Table 6. Spotted spurge control as affected by fall application of isoxaben and oxadiazon, in 1995, using a soil bioassay.

Treatment	Rate (kg/ha)	Percent Control [a]				
		0 MAT	1 MAT	3 MAT	6 MAT	L.S.D (0.05)
Oxadiazon	3.36	53	15	27	16	26
Isoxaben	0.56	48	45	50	25	18
Isoxaben	0.84	39	70	55	25	20
Isoxaben	1.12	55	60	68	38	13
L.S.D (0.05)		23	NS	NS	NS	
Count in Control		30	15	16	20	

[a] Percent control was calculated by comparing weed count in the treated flats to that in the untreated flats.

CHAPTER V

EFFECT OF ISOXABEN APPLICATION RATE AND TIMING ON RESIDUAL BROADLEAF WEED CONTROL IN TURF

Abstract. Field experiments evaluated duration and spectrum of PRE weed control following isoxaben application at 0.56, 0.84, and 1.12 kg ai/ha in spring, fall, and spring plus fall. Residual activity was assessed by monitoring weed counts at two locations for 12 months after application. Spring-applied isoxaben at 1.12 kg/ha controlled buckhorn plantain, white clover and dandelion at Blacksburg for 4 to 5 MAT in one study. Fall application of isoxaben at 1.12 kg/ha in Blacksburg controlled buckhorn plantain and white clover >90% when evaluated at 9 and 12 MAT, respectively. Multiple application of isoxaben improved weed control at Virginia Beach but results were inconclusive at Blacksburg. The comparison herbicide oxadiazon controlled white clover and dandelion for 1 MAT following spring application. At later dates, isoxaben provided superior broadleaf weed control compared to oxadiazon. Fall application of isoxaben would be beneficial for PRE control of winter annuals and certain summer annuals that germinate early the following spring. A spring application of isoxaben at 1.12 kg/ha controlled summer annuals and early germinating winter annuals. A 25 cm precipitation within two weeks after spring treatments in one study resulted in poor weed control. **Nomenclature:** Isoxaben, N-[3-(1-ethyl-1-methlypropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide; oxadiazon, 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3*H*)-one; Kentucky bluegrass *Poa pratensis* L.; tall fescue, *Festuca arundinacea* Schreb.; buckhorn plantain, *Plantago lanceolata* L. #[11] PLALA; common chickweed, *Stellaria media* (L.) Vill. # STEME; dandelion, *Taraxacum officinale* Weber in Wiggers # TAROF; corn speedwell, *Veronica officinalis* L. #VEROF ; yellow woodsorrel, *Oxalis stricta* L. # OXAST; henbit, *Lamium amplexicaule* L. # LAMAM; spotted spurge, *Euphorbia maculata* L. # EPHMA; white clover, *Trifolium repens* L. # TRFRE; white sweet clover, *Melilotus alba* Medicus # MEUAL. **Additional index words**. preemergence herbicides, herbicide breakdown, EL-107, cool season turfgrass.

[11] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds. Revised 1989. WSSA, 1508 West University Ave., Champaign, IL 61821-3133

Abbreviations: DAT, days after treatment; MAT, months after treatment; POST, postemergence; PRE, preemergence.

Introduction

Broadleaf weed control is an important aspect of turfgrass management. Although current chemical control strategies primarily utilize POST herbicides, use of a PRE herbicide with extended residual activity could offer several advantages. These benefits may include better turf appearance from control of weeds before emergence, possible reduction in number of herbicide applications due to season-long weed control, and consequent decrease in weed seed production (Bingham et al. 1995). Isoxaben is a preemergence, broad-spectrum herbicide for broadleaf weed control in turf and ornamentals (Colbert and Ford 1987; Neal and Senesac 1988). Limited information is available on the effect of timing and rate of application on its residual activity and spectrum of weed control.

In a turf study, isoxaben applied at 0.56 to 0.84 kg ai/ha provided 80 to 100% control of common chickweed, lawn burweed [*Soliva pterosperma* (Juss.) Less. # SOVPT], smallflower buttercup (*Ranunculus arbortivus* L. # RANAB), large hop clover (*Trifolium campestre* Schreb. # TRFCA), and henbit (Grant et al. 1990). Control of parsley-piert (Aphanes arvensis L.# APHAR), curly dock (*Rumex crispus* L. # RUMCA), and Carolina geranium (*Geranium carolinianum* L. # GERCA) ranged from 47 to 80% for isoxaben applied at 0.56 to 0.84 kg/ha. Isoxaben did not cause any turf injury to 'Common' and 'Tifton 419' bermudagrass [*Cynodon dactylon* (L.) Pers.], and bahiagrass (*Paspalum notatum* Fluegge.) (Grant et al). Most cool-season turfgrasses were found to tolerate isoxaben applied at 2.24 kg/ha (Colbert and Ford 1987).

Isoxaben at 0.56 kg/ha provided excellent control of common chickweed, common groundsel (*Senecio vulgaris* L.# SENVU), Virginia pepperweed (*Lepidium virginicum* L.# LEPVI), dandelion, common yellow woodsorrel, and witchgrass (*Panicum capillare* L.# PANCA) in a container-ornamental study (Neal and Senesac 1988). Isoxaben applied at 0.56 kg/ha controlled creeping woodsorrel (*Oxalis corniculata* L. # OXACO) 60 to 70%; however, greater than 90% control was attained when the rate was increased to 1.12 kg/ha. Greater than 90% control of dandelion and common groundsel was observed 3 MAT when isoxaben was applied at 1.12 kg/ha in container-grown nursery crops (Neal and Senesac 1990). Isoxaben at 0.2 kg/ha provided greater than 90% control of redroot pigweed (*Amaranthus retroflexus* L. # AMARE), common lambsquarter (*Chenopodium album* L. # CHEAL), common ragweed

(*Ambrosia amtemisiifolia* L. # AMBEL) , field pennycress (*Thlapsi arvense* L.# THLAR), common chickweed and shepherd's-purse (*Capsella bursa-pastoris* (L.) Medicus. # CAPBP) in a Canadian study (Anderson et al. 1984). Excellent control of certain weeds in the Cruciferae family was obtained with a dose of 0.05 kg/ha.

The herbicidal activity of isoxaben was not lost from shallow incorporation of this compound into the soil, and greater than 75% of the compound remained in the top 0 to 7.5 cm profile of the soil after incorporation (Colbert and Ford, 1987). The soil half life of isoxaben after fall application was approximately 5 months, with 20% of the applied herbicide persisting after 12 months.

Limited information exists on the effect of isoxaben application timing and rates on broadleaf weed control in turf for a period of 12 MAT. The objective of the study was to determine the effect of isoxaben applied at three rates in spring, fall, or spring plus fall on duration of broadleaf weed control in turf.

Materials and Methods

General Conditions. Field studies were conducted on established turf in Blacksburg and Virginia Beach, VA. Each study lasted for a period of approximately one year following treatment. Isoxaben was applied at 0.56, 0.84, and 1.12 kg/ha, which represent the low, intermediate, and high use rates. A 2% granular formulation of oxadiazon was applied at the intermediate rate of 3.36 kg/ha for comparison. The application timings evaluated in the study were spring, fall, and spring followed by fall (double application). All sprayable formulations were applied using flat fan nozzles[12] and a CO_2-pressurized boom sprayer delivering 230 L/ha with water as the carrier. Oxadiazon was applied using a drop spreader, calibrated to deliver the required quantity by making two passes at right angles to each other, at Blacksburg, and using a shaker jar at Virginia Beach. The study areas were fertilized twice a year to provide N at 5 g/m^2. Irrigation was applied as needed. Existing broadleaf weeds in the study areas were controlled by applying a tank mixture of 2,4-D amine [(2,4-dichlorophenoxy)acetic acid] at 0.53 kg/ha and triclopyr amine (3,5,6-trichloro-2-pyridinyloxyacetic acid) at 0.42 kg/ha prior to PRE herbicide application. Turfgrass was mowed at a height of 6 cm at regular intervals throughout the growing season. Plots were seeded with selected broadleaf weeds in single rows about

[12] Teejet 8003 flat fan spray nozzles, Spraying Systems Co., North Ave., Wheaton, IL 60788

two to four weeks after treatment. Counts of seeded as well as natural weed populations were taken for up to one year following herbicide application.

Percent control was calculated by comparing mean weed counts from treated plots to that from control plots. The control ratings were described as excellent (90 to 100% control), good (80 to 90%), fair (60 to 80%), or poor (<60%). All data were subjected to analysis of variance (ANOVA) and the means were separated by the Least Significant Differences (LSD) test at the 0.05 probability level. Results for the two studies at Blacksburg are reported separately because an excessive rainfall after one study affected the results, while those of the studies at Virginia Beach were averaged after testing for homogeneity.

Blacksburg location. Field studies were conducted on a mature stand of 'Common' Kentucky bluegrass at the Virginia Tech Turfgrass Research Center, Blacksburg , VA during 1994 to 1995. The underlying soil was a Groseclose silt loam (clayey, kaolinitic, mesic Typic Hapludult) with a pH of 7.1 and an organic matter content of 4.0%. The area was dethatched two weeks prior to initial herbicide application to enhance better soil contact of seeded weed species. Plots were 2.7 by 3.6 m and the treatments were replicated four times in a randomized complete block design.

Study 1. Spring treatments were applied on May 17, 1994. Cloud cover was 10%, air temperature was 17 C, and soil temperature at a 5-cm depth was 19 C. Wind velocity at the time of application was 0 to 8 km/h. The first rainfall occurred five days after treatment and totaled 1.3 cm. The plots were seeded with buckhorn plantain and white sweet clover on June 1, 1994. Fall treatments were applied on October 6, 1994. Cloud cover was 100%, air temperature was 16 C, and soil temperature at a 5-cm depth was 22 C. Wind velocity at the time of application was 0 to 8 km/h. The first rainfall after application occurred one day after treatment and totaled 0.5 cm. The plots were seeded with buckhorn plantain and white sweet clover on October 27, 1994.

Study 2. Fall treatments were applied on October 17, 1994. Cloud cover was 50%, air temperature was 17 C, soil temperature at a 5-cm depth was 18 C, and there was no wind. The study area was irrigated (1.3 cm) 10 days after treatment (DAT) to activate the PRE treatments. Spring treatments were applied on June 6, 1995. Cloud cover was 20%, air temperature was 18 C, and soil

temperature at a 5-cm depth was 22 C, and there was no wind. The total rainfall within 2 weeks after treatment was 25.1 cm.

Virginia Beach location. Field studies were conducted on a one-year old stand of 'Shenandoah' tall fescue at the Hampton Roads Agriculture Research and Extension Center, Virginia Beach during 1994 to 1995. The underlying soil was a Tetotum loam (fine-loamy, mixed, thermic Typic Hapludult) with a pH of 5.7 and an organic matter content of 1.8%. Plots were 1.8 by 4.9 m and the treatments were replicated four times in a randomized complete block design.

Study 1. Fall treatments were applied on September 16, 1994. Cloud cover was 0%, air temperature was 29 C, and soil temperature at a 5-cm depth was 23 C. Wind velocity at the time of application was 0 to 8 km/h. The first precipitation (0.5 cm) occurred one day after treatment. Spring treatments were applied on June 22, 1995. Wind velocity at the time of application was 0 to 8 km/h. Cloud cover was 100%, air temperature was 24 C, and the soil temperature at a 5-cm depth was 25 C. The study area was irrigated 1 day after spring treatments to provide 1.3 cm of water.

Study 2. Fall treatments were applied on October 17, 1994. Cloud cover was 0%, air temperature was 17 C, and the soil temperature at 5-cm depth was 15 C. Wind velocity at the time of application was 8 to 25 km/h. The study area was irrigated 1 day after fall treatments to provide 1.3 cm of water. Spring treatments were applied on June 23, 1995. Wind velocity at the time of application was 0 to 8 km/h NE. Cloud cover was 100%, air temperature was 24 C, and the soil temperature at a 5-cm depth was 25 C. The study area was irrigated 1 day after spring treatments to provide 1.3 cm of water.

Results and Discussion

Blacksburg Location

Study 1. Isoxaben applied at 0.56, 0.84 and 1.12 kg/ha and oxadiazon at 3.36 kg/ha gave complete control of white sweet clover one month after spring treatment (Table 1). At 4 MAT, isoxaben applied at 0.84 and 1.12 kg/ha provided complete control of buckhorn plantain, and good to excellent control of dandelion. Low densities of naturally-occurring corn speedwell and yellow woodsorrel were seen at 4 MAT, hence, limited conclusions could be made on treatment responses. However, isoxaben at 1.12 kg/ha controlled corn speedwell but did not control yellow woodsorrel

at 4 MAT. Isoxaben at all three rates provided poor control of all broadleaf weeds at 12 MAT. At 1 MAT, isoxaben applied at 1.12 kg/ha gave approximately 75% large crabgrass (*Digitaria sanguinalis* L. Scop. # DIGSA) control (data not shown), but poor control was obtained at later evaluation timings.

Although oxadiazon is used primarily as a PRE grass herbicide, it controlled dandelion and white sweet clover for one month. Control of these weeds by oxadiazon, however, was unacceptable at 4 MAT.

At 9 months after fall application, all three rates of isoxaben gave excellent control of buckhorn plantain (Table 2); this weed germinated six to seven months after the fall applications. Control of dandelion that germinated approximately 8 MAT was fair from isoxaben applied at 0.84 and 1.12 kg/ha. Isoxaben applied at 1.12 kg/ha gave poor control of spotted spurge (previously referred to as prostrate spurge) but gave complete control of white sweet clover at 9 MAT. As expected, oxadiazon did not provide acceptable weed control 9 months after fall application. In a home-lawn study, isoxaben at 1.12 kg/ha combined with a commercial herbicide mixture containing 2,4-D, mecoprop ((±)-2-(4-chloro-2-methylphenoxy)propanoic acid), and dicamba (3,6-dichloro-2-methoxybenzoic acid) controlled dandelion and speedwells at 6 MAT (Keese and Forth, 1997). Jagshitz and Sawyer (1989) noted almost 100% control of spotted spurge 4 MAT when isoxaben was applied in spring at 0.84 kg/ha.

Weed counts in plots that received multiple applications of isoxaben appeared to be similar to that in plots that received single fall application the previous year (Table 2). Repeat application of isoxaben had enhanced weed control in a different experiment (Norcini and Aldrich 1992). In this container study, isoxaben at 1.12 kg/ha reduced spotted spurge stand per container by 84% when compared to untreated containers at 10 WAT. However, under a more dense weed population, a single application of isoxaben at 1.12 kg/ha reduced spotted spurge count by only 23%. Ten weeks after a second application of isoxaben at 1.12 kg/ha, the spotted spurge stand per container was reduced by 85%.

Fall application of oxadiazon at 2.8 kg/ha in Rhode Island gave >90% control of henbit and yellow woodsorrel and 78% control of purslane speedwell (*Veronica peregrina* L. # VERPG) that germinated during the following spring (Jagshitz and Sawyer 1988). In that study, isoxaben at 0.14 kg/ha provided almost 100% control of henbit, common chickweed, and purslane speedwell at 6 MAT, but control of yellow woodsorrel was only 71%. Fall

followed by spring applications of oxadiazon provided 100% control of these weeds when control ratings were taken 2 months after the second herbicide application. Multiple isoxaben applications provided 100% control of henbit, common chickweed, and purslane speedwell and 99% control of yellow woodsorrel 2 months after the second application. Improved weed control may be attributed to lower mean soil temperatures of Rhode Island compared to the sites in Virginia.

Study 2. In this site, weed density was insufficient during winter and spring months to obtain conclusive data. Eight months after fall application, isoxaben at 1.12 kg/ha gave good to excellent control of white clover and buckhorn plantain and fair control of dandelion (Table 3). Oxadiazon and the lowest rate of isoxaben did not provide acceptable control of these weeds at 8 MAT. Isoxaben applied at 0.84 or 1.12 kg/ha gave good to excellent control of white clover and common chickweed at 12 MAT. At this time, dandelion and buckhorn plantain control was only fair from the highest rate of isoxaben. Fall application of oxadiazon did not provide broadleaf weed control 12 MAT.

Single application of isoxaben during fall provided greater control of dandelion, buckhorn plantain and white clover one year later compared to control of these weeds at 12 months after single spring application (Tables 1 and 3). However, some of these weeds may have germinated earlier. The primary means of breakdown of isoxaben in the soil is microbial degradation (Rouchaud et al. 1993). Microbial activity is known to be much higher during summer months compared to winter months.

Isoxaben applied in spring at all rates gave poor weed control in the second study when evaluated at 4 MAT (Table 3). These results were contrary to those observed in study 1 (Table 1). The site for the second study received 25.1 cm of precipitation within two weeks after treatment (Hadean 1995). This excessive rainfall may have led to runoff or leaching of isoxaben, even though its water solubility is only 1 ppm. Isoxaben residues in runoff at a container nursery were recorded as 9.2% of the applied herbicide following the first irrigation (Wilson et at. 1997). These observations may imply that reapplication of isoxaben would be necessary if abnormally high precipitation is encountered. Fall followed by spring treatments gave similar or slightly higher levels of weed control as opposed to single fall application of isoxaben.

Virginia Beach Location. Fall application of isoxaben gave

excellent control of common chickweed, corn speedwell and henbit at approximately 2.5 MAT at all three rates (Table 4). The highest rate of isoxaben gave complete control of white clover at this time. At 8.5 MAT, all rates of isoxaben gave complete control of buckhorn plantain but poor to no control of dandelion. At 12 MAT, buckhorn plantain control decreased to 70 to 85%, depending upon isoxaben rate. Fall-applied isoxaben did not control white clover at 12 MAT. However, isoxaben at 0.84 kg/ha or higher provided good to excellent control of this weed at the Blacksburg study 12 months after fall application (Table 3). In a different study, Keese and Forth (1997) obtained total control of buckhorn plantain and dandelion at 6 MAT from a tank-mix of isoxaben at 1.12 kg/ha and a commercial 3-way premix containing 2,4-D, mecoprop and dicamba. Soils at the Blacksburg and Virginia Beach study-sites are classified under two temperature classes[13]. Soil at the Blacksburg location is classified as mesic (mean annual soil temperature of 8 to 15 C) and that of the Virginia Beach location is classified as thermic (15 to 22 C). Therefore, degradation of isoxaben by microbes should be faster at Virginia Beach than Blacksburg.

Spring application of isoxaben gave excellent control of buckhorn plantain and white clover at 4 MAT (Table 4). Repeat application of isoxaben in spring and fall enhanced weed control numerically when compared to single spring application.

Isoxaben applied at 0.84 and 1.12 kg/ha during spring provided acceptable control of the broadleaves evaluated for 3 to 4 MAT (Tables 1 and 4). However, spring-applied isoxaben did not provide acceptable control at 12 MAT. Fall-applied isoxaben at 1.12 kg/ha not only provided excellent control of broadleaf winter annuals, but also gave good to excellent control of buckhorn plantain and white clover that germinated in the following spring or early summer (Tables 2 and 3). Multiple application of isoxaben did not yield conclusive weed control results in Blacksburg but did improve weed control in Virginia Beach. Oxadiazon gave short term weed control of white clover and dandelion.

Differential sensitivity to isoxaben appeared to exist among the broadleaf weed species evaluated. Common chickweed, buckhorn plantain, white clover, and corn speedwell were the most sensitive to isoxaben, dandelion was moderately sensitive, and spotted spurge and yellow woodsorrel were generally least

[13] Soil Survey Staff. 1990. Keys to Soil Taxonomy. 4th Ed. SMSS Technical Monograph No. 6. Department of CSES, Virginia Tech, Blacksburg, VA 24061.

sensitive. Seasonal soil temperature may have affected the length of soil residual of isoxaben. It is speculated that single fall application at 1.12 kg/ha may control winter annuals for 5 to 6 MAT and certain broadleaf weeds that germinate during the following spring, especially in temperate regions. Spring application may be more effective to control broadleaf weeds that germinate during late summer. In general, fall application provided acceptable weed control for 6 to 9 MAT, while spring application provided weed control for 4 to 5 MAT. A 25 cm precipitation soon after the 1995 spring treatments resulted in poor weed control, indicating the need for repeat application in similar circumstances.

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