Weed Technology 2012 26:304–307

Purple Nutsedge (*Cyperus rotundus*) Control in Bermudagrass Turf with Imazosulfuron

Gerald M. Henry, Bradley S. Sladek, Andrew J. Hephner, and Tyler Cooper*

Purple nutsedge response to various rates and timings of imazosulfuron was evaluated in 2007 and 2008 in Abilene, TX. Bermudagrass phytotoxicity never exceeded 4% throughout the duration of the trial and all bermudagrass recovered within 7 d of herbicide application. Imazosulfuron (0.56 kg ai ha^{-1}) followed by (fb) imazosulfuron 1 wk after initial treatment (WAIT), imazosulfuron at 1.12 kg ai ha^{-1}, and trifloxysulfuron at 0.03 kg ai ha^{-1} exhibited 94 to 96% control 4 WAIT. Imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 2, 3, and 4 WAIT exhibited 99% control 4 WAIT. Eight weeks later (12 WAIT), imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 3 WAIT controlled purple nutsedge 91%, whereas similar control (82 to 84%) was observed with a single application of trifloxysulfuron and imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 2 and 4 WAIT. A single application of imazosulfuron at 1.12 kg ai ha^{-1} and sequential treatment with imazosulfuron (0.56 kg ai ha^{-1}) on a 1-wk interval only controlled purple nutsedge 51 to 69% 12 WAIT. Timing of sequential imazosulfuron application was identified as an important component of the purple nutsedge control program. Waiting 2, 3, or 4 WAIT for sequential imazosulfuron applications, rather than 1 WAIT, increased purple nutsedge control 31 to 40% 12 WAIT. The highest level of purple nutsedge control (91%) was observed with applications of imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 3 WAIT applied during midsummer. However, control with this treatment was statistically similar to control with a single application of trifloxysulfuron (82%).

Nomenclature: Imazosulfuron (2-chloro-N-[[4,6-dimethoxy-2-pyrimidinyl-amino]carbonyl]imidazo[1,2-a]pyridine-3-sulfonamide); trifloxysulfuron; common bermudagrass, *Cynodon dactylon* (L.) Pers. CYNDA; purple nutsedge, *Cyperus rotundus* L. CYPRO.

Key words: Turfgrass, golf course, weed management.

La respuesta de *Cyperus rotundus* a varias dosis y tiempos de aplicación de imazosulfuron fue evaluada en 2007 y 2008 en Abilene, Texas. La fitotoxicidad de *Cynodon dactylon* nunca excedió 4% a lo largo de la duración del estudio y se recuperó antes de 7 días después de la aplicación del herbicida. Imazosulfuron (0.56 kg ia ha^{-1}) seguido por imazosulfuron 1 semana después del tratamiento inicial (SDTI), imazosulfuron a 1.12 kg ia ha^{-1} y trifloxysulfuron a 0.03 kg ia ha^{-1} lograron de 94 a 96% de control 4 SDTI. Imazosulfuron (0.56 kg ia ha^{-1}), seguido por imazosulfuron 2, 3 y 4 SDTI alcanzaron 99% de control 4 SDTI. Ocho semanas más tarde (12 SDTI), imazosulfuron (0.56 kg ia ha^{-1}) seguido por imazosulfuron 3 SDTI controlaron el *C. rotundus* 91%, mientras que un control similar (82 a 84%) se observó con una sola aplicación de trifloxysulfuron e imazosulfuron (0.56 kg ia ha^{-1}) seguido por imazosulfuron 2 y 4 SDTI. Una sola aplicación de imazosulfuron a 1.12 kg ia ha^{-1} y tratamiento secuencial con imazosulfuron (0.56 kg ia ha^{-1}) con 1 semana de intervalo, solamente controló *C. rotundus* de 51 a 69% a las 12 SDTI. El tiempo de la aplicación secuencial de imazosulfuron fue identificado como un componente importante del programa de control de *C. rotundus*. Esperar 2, 3 o 4 SDTI para las aplicaciones secuenciales de imazosulfuron, en lugar de 1 SDTI, incrementó el control de *C. rotundus* de 31 a 40% a las 12 SDTI. El mayorcontrol de *C. rotundus* (91%) se observó con aplicaciones de imazosulfuron (0.56 kg ia ha^{-1}) seguido por imazosulfuron 3 SDTI, aplicado a medio verano. Sin embargo, el control con este tratamiento fue similar estadísticamente al control con una sola aplicación de trifloxysulfuron (82%).

Purple nutsedge has been described as one of the 10 most troublesome weeds throughout the southern United States (Webster 2008). It is primarily a problem throughout the southern United States north to Kentucky and West Virginia, west to central Texas, and in Southern California (Bendixen and Nandihalli 1987; McCarty et al. 2008; Reed 1970). Infestations predominantly originate in irrigated or low-lying, poorly drained areas, but can easily spread through the disturbance and growth of aggressive rhizomes (McCarty et al. 2008). Chains of slender rhizomes produce numerous brownish-black tubers covered in hairs that sprout repeatedly from abundant carbohydrate reserves (Horowitz 1992; McCarty et al. 2008; Stoller and Sweet 1987; Thullen and Keeley 1979; Wills 1987). Summerlin et al. (2000) observed the production of 174 to 554 purple nutsedge tubers from a single plant (6 cm) after 18 wk of undisturbed growth. Tumbleson and Kommedahl (1961) reported that a single purple nutsedge tuber gave rise to 1,900 clonal plants and nearly 6,900 tubers in 1 yr. Tubers may remain viable for more than 3 yr if soil remains moist (Stoller and Sweet 1987), but survival in dry soil only lasts for a short period of time. The most important adaptation that enables purple nutsedge to persist in turf is tuber dormancy. Dormancy prevents tubers from sprouting all at once, helping to maintain a reservoir for potential new plants in the soil profile (Stoller and Sweet 1987).

Long-term purple nutsedge control may be obtained if management strategies focus on the reduction of tuber development and viability in the soil. McCarty and Murphy (1994) identified proper mowing practices as a valuable

DOI: 10.1614/WT-D-11-00109.1

* Assistant Professor and Graduate Research Assistants, Department of Plant and Soil Science, Texas Tech University, Lubbock, TX 79409. Corresponding author's E-mail: gerald.henry@ttu.edu

component of weed-control practices. Summerlin et al. (2000) reported reductions in purple nutsedge rhizome length, tuber size, and tuber production when plants were mowed at 1.3 and 3.8 cm compared with a nonmowed check. Brecke et al. (2005) noted that purple nutsedge control, averaged across all herbicides, improved from 60 to 66% when mowed weekly. Although mowing has been shown to suppress growth, additional control methods must be used to effectively reduce purple nutsedge populations over time.

No herbicides are currently registered for the PRE control of purple nutsedge in warm-season turf (Blum et al. 2000). PRE applications of *S*-metolachlor are registered for control of yellow nutsedge (*Cyperus esculentus* L.) but not purple nutsedge (Anonymous 2010). Several selective herbicides are labeled for the POST control of purple nutsedge in bermudagrass turf. Most of these chemistries belong to the sulfonylurea herbicide family. Sulfonylurea herbicides inhibit the enzyme acetolactate synthase (ALS), thereby blocking the biosynthesis of the branched-chain amino acids valine, leucine, and isoleucine (Brown 1990; Senseman and Armbrust 2007). Inhibition leads to the termination of plant cell division and growth. Cessation of plant growth in conjunction with long-term reductions in new leaves and reproductive organs may be attributed to the accumulation of ALS substrates such as alpha-ketobutyrate in leaf tissue (Brown 1990; LaRossa and Van Dyk 1987).

Baumann et al. (2004) and Brecke et al. (2005) observed 73 to 85% purple nutsedge control 12 to 15 wk after treatment (WAT) with applications of halosulfuron at 0.07 kg ai ha^{-1}, whereas Blum et al. (2000) only reported 17% control 15 WAT. Baumann et al. (2004) observed 80 to 85% purple nutsedge control 15 WAT with applications of sulfosulfuron at 0.052 kg ai ha^{-1}, whereas Hinton and Yelverton (2003) reported $> 90\%$ control 12 WAT with applications of sulfosulfuron at 0.134 kg ai ha^{-1}. Flazasulfuron at 0.025 to 0.1 kg ai ha^{-1} exhibited 75 to 86% purple nutsedge control 12 WAT (Yelverton et al. 2003).

The presence of numerous rhizomes may enable purple nutsedge to regenerate from abundant carbohydrate reserves following defoliation. Therefore, turfgrass managers often make sequential herbicide applications after regrowth. Sequential applications of halosulfuron at 0.07 kg ai ha^{-1} exhibited 80 to 90% control 11 to 15 wk after initial treatment (WAIT) (Blum et al. 2000; Brecke et al. 2005; Hinton and Yelverton 2003). Sequential applications of sulfosulfuron at 0.067 kg ai ha^{-1} exhibited $> 90\%$ control 49 d after initial treatment (DAIT) (Hubbard et al. 2007), whereas sequential applications at 0.078 kg ai ha^{-1} exhibited 90 to 95% control at the end of the season (Brecke et al. 2007). Hubbard et al. (2007) reported $> 90\%$ purple nutsedge control 49 DAIT with sequential applications of trifloxysulfuron at 0.03 kg ai ha^{-1}, whereas Hinton and Yelverton (2003) reported $> 90\%$ control 12 WAIT with the same applications.

Although moderate to good purple nutsedge control has been documented over short time periods ($\leq$ 12 WAIT), long-term reductions in tuber development and viability are still very difficult to achieve. Chains of linked tubers often regenerate even after sequential herbicide applications. Imazosulfuron, a sulfonylurea herbicide, was commercialized in Japan in 1993 (Ishida et al. 1993; Ohta et al. 1993) and is currently being developed and tested by Valent U.S.A. for registration and use in turf. Effective purple nutsedge control is likely limited by the amount of herbicide absorption and translocation to perennial plant structures (Sprankle et al. 1975). Ikeda et al. (1999) reported that 40% of absorbed ^{14}C-imazosulfuron translocated to the tip and base of purple nutsedge treated leaves 5 d after treatment. Furthermore, ^{14}C-imazosulfuron was detected in the basal bulb of the mother plant and adjoining daughter plants (Ikeda et al. 1999). This level of translocation may improve purple nutsedge control but data evaluating imazosulfuron for purple nutsedge control in turf has not been published. Therefore, the objectives of our research were to evaluate imazosulfuron for the control of purple nutsedge, determine the optimal timing for sequential applications, and determine the safety of imazosulfuron on bermudagrass turf.

Table 1. Treatments and application dates for 2007 and 2008 in Abilene, TX.

	Rate	Application dates	
Treatment	kg ai ha^{-1}	2007	2008
Untreated check	—	—	—
Imazosulfuron[a]	0.56 + 0.56	July 10 + July 17	July 3 + July 10
	0.56 + 0.56	July 10 + July 24	July 3 + July 17
	0.56 + 0.56	July 10 + July 31	July 3 + July 24
	0.56 + 0.56	July 10 + August 6	July 3 + July 31
	1.12	July 10	July 3
Trifloxysulfuron	0.03	July 10	July 3

[a] Imazosulfuron and trifloxysulfuron were applied with a nonionic surfactant at 0.25% v/v.

Materials and Methods

Field experiments were initiated during the summer of 2007 and 2008 at Abilene Country Club in Abilene, TX on a Hamby loamy fine sand (fine, mixed, active, Thermic Typic Paleustalfs) soil with a pH of 7.8 and organic matter content of 1.6%. Research was performed on established purple nutsedge infestations present in a common bermudagrass rough maintained at a height of 5.1 cm. Plots measured 1.5 by 1.5 m and were arranged in a randomized complete block design with four replications. Purple nutsedge cover (50 to 90%) within each plot was determined at the time of initial herbicide application through grid counts using a 0.3-m^2 grid (25 intersecting points) tossed into each plot. All experimental areas were mowed 24 h before herbicide application and once weekly thereafter. There was no rain or irrigation during the 24-h period after herbicide treatment.

Herbicide treatments included an untreated check, imazosulfuron (V-10142, Valent U.S.A. Corp., P.O. Box 8025, Walnut Creek, CA 94596-8025) at 0.56 kg ai ha^{-1} followed by (fb) imazosulfuron at 0.56 kg ai ha^{-1} at various timing intervals, imazosulfuron at 1.12 kg ai ha^{-1}, and trifloxysulfuron (Monument, Syngenta Crop Protection, LLC, P.0. Box 18300, Greensboro, NC 27419) at 0.03 kg ai ha^{-1} (Table 1). Imazosulfuron and trifloxysulfuron treatments were applied with a nonionic surfactant (Induce, Helena Chemical Company, 225 Schilling Blvd., Suite 300, Collierville, TN 38017) at 0.25% v/v.

Table 2. Control of purple nutsedge present in bermudagrass turf 4 and 12 WAIT[a] in Abilene, TX.[b]

Treatment	Rate	4 WAIT	12 WAIT
	—— kg ai ha^{-1} ——	———% control ———	
Untreated check	—	0 c[c]	0 d
Imaz fb imaz 1WAIT	0.56 + 0.56	96 ab	51 c
Imaz fb imaz 2 WAIT	0.56 + 0.56	99 a	82 ab
Imaz fb imaz 3 WAIT	0.56 + 0.56	99 a	91 a
Imaz fb imaz 4 WAIT	0.56 + 0.56	99 a	84 a
Imazosulfuron	1.12	94 b	69 b
Trifloxysulfuron	0.03	96 ab	82 ab

[a] Abbreviations: WAIT, weeks after initial treatment; imaz, imazosulfuron; fb, followed by.

[b] Data were pooled over experimental years.

[c] Means within a column followed by the same lowercase letter are not significantly different at $P \leq 0.05$ according to Fisher's Protected LSD test.

Treatments were initiated on July 10, 2007 and July 3, 2008 with sequential applications made 1, 2, 3, and 4 WAIT. Treatments were applied using a CO_2-pressurized backpack sprayer equipped with two XR8003VS flat-fan extended-range spray tips (Teejet, Spraying Systems Co., North Ave. and Schmale Rd., Wheaton, IL 60129) and calibrated to deliver 304 L ha^{-1} at 276 kPa.

Data collected included bermudagrass phytotoxicity and purple nutsedge control based on digital image analysis and grid counts, respectively. Digital photographs were taken 1, 2, 3, 4, 5, and 6 WAIT with a Nikon (Coolpix P5000, Nikon Inc. USA, Melville, NY) camera capable of capturing 10 million pixels per image mounted on a 0.28-m^2 light box equipped with four compact fluorescent light bulbs (N:Vision 14-Watt [60W] Daylight CFL Light Bulbs, N:Vision, Atlanta, GA), each with a light output of 172 µmol m^{-2} s^{-1}. Digital images were analyzed using WinCam 2007 software to determine percent bermudagrass leaf firing (i.e., chlorotic or necrotic tissue). Percent bermudagrass leaf firing was converted to percent bermudagrass phytotoxicity by comparing each plot with the untreated check within each experimental replication. Grid counts were taken 2, 4, 6, 8, and 12 WAIT using a 0.3-m^2 grid (25 intersecting points) tossed into each plot. Plants directly under each line intersection were identified and totaled for each plot. Grid counts were converted to percent purple nutsedge control by comparing each plot with the cover recorded at initial herbicide application.

Percent bermudagrass phytotoxicity and purple nutsedge control were arcsine square root transformed before analysis. Transformation did not improve variance homogeneity; therefore, nontransformed data were used in analysis and presentation. There was no significant year-by-treatment interaction so data were combined and ANOVA (SAS, Statistical Analysis Systems, 2002–2008, Release 9.2, Statistical Analysis Systems Institute, Cary, NC 27513) was performed. Means were separated using Fisher's Protected LSD test at the 0.05 significance level.

Results and Discussion

Bermudagrass phytotoxicity never exceeded 4% on any observation date and all bermudagrass recovered within 7 d of herbicide application (data not shown). Herbicide treatment main effects were observed for purple nutsedge control 4 and 12 WAIT (Table 2). Imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 1 WAIT, imazosulfuron at 1.12 kg ai ha^{-1}, and trifloxysulfuron (0.03 kg ai ha^{-1}) exhibited 94 to 96% control 4 WAIT (Table 2). Imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 2, 3, and 4 WAIT exhibited 99% control 4 WAIT. Felix and Boydston (2010) observed similar control of yellow nutsedge (92 to 99%) with imazosulfuron applied PRE and POST at 0.34 to 0.56 kg ai ha^{-1} 42 DAIT. Yelverton et al. (2003) reported similar purple nutsedge control (> 85%) 4 WAIT with applications of flazasulfuron at 0.025 to 0.1 kg ai ha^{-1}. Previous research with significantly lower rates of imazosulfuron (0.09 kg ai ha^{-1}) caused reductions in dry weight (≥ 80%) 28 DAIT of late watergrass (*Echinochloa oryzicola* (Vasinger) Vasinger), monochoria (*Monochoria vaginalis* (Burm. F.) Kunth), common falsepimpernel (*Lindernia procumbens* (Krock.) Philcox), Indian toothcup (*Rotala indica* (Willd.) Koehne), dwarf arrowhead (*Sagittaria pygmaea* Miq.), three-leaf arrowhead (*Sagittaria trifolia* L.), Java waterdropwort (*Oenanthe javanica* (Blume) DC.), pondweed (*Potamogeton distinctus* A. Benn.), bulrush (*Scirpus juncoides* Roxb.), tidalmarsh flatsedge (*Cyperus serotinus* Rottb.), sea club rush (*Scirpus planiculmis*), and spikerush (*Eleocharis kuroguwai*) (Tanaka et al. 1995).

Eight weeks later (12 WAIT), imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 3 WAIT controlled purple nutsedge 91%, whereas similar control (82 to 84%) was observed with a single application of trifloxysulfuron and imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 2 and 4 WAIT (Table 2). Baumann et al. (2004) observed similar control (80 to 85%) 104 DAT with sequential applications of sulfosulfuron at 0.05 to 0.1 kg ai ha^{-1} and halosulfuron at 0.07 kg ai ha^{-1}. Season-long purple nutsedge control (90 to 95%) has been observed with sequential applications of sulfosulfuron at 0.078 kg ai ha^{-1} (Brecke et al. 2007). Hinton and Yelverton (2003) observed greater control (> 90%) 12 WAIT with sequential applications of trifloxysulfuron at 0.03 kg ai ha^{-1} than was observed with a single trifloxysulfuron application in our research. Purple nutsedge control with imazosulfuron (0.56 kg ai ha^{-1}) fb imazosulfuron 1 WAIT and imazosulfuron at 1.12 kg ai ha^{-1} declined to 51 and 69% control, respectively, 12 WAIT.

Timing of sequential imazosulfuron application was identified as an important component of the purple nutsedge control program. Waiting 2, 3, or 4 WAIT for sequential imazosulfuron applications, rather than 1 WAIT, increased purple nutsedge control 31 to 40% 12 WAIT (Table 2). However, control with these treatments was not statistically different from control with a single application of trifloxysulfuron 12 WAIT. Hubbard et al. (2007) observed similar control (> 90%) 49 DAIT with sulfosulfuron (0.039 kg ai ha^{-1}) fb sulfosulfuron 25 DAIT, trifloxysulfuron (0.017 kg ai ha^{-1}) fb trifloxysulfuron 25 DAIT, and imazaquin (0.56 kg ai ha^{-1}) fb imazaquin 25 DAIT. However, Hinton and Yelverton (2003) observed > 90% control of purple nutsedge 11 WAIT when waiting to make sequential applications of halosulfuron (0.07 kg ai ha^{-1}), trifloxysulfuron (0.03 kg ai ha^{-1}), and sulfosulfuron (0.053 to 0.079 kg ai ha^{-1}) 6 WAIT. Sequential applications made several weeks later may allow for increased

https://doi.org/10.1614/WT-D-11-00109.1 Published online by Cambridge University Press

herbicide uptake due to the presence of more leaf tissue after regrowth. Therefore, decreased purple nutsedge control 12 WAIT exhibited by sequential imazosulfuron applications 1 WAIT may have been in response to reduced herbicide uptake and subsequent translocation.

Acknowledgments

The authors acknowledge the cooperation of Travis Williams, Aaron Holbrook, and Leslie Beck for their excellent technical assistance in this project. Appreciation is also extended to Valent Corp. for providing the imazosulfuron. Also, thanks to Steve McMillan at Abilene Country Club in Abilene, TX for the use of his facility.

Literature Cited

Anonymous. 2010. Pennant Magnum herbicide label. Greensboro, NC: Syngenta Crop Protection.

Baumann, P. A., F. T. Moore, and M. E. Matocha. 2004. Purple nutsedge (*Cyperus rotundus* L.) control from sulfosulfuron applications to turfgrass. Proc. South. Weed Sci. Soc. 57:98.

Bendixen, L. E. and U. B. Nandihalli. 1987. Worldwide distribution of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). Weed Technol. 1:61–65.

Blum, R. R., J. Isgrigg, III., and F. H. Yelverton. 2000. Purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*C. esculentus*) control in bermudagrass (*Cynodon dactylon*) turf. Weed Technol. 14:357–365.

Brecke, B. J., K. C. Hutto, and J. B. Unruh. 2007. Sulfosulfuron: weed management and turfgrass tolerance. Proc. South. Weed Sci. Soc. 60:114.

Brecke, B. J., D. O. Stephenson, IV., and J. B. Unruh. 2005. Control of purple nutsedge (*Cyperus rotundus*) with herbicides and mowing. Weed Technol. 19:809–814.

Brown, H. M. 1990. Mode of action, crop selectivity, and soil relations of the sulfonylurea herbicides. Pestic. Sci. 29:263–281.

Felix, J. and R. A. Boydston. 2010. Evaluation of imazosulfuron for yellow nutsedge (*Cyperus esculentus*) and broadleaf weed control in potato. Weed Technol. 24:471–477.

Hinton, J. D. and F. H. Yelverton. 2003. Purple nutsedge control in bermudagrass with sulfonylurea herbicides. Proc. South. Weed Sci. Soc. 56:104.

Horowitz, M. 1992. Mechanisms of establishment and spreading of *Cyperus rotundus*—the worst weed of warm regions. Proc. First Int. Weed Cont. Congr. 1:94–97.

Hubbard, L. R., A. G. Estes, and L. B. McCarty. 2007. New options for purple nutsedge control in bermudagrass turf. Proc. South. Weed Sci. Soc. 60:111.

Ikeda, H., N. Shimizu, and H. Yoshikawa. 1999. Translocation of foliar-applied imazasulfuron in purple nutsedge (*Cyperus rotundus* L.). J. Weed Sci. Technol. 44:189–194.

Ishida, Y., K. Ohta, S. Itoh, T. Nakahama, H. Miki, and H. Yoshikawa. 1993. Synthesis of novel herbicidal sulfonylurea compounds with imidaz [1,2-a] pyridine moiety. J. Pestic. Sci. 18:175–182.

LaRossa, R. A. and T. K. Van Dyk. 1987. Metabolic mayhem caused by 2-ketoacid imbalances. BioEssays 7:125–130.

McCarty, L. B. and T. Murphy. 1994. Control of turfgrass weeds. Pages 209–248. *in* A. J. Turgeon, ed. Turf Weeds and Their Control. Madison, WI: American Society of Agronomy.

McCarty, L. B., J. W. Everest, D. W. Hall, T. R. Murphy, and F. Yelverton. 2008. Color Atlas of Turfgrass Weeds. 2nd ed. Chelsea, MI: Ann Arbor Press. 13 p.

Ohta, K., S. Itoh, J. Yamada, K. Masumoto, H. Yoshikawa, and Y. Ishida. 1993. Synthesis of herbicidal sulfonylurea compounds with imidazo [2,1-b] thiazole moiety. J. Pestic. Sci. 18:183–189.

Reed, C. F. 1970. Selected Weeds of the United States. Washington, DC: U.S. Department of Agriculture Handbook 366. Pp. 96–99.

Senseman, S. A. and K. Armbrust. 2007. Herbicide Handbook. Lawrence, KS: Weed Science Society of America. 121 p.

Sprankle, P., W. F. Meggitt, and D. Penner. 1975. Absorption, action, and translocation of glyphosate. Weed Sci. 23:235–240.

Stoller, E. W. and R. D. Sweet. 1987. Biology and life cycle of purple and yellow nutsedges (*Cyperus rotundus* and *Cyperus esculentus*). Weed Technol. 1:66–73.

Summerlin, J. R. Jr., H. D. Coble, and F. H. Yelverton. 2000. Effect of mowing on perennial sedges. Weed Sci. 45:501–507.

Tanaka, Y., K. Ideno, T. Yamawaki, and H. Yoshikawa. 1995. Imazosulfuron, a new sulfonylurea herbicide, applicable in rice paddy fields. 15th Asian-Pacific Weed Sci. Soc. Conf. pp. 227–232.

Thullen, R. J. and P. E. Keeley. 1979. Seed production and germination in *Cyperus esculentus* and *Cyperus rotundus*. Weed Sci. 27:502–505.

Tumbleson, M. E. and T. Kommedahl. 1961. Reproductive potential of *Cyperus esculentus* by tubers. Weeds 9:646–653.

Webster, T. M. 2008. Weed survey—southern states, grass crop subsection. Proc. South. Weed Sci. Soc. 57:420–423.

Wills, G. D. 1987. Description of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). Weed Technol. 1:2–9.

Yelverton, F. H., T. W. Gannon, J. D. Hinton, and L. S. Warren. 2003. Weed control and turfgrass tolerance to flazasulfuron. Proc. Southern Weed Sci. Soc. 56:101.

Received July 26, 2011, and approved January 9, 2012.