THE CONTROL OF YELLOW AND PURPLE NUTSEDGE

(*Cyperus esculentus* and *rotundus*) IN TURFGRASS UTILIZING HALOSULFURON

by

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(ABSTRACT)

Yellow and purple nutsedge are difficult to control world wide. In turfgrass, the availability of herbicides that provide selective control of these weeds is limited. To address this problem, a sulfonylurea herbicide, halosulfuron, is being developed for the control of both yellow and purple nutsedge. To confirm preliminary results, evaluations of this herbicide were performed in both field and greenhouse studies during 1993 and 1994. The objectives of the field studies were to evaluate halosulfuron for turfgrass tolerance (safety to turfgrass) and efficacy for yellow and purple nutsedge control. Greenhouse studies were performed to determine the extent of translocation of halosulfuron in yellow and purple nutsedge.

Four species of turfgrass were evaluated for halosulfuron tolerance: Kentucky bluegrass (*Poa pratensis* L. 'Plush'), tall fescue (*Festuca arundinaceae* Schreb. 'Confederate'), bermudagrass (*Cynodon dactylon* (L.) Pers. '419' and 'Vamont') and zoysiagrass (*Zoysia japonica* Steud. 'Meyers'). Over a two year period, injury to these turfgrass species did not exceed 10% and in most cases was non-existent. In these studies, yellow nutsedge control with halosulfuron at 0.14 kg ai/ha averaged 90% after six

weeks in the four turfgrasses. However, after six weeks, yellow nutsedge regrowth did occur. Purple nutsedge control was evaluated only in Kentucky bluegrass and was uniformly transplanted into the study area. Purple nutsedge control averaged 96% in Kentucky bluegrass at 6 weeks after treatment.

Yellow and purple nutsedge contain a well developed rhizome/tuber system, and as was seen in several of the studies, have the ability to regrow after herbicide treatment. Two greenhouse studies were designed to determine halosulfuron translocation into the tuber and connecting shoot and through a rhizome into another shoot. In the first study, a tuber was only allowed to develop two shoots from separate buds on the tuber. After a month, one of the shoots was treated with halosulfuron, and control ratings were taken on both shoots. In the second study, a plant was placed in one of two connected pots and allowed to grow. A rhizome from this plant (mother plant) was guided into the connecting pot where a new plant developed. After a month, the mother plant was treated with halosulfuron, and control ratings were taken on both mother and new plant. From both of these tests, there is statistically significant evidence that translocation was occurring through both the tuber and the rhizome. This translocation occurred not only at rates used for nutsedge control but at rates well above and below 0.14 kg ai/ha. More work, however, needs to be performed using radiolabeled tracers or immunological techniques to confirm movement of halosulfuron in yellow and purple nutsedge.

Although regrowth of yellow and purple nutsedge was seen in both field and greenhouse studies, halosulfuron does provide good inital control of both species. Sequential applications of halosulfuron are desirerable in poorly established turfgrass.

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INTRODUCTION

Introduction.

A well-established, well-maintained turf does not happen by accident. It requires well-implemented management practices. One important aspect to turf management is weed control. There are several economically important weeds in turf. The type and severity of weed species depends on many aspects of turf management. These may include type of turf, location, soil type, and soil fertility. Two problem weeds in turf are yellow and purple nutsedge (*Cyperus esculentus* L. and *rotundus* L.). Both are among the most noxious weeds in the world (3, 13, 15). In turf, these weeds are very difficult to control because of their rhizome and tuber systems (2, 29, 41, 42), their tremendous reproductive potential (34, 36, 41, 42), and their ability to survive in extremely diverse environment (3).

In turfgrass, nutsedge control is achieved mainly by the use of postemergence herbicides (6, 38), although metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide], a preemergence herbicide, is used for the control of yellow nutsedge in warm-season turfgrass (37). With nutsedges' extensive tuber and rhizome system, preemergence herbicides are not as effective as postemergence herbicides. Postemergence herbicides make contact with the foliage, allowing for more efficient entry of the herbicide into the plant. As well as having better efficacy, there are more postemergence herbicides available to control yellow and purple nutsedge (37). For postemergence yellow and purple nutsedge control, bentazon [3-(-1-methlethyl)-(-1H)-

2,1,3-benzothiadiadiazin-4(3H)-one 2,2-dioxide] and imazaquin [2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidzol-2-yl]-3-quinolinecarboxylic acid] are the industry standards (6), respectively. The organic arsenical herbicides provide some postemergence control of nutsedges in turfgrass. MSMA [monosodium salt of methylarsonic acid] is the main arsenical used by the turfgrass industry; however, multiple applications are required in order to achieve appreciable yellow and purple nutsedge control. Furthermore, the standard postemergence products are not without their problems. Bentazon, unfortunately, requires multiple applications to attain good control and probably does not kill nutsedge tubers (29). Moreover, under the right environmental conditions, bentazon can cause severe injury to perennial ryegrasses. Imazaquin is mainly used for purple nutsedge control in warm-season grasses; although, it may be tank mixed with MSMA to provide some degree of yellow nutsedge control. At present there are no effective herbicides available for purple nutsedge control in cool-season grasses, and very few herbicides are available for yellow nutsedge control in perennial ryegrass.

From discussions with county extension agents, chemical company representatives, and university professors, it is apparent that nutsedge both purple and yellow are becoming more and more of a problem (8, 26, 33). There are probably three major reasons for this occurrence. First, there has been great progress made in the ability to control most broadleaf and annual grass weeds; and, with little or no competition from turf, nutsedge will occupy voids once held by these weeds. Secondly, yellow and purple nutsedge, because of their similarities, are easily misidentified, resulting in the wrong herbicide being applied. The industry standard for yellow nutsedge control, bentazon, does not control purple nutsedge; furthermore, imazaquin, the industry standard for purple nutsedge control, does not control yellow nutsedge. Although, both of these herbicides may injure both species of nutsedge, control is only attained when the right herbicide is applied to the right plant. The third reason is that herbicide sensitivity within and between the nutsedge species varies, and this has been noted in yellow nutsedge (9).

A turf herbicide that selectively controls both yellow and purple nutsedge is needed. Halosulfuron [methyl 5-{[(4,6-dimethoxy-2-pyrimidinyl)amino] carbonylaminosulfonyl}-3-chloro-1-methyl-1-H-pyrazole-4-carboxylate] is being developed for this purpose. There are many positive aspects of this herbicide: low use rate, pre and postemergence activity, low mammalian toxicity, and safety to all major turfgrasses. Preliminary tests have shown that halosulfuron has excellent activity on both yellow and purple nutsedge (16) and safety to all major turf species (35). The purpose of this research was to confirm these field results and also to determine whether there is translocation of halosulfuron through the nutsedge plant into the rhizomes and tubers.

Literature review

Numerous articles in various publications have documented severe infestations of yellow (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.) in agromic crops, turf, vegetables, and ornamentals (3, 9, 15, 18, 19, 20, 22, 23, 30, 32, 38, 40). Yellow and purple nutsedge are poor competitors with other plants for light, water, and nutrients (29, 30). Yet both of these plants have established themselves as noxious weeds. Yellow and purple nutsedge are in the Cyperaceae. This family is similar to the grass family but is distinguished by having three-ranked leaves, closed leaf sheaths, and solid stems (42). Although usually present in crop weed populations, before the 1960s, yellow and purple nutsedge were not considered an important weed problem (2, 33, 39). Since the early 1960s, huge contributions have been made to agricultural production by the introduction of selective herbicides. With the advent of selective herbicides, the control of weeds that had caused problems for decades was now possible. However, controlling 95% of one or two weed species created opportunities for weed species that were normally poor competitors. Without competition, weeds such as nutsedge exploded in numbers (29, 30, 32, 33, 39, 42). This circumstance raised the need for changes in weed control methods and for different herbicides with different modes of action.

In turfgrass, as with field crops, nutsedge has become a major weed problem. Selective herbicides used to control dicot weeds in turfgrass forced the weed flora to shift to monocot species. This led to the development of preemergence herbicides that controlled annual grasses. With little competition from broadleaf and annual grass weeds, nutsedge then flourished (8, 32, 40). The development of selective herbicides was probably the most influential factor in shifting the weed flora, but other factors were also very important. With turf being a permanent monoculture, some important aspects of cultural weed control cannot be practiced. Crop rotation not only allows the use of several different classes of herbicides but also allows the use of plants with different growth characteristics, thus placing different competitive strains on the weed flora. Both of these are powerful means of weed control in grain and vegetable crops (11, 18, 19, 20, 21, 30, 32). Cultivation is also a very viable means of control in grain and vegetable crops (11). In turfgrass, for obvious reasons, these weed control methods cannot be used.

As mentioned earlier, nutsedges do not compete well with plants for water, nutrients, and light; but, in most turfgrass, nutsedges compete quite well. One would not expect nutsedges to perform well in turfgrass because of competition and constant removal of nutsedge foliage due to close mowing heights associated with turfgrasses (36). Some of the reasons that nutsedge competes well with turf are as follows. First, both yellow and purple nutsedge are C_4 plants (14, 15, 41). With this superior ability to obtain carbon, it is difficult to reduce the carbohydrate reserve in nutsedge with frequent mowings. Secondly, the reproductive potential of the plant is astounding. In a situation with little competition, one yellow nutsedge tuber has produced upwards of 7,000 tubers in one season (2, 11, 13, 34). Even with a fraction of this tuberization occurring, it is easily understood why these plants can become such a problem. To further compound this issue, nutsedge tubers break dormancy erratically (4, 28). According to Stroller (30), tubers near the soil surface break dormancy much more quickly than tubers located deeper. He also indicated that factors such as moisture, temperature, and level of maturity affected the length of dormancy. With tubers breaking dormancy throughout the season, it is difficult to select a time frame that will allow a herbicide to provide acceptable control.

With pressures to develop nonchemical control, biological nutsedge control has been considered as an alternative (24). Attempts to control both yellow and purple nutsedge using either fungi or insects have been made. Yellow nutsedge control with the rust *Puccinia canaliculata* (1) and purple nutsedge control with the fungus *Balansia cyperi* have been evaluated (31). Both fungi reduced nutsedge growth; however, neither was very effective in providing adequate control. Some promising research with the genus of moth *Bactra* has indicated that control of purple nutsedge is possible under managed conditions (24). However, it is difficult to contain the moths in one location, and a cost effective procedure has not been developed for field use.

Attempts to control yellow nutsedge with allelopathic compounds have been made; one study has utilized extract from sweet potato periderm (12). This compound has been reported to impair the uptake of nutrients Ca, Mg, and S. The activity of the compound on yellow nutsedge is relatively high, but this compound, as with most allelopathic compounds, lacks selectivity. Although much knowledge has been gained by researching biocontrol methods, much work needs to be done before any viable compound is developed.

Until the mid 1980s, no selective herbicide was available to control nutsedges in turfgrass. Compounds such as 2,4-D [(2,4-dichlorophenoxy) acetic acid], dicamba [3,6-dichloro-2-methoxybenzoic acid], metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide], and MSMA [monosodium salt of methylarsonic acid] were available (9, 19); but none of the compounds was very effective without multiple applications. Dicamba, metolachlor, and MSMA had limited ranges of safety on turfgrass (8). With the development of bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] and imazaquin [2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-quinolinecarboxylic acid] in the mid to late 1980s, it was possible to control yellow nutsedge in cool- and warm-season turfgrasses and purple nutsedge in warm-season turfgrasses, respectively. These products provided superior nutsedge control but with limitations. Usually bentazon and imazaquin require multiple applications. Also, herbicides to selectively control purple nutsedge in cool-season turfgrass were not available (8, 16, 21, 37).

In the early 1990s, a sulfonylurea herbicide, halosulfuron [methyl 5-{[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonylaminosulfonyl]-3-chloro-1-methyl-1-H-pyrazole-4-carboxylate] was being developed for the control of small-seeded broadleaf weeds; however, in the development process, it was found that the herbicide had excellent efficacy on nutsedge (27, 28). With a large market available for a herbicide that selectively controls nutsedge in turfgrasses, research was initiated with halosulfuron.

Sulfonylurea herbicides inhibit the enzyme acetolactate synthase. This enzyme is involved in the conversion of pyruvate to valine or leucine and the conversion of alpha-ketobutyrate into isoleucine (5, 10). This is the only pathway involved in the production of these three amino acids; and, without this pathway functioning at full capacity, plants will generally perish. There are thought to be several reasons why selectivity occurs with sulfonylurea herbicides, and many of these have been elucidated (10). Very few papers have been published explaining why certain sulfonylurea herbicides are so toxic to nutsedges. Reddy and Benedixen (25) indicated that the sulfonylurea, chlorimuron [2-[[[[(4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid], is readily absorbed and translocated through the nutsedge plant and that nutsedge species are unable to degrade the compound readily. To date, no studies have been published on absorption and translocation of halosulfuron in nutsedge. However, research has shown that halosulfuron is promising for control of nutsedge in turfgrass (7, 16, 21, 35).

OBJECTIVES

The objectives of this research were two fold. First, field tests were performed to investigate the efficacy of halosulfuron on yellow and purple nutsedge, and at the same time the safety of halosulfuron on several major turfgrass species. Secondly, two greenhouse studies were conducted to evaluate translocation aspects of halosulfuron in yellow and purple nutsedge.

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CHAPTER I

The Control of Yellow and Purple Nutsedge (*Cyperus esculentus* and *Cyperus rotundus*) in Turfgrass with Halosulfuron.

Abstract. Field studies were conducted to evaluate halosulfuron for turfgrass tolerance and yellow and purple nutsedge control. The availability of herbicides for selective control of these weeds in turfgrass is very limited. A sulfonylurea compound, halosulfuron, has recently received attention for selective control of the nutsedges in turfgrass. Two years of field studies were performed on four grass species: Kentucky bluegrass, tall fescue, bermudagrass, and zoysiagrass. With halosulfuron applied at 0.07 to 0.14 kg ai/ha, injury did not exceed 10% in any of the turfgrass species. Yellow nutsedge control averaged over all test was 90% at six weeks. However, after six weeks nutsedge regrowth did occur. Purple nutsedge control averaged 96% at six weeks after treatment in Kentucky bluegrass.

Nomenclature: Yellow nutsedge (*Cyperus esculentus* L.); purple nutsedge (*Cyperus rotundus* L.); Kentucky bluegrass (*Poa pratensis* L. 'Plush'); tall fescue (*Festuca arundinaceae* Schreb. 'Confederate'); bermudagrass (*Cynodon dactylon* (L.) Pers. '419' and 'Vamont'); zoysiagrass (*Zoysia japonica* Steud. 'Meyer'); bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide]; imazaquin [2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-quinolinecarboxylic acid]; halosulfuron [methyl 5-{[(4,6-dimethoxy-2-

pyrimidinyl)amino]carbonylaminosulfonyl]-3-chloro-1-methyl-1-H-pyrazole-4-carboxylate].

Additional index words: bentazon, imazaquin, MON 12051, CYPES, CYPRO, FESAR, POAPR, CYNDA, ZOYJA.

INTRODUCTION

Yellow and purple nutsedge are difficult weeds to control world wide (8). They cause severe economic loss in both agronomic and horticultural crops (3, 8, 13, 17, 20, 21). Both plants were not considered to be a serious weed problem until the 1960s (1); however, enormous opportunities were created for nutsedges with the advent of selective herbicides (13). When more dominant weed species were controlled with selective herbicides, less aggressive weed species, such as nutsedges, exploded in number (13, 17). In warm- and cool-season turfgrasses, both species are difficult to control (3, 5, 12, 17); but, with the introduction of the herbicides bentazon and imazaquin, controlling yellow and purple nutsedge has been made easier. There are, however, still voids in the ability to control both weeds.

Yellow nutsedge is predominantly found in cool-season turfgrasses and is controlled with the herbicide bentazon (12, 19). Purple nutsedge, predominantly found in warm-season turfgrasses, is controlled with the herbicide imazaquin (5, 19). Problems occur in transitional zones, such as in Virginia, where it is possible to grow both warm- and cool-season turfgrasses (4). Here, purple nutsedge has the opportunity to move into cool season turfgrasses. Also, combined infestation of purple and yellow nutsedge can occur (2). At present, there are no compounds available to control such problems efficiently.

Halosulfuron is being developed for the control of yellow and purple nutsedge in turfgrass. In preliminary studies with halosulfuron, safety to all major turfgrass species (18) as well as good control (> 80 %) of both yellow and purple nutsedge was observed (9). Halosulfuron will likely help alleviate nutsedge control problems in transitional zones as well as be an excellent addition to the arsenal of nutsedge herbicides presently available. The purpose of this research was to investigate the efficacy of halosulfuron on both yellow and purple nutsedge and to evaluate the safety of halosulfuron on several different species of turfgrass.

MATERIALS AND METHODS

In 1993 and 1994, field studies were conducted at two sites in Virginia, Blacksburg and Baskerville. These sites, being 370 km apart, were of different climatic conditions. Blacksburg, being 640 m above sea level, is more suited for growing cool-season turfgrasses, while Baskerville, being only 90 m above sea level, is more suited for growing warm-season turfgrasses. Study sites were chosen in turfgrass stands known to have nutsedge infestations (Table 1.1). Over two years at both locations, a severe natural infestation of yellow nutsedge was present. The average count of yellow nutsedge found at Blacksburg during the 1993 and 1994 seasons was 90 plants/m^2 . At Baskerville, the

Table 1.1. Locations, turf type, times treated, weed controlled.

Turf Type	Location	Initiation of experiment	Weed
Kentucky bluegrass 'Plush'	Blacksburg	8/07/93*	Yellow nutsedge
Kentucky bluegrass 'Plush'	Blacksburg	8/07/94*	Yellow nutsedge
Tall fescue 'Confederate'	Baskerville	6/15/93*	Yellow nutsedge
Tall fescue 'Confederate'	Baskerville	6/28/94*	Yellow nutsedge
Bermudagrass 'Vamont'	Baskerville	6/28/94*	Yellow nutsedge
Zoysiagrass 'Meyer'	Baskerville	7/14/94*	Yellow nutsedge
Kentucky bluegrass 'Plush'	Blacksburg	8/07/93	Purple nutsedge
Kentucky bluegrass 'Plush'	Blacksburg	8/07/94	Purple nutsedge

*A second application of bentazon followed at approximately 14 days averaged count of yellow nutsedge was 250 plants/m^2 over the 1993 and 1994 seasons.

Difficulties were encountered in locating uniform stands of purple nutsedge in cool-season turfgrasses. Therefore, a uniform test area was created. An established Kentucky bluegrass stand was chosen for the test. Purple nutsedge[1] tubers were placed in a Promix[2] medium which was in flats[2] containing 60 (2.5 x 7.5 cm) cells. Plants were grown under greenhouse conditions for approximately one month. These purple nutsedge plugs were then transplanted to the test area (12 plants/plot) in early June of 1993 and 1994. This test area was irrigated as needed, and purple nutsedge was allowed to grow for approximately 2 months before treatments were applied.

Baskerville Location. At Baskerville, three turfgrass species with severe yellow nutsedge infestations were treated. In 1994, tests on bermudagrass and zoysiagrass were conducted on sites where sod had been harvested the previous year. For tall fescue, in 1993 and 1994, tests were established using recently (< 60 days) seeded fields. Consequently, the tall fescue provided poor competition with the emerging yellow nutsedge.

In both 1993 and 1994, maintenance of all tests sites was similar. Watering was performed on an as-needed basis. Two commonly occurring diseases, brown patch (*Rhizoctonia solani* Kühn) and dollar spot (*Selerotinia homoeocarpa* F. T. Bennett), were

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[1] Azlin Seed Service, P.O. Box 914, Leland, MS 38756

[2] E.C. Geiger, Inc., P.O. Box 285, Harleysville, PA 19438-0332.

treated with chlorathalonil [tetrachloroisophthalonitrile] at 4.2 to 17.5 kg ai/ha. The insect problems, primarily grubs, were treated with isofenphos [1-methylethyl 2-[[ethoxy[(1-methylethylamino]phosphinothioyl] oxy]benzoate] at a 2.2 kg ai/ha. Ammonium nitrate was applied to turfgrasses at a rate of 75 to 100 kg of nitrogen (N) /ha per year. For annual grass control, either prodiamine [N^3,N^3-di-*n*-propyl-2,4-dinitro-6-(trifluoromrthyl)-*m*-phenylenediamine] at a 0.8 kg ai/ha or oxadiazon [3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one] at 2.1-4.5 kg ai/ha was used. A mixture of 2,4-D [(2,4-dichlorophenoxy)acetic acid] at 0.6 kg ai/ha and dicamba [3,6-dichloro-2-methoxybenzoic acid] at 0.3 kg ai/ha was used to control broadleaf weeds.

Mowing heights were different among turf species. Tall fescue was maintained at 7.5 to 8.75 cm. Bermudagrass and zoysiagrass were maintained at 2.5 cm. Mowing was performed either two or three times per week depending on turfgrass type and weather conditions.

The site at Baskerville was underlain by an Appling sandy loam (clayey, koaolinitic, thermic typic Hapludult) with a pH of 6.2 and an organic matter content of 1.9%.

In 1993, herbicide treatments were applied to tall fescue on 15 and 30 June. In 1994, herbicide treatments were applied to bermudagrass on 28 June and 13 July, to zoysiagrass on 14 and 26 July, and to tall fescue on 28 June and 14 July.

Blacksburg Location. At the Blacksburg location, an established Kentucky bluegrass turf was treated. The area had a naturally high infestation of yellow nutsedge.

Maintenance of the Kentucky bluegrass sites was the same over the 1993 and 1994 growing seasons. During both years, areas were watered on an as-needed basis. In April of both years, the test area was aerified and vertically mowed. To control annual grasses, the test areas were treated in April of both years with pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] in April of both years, at the rate of 3.36 kg ai/ha. Broadleaf weed control was performed in May of both years using 2,4-D at 0.6 kg ai/ha and dicamba at 0.3 kg/ha. The Blacksburg site is a Groseclose-Urban land complex (Clayey, mixed, mesic typic Hapludults) with a pH of 6.35 and 2.0% organic matter. In 1993 and 1994, herbicide treatments were applied 7 August followed by a second application of bentazon approximately 14 days later.

Post emergence treatments were applied to either 1.8 x 1.8 m or 1.8 x 3.6 m plots using a randomized complete block design with either three or four replications. Treatments were applied with either a CO_2 bicycle sprayer[3] or a CO_2 backpack sprayer with a pressure of 210 kPa, using 8004 flat fan nozzle tips[4] to apply 280 L/ha. Nutsedges were treated at the three- to five- leaf stage. Herbicide rates were selected to include labeled rates and consisted of bentazon at 2.24 kg ai/ha (split into two applications of 1.12) and 2.24 kg ai/ha (single application). Bentazon applications contained 0.25% v/v

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[3] R & D Sprayers Inc., 790 E. Natchez Blve., Opelousas, LA 70570.

[4] Spraying System Co., North Ave., Wheaton, IL 60187-7900.

crop oil concentrate[5]. Imazaquin was applied at 0.21 and 0.43 kg ai/ha with 0.25% v/v surfactant (X-77[6] in 1993 and Kinetic[7] in 1994). Halosulfuron was selected to include the rate range recommended in an experimental product label (15) and consisted of 0.07 and 0.14 kg ai/ha with 0.50% v/v surfactant (X-77 in 1993 and Kinetic in 1994). Ratings on turf injury, turf quality, and nutsedge control were taken at 2, 4, and 6 weeks after herbicide treatment. Turf quality was rated on a 1 to 9 scale, where the numbers indicate the following:

- 1 — considerable bare soil and apparently dead turf
- 2, 3, 4 — unacceptable turf, up to 15% weeds and some injury symptoms
- 5 — minimum acceptable turf, up to 15% weeds
- 6, 7, 8 — good to highly acceptable turf, less than 15% weeds
- 9 — no to few weeds and excellent quality turf

Turf injury was rated on a 0 to 10 scale. The numeric values indicate the following:

- 0 — no apparent injury to turfgrass
- 1 to 3 — slight injury, acceptable color, very little discoloration

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[5]BASF Corp., Consumer Products & Life Science Div. Agricultural Products Group, Research Triangle Park, NC 27709-3528.

[6]Valent USA Corp., Walnut Creek, CA 94596. Alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanols are the major functioning agents.

[7]Helena Chem. Co., 6075 Popular Ave., Memphis, TN 38119. Organosilicon and nonionic surfactant mixture.

•4 to 6	definite turfgrass injury, noticeable discoloration or phytotoxicity
•7 to 9	unacceptable injury to serious injury, necrosis
•10	dead and brown turfgrass

Nutsedge control was rated on a 0 to 100 scale. The numeric values indicate the following:

•0	no apparent response
•10, 20, 30, 40	slight control or injury, light green to discoloration
•40, 50, 60	poor control, numbers reduced or injured, unacceptable
•70, 80	fair control, number reduced, suppression in size or discolored
•80, 90	good weed control, 80 to 90% control, number reduced, severe phytotoxicity or necrosis
•90, 92, 95, 97, 98, 99	excellent weed control, 90 to 99% control, few remaining plants, size may or may not be reduced
•100	complete control of targeted weed

These rating scales were similar to rating scales utilized by other turfgrass researchers (7, 10, 11, 16).

Data were analyzed[8] using analysis of variance followed by Duncan's mean separation procedure with a significance level of α=0.05 (14). With no systematic variation among the nutsedge plants at the times of treatment, blocking was not necessary. Thus, when two years of data were available, both tests were treated as one randomized complete

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[8]Gylling Data Management, Inc., 405 Martin Blvd., Brookings, SD 57006.

block design of 6 or 7 replications and analyzed.

RESULTS AND DISCUSSION

YELLOW NUTSEDGE CONTROL AND TURF INJURY

Kentucky bluegrass. Treatments with halosulfuron and bentazon caused little injury to the turfgrass at 2 weeks after treatment (WAT) (Table 1.2). Yellow nutsedge control with both treatments of bentazon was greater than 82%. However, yellow nutsedge control with halosulfuron was poor to fair at this point, with a 60% control rating (Table 1.2). By 6 WAT, there was no indication of injury from either bentazon or halosulfuron (Table 1.3). Moreover, yellow nutsedge control with halosulfuron at both rates had improved to complete control. With the yellow nutsedge infestation, the quality of the turfgrass was barely acceptable at 2 WAT (Table 1.2). Although no significance was recorded, there was some improvement of turfgrass quality at 6 WAT (Table 1.3).

Tall fescue. There was no significant injury to tall fescue with any of the rates of halosulfuron or bentazon (data not shown). Halosulfuron provided good yellow nutsedge control at all rating dates (Table 1.4). Bentazon provided slight to poor yellow nutsedge control at all rating dates. With the severe nutsedge infestation, the overall quality of the tall fescue was poor. There was improvement in tall fescue quality for treatments that controlled yellow nutsedge (no data shown). However, being a bunch type grass, tall fescue is slow to fill in, and turfgrass quality was slow to improve.

Bermudagrass. With the severe nutsedge infestation, bermudagrass quality was poor at initation of the test; but, by 6 WAT, quality ratings were between 4 and 6 (no other data shown). No injury (data not shown) from any of the treatments was recorded on the bermudagrass at 2, 4, and 6 WAT. Yellow nutsedge control was fair with both bentazon treatments (Table 1.5). At 4 and 6 WAT, bentazon provided poor nutsedge control and was no longer significantly different from the control. Halosulfuron provided good to excellent control of yellow nutsedge at 2, 4 and 6 WAT.

Zoysiagrass. With the zoysiagrass sod having been recently harvested, the percent cover for the entire test area was poor (<70%). With the lack of competition from the zoysiagrass, there was a severe yellow nutsedge infestation (average of 150 plants/m^2). With the severe yellow nutsedge population and the poor cover with zoysiagrass, none of the turfgrass quality ratings reached 5 during the rating periods (no data shown). At 2, 4 and 6 WAT, there was no injury observed on any of the zoysiagrass (data not shown). Yellow nutsedge control was very good with both of the bentazon and halosulfuron treatments during 2 and 4 WAT (Table 1.6). However, the single application of bentazon did not provided adequate control of yellow nutsedge at 6 WAT.

Summary of control of yellow nutsedge and injury to turfgrass by halosulfuron.

Halosulfuron was safe on all turfgrasses in this study (Kentucky bluegrass, tall fescue, bermudagrass, and zoysiagrass). Halosulfuron provided good to excellent yellow nutsedge control for at least a 6-week period. Generally, halosulfuron provide above 80% control of yellow nutsedge and averaged 90% overall experiments.

Halosulfuron is generally a slow acting herbicide. Bentazon, which inhibits electron transport in Photosystem II (6), typically causes injury symptoms to appear in 2 to 5 days. Halosulfuron, which inhibits the acetolactate synthase enzyme (6), causes injury symptoms to appear in 7 to 14 days. However, halosulfuron tended to provide a longer period of control than bentazon and was applied at approximately 1/16 the rate of bentazon. There was regrowth of the yellow nutsedge in most treated plots, but it tended to be less in the halosulfuron-treated plots.

PURPLE NUTSEDGE CONTROL AND TURF INJURY.

The herbicide standard for purple nutsedge control in warm-season turfgrass is imazaquin. At present there are no registered herbicides for the control of purple nutsedge in cool-season turfgrass (19). Although not labeled for use in Kentucky bluegrass, imazaquin was chosen as the standard to compare to halosulfuron in evaluating purple nutsedge control.

Imazaquin caused injury to Kentucky bluegrass, with ratings of 2.0 and 2.6 at 2 WAT (data not shown). By 6 WAT, however, there were no injury symptoms noted with any of the treatments. At 2 WAT, both imazaquin and halosulfuron provided poor purple nutsedge control. At 6 WAT, halosulfuron provided excellent purple nutsedge control, while control with imazaquin was poor (Figure 1.1). Better control of purple nutsedge was expected with imazaquin (current herbicide standard).

At present there is no herbicide available to selectively control purple nutsedge in cool-season grasses. With the growing problem of purple nutsedge moving into cool season turfgrasses, a selective herbicide is needed to remove this weed. From these studies it appears that halosulfuron can fill this niche.

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Table 1.2 Effectiveness of halosulfuron and bentazon for control of yellow nutsedge in bluegrass at 2 WAT in Blacksburg in 1993 and 1994.[a]

Treatment[b]		Percent Nutsedge		
Herbicide	kg ai/ha	Control[c]	Turf Injury[d]	Turf Quality[e]
Halosulfuron	0.07	58 b	0.5 ab	5a
Halosulfuron	0.14	65 b	0.9 a	5a
Bentazon	1.12 + 1.12	83 a	0.8 a	5a
Bentazon	2.24	92 a	0.9 a	5a
Check		0 c	0.0 b	4a

[a]Means within a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test. Data was combined over years.
[b]Treatments were applied 7 August of both years. The sequential bentazon application was applied approximately 14 days later.
[c] Nutsedge control on 0-100 scale.
[d]Turf injury on 0-10 scale
[e]Turf quality on 1-9 scale

Table 1.3 Effectiveness of halosulfuron and bentazon for control of yellow nutsedge in bluegrass at 6 WAT in Blacksburg in 1993 and 1994.[a]

Treatments[b]		Percent Nutsedge		
Herbicide	kg ai/ha	Control[c]	Turf Injury[d]	Turf Quality[e]
Halosulfuron	0.07	100 a	0 a	5ab
Halosulfuron	0.14	100 a	0 a	6a
Bentazon	1.12 + 1.12	70 b	0 a	6a
Bentazon	2.24	86 ab	0 a	5ab
Check		0 c	0 a	4b

[a]Means within a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test. Data was combined over years.
[b]Treatments were applied 7 August of both years. The sequential bentazon application was applied approximately 14 days later.
[c]Nutsedge control on 0-100 scale.
[d]Turf injury 0-10 scale
[e]Turf quality on 1-9 scale

Table 1.4 Effectiveness of halosulfuron and bentazon for control of yellow nutsedge in tall fescue at Baskerville in 1993 and 1994.[a]

Treatments[b]		Percent Nutsedge control[c]		
Herbicide	kg ai/ha	2 WAT	4 WAT	6 WAT
Halosulfuron	0.07	60 a	64 a	80 a
Halosulfuron	0.14	61 a	68 a	77 a
Bentazon	1.12 + 1.12	37 a	58 a	30 b
Bentazon	2.24	44 a	39 a	13 bc
Check		0 b	0 b	0 c

[a]Means within a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test. Data was combined over years.
[b]Treatments were applied 15 June 1993 and 23 June 1994. The sequential bentazon application was applied approximately 14 days later.
[c]Nutsedge control on 0-100 scale, WAT (Weeks after treatment)

Table 1.5 Effectiveness of halosulfuron and bentazon for control of yellow nutsedge in bermudagrass at Baskerville in 1994.[a]

Treatments[b]		Percent Nutsedge Control[c]		
Herbicide	kg ai/ha	2 WAT	4 WAT	6 WAT
Halosulfuron	0.07	87 ab	92 a	57 ab
Halosulfuron	0.14	100 a	97 a	87 a
Bentazon	1.12 + 1.12	63 b	50 ab	43 bc
Bentazon	2.24	57 b	32 ab	23 bc
Check		10 c	0 b	7 c

[a]Means with in a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.
[b]Treatments were applied 28 June 1994. The sequential bentazon application was applied approximately 14 days later.
[c]Nutsedge control on 0-100 scale, WAT (Weeks after treatment)

Table 1.6 Effectiveness of halosulfuron and bentazon for control of yellow nutsedge in zoysiagrass at Baskerville in 1994.[a]

Treatments[b]		Percent Nutsedge Control[c]		
Herbicide	kg ai/ha	2 WAT	4 WAT	6 WAT
Halosulfuron	0.07	73 a	100 a	73 ab
Halosulfuron	0.14	90 a	100 a	90 a
Bentazon	1.12 + 1.12	98 a	93 a	69 ab
Bentazon	1.8	100 a	100 a	30 bc
Check		27 b	0 b	0 c

[a]Means within a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.
[b]Treatments were applied 14 July 1994. The sequential bentazon application was applied approximately 14 days later.
[c]Nutsedge control on 0-100 scale, WAT (Weeks after treatment)

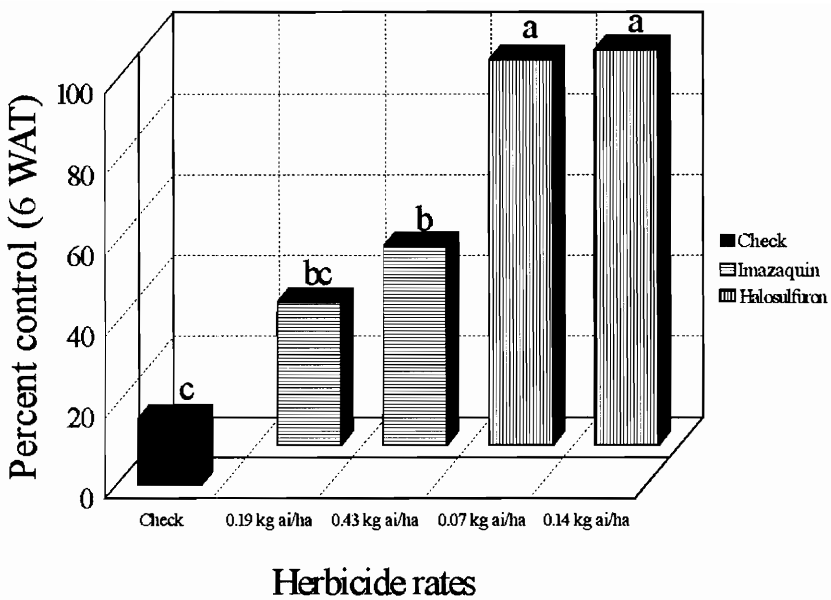

Figure 1.1 Effectiveness of halosulfuron and imazaquin for the control of purple nutsedge in Kentucky bluegrass at Blacksburg at 6 WAT in 1993 and 1994. Means followed by the same letter are not significantly different at α=0.05 as determined by Duncan's mean separation procedure. Control rating scale was on 0-100

CHAPTER II

The Translocation of Halosulfuron in Yellow and Purple Nutsedge (*Cyperus esculentus* and *rotundus*).

Abstract. In 1993 and 1994, field studies indicated that halosulfuron provided good initial control of yellow nutsedge. By 6 weeks after treatment, however, many of the halosulfuron treated plots were beginning to show further emergence of yellow nutsedge shoots. Greenhouse studies were conducted to evaluate translocation of halosulfuron from a treated shoot to an untreated shoot. Translocation of halosulfuron was observed by symptoms on untreated shoots. Halosulfuron symptoms were observed on the treated shoots of yellow and purple nutsedge within 2 weeks, and severe injury was noted within 4 weeks. Symptoms on the untreated shoot on the same tuber was slow to develop and showed less overall injury; however, halosulfuron translocation was evident in both yellow and purple nutsedge. Halosulfuron failed to translocate through a yellow nutsedge rhizome in amounts great enough to produce injury on the untreated connecting shoot in the first experiment. However, significant translocation occurred in a repeated study with yellow nutsedge. Halosulfuron translocation through a rhizome was readily observed in the form of symptoms on the untreated purple nutsedge shoots.

Nomenclature: Yellow nutsedge (*Cyperus esculentus* L.); purple nutsedge (*Cyperus rotundus* L.); halosulfuron [methyl 5-{[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonylaminosulfonyl]-3-chloro-1-methyl-1-H-pyrazole-4-carboxylate].

Additional index words: Sulfonylurea, translocation through tubers, translocation through rhizomes.

INTRODUCTION

Yellow and purple nutsedge are recognized as among the worst weeds in the world (7). With both species of nutsedge, the chief means of propagation is tubers (19). Yellow and purple nutsedge are similar morphologically, and can be difficult to distinguish in a mixed stand. However, flowers, leaf tips, and tubers are used to distinguish between the two species.

In turfgrass, yellow and purple nutsedge are very difficult to selectively control. Difficulty in nutsedge control is encountered because mechanical control, crop rotation, and herbicide incorporation, which are major means of nutsedge control in cultivated crops, are not an option in turfgrass (17, 20). Also, the number and effectiveness of herbicides for selective yellow and purple nutsedge control are limited (2). The present standard for yellow nutsedge control in both cool- and warm-season turfgrass is bentazon [3-(-1-methlethyl)-(-1H)-2,1,3-benzothiadiadiazin-4(3H)-one 2,2-dioxide] (11, 16, 17). Although this compound provides good initial control of yellow nutsedge, bentazon does not appear to be translocated throughout the plant (6). The standard for purple nutsedge control in warm-season turfgrass is imazaquin [2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-quinolinecarboxylic acid] (3). Along with effectively controlling purple nutsedge, imazaquin is a systemic herbicide (6, 22) and does enter the entire nutsedge vascular system (13). Imazaquin provides poor control of yellow nutsedge and is not labeled for use in cool-season turfgrasses. In states where both warm- and cool-season turfgrasses are grown, mixed stands of yellow and purple nutsedge occur. Up to now, different herbicides have been used for control of yellow and purple nutsedge. Halosulfuron, released earlier this year, has the ability to control both yellow and purple nutsedge in all major turfgrasses (8, 18).

In field studies conducted in 1993 and 1994, halosulfuron provided excellent short-term control of yellow nutsedge (4). After approximately six weeks, however, some regrowth of yellow nutsedge had occurred. Shoots of yellow nutsedge were arising from three sources: dormant unattached tubers, dormant tubers that were attached to treated plants by way of a rhizome, and tubers in which shoots were killed but the tuber was not killed. Not much can be done to effectively control the dormant tubers until they germinate. However, with the systemic properties of sulfonylurea herbicides (6, 22), such as halosulfuron, and the ability of these herbicides to efficiently inhibit the targeted acetolactate synthase (ALS) enzyme (14), it seems unprobable that regrowth of the treated nutsedge plants is possible. In unpublished data, the Monsanto company indicated that low rates (35 g ai/ha) of halosulfuron would kill only treated shoots, but adventitious buds would develop from the basal tuber. Higher rates of halosulfuron (70 g ai/ha) killed the entire basal tuber and connecting tillers, but a sublethal dose was translocated to connecting tubers (8, 9). Moreover, sublethal doses of other ALS inhibiting herbicides caused the sprouting of adventitious buds (13, 15).

Halosulfuron is a new sulfonylurea herbicide effective on yellow and purple nutsedge as well as many broadleaf weeds (4, 8, 21). Testing both yellow and purple nutsedge, the objectives of these studies were to determine if translocation of halosulfuron occurred through a treated shoot to an untreated shoot.

MATERIALS AND METHODS

During 1993 and 1994, greenhouse studies were conducted involving the translocation of halosulfuron in yellow[1] and purple[2] nutsedge. Two special tests were designed to evaluate translocation of halosulfuron from a treated shoot to an untreated shoot through either a tuber or rhizome.

General procedure. Yellow and purple nutsedge plants were analyzed in separate experiments, but tubers and plants of both species were treated identically during the initiation of the experiment. About 50 to 60 tubers were placed into a container with 500 ml of tap water and soaked for 24 to 48 hours. These tubers were then transferred to a 23 by 33 cm flat glass baking dish lined with wet paper towels. The dish was covered with aluminum foil and left in a shaded spot of the greenhouse with average temperatures of 25 to 35°C. As the tubers germinated, they were placed in standard 15 cm plastic pots[3] containing Pro-mix BX[3].

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[1] Valley Seed Service, P.O. Box 9335, Fresno, Ca 93791.

[2] Azlin Seed Service, P.O. Box 914, Leland, MS 38756

[3] E.C. Geiger, Inc., P.O. Box 285, Harleysville, PA 19438-0332

To perform the rhizome translocation study, a special two-pot design was needed. First, a 2.5 cm square notch was cut on the rim of two 15 cm pots. These pots were then connected with a heavy duty stapler, so that the two notches aligned and would allow the rhizome to pass. Both of these pots were filled with Pro-mix BX, and a germinated tuber was placed in one of the two connecting pots. Plants were then grown in the greenhouse with temperatures maintained between 25 and 35°C. Watering was performed daily by appling apporoximately 250 ml H_2O/pot, and day length was extended to 16 hours with supplemental lighting being provided by 1000W high pressure sodium lights.

Translocation through the tuber. Tubers were only allowed to produce two shoots, other shoots were manually removed every three days. When shoots were at the three-to five-leaf stage, one shoot was covered with a plastic sandwich bag and stapled to provide a tight-fitting cover. The growth media surface was covered with vermiculite so as to seal the plastic bag and avoid any herbicide entry to the covered plant or the growth media.

Translocation through rhizome. Nutsedge was allowed to grow until several rhizomes developed into shoots. At this point the nutsedge plants were removed from the pot, and the growth medium was removed by gently shaking the plant system. All but the longest, healthiest, rhizome/shoot were carefully cut from the original tuber/plant. The original plant was then placed in one of the two connecting pots. The rhizome was placed through the notch and the second or daughter plant was transplanted in the second pot. The rhizome was then carefully covered. These plants were grown for approximately two to four weeks. When the main shoots of the connecting daughter plant reached the three to five leaf stage, this pot was covered with a plastic bag.

Spraying and rating procedures. All tests were sprayed on a belt sprayer, using an 80015E spray tip[4], which was calibrated to deliver 280 L/ha. Two rates of halosulfuron were selected according to an experimental product label (12) and consisted of 0.035 and 0.07 kg ai/ha with 0.50% v/v surfactant (Kinetic[5]). Each test consisted of four or five replications and was repeated (Table 2.1). Plants were always sprayed in the afternoon and allowed to sit overnight (12 to 18 hours). The following morning, plastic bags (and vermiculite in tuber test) were carefully removed from untreated shoots so as to avoid herbicide contamination. Tests were arranged on greenhouse benches as randomized complete blocks. Plants were then grown in the greenhouse conditions as before. Watering was performed carefully so as not to wet foliage. Control ratings were taken on both the treated and untreated shoot at either 2 and 4 weeks after treatment (WAT) or 1, 2, and 4 WAT. Control ratings were based on a visual scale of 0 to 100 with the untreated shoot used as a standard of comparison. The numeric values indicate the following:

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[4] Spraying System Co., North Ave., Wheaton, IL 60187-7900.

[5]Helena Chem. Co., 6075 Popular Ave., Memphis, TN 38119. Organosilicon and nonionic surfactant mixture.

Table 2.1 Tests involving the translocation of halosulfuron, 1993-1994

Trial	Sedge Tested	Origin for translocation	Test Performed
1	Yellow	Shoots on same tuber	1993
2	Yellow	Shoots on same tuber	1994
1	Purple	Shoots on same tuber	1993
2	Purple	Shoots on same tuber	1994
1	Purple	Shoots separated by a rhizome	1993
2	Purple	Shoots separated by a rhizome	1994
1	Yellow	Shoots separated by a rhizome	1993
2	Yellow	Shoots separated by a rhizome	1994

•0	no apparent injury
•10, 20, 30	slight control or injury, light green
•40, 50, 60	poor control, numbers reduced or significant injury, unacceptable control
•70, 80	fair to good control, number of shoots reduced, size suppressed, chlorosis, purpling, acceptable control
•85 to 95	good shoot control 80 to 90% control, severe injury, number reduced, size suppressed, necrosis
•95 to 99	excellent shoot control 90 to 99% control, severe injury, necrosis, few remaining plants
•100	death of all shoots

Control scales were similar to control scales used by other turf researchers (3, 5). Data were analysed using SAS (Version 6.0)[6]. Analysis of variance, followed by Duncan's multiple range test was performed on the data.

RESULTS AND DISCUSSION

Translocation through the tuber. Do to variation between experiments, data were analyzed separately.

Yellow nutsedge. Control of treated shoots was good to excellent by 4 WAT in both trials (Table 2.2 and 2.3). Control symptoms on untreated shoots, indicating slight to poor translocation through a tuber, began to appear with the higher rate of halosulfuron at 2 WAT. By 4 WAT, injury to the untreated shoot had intensified with both rates of

[6] SAS Institute Inc. SAS Campus Dr., Cary, NC 27513.

halosulfuron, however, new shoots were beginning to emerge around the untreated shoot from the subtending tuber (Figure 2.1).

Purple nutsedge. Translocation through a tuber in purple nutsedge was similar to yellow nutsedge. With the high rate of halosulfuron, fair to good control of the treated purple nutsedge shoots was recorded at 4 WAT (Table 2.4 and 2.5). Significant control of the untreated shoots, at 2 WAT, was indicated with both rates of halosulfuron in both trials. At 4 WAT, control ratings of the untreated shoots had drop in trial one, but intensified slightly in trial two. At 4 WAT, however, shoots had began to emerge around the untreated shoot from the subtending tuber (Figure 2.2).

Conclusions from tuber study. It appeared, in this case, that, even though the treated and untreated shoots of yellow and purple nutsedge exhibited significant control symptoms, lethal doses of halosulfuron did not translocate to the meristem or dormant buds of the tubers.

Even though halosulfuron is a potent inhibitor of the ALS enzyme, many of the tubers containing a treated shoot were able to resprout. Nandihalli and Bendixen (13), who worked with imazaquin (another ALS herbicide), stated that shoot proliferation in yellow and purple nutsedge is enhanced by a sublethal dose of the herbicide. Also, tubers of both species contain up to seven adventitious buds (18). These two factors could help explain why both species of nutsedge were able to resprout after treatment with a sulfonylurea herbicide. However, it must be noted that only the higher rate of halosulfuron was a labeled rate, and in a field situations, competition with crops would limit the regrowth of nutsedge after a herbicide treatment (10, 17).

Translocation through the rhizome. As with the previous data, tests from 1993 and 1994 were analyzed separately because variation between experiments was significant.

Yellow nutsedge. With both rates of halosulfuron, poor control of treated yellow nutsedge shoots was recorded at 2 WAT (Figure 2.3 and 2.4). In trial one, there was no recordable control to the untreated yellow nutsedge shoots (Figure 2.3). In the second trial, slight control of the untreated yellow nutsedge shoots was observed at 2 WAT (Figure 2.4). Some translocation of halosulfuron to the untreated shoots was expected in trial one. The rhizome connecting the shoots (between pots) in trial one was exposed to air and elements more than in the second trial. Since rhizomes of yellow nutsedge are less lignified than purple nutsedge (23), there was substantial deteriorated of the yellow nutsedge rhizome before the herbicide treatment which accounted for the lack of translocation. By 4 WAT in the second trial, new shoots began to emerge in the pots containing untreated shoots (Figure 2.5). Trial one, however, did not display this characteristic.

Purple nutsedge. Halosulfuron provided slight to good control of treated purple nutsedge shoots by 2 WAT (Figure 2.6). By 4 WAT, poor to good control of the treated purple nutsedge shoots was recorded (Figure 2.6 and 2.7). Although not significant, slight symptoms on the untreated purple nutsedge shoots was recorded in trial one at 1 and 2 WAT with both rates of halosulfuron (Figure 2.6). In trial 2, poor to fair control of the untreated purple nutsedge shoots was recorded with both rates of halosulfuron at 2 and 4 WAT (Figure 2.7). At 4 WAT, new shoots of purple nutsedge began to resprout in untreated pots (Figure 2.8).

Conclusions from Rhizome Tests. This data indicated that translocation of halosulfuron is better in purple nutsedge than yellow nutsedge. According to the data, little halosulfuron is translocated through the rhizome of yellow nutsedge, while it is apparent that some translocation of halosulfuron is occurring through the rhizomes of purple nutsedge. However, in studies using higher rates of halosulfuron, untreated yellow and purple nutsedge shoots displayed greater injury symptoms than appeared with the lower rates (Figure 2.9). This indicates that higher rates of halosulfuron are capable of translocating through the nutsedge plants.

As with other sulfonylurea herbicides, halosulfuron is a ambimobile and was able to move from a treated shoot through the rhizome to an untreated shoot (1). A few papers have been published on the movement of ALS inhibiting herbicides in yellow and purple nutsedge. Data from those papers correlates with data presented here. Reddy and Benedixen (15) indicated that overall translocation of chlorimuron was better in purple nutsedge than in yellow. Data with imazaquin was similar to that seen with chlorimuron (13). In these publications dealing with the translocation of herbicides in yellow and purple nutsedge, purple nutsedge was said to have better absorption and translocation ability. The primary reason for this is that purple nutsedge has a more resilient (lignified) rhizome that is highly resistant to deterioration (23).

General Conclusions. It is apparent that regrowth of both yellow and purple nutsedge is possible even with the use of labelled rates of halosulfuron. Also, at least in yellow nutsedge, halosulfuron appears to be poorly translocated through rhizomes to connecting shoots and tubers. With the capacity to produce new shoots from previouly treated tubers, it is apparent that multiple applications of halosulfuron will probably be necessary, particularly in heavy infestations of nutsedges. Even with need for multiple applications, halosulfuron has proven to be a excellent nutsedge compound, with the ability to control both species of nutsedge in all major species of turfgrass (4).

With both of these plants dominating much of the weed flora throughout the world, more research in many aspects of anatomy and physiology can be justified. More research on rhizome physiology and morphology would help to clarify our understanding of how long rhizomes have the ability to translocate systemic herbicides. Understanding these properties would help us achieve optimal herbicide control of yellow and purple nutsedge.

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Table 2.2 (Trial 1)[a] The translocation of halosulfuron in yellow nutsedge from a treated shoot, through a tuber, to an untreated shoot.

	Control of Treated Shoot*		Control of Untreated Shoot*	
Halosulfuron (kg ai/ha)	2 WAT	4 WAT	2 WAT	4 WAT
0.0	0 b	0 b	0 b	0 b
0.035	12 ab	96 a	12 b	66 a
0.07	28 a	98 a	28 a	76 a

*Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control
[a] Means in a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

Table 2.3 (Trial 2)[a] The translocation of halosulfuron in yellow nutsedge from a treated shoot, through a tuber, to an untreated shoot.

	Control of Treated Shoot*			Control of Untreated Shoot*		
Halosulfuron (kg ai/ha)	1 WAT	2 WAT	4 WAT	1 WAT	2 WAT	4 WAT
0.0	0 b	0 b	0 b	0 b	0 b	0 c
0.035	54 a	82 a	80 a	8 ab	24 ab	48 b
0.07	60 a	98 a	100a	20 a	52 a	92 a

*Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control
[a] Means in a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

Table 2.4 (Trial 1)[a] The translocation of halosulfuron in purple nutsedge from a treated shoot, through a tuber, to an untreated shoot.

	Control of Treated Shoot*		Control of Untreated Shoot*	
Halosulfuron (kg ai/ha)	2 WAT	4 WAT	2 WAT	4 WAT
0.0	0 c	0 c	0 c	0 c
0.035	68 b	24 b	54 b	32 b
0.07	89 a	68 a	82 a	68 a

*Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control
[a] Means in a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

Table 2.5 (Trial 2)[a] The translocation of halosulfuron in purple nutsedge from a treated shoot, through a tuber, to an untreated shoot.

	Control of Treated Shoot*			Control of Untreated Shoot*		
Halosulfuron (kg ai/ha)	1 WAT	2 WAT	4 WAT	1 WAT	2 WAT	4 WAT
0.0	0 b	0 b	0 c	0 a	0 b	0 b
0.035	30 a	58 a	94 a	24 a	56 a	76 a
0.07	44 a	77 a	78 b	28 a	52 a	66 a

*Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control
[a] Means in a column followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

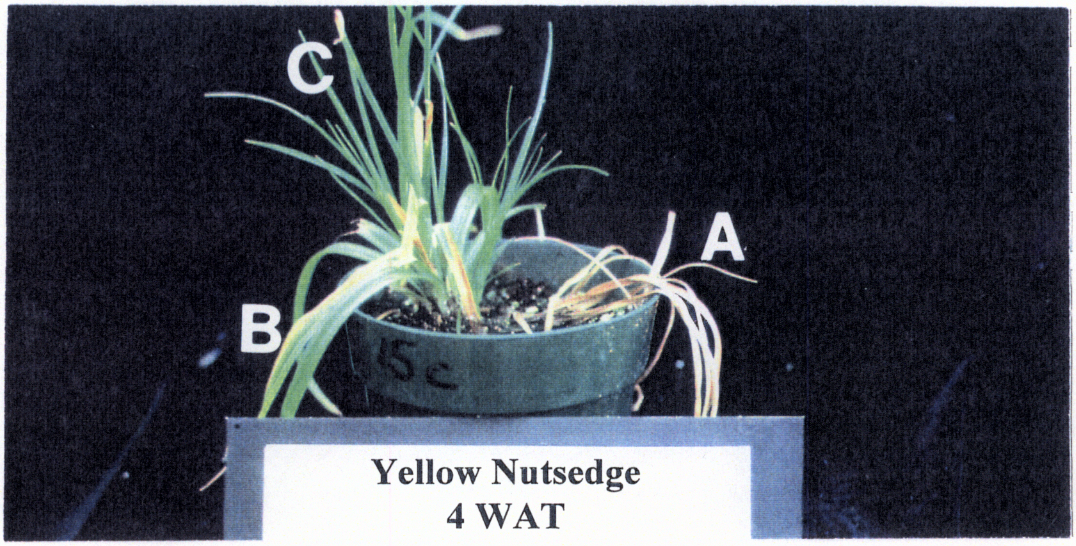

Figure 2.1 (Trial 1) The formation of new shoots on the untreated side of yellow nutsedge.
A=treated nutsedge shoot (0.035 kg ai/ha); B=untreated nutsedge shoot; C=new shoots

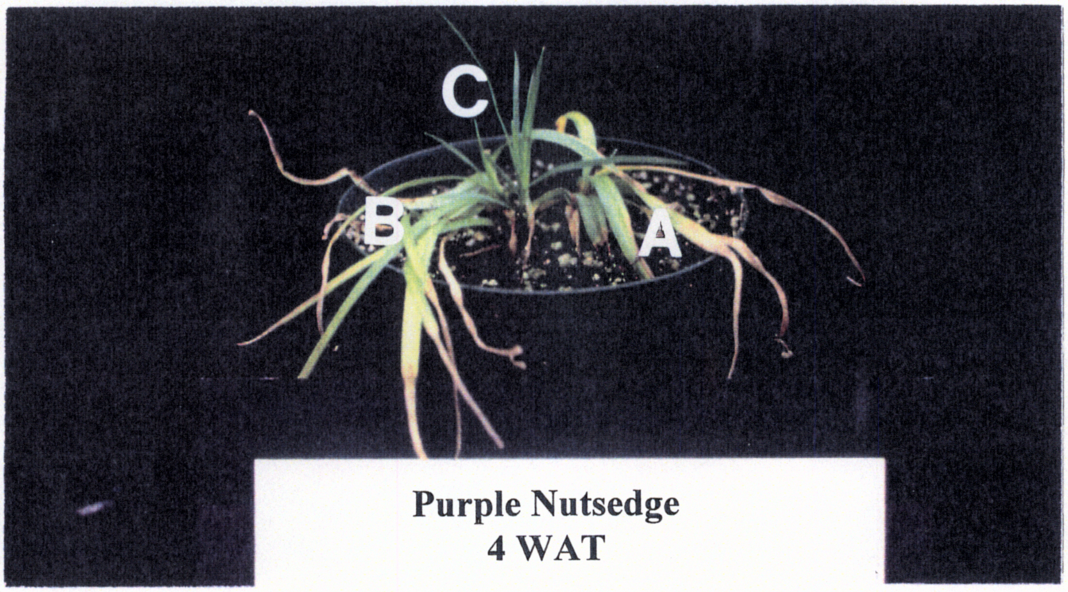

Figure 2.2 (Trial 2) The formation of new shoots on the untreated side of purple nutsedge.
A=treated nutsedge shoot (0.07 kg ai/ha); B=untreated nutsedge shoot; C=new shoots

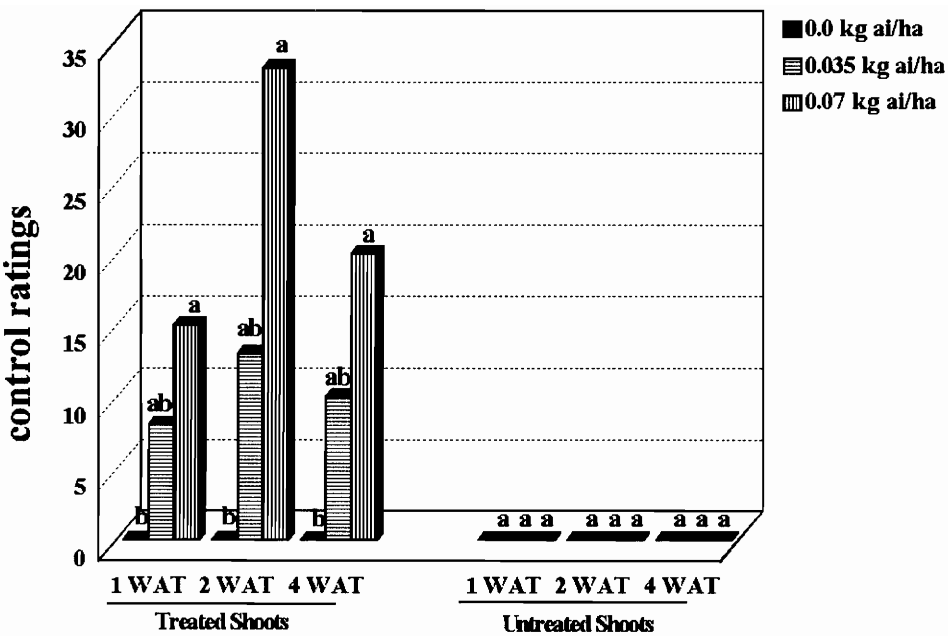

Figure 2.3 (Trial 1) The translocation of halosulfuron from a treated shoot to an untreated shoot through a rhizome in yellow nutsedge.
Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control
Means within a rating date followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

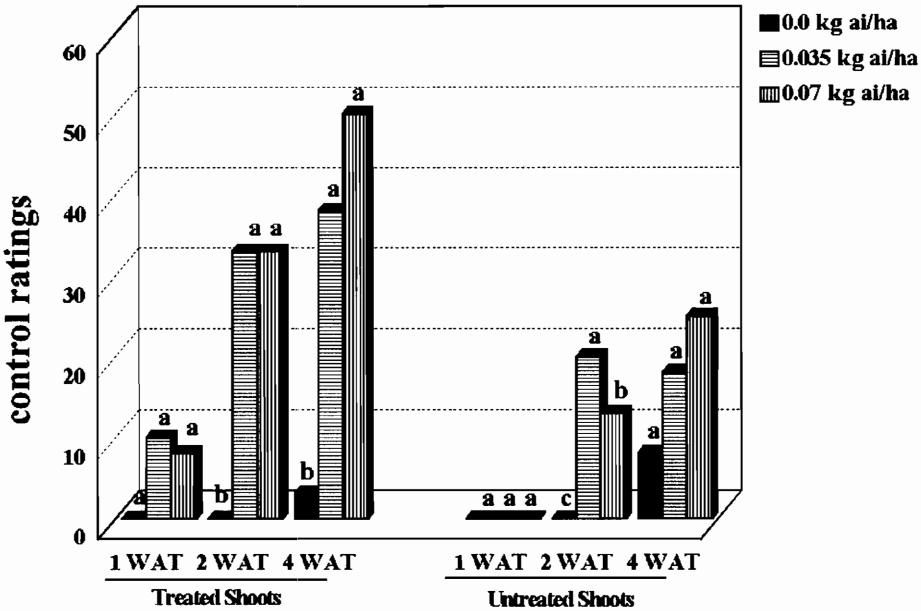

Figure 2.4 (Trial 2) The translocation of halosulfuron from a treated shoot to an untreated shoot through a rhizome in yellow nutsedge. Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control
Means within a rating date followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

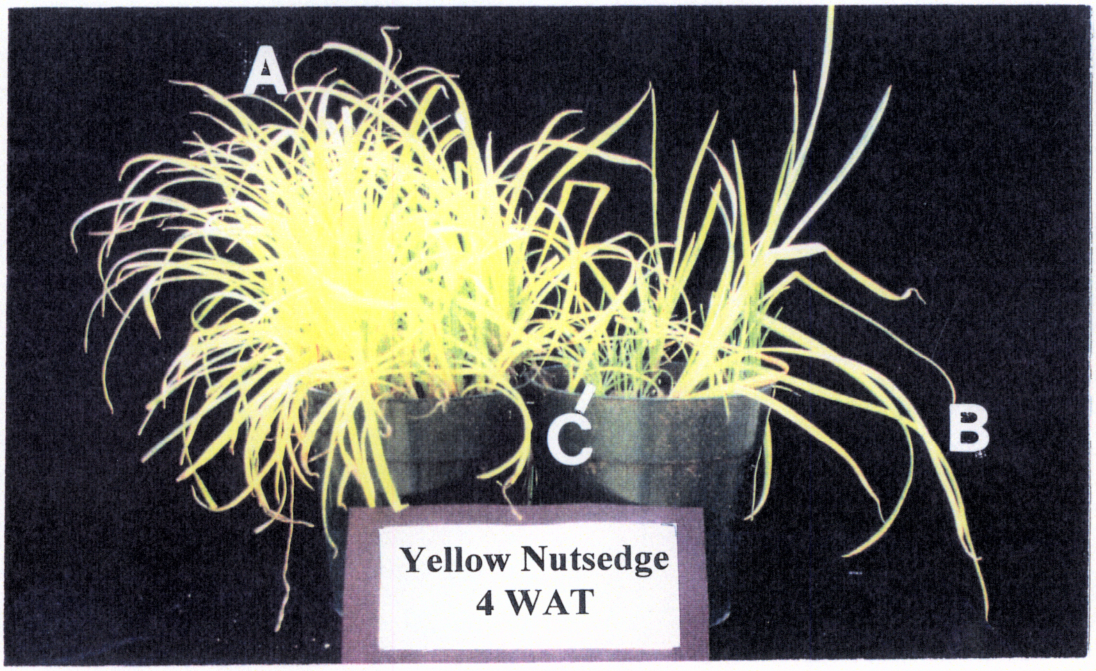

Figure 2.5 (Trial 2) New shoot formation by untreated yellow nutsedge shoots which were connected by a rhizome to a treated shoot.
A=treated nutsedge shoots (0.035 kg ai/ha); B=untreated nutsedge shoots; C=new shoots

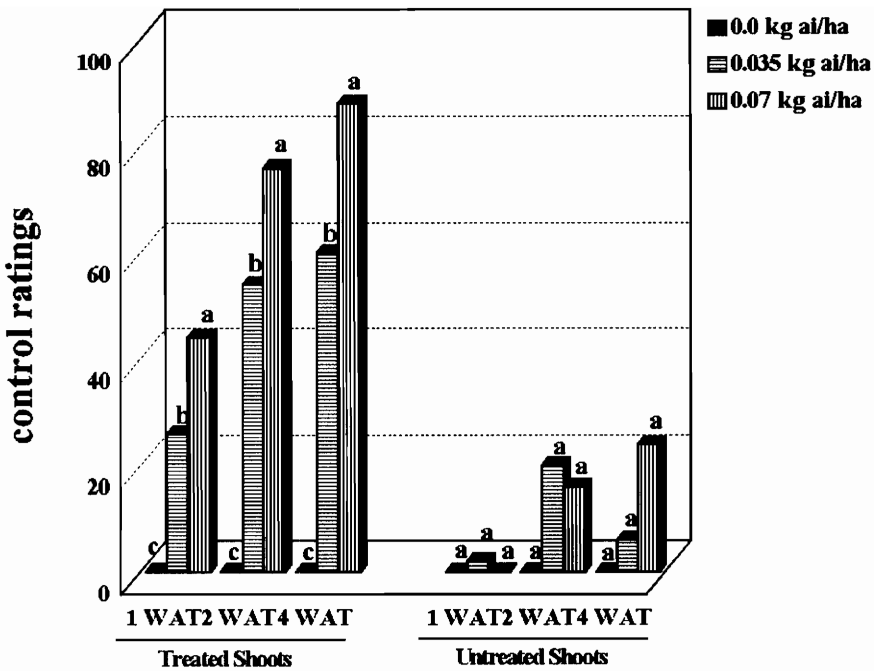

Figure 2.6 (Trial 1) The translocation of halosulfuron from a treated shoot to an untreated shoot through a rhizome in purple nutsedge.

Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control Means within a rating date followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

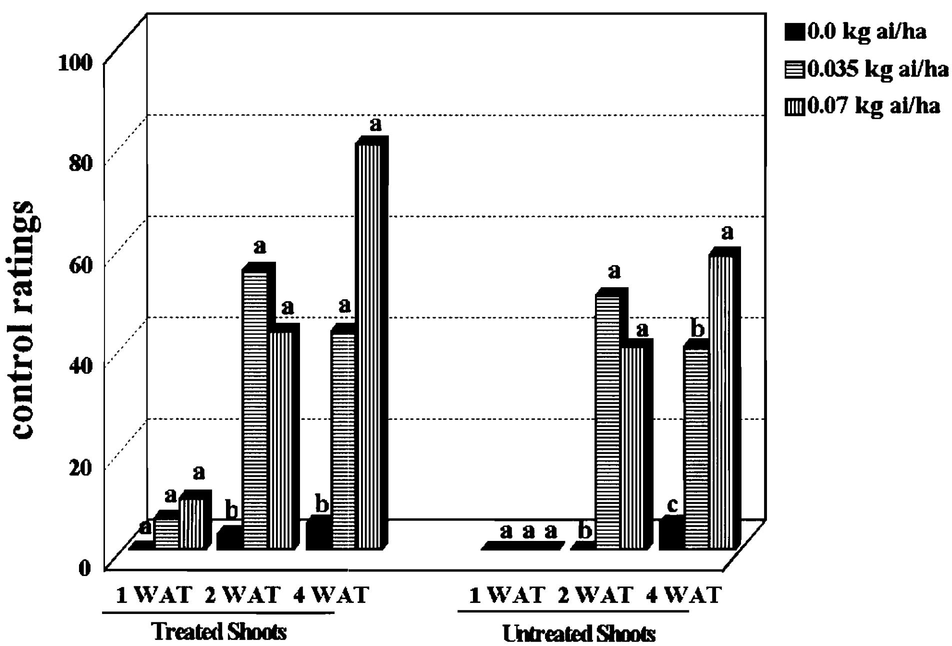

Figure 2.7 (Trial 2) The translocation of halosulfuron from a treated shoot to an untreated shoot through a rhizome in purple nutsedge.
Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control
Means within a rating date followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

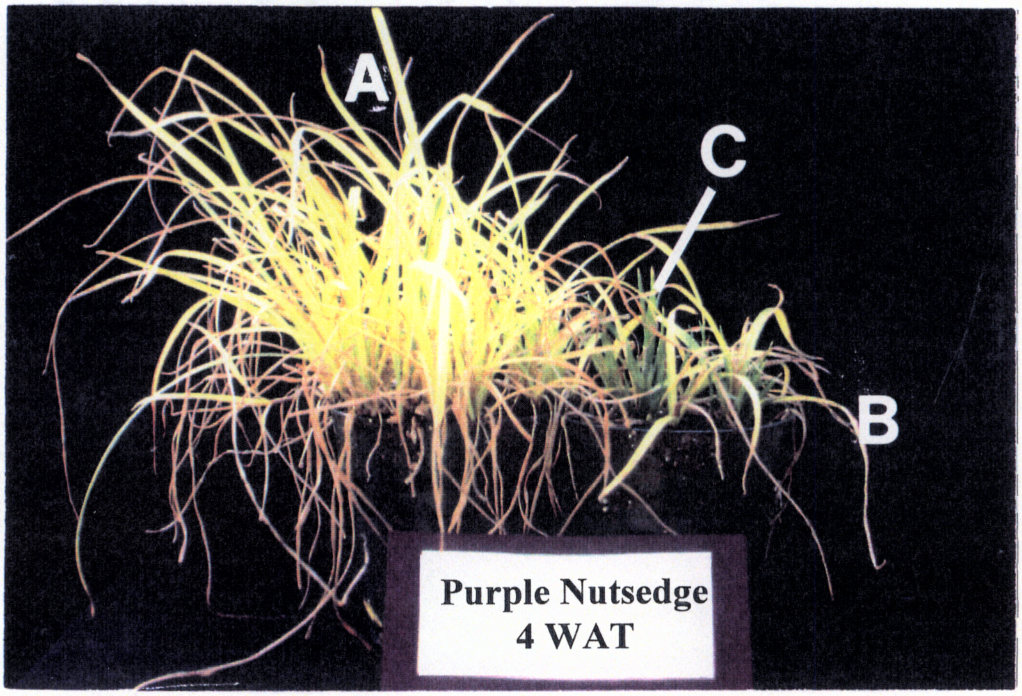

Figure 2.8 (Trial 2) New shoot formation by untreated purple nutsedge shoots which were connected by a rhizome to a treated shoot.
A=treated nutsedge shoots (0.035 kg ai/ha); B=untreated nutsedge shoots; C=new shoots

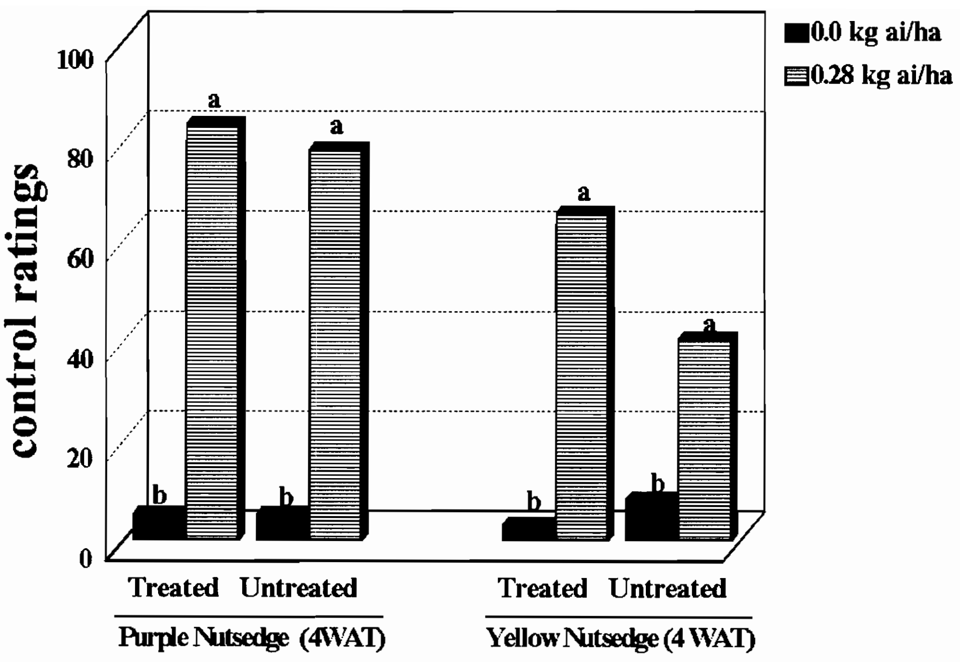

Figure 2.9 The translocation of halosulfuron from a treated shoot to an untreated shoot through a rhizome in yellow (Trial 2) and purple (Trial 2) nutsedge. Control ratings were on a 0 to 100 scale units 0=no control and 100=complete control. Means among plant species followed by the same letter are not significantly different at α=0.05 as determined by Duncan's multiple range test.

VITA

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