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EFFECT OF DIFFERENT HERBICIDES ON CONTROL OF PURPLE NUTSEDGE (*Cyperus rotundus* L.)

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ABSTRACT

Purple nutsedge management with herbicides (halosulfuron, imazaquin, MSMA, S-metolachlor, and sulfentrazone) was investigated in a bare ground homogenous purple nutsedge field site. Sequential applications of halosulfuron, MSMA, and sulfentrazone provided at least 80% control of purple nutsedge shoots, whereas imazaquin sequential application controlled purple nutsedge shoots by 68%. All herbicide treatments reduced purple nutsedge total and viable tuber densities at least 40%. S-metolachlor PRE reduced total and viable tuber densities by 65 and 69%, respectively. Sequential applications of sulfentrazone emerged as the top ranking treatment by reducing the total and viable tuber density to the tune of 85 and 89%, respectively. Sequential application of the herbicides tested offered a better control of purple nutsedge as compared to their single applications. Our data indicate that sulfentrazone PRE followed by EPOST applications will provide purple nutsedge shoot and tuber control, but additional research needs to be conducted to investigate sulfentrazone control of purple nutsedge in established turfgrass.

KEY WORDS: Herbicides, Mowing, Purple nutsedge control, nutsedge tuber viability.

INTRODUCTION

Purple nutsedge (*Cyperus rotundus* L.) is one of the most problematic weeds in tropical and subtropical climates and has been described as the world's worst weed (Holm *et al.*, 1991). It is a problem associated with at least 52 crops in 92 countries (Bendixen and Nandihalli 1987; Holm *et al.*, 1991). Purple nutsedge reproduces predominately by basal bulbs, rhizomes, and tubers (Bendixen and

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Nandihalli 1987; Horowitz 1992; Stoller and Sweet 1987; Wills 1987), which allow it to flourish under a wide range of growing conditions. Purple nutsedge is also a problematic weed in warm-season turfgrass and is listed among the 10 most common and difficult to control turfgrass weeds in Alabama, Florida, Georgia, Kentucky, Louisiana, and Texas (Webster 2004). No herbicides are currently registered for pre-emergence (PRE) control of purple nutsedge in warm-season turf (Blum *et al.*, 2000). Pre-emergence applications of *S*-metolachlor are registered for control of yellow nutsedge (*Cyperus esculentus* L.), but not purple nutsedge (Anonymous, 2004). There are no reports of *S*-metolachlor PRE efficacy on purple nutsedge in turfgrass. However, Gilreath *et al.*, (2004) reported that metolachlor PRE provided poor control of purple nutsedge in vegetables. Halosulfuron, imazaquin, and MSMA are registered for post-emergence (POST) application in warm-season turfgrasses for purple nutsedge control (Anonymous, 2005a, 2005b, 2005c). Research has shown halosulfuron applied POST controls purple nutsedge (Blum *et al*., 2000; Czarnota and Bingham 1997; Grichar *et al*., 2003; Molin *et al.*, 1999; Vencill *et al.*, 1995) without causing injury to hybrid bermudagrass (*Cynodon dactylon* L. Pers 3 *C. transvaalensis* Burtt-Davy) or zoysiagrass. Imazaquin applied POST controlled purple nutsedge better than when applied PRE, and POST applications did not injure centipedegrass, common bermudagrass (*Cynodon dactylon* L.), hybrid bermudagrass, St. Augustinegrass or zoysiagrass (Coats *et al.*, 1987). MSMA also controls purple nutsedge, but can cause discoloration of bermudagrass for 1 to 2 wk after application (Blum *et al.*, 2000; Coats *et al.*, 1987). Sulfentrazone has potential use for purple nutsedge control in turfgrass. Blum *et al.*, (2000) documented slight bermudagrass discoloration from sulfentrazone applications lasting not more than 14 d after application and that sulfentrazone POST reduced purple nutsedge shoot number.

Along with herbicides, mowing, a standard component of turfgrass management, is an important part of weed management strategies in turfgrass. Proper mowing practices are a valuable weed control method (McCarty and Murphy, 1994). Mowing can decrease purple nutsedge rhizome length, tuber number, and plant size, but eradication with mowing is unlikely (Summerlin *et al*., 2000). Research has documented the utility of the aforementioned herbicides in turfgrass for control of purple nutsedge shoots; however, information is limited concerning the effects that herbicides have on purple nutsedge tubers. Furthermore, research has not investigated the effect of herbicides in conjunction with mowing on purple nutsedge populations. The objective of this study was to evaluate the response of purple nutsedge shoots and tubers to mowing and herbicides.

MATERIALS AND METHODS

Experiments were conducted in 2006 and 2007 at the Tirtash Research and Education Center Tobbaco in Mazanderan State, Iran. Soil was an Orangeburg fine sandy loam (fine-loamy, siliceous, thermic Typic Paleudults) with 77% sand, 14% silt, 9% clay, and 2% organic matter, pH 5.8. The study area was infested with a native purple nutsedge population at a density of 600 (645) shoots m^{-2} (in nontreated plots). Plot size was 6 m long by 3 m wide. The study area was moldboard-plowed and disk-harrowed before herbicide application. Pendimethalin at 840 g ha^{-1} was applied PRE on May 8, 2006 and May 20, 2007 to the entire test area for annual grass control.

Standard bermudagrass turfgrass fertilization recommendations were followed (Sartain, 2000). The study area was free of turfgrass to facilitate tuber density sampling. A randomized complete block experimental design with four replications was used. The treatments consisted of 10 herbicidal applications. The height of purple nutsedge plants was 13 and 20 cm for the early post-emergence (EPOST) and late post-emergence (LPOST) applications, respectively. Supplemental irrigation was applied on needed basis to prevent moisture stress of purple nutsedge. Nonionic surfactant 5 (0.25% v/v) was added to all POST applications except MSMA, which contained a nonionic surfactant in the formulation. Herbicide treatments were applied with a CO_2 backpack sprayer calibrated to deliver 187 L ha^{-1} at 276 kPa pressure using TeeJett 11002, flat-fan nozzles. Visual control ratings (0 = no control; 100 = complete purple nutsedge death) were recorded 3 wk after LPOST application (WALP). The total number of tubers was sampled 9 WALP in 2006 and 8 WALP in 2007 by excavating a 0.05 m^3 (0.2 m deep by 0.25 m^2) volume of soil. Purple nutsedge tubers are generally concentrated in the upper 0.15–0.2 m of soil (Horowitz 1992; Stoller and Sweet, 1987). Tubers were separated from soil by sifting through a 0.5-cm screen and total tuber number 0.05 m-3 was recorded. Following extraction from soil, all tubers collected from each plot, up to a maximum of 50, were planted in 24 by 40 by 2.5-cm plastic trays in herbicide-free soil medium to determine tuber viability. Trays were irrigated daily with overhead irrigation. Tubers were allowed to germinate, and the total number of germinated tubers was counted after 4 wk. Before analysis, total and viable tuber counts were transformed to percent reduction compared to the non treated. Data were subjected to ANOVA using PROC GLM in SAS, tested for homogeneity, and pooled when interactions were not indicated. Means were separated with Fisher’s protected LSD test at the 0.05 level of probability.

RESULTS AND DISCUSSION

Purple Nutsedge Shoot Control

The Analysis of Variance indicated no year by herbicide interaction; therefore, data were pooled across years.

Santos *et al.*, (1997) found that mowing decreases high populations of purple nutsedge through removal of shoot biomass. Sequential applications of sulfentrazone PRE followed by EPOST controlled purple nutsedge shoots 13% better than a single application of sulfentrazone PRE (86 vs. 73%) (Table-1). Previous research with sulfentrazone has yielded conflicting results. In established bermudagrass turf, visual purple nutsedge control with single (421 g ha^{-1}) and sequential (421 followed by 140 g ha^{-1}) sulfentrazone POST applications did not exceed 50% (Blum *et al.*, 2000). In potato (*Solanum tubersum* L.), Grichar *et al.*, (2003) reported sulfentrazone PRE at 280 g ha^{-1} or POST at 140 g ha^{-1} controlled purple nutsedge ≥90%. In a greenhouse experiment, sulfentrazone controlled purple nutsedge 80 to 90% and was more effective when placed in the root zone, indicating increased efficacy of sulfentrazone when absorbed by the roots (Wehtje *et al.*, 1997).

A possible explanation for the variations in purple nutsedge control observed with sulfentrazone may be the experimental area used in each trial. Our research was conducted on bare ground in a purple nutsedge mono culture. Blum *et al.*, (2000) conducted their research with established common bermudagrass, Grichar *et al.*, (2003) with potato, and Wehtje *et al.*, (1997) in the greenhouse. Our results are however, similar to those of Grichar *et al.*, (2003) and Wehtje *et al.*, (1997), in which sulfentrazone was applied to bare soil and provided 70 to 100% purple nutsedge control. However, Blum *et al.*, (2000) applied sulfentrazone to bermudagrass infested with purple nutsedge and documented ≤50% control. Sulfentrazone applied to bermudagrass may have been adsorbed to the bermudagrass thatch layer. Thatch may retain pesticides, and soil beneath a thatch layer contains an average of 58% less pesticide than found within the thatch (Horst *et al.*, 1996). Furthermore, they found that pesticides degraded more rapidly in a turfgrass environment than is typically reported for other agronomic cropping systems. Control of purple nutsedge is greatest when sulfentrazone is absorbed by roots (Wehtje *et al.*, 1997) and if sulfentrazone is retained within the thatch layer, less sulfentrazone was available for absorption by purple nutsedge, resulting in reduced purple nutsedge control in a turfgrass regime compared to the other regimes in which thatch was not present.

Presently, sulfentrazone is not registered for use in bermudagrass turf, but Blum *et al.*, (2000) found that sulfentrazone did not decrease bermudagrass quality, with only 5 to 10% injury lasting less than 14 d, indicating tolerance of bermudagrass to sulfentrazone applications. Sequential MSMA applications provided more than 90% purple nutsedge control, nearly twice the control observed with a single EPOST treatment (92 vs. 47%) (Table-1). In previous research, more effective purple nutsedge control was observed with multiple applications compared with a single treatment (Coats *et al.*, 1987; Hamilton, 1971). McElroy *et al*., (2003) determined that MSMA reduced purple nutsedge shoot number by 60% 9 wk after treatment (WAT) with a single application in the greenhouse. However, Blum *et al*., (2000) reported only 16% purple nutsedge control 9 wk after sequential MSMA applications at 2,808 g ha^{-1} in common bermudagrass. Documented control of purple nutsedge with 2,808 g ha^{-1} of MSMA in the Blum *et al.*, (2000) research was less than purple nutsedge control observed in our research following sequential MSMA applications at 2,240 g ha^{-1}. Differences in control may be attributed to increased coverage of purple nutsedge foliage by MSMA applications in our bare ground purple nutsedge monoculture research, as opposed to MSMA applications in bermudagrass turf by Blum *et al.*, (2000). Halosulfuron applied EPOST followed by LPOST at 70 g ha^{-1} controlled purple nutsedge shoots 81%, but control was not better than that observed with a single application of halosulfuron EPOST (Table-1). Blum *et al.*, (2000) reported single applications of halosulfuron provided 28% purple nutsedge control, but control improved to 94% following a sequential application in bermudagrass (Blum *et al.* 2000). Czarnota and Bingham (1997) reported that single applications of halosulfuron at 70 g ha^{-1} controlled purple nutsedge 95% 6 WAT in cool- and warm-season turfgrasses. Purple nutsedge shoot density in bermudagrass was reduced by 66% with single applications of halosulfuron at 72 g ha^{-1} in bermudagrass (Molin *et al*., 1999). Imazaquin, regardless of whether applied as a single or sequential treatment, provided greater than 70% purple nutsedge control (Table-1). Others reported similar results where imazaquin POST provided 66% shoot reduction in the greenhouse (Rao and Reddy, 1999) and 68% purple nutsedge control 5 WAT in a common bermudagrass golf fairway (Coats *et al.*, 1987). Purple nutsedge was controlled 75% by *S*-metolachlor PRE at 4,480 g ha^{-1} (Table-1). This level of control was equal to or greater than that observed with single applications of halosulfuron, imazaquin, MSMA, and sulfentrazone. In previous research with crops such as cotton (*Gossypium hirsutum* L.) and peanut (*Arachis hypogaea* L.), *S*-metolachlor PRE provided only 30% control 9 WAT when applied at 1,070 to 1,420 g ha, $^{-1}$ rates much lower than the maximum of 4,480 g ha^{-1} registered for turf (Akin and Shaw, 2001; Grichar *et al*., 1992). Other studies conducted in bermudagrass indicated that metolachlor at

3,400 g ha^{-1} and 4,480 g ha^{-1} failed to provide adequate control of either yellow nutsedge (*Cyperus esculentus* L.) or cocks-comb (*Kyllinga squamulata* Thonn. ex Vahl), respectively (Bunnell *et al.*, 2001; Lowe *et al*., 2000). Only sequential applications of sulfentrazone, halosulfuron, and MSMA provided 81-92% control of purple nutsedge shoots. Single applications of *S*-metolachlor, sulfentrazone, and halosulfuron provided 47-75% control of purple nutsedge shoots, indicating that sequential applications are needed for greater shoot control. Sequential applications of sulfentrazone or MSMA appear to be the best options to achieve maximum purple nutsedge shoot control when compared to the other herbicides in this study.

Purple Nutsedge Tuber Control

ANOVA indicated no year by mowing regime, year by herbicide interaction or for total and viable tuber densities; therefore, data were pooled across years and herbicide (Table-1). Sequential applications of sulfentrazone reduced total and viable tuber densities 85 and 89%, respectively (Table-1). Conversely, Blum *et al.*, (2000) found that sulfentrazone applications did not reduce purple nutsedge tuber viability when applied in bermudagrass. Sequentially applied sulfentrazone did not differ from *S*-metolachlor PRE, sulfentrazone PRE, or MSMA EPOST followed by LPOST (Table-1). No differences were noted for reduction of tuber densities between single or sequential applications of halosulfuron or imazaquin (Table-1). Under single and sequential application of Halosulfuron reduced total and viable tuber densities an average of 50 and 59%, respectively. Similarly, imazaquin reduced total and viable tuber densities an average of 55 and 60%, respectively (Table-1). In other research, sequential applications of halosulfuron reduced purple nutsedge tuber viability (Blum *et al.*, 2000; Molin *et al.*, 1999), but tuber weight and number were not affected by halosulfuron application (Molin *et al.*, 1999). Imazaquin did not reduce tuber viability in bermudagrass (Blum *et al*., 2000). MSMA EPOST reduced total and viable tuber densities 40 and 52%, respectively, whereas sequential MSMA applications decreased total and viable tuber densities 71 and 78% (Table-1). However, Blum *et al.*, (2000) found that MSMA did not reduce tuber viability in bermudagrass. Our data showed that *S*-metolachlor PRE, sulfentrazone PRE-only or sequentially applied, and sequential applications of MSMA provided control of purple nutsedge foliage and reduced total and viable tuber density.

Even though the *S*-metolachlor and MSMA reduced tuber density, sequential applications of sulfentrazone reduced tuber densities most effectively. Others have reported that halosulfuron and imazaquin require shoot and root exposure to achieve purple nutsedge control even when applied to foliage (Nandihalli and Bendixen, 1988; Vencill *et al*., 1995). Halosulfuron and imazaquin were applied POST to purple nutsedge foliage and not exposed to the roots, which may explain the lower total and viable tuber reductions with these two herbicide treatments in our research. Furthermore, MSMA and sulfentrazone are not systemic herbicides (Vencill, 2002), and translocation may be limited to the tuber for viability reduction. A plausible explanation for the observed reduction of purple nutsedge tuber number and viability, especially for the non translocated herbicides, is a reduction in size of the tuber caused by removal of foliage. Santos *et al.*, (1997) found that continuous removal of shoot biomass caused depletion of tuber carbohydrate reserves. In the absence of competition from turfgrasses, mowing purple nutsedge to 1.3 and 3.8 cm reduced tuber number and size (Summerlin *et al.*, 2000). Therefore, the control of shoot biomass by mowing or herbicide applications may lead to depletion in total tuber number and tuber viability by reducing carbohydrate reserves.

We hypothesize that sequential applications of sulfentrazone applied on a yearly basis may reduce purple nutsedge tuber density in the soil seed bank and greatly reduce purple nutsedge as a troublesome weed species. However, two factors that were not evaluated in this study need to be addressed to relate this research to turfgrass weed management. First, the effect of the competitive interaction between turfgrass and purple nutsedge needs to be assessed. It was not considered in our experiment because our research was conducted on a homogenous purple nutsedge site with no competition from turfgrass to facilitate tuber sampling. Second, as discussed earlier, the potential for the turfgrass thatch layer to adsorb herbicides that require root exposure to control purple nutsedge should be determined because this may lead to less reduction in tuber numbers and greater viability. Both of these factors may be important because Blum *et al.*, (2000) observed no reduction in tuber viability following sulfentrazone application in bermudagrass turf.

However, Wehtje *et al.*, (1997) found consistent control of germinating purple nutsedge tubers by sulfentrazone PRE with combined root and shoot zone exposure in the greenhouse. Our data indicate that sulfentrazone PRE followed by EPOST applications will provide purple nutsedge shoot and tuber control, but additional research needs to be conducted to investigate sulfentrazone control of purple nutsedge in established turfgrass.

Table-1. Herbicide rates and time of application for control of purple nutsedge Shoots and Tuber density reduction (%).

Herbicide	Timing	Rate g ha^{-1}	Tuber density reduction %		
			Shoot control	Total	Viable
S-metolachlor	PRE	4,480	75	65	69
Sulfentrazone	PRE	420	73	71	76
Halosulfuron	EPOST	70	73	54	55
Imazaquin	EPOST	430	63	49	53
MSMA	EPOST	2,240	47	40	52
Sulfentrazone fb sulfentrazone	PRE fb EPOST	420 fb 140	86	85	89
Halosulfuron fb halosulfuron	EPOST fb LPOST	70 fb 36	81	45	62
Imazaquin fb imazaquin	EPOST fb LPOST	430 fb 430	68	60	66
MSMA fb MSMA	EPOST fb LPOST	2,240 fb 2,240	92	71	78
Untreated			-	-	-
LSD$_{0.05}$			**9**	**23**	**20**

Mention total number of tuber/m^2 in the untreated control the footnote here.

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