part of a turfgrass community, the definition can be expanded to an undesirable plant because of its disruptive effect on the esthetic appearance, stabilizing capacity, or the overall utility of a turf stand (Turgeon, 1996). The most undesirable characteristic of weeds in turfgrass situations is the disruption of the visual uniformity (McCarty, 1994).

Torpedograss is a troublesome weed of turfgrasses throughout the Southern United States (McCarty et al., 1993). Fleming et al. (1978) estimated that as much as ninety percent of the golf courses in southern Mississippi have some degree of torpedograss infestation. The weed has invaded golf courses and home lawns throughout south Louisiana. It is a particularly troublesome weed in the New Orleans area where rhizome contaminated river silt from the Bonne Carre Spillway is used for lawn repair and construction (Koske[1], personal communication).

Intensively managed fine turfgrasses require frequent mowings and an ample quantity of nutrients for optimal growth. Weeds that are major problems in turfgrass are those that can withstand frequent close mowings (Ross and Lembi, 1985). Because of the tremendous regenerative capacity of torpedograss, frequent clippings do not suppress growth (Manipura and Somaratine, 1974). Torpedograss growth and photosynthetic responses are enhanced by adequate nitrogen availability (Bowman, 1991). The weed is very competitive and can reduce common bermudagrass (*Cynodon dactylon* L.) yield by as much as 37 % (Wilcut et al., 1988).

Torpedograss Control. Perennial grasses are the most difficult group of weeds to remove selectively from any established turf (Ross and Lembi, 1985). Torpedograss has invaded fine turfgrasses in the southern United States due to its tolerance to the most commonly used turfgrass herbicides (McCarty et al., 1993). Successful torpedograss control requires the destruction of the underground rhizome

---

[1]Dr. Tom Koske, Professor, Department of Horticulture, Louisiana State University

system and rhizome buds as well as the destruction of top growth (Chandrasena, 1990). Moderate cultivation fails to control torpedograss and may contribute to the spread of the weed (Kigel and Koller, 1985). Torpedograss control has been limited to nonselective herbicides such as glyphosate (Manipura and Somaratine, 1974; Burt 1980; Baird et al., 1983), paraquat (Manipura and Somaratine, 1974) and dalapon (Fleming et al., 1978). Glyphosate provides excellent torpedograss control at rates of 2.24 kg ha^{-1} but inconsistent control at 1.12 kg ha^{-1} (Burt and Dudeck, 1975). Rates as high as 4.48 kg ha^{-1} may be necessary for 100% control of all rhizome buds in well-developed rhizome systems (Chandrasena, 1990). Baird et al. (1983) reported better control with glyphosate applications in the fall than in the spring (Baird et al., 1983). Unfortunately, nonselective herbicides injure most desired turfgrass species (Fleming et al., 1978; Burt, 1980).

Individual turf species respond differently to various herbicides (Ross and Lembi, 1985). Bentgrass (*Agrostis* sp. L.) and St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze) are particularly susceptible to injury from herbicides. Asulam, registered for grassy weed control in St. Augustinegrass, gives immediate control of torpedograss; although, torpedograss recovers very quickly (Fleming et al., 1978). MSMA, registered for use in bermudagrass, is not effective for torpedograss control (Fleming et al., 1978; McCarty et al., 1993). Quinclorac was developed for annual grass and broadleaf weed control in rice (Street et al., 1988). However, research has shown quinclorac can be effective in the selective removal of torpedograss in bermudagrass turf (McCarty, 1992). The herbicide is safe to moderately safe on common and hybrid bermudagrass but it severely injures centipedegrass (Johnson and Murphy, 1989; Johnson, 1997).

Singh and Tucker (1986) reported that sethoxydim and fluazifop were effective herbicides for controlling torpedograss in citrus. However, repeat applications of sethoxydim were necessary due to regrowth. Most southern turfgrass species, excluding zoysiagrass (*Zoysia* sp.) are intolerant of fluazifop (Fusilade[2]) and the only southern turfgrass species tolerant to sethoxydim (Vantage[3]) is centipedegrass (*Eremochloa ophiuroides* [Munro.] Hack.) (Ross and Lembi, 1999).

Centipedegrass is one the most common turfgrass species utilized for lawns in Louisiana. The turf is popular because of its low fertility requirements and its resistance to disease and insects (Turgeon, 1996). Another advantage of centipedegrass is its excellent tolerance to the graminicide, sethoxydim. Sethoxydim, a cyclohexanedione herbicide, is very effective in controlling annual and perennial grasses in established centipedegrass turf (Ross and Lembi, 1999). Sethoxydim kills susceptible grasses by inhibiting lipid biosynthesis (Anderson, 1996). Although sethoxydim has been reported to be effective on torpedograss in citrus, the herbicide has not provided satisfactory control of the weed in centipedegrass (Lobbs Horticultural Services[4], personal communication). Control is

---

[2]Fusilade II™ herbicide label. Syngenta Turf and Ornamental Products. P. O. Box 18300, Greensboro, NC 27419.

[3]Vantage™ herbicide label. TopPro™ Specialties 530 Oak Court Drive, Suite 100. Memphis, TN 38117.

[4]Lobbs Horticultural Spray, Baton Rouge, LA 70821.

not achieved and costly retreatments are necessary for weed suppression. Infestations are so severe in some lawns that total renovation is necessary.

Clethodim, also in the cyclohexanedione family, has been shown to be more effective on creeping perennial grasses than sethoxydim (Ross and Lembi, 1999). Cox et al. (1999) reported better control of bermudagrass with clethodim compared to sethoxydim and minimal centipedegrass injury. Information concerning the efficacy of clethodim on torpedograss is not available.

Clethodim performance can be influenced by the type of adjuvant used in the spray solution (Jordan et al., 1996). The primary role of adjuvants in the spray solution is to enhance herbicide efficacy primarily through increasing herbicide absorption (Wanamarta and Penner, 1989). Improved surface coverage by the spray solution can increase herbicide absorption (Wannamarta and Penner, 1989). However, increased absorption does not always translate into an increased in efficacy. There is no information comparing clethodim efficacy applied with various spray adjuvants for improved cuticular penetration and control of torpedograss.

Torpedograss is the most invasive perennial grass that infests centipedegrass in southeast Louisiana. To date, there are no effective cultural practices or registered herbicides that provide selective removal of torpedograss in centipedegrass. The objective of this research was to determine the efficacy of clethodim for torpedograss control in centipedegrass.

MATERIALS AND METHODS

Torpedograss Control in Centipedegrass. Field studies were conducted on home lawns in 2001 in St. John Parish, Laplace, LA on Commerce silt loam (fine silty, mixed, thermic Fluvaquentic Endoaquepts) with 1.1% organic matter and a pH of 5.9 and St. Tammany Parish, Slidell, LA on Myatt fine sandy clay loam (fine loamy siliceous, thermic Typic Endoaquults) with 1% organic matter and a pH 5.7. The areas tested had established centipedegrass for at least the past four years and a severe natural infestation of torpedograss (30 to 50% ground cover). This level of torpedograss infestation is typical for lawns in southeast Louisiana.

The study design was a randomized complete block design (RCBD) with four replications. The plot size 1.50 m x 1.60 m. Clethodim at 0.30 and 0.60 kg ha^{-1} and sethoxydim at 0.31 kg ha^{-1} were applied to separate plots as single applications and sequentially. The initial application of each herbicide was made July 17 at LaPlace and July 23 at Slidell, followed by (fb) a second application 2 weeks later (July 31 and August 6). An untreated check was included in each study. All herbicides were applied with X-77[5] nonionic surfactant at 0.25% volume per volume (v/v) as recommended by the herbicide manufacturer. Studies at both locations were concluded 8 weeks after initial herbicide applications occurred.

Approximately four days prior to herbicide application, all turf areas were mowed at the recommended height of 5.08 cm with a rotary mower. Clippings were

---

[5]X-77, alkylarlpolyoxy-ethylene glycols, free fatty acids, and isopropanol. Chevron Chemical., Richmond, CA 90142.

not removed from the experimental site. After herbicide applications occurred, the centipedegrass was mowed weekly to maintain desired height. Turfgrass was irrigated when necessary for the duration of the studies to maintain optimum growth and prevent drought stress. Rainfall totals for the two locations were 5.7 cm for LaPlace (July 17 to September 11) and 5.0 cm (July 23 to September 17) for the Slidell location. Supplemental irrigation maintained optimum moisture conditions for the duration of these studies.

Herbicide applications were made to torpedograss with a hand boom equipped with two Teejet 8003[6] flat fan nozzles spaced 41 cm apart. The herbicides were mixed in water in 3L containers and applied as a broadcast spray at a spray volume of 280 L ha^{-1} of water using a CO_2 pressurized backpack sprayer.

Torpedograss control was determined by visual control ratings as described by Willard (1958). Control ratings are subjective visual ratings, where 0 = no control and 100 % = death of the plant. A control rating of 85% is considered acceptable. Control ratings began 1 week after the initial herbicide application and concluded 8 weeks later. Visual ratings of turfgrass injury were made biweekly and concluded 8 weeks after initial herbicide application. Turfgrass injury ratings were based on a 0 to 100 scale, where 0 = no injury, 1 to 15 = minor leaf discoloration, 16 to 30 = moderate discoloration with some plant necrosis, > 30 = moderate to severe leaf discoloration and plant necrosis, and 100 = complete kill. An injury rating >30% would be considered unacceptable for the turfgrass.

---

[6]Teejet 8003 flat fan nozzle. Spray Systems Co., Wheaton, IL 60287.

All experiments were repeated over location in 2001 and data were subjected to ANOVA using SAS (SAS, 1989). Means were separated by Fisher's protected LSD at the 5% level. If no interactions occurred, data were pooled over locations.

Clethodim + Adjuvant Evaluation. Studies were conducted in greenhouse facilities at the Hill Farm, on the campus of Louisiana State University, Baton Rouge, LA in 2002. The objective of the studies was to compare the efficacy of clethodim at 0.30 and 0.60 kg ha^{-1} applied with various adjuvants for torpedograss control. Adjuvants evaluated were X-77, Agri-Dex[7], Class Act[8], and Silwet L-77[9].

Torpedograss rhizome sections were collected from natural infestations located at the Burden Research Center, Baton Rouge, LA in 2001. Prior to planting, rhizomes were cut into one or two node sections and placed horizontally in 10 cm x 10 cm square plastic pots containing Jiffy-Mix Plus[10]. Rhizome sections were covered to a depth of 1.54 cm and the media was lightly compacted to insure good soil contact. Plantings were placed in a greenhouse maintained at 26^{o}C, and irrigation was applied as needed.

---

[7]Agri-Dex, paraffin-based petroleum oil and surfactant blend. Helena Chemical Co. Memphis, TN 38119.

[8]Class Act, corn based nonionic surfactant plus ammonium sulfate solution. Agriliance Co. St. Paul, MN 55164.

[9]Silwet L-77, silicone-polyether copolymer adjuvant. Loveland Industries Inc, Greely, CO 80632.

[10]Jiffy-Mix Plus, potting media consisting of 50% sphagnum peat and 50% vermiculite. Jiffy Products Inc. Batavia, IL 60510

Plants were allowed to establish for approximately 2-3 weeks until plants had at least 3 shoots emerged from the rhizome sections.

Four days prior to herbicide applications, torpedograss shoots were trimmed back evenly with a rechargeable Black and Decker grass shear. Plants were trimmed to provide a uniform plant height of 10.16 cm above the potting media surface. Herbicide applications were made to knotgrass with a hand boom equipped with two Teejet 8003 flat fan nozzles spaced 41 cm apart. Herbicides were mixed in water in 3L containers and applied as a broadcast spray at a spray volume of 280 L ha^{-1} of water using a CO_2 pressurized backpack sprayer.

The experimental design was a randomized complete block (RCB) with a factorial arrangement of treatments and four replications. Treatment factors were herbicide rates (clethodim at 0.30 and 0.60 kg ha^{-1}) and adjuvants (X-77, Agri-Dex, Class Act, and Silwet L-77). Data collected included visual control ratings taken biweekly and torpedograss regrowth. Torpedogras regrowth was determined at the conclusion of the experiments (8 weeks after herbicide application) by harvesting the surviving shoots above the soil line with rechargeable grass shears. Plant shoots were placed in a forced air draft oven at $60^{o}C$ for 7 days and dry weights were determined. Data were subjected to the ANOVA test for treatment effects and interactions, and means were separated using Fisher's Protected Least Significant Difference (LSD) Test at the 5% level of probability.

RESULTS AND DISCUSSION

Torpedograss Control in Centipedegrass. There were no interactions observed between treatments and locations, therefore torpedograss control data (Table 3.1) were combined over locations. At 1 week after the initial application (WAI), torpedograss control was greater with clethodim applications at the high rate (0.60 kg ha^{-1}) than all other herbicide treatments. However, by 2 WAI, torpedgrass control was similar for all rates of clethodim (≤ 25%). Control observed with clethodim applied at the high and low rate sequential treatments were greater than control observed with sethoxydim applications. Sequential applications were applied 2 WAI.

Table 3.1. Torpedograss control[a] in centipedegrass as affected by herbicide applied in a single application or sequentially[b] at Slidell and LaPlace, LA in 2001.

		WAI[c]				
Treatment	Rate	1	2	4	6	8
	kg ha^{-1}			%		
Untreated		0	0	0	0	0
Clethodim	0.30	5	20	31	53	58
Clethodim	0.60	10	23	46	68	69
Clethodim	0.30 fb 0.30	5	20	39	61	66
Clethodim	0.60 fb 0.60	11	25	53	78	69
Sethoxydim	0.31	6	8	30	44	40
Sethoxydim	0.31 fb 0.31	5	8	29	44	55
$LSD_{0.05}$		2	15	12	14	8

[a]Data pooled over locations.
[b]Sequential applications occurred 2 weeks after initial.
[c]Abreviation: WAI = Weeks after initial application.

By 4 WAI (2 week after sequential), single and sequential applications of clethodim applied at 0.60 kg ha^{-1} provided 46 and 53% control, respectively. Sethoxydim applications were equivalent to clethodim single and sequential applications at 0.30 kg ha^{-1}, but torpedograss control did not exceed 30% for sethoxydim. At 6 WAI, clethodim applied sequentially at its high rate provided 34% higher control than single or sequential sethoxydim applications. Additionally, clethodim applied sequentially at its low rate provided better control than sethoxydim.

By 8 WAI (6 weeks after sequential), single applications of clethodim at 0.30 kg ha^{-1} and sequential applications of sethoxydim provided 58 and 55% torpedograss control, respectively. At this late rating period, there was no advantage to single or sequential high rates of clethodim when compared to the low rate applied sequentially. However, throughout the experiment, there was a trend toward better control from single or sequential high clethodim rates than single or sequential low rates. Single or sequential clethodim applications at 0.60 kg ha^{-1} or sequential applications at 0.30 kg ha^{-1} were more effective than sethoxydim. Torpedograss control with sethoxydim never exceeded control observed with clethodim.

Results of these studies support information provided by Ross and Lembi (1999) concerning the performance of these two herbicides on creeping perennials. However, in the present study clethodim did not provide acceptable torpedograss control (< 85%). Control did not exceed 79% for clethodim treatments. In studies conducted in Louisiana, clethodim provided as much as 100% control of rhizomatous johnsongrass (*Sorghum halepense* L.) (Jordan et al., 1996). Cox et al. (1999) reported greater than 95% control of bermudagrass with clethodim at 0.60 kg ha^{-1} applied sequentially, 8 WAI. In the same study, sethoxydim provided 80 to 90% bermudagrass control. For comparison, from the present study torpedograss control never exceeded 55% with sethoxydim with single or sequential applications.

Turfgrass Injury. A treatment by location interaction was not observed for centipedegrass injury (Table 3.2). Injury did not reach unacceptable levels for any of the rating periods. At 2 and 4 WAI, some leaf discoloration was noted for plots treated with clethodim (injury ≤ 15%). By 6 WAI, clethodim applied sequentially at 0.60 kg ha^{-1} caused significantly higher injury (29%) than all other herbicide treatments. Although still commercially acceptable, some turf chlorosis and moderate necrosis (19% injury) was still visible 8 WAI in plots of this same treatment. However, centipedgrass injury never exceeded 5% for applications of sethoxydim. Cox et al. (1999) reported less centipedegrass injury (< 13%) from sequential 0.60 kg ha^{-1} applications. Sethoxydim caused minimal centipedegrass injury in either study and was 5% or less in the present study.

Table 3.2. Centipedegrass injury[a] as affected by herbicide applied in a single application or sequentially[b] at Slidell and LaPlace, LA in 2001.

		Turfgrass Injury			
		WAI			
Treatment	Rate	2	4	6	8
	kg ha^{-1}	%			
Untreated		0	0	0	0
Clethodim	0.30	10	9	9	5
Clethodim	0.60	13	15	13	5
Clethodim	0.30 fb 0.30	9	9	13	10
Clethodim	0.60 fb 0.60	14	14	29	19
Sethoxydim	0.31	5	4	3	1
Sethoxydim	0.31 fb 0.31	5	5	5	5
$LSD_{0.05}$		4	5	6	5

[a]Data pooled over locations.
[b]Sequential applications occurred 2 weeks after initial

Clethodim + Adjuvant Studies. Significant interactions among herbicide rate, spray adjuvants, and experiments were not observed (Table 3.3). Only herbicide rate differed significantly. Therefore, herbicide rate means were pooled over all other factors. Shoot regrowth biomass was not significantly different (Table 3.4).

Averaged across all factors, applications of clethodim at 0.60 kg ha^{-1} provided better control than the 0.30 kg ha^{-1} rate throughout the study. However, torpedograss control never exceeded 62%. Results of the greenhouse studies indicate that torpedograss control is more dependent on clethodim rate than the

Table 3.3. Torpedograss control as influence by clethodim rate in greenhouse at the Hill Farm, Baton Rouge, LA in 2002.

	Torpedograss Control[a]		
	WAT[b]		
Rate	2	4	6
		%	
0.30	31	47	44
0.60	40	59	62
$LSD_{0.05}$	5	5	6

[a]Clethodim rate data are pooled over all levels of other factors.
[b]Abreviation: WAT = Weeks after treatment.

adjuvant (Table 3.3). Future torpedograss control research in centipedgrass should center on investigating the efficacy of higher clethodim rates. In field studies conducted by Cox et al. (1999), clethodim rates as high as 1.20 kg ha^{-1} applied sequentially caused minimal centipedgrass injury.

Table 3.4. Shoot biomass as influenced by spray adjuvant in greenhouse studies conducted at Hill Farm, Baton Rouge, LA.

Adjuvant	Shoot Biomass
	g
X-77	1.44
Agri-Dex	2.02
Class Act	1.53
Silwet	1.83
$LSD_{0.05}$	NS

In summary, results of field studies indicate that clethodim provides better knotgrass control than sethoxydim. However, control is still far below the acceptable level for a turfgrass situation. Centipedegrass injury was acceptable for all herbicides and rates investigated. However, clethodim at 0.60 kg ha^{-1} applied sequentially caused some centipedegrass chlorosis and necrosis by 6 and 8 WAI (29 and 19%). Results of the greenhouse studies indicate that clethodim rate influences torpedograss control more than adjuvant chosen.

LITERATURE CITED

Anderson W. P. 1996. Weed Science Principles and Application. West Publishing Co. p. 104.

Baird, D. D., V. M. Urrutia, and D. P. H. Tucker. 1983. Management systems with glyphosate on torpedograss in citrus. Proc. South. Weed Sci. 36:201.

Bowman, W. D. 1991. Effect of nitrogen nutrition on photosynthesis and growth in C_4 *Panicum* species. Plant, Cell and Environment. 14:295-301.

Burt, E. O. 1980. Glyphosate for torpedograss and bermudagrass control. p. 257-262 in J. B. Beard, ed. Prod. Int. Turfgrass Res. Conf., 3rd. Madison, WI.

Burt. E. O., and A. E. Dudeck. 1975. Glyphosate - Four years of results. Proc. South. Weed Soc. 28:152-153.

Chandrasena, J. P. N. R. 1990. Torpedograss (*Panicum repens* L.) control with lower rates of glyphosate. Trop. Pest Management. 36(4)336-342.

Christians, N. 1998. Fundamentals of turfgrass management. Ann Arbor Press, Chelsea, Michigan. p. 64.

Cox C. J., L. B. McCarty, and J. K. Higingbottom. Envoy (clethodim) for bermudagrass control and centipedegrass tolerance. Proc. South. Weed Sci. 52:68.

Fleming, D. C., H. D. Palmertree, and D. W. Houston. 1978. Screening herbicides for torpedograss control in turf. Proc. South. Weed Sci. Soc. 30:136.

Holm, L., G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. The Worlds Worst Weeds Distribution and Biology. Univ. Press of Hawaii Honolulu. 609 pp.

Johnson, B. J. 1976. Renovation of turfgrass with herbicides. Weed Sci. 24:467-472.

Johnson, B. J. 1997. Preemergence and postemergence herbicides for large crabgrass (*Digitaria sanguinalis*) control in centipedegrass (*Eremochloa ophiuroides*). Weed Technol. 11:144-148.

Johnson, B. J. and T. R. Murphy. 1989. Summer annual weed control in turfgrass. Ga. Agric. Res. Bull. 388:29.

Jordan, D. L., P. R. Vidrine, J. L. Griffin, and D. B. Reynolds. 1996. Influence of adjuvants on efficacy of clethodim. Weed Technol. 10:738-743.

Kigel, J. and D. Kollier. 1985. Asexual reproduction in weeds. Pages 65-100 in S. O. Duke, ed. Weed Physiology. Volume I. Reproduction and Ecophysiology. CRC Press, Boca Raton, FL.

Manipura, W. B. and A. Somaratine. 1974. Some of the effects of manual and chemical defoliation on the growth and carbohydrate reserves of *Panicum repens*. Weed Res. 14:167-172.

McCarty, L. B. 1992. Quinclorac evaluations in warm-season turfgrasses. Proc. South. Weed Sci. Soc. 45:136.

McCarty, L. B. 1994. Weed management. In: Best Management Practices for Florida Golf Courses. Univ. Florida, Gainsville p. 128-143.

McCarty, L. B., J. M. Higgins, and L. C. Miller, and T. Whitwell. 1986. Centipede tolerance to postemergence grass herbicides. HortSci. 21:1405-1407.

McCarty, L. B., J. M. Higgins, and D. L. Colvin. 1993. Selective torpedograss (*Panicum repens*) control in bermudagrass (*Cynodon* spp.) turf. Weed Tech. 7:911-915.

Moreira, I. 1978. Propagation of *Panicum repens* by seed. Weeds and herbicides in the Mediterranean Basin. Proc. Mediterr. Herb. Symp. Vol. 1:1-7.

Murphy, T. R., L. B. McCarty, D. Hall, D. L. Colvin, R. Dickens, and J. W. Everest. 1992. Weeds of Southern Turfgrasses. Fla. Coop. Ext. Serv., Gainsville, Fl. 208.

Peng, S. Y. 1984. The biology and control of weeds in sugarcane. Developments in Crop Science (4). New York: Elsevier Science.

Ross, M. A., and C. A. Lembi. 1999. Applied Weed Science. Macmillan Publishing Co. New York. p. 202.

Ross, M. A., and C. A. Lembi. 1985. Applied Weed Science. Macmillan Publishing Co. New York. p. 262.

[SAS] Statistical Analysis Systems. 1989. Version 6, 4th ed, Volume 2. Cary, NC: Statistical Analysis Systems Institute. 846 p.

Singh, M. and D. P. H. Tucker. 1986. Fluazifop-butyl and sethoxydim for grass control in citrus. Proc. South. Weed Sci. Soc. 39:184.

Soerjani, M., A. J. G. H. Kostermans, and G. Tjitrosoepomo. 1987. Weeds of Rice in Indonesia.

Street, J. E., M. E. Kurtz, and C. E. Snipes. 1988. Efficacy of BAS 51400H in rice. Abstr. Weed Sci. Soc. Am. No. 2.

Tarver, D. P. 1979. Torpedograss (*Panicum repens* L.). Aquatics 1:5-6.

Turgeon A. J. 1996. Turfgrass Managment. Prentice Hall, New Jersey. p. 234.

Wanamarta, G. and D. Penner. 1989. Foliar penetration of herbicides. Rev. Weed Sci. 4:215-231.

Willard, C. J. 1958. Rating scales for weed control experiments. Weeds 6:327-328.

Wilcut John W., R. R. Dute, B. Truelove, and D. E. Davis. 1988. Factors limiting the distribution of cogongrass (*Imperata cylindrica*) and torpedograss (*Panicum repens*). Weed Sci. 36:577-582.

CHAPTER 4

SUMMARY

Creeping perennial grasses cause particularly serious weed control problems in turfgrasses because of their resistance to control methods. Knotgrass (*Paspalum distichum* L.) and torpedograss (*Panicum repens* L.) are two of the most troublesome creeping perennial weeds of turfgrasses in Louisiana.

Three separate pot studies were conducted at the Burden Research Station in Baton Rouge, LA in 1998 and 1999 to evaluate herbicides for knotgrass control. Knotgrass control experiments included a graminicides study, nonselective herbicide comparison, and an evaluation of quinclorac.

In the graminicide studies, fenoxaprop and diclofop resulted in less than 40% control from 3 to 8 weeks after initial application (WAI). The exception was diclofop at the high rate, which resulted in 54 to 68% control. Single or split applications of fluazifop or quizalofop provided excellent knotgrass control (88-95%). Single applications of sethoxydim at 0.62 kg ha^{-1} were similar (85%) to sequential applications at 0.31 kg ha^{-1} (90%). By 8 WAI (4 weeks after sequential) split applications of MSMA did not increase control when compared to single high rate applications and control was very poor overall with this herbicide (< 40%). Applications of sethoxydim, fluazifop, clethodim, and quizalofop were more effective than MSMA applications. Fluazifop applied at the low rate (0.28 kg ha^{-1}) provided 56% greater knotgrass control than MSMA. All applications of fluazifop provided better knotgrass control than single low rate (0.30 kg ha^{-1}) applications of clethodim. However, single or split applications of fenoxaprop at 0.21 kg/ha and single applications of diclofop at 0.84 kg/ha were no better than the untreated check. Averaged across two years, knotgrass shoot weights were reduced by all herbicide applications when compared to the untreated check. Shoot weights were similar for all rates and timings of sethoxydim, fluazifop, clethodim, and quizalofop treatments (0.24 to 1.40 g). Single fenoxaprop applications at 0.42 kg ha^{-1} reduced shoot weight 38% when compared to single applications of fenoxaprop at 0.21 kg ha^{-1} (4.55 vs 7.54 g). MSMA applied sequentially reduced knotgrass shoot weights more than single high or low rates of MSMA. In 1998 root weights were reduced by all herbicide applications when compared to the untreated check. As with shoot weights, regardless of the rate or the sequential application, root weights were most reduced by sethoxydim, fluazifop, clethodim, and quizalofop (0.86 to 1.91 g) and similar to diclofop (1.06 g) applied at 0.1.70 kg ha^{-1}. In 1999, knotgrass root weights were not significantly reduced by single or split applications of fenoxaprop at 0.21 kg ha^{-1}. Single high rate applications of fluazifop (0.56 kg ha^{-1}) caused lower root weights than single high (0.62 kg ha^{-1}) or low (0.31 kg ha^{-1}) sethoxydim rates (0.28 vs 1.28 and 1.44 g). Root weights were similar for all fluazifop and quizalofop treatments (0.28 to 0.79 g).

In nonselective studies, glyphosate, glufosinate, and sulfosate were evaluated at equivalent rates (1.12, 2.24, or 4.48 kg ha^{-1}). By 1 WAT (week after treatment), all glufosinate treatments controlled knotgrass 80%. Glyphosate and sulfosate controlled knotgrass < 20%. The symptom observed most often in plants treated with glyphosate or sulfosate in the 1 WAT evaluation was chlorosis on new growth. By 4 WAT, all rates of glyphosate were as effective as glufosinate (94 to 98%).

Control observed with sulfosate at 2.24 and 4.48 kg/ha was similar to glyphosate and glufosinate. However, sulfosate at 1.12 kg/ha was the least effective herbicide treatment (< 80%). By 7 WAT, knotgrass control was at 99% for glufosinate treatments, regardless of rate applied.

In quinclorac evaluation studies, For 2-7 WAT, knotgrass control was greater with quinclorac at its highest rate (2.24 kg ha^{-1}) than all other herbicide treatments. Knotgrass was not satisfactorily controlled, however, as control never exceeded 35%.

Results of the knotgrass control studies indicate that control is possible with many of the herbicides that are labeled for use in Southern turfgrasses. Clethodim (Envoy) and sethoxydim (Vantage), labeled for grassy weed control in centipedegrass, are very effective herbicides for knotgrass control. Knotgrass infestations in zoysiagrass can be managed with fluazifop (Fusilade II). However, diclofop (Illoxan), quinclorac (Drive), and MSMA, registered for use in bermudagrass, did not provide acceptable control. Sporadic infestations may be removed effectively with nonselective herbicides glyphosate and glufosinate (Liberty/Finale).

Field studies were conducted in LaPlace and Slidell, LA in 2001, to evaluate single and sequential rates of clethodim for torpedograss control in centipedegrass. By 8 WAI (6 weeks after sequential), single applications of clethodim at 0.30 kg ha^{-1} and sequential applications of sethoxydim provided 58 and 55% torpedograss control, respectively. There was no advantage to single or sequential high rates (0.60 kg ha^{-1}) of clethodim when compared to the low rate (0.30 kg ha^{-1}) applied sequentially. However, throughout the experiment, there was a trend toward better control from single or sequential high clethodim rates than single or sequential low rates. Torpedograss control with sethoxydim never exceeded control observed with clethodim. However, clethodim did not provide acceptable torpedograss control overall (< 85%). Control was no greater than 79% for any of the clethodim treatments. Although still commercially acceptable (< 30% injury), clethodim caused some moderate centipedegrass injury (19%). However, centipedgrass injury was no greater than 5% for applications of sethoxydim.

Greenhouse studies were conducted to evaluate several spray adjuvants to investigate potential for increased efficacy with clethodim on torpedograss.   Results indicated that herbicide rate is more critical than the adjuvant. Averaged across adjuvants, clethodim at 0.60 kg ha^{-1} controlled torpedograss better than the 0.30 kg ha^{-1} rate (62 vs 44%).

Perennial grasses are very difficult to remove in established turf, however, there are viable options for knotgrass control in centipedegrass and zoysiagrass. Clethodim has potential for the selective removal of torpedograss infesting centipedegrass. Future torpedograss control research in centipedegrass should center on investigating the efficacy of higher clethodim rates and turfgrass tolerance.

VITA

Ronald Eugene Strahan is the youngest child of B. H. and Ola Strahan. Ronald grew up near the town of Rayville in rural northeast Louisiana on a small cotton farm. He attended elementary and high school at Riverfield Academy in Rayville. Ronald graduated *magna cum laude* with a bachelor of science degree in agriculture business from Northeast Louisiana University in May 1992. While at Northeast Louisiana University he was awarded the Goul S. Brown Memorial Award for outstanding academic achievement. He received a master of science degree in weed science in 1996 under the direction of Dr. Jim Griffin. Ronald is a member of the Gamma Sigma Delta Honor Society of Agriculture.

In 1998, Ronald enrolled in the Department of Horticulture under the direction of Dr. James N. McCrimmon. He is currently a candidate for the Doctor of Philosophy degree in horticulture with a research emphasis in turfgrass science.