HortScience 39(5):1148–1152. 2004.

Cultural and Chemical Control of Ground Ivy (*Glechoma hederacea*)

Eric A. Kohler[1]
Department of Agronomy, Purdue University, 915 W. State St., West Lafayette, IN 47907-2054

Clark S. Throssell[2]
Golf Course Superintendents Association of America, 1421 Research Park Drive, Lawrence, KS 66049-3859

Zachary J. Reicher[3]
Department of Agronomy, Purdue University, 915 W. State St., West Lafayette, IN 47907-2054

Additional index words. nitrogen, preemergence herbicide, postemergence herbicide, kentucky bluegrass, *Poa pratensis*

***Abstract*. Ground ivy is a common broadleaf weed that disrupts turf uniformity and is difficult to control. The objective of this field research was to evaluate cultural and chemical control of ground ivy. Increasing annual nitrogen fertilizer applications from 0 to 196 and 293 kg·ha^{-1} reduced ground ivy cover by 24% and 32%, respectively. At 26 weeks after treatment, 1.1 kg·ha^{-1} isoxaben applied in May limited ground ivy spread by 34% compared to the control. Triclopyr, 2,4-D, or fluroxypyr applied at the highest-labeled rate in October provided superior ground ivy control by the following May. Combining an annual fertility program of 196 kg·ha^{-1} nitrogen and an application of 1.1 kg·ha^{-1} isoxaben with or after an application of 2,4-D, fluroxypyr, or triclopyr in the fall can maximize ground ivy control. Chemical names used: *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide (isoxaben); [(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid (triclopyr); (2,4-dichlorophenoxy)acetic acid (2,4-D); [(4-amino-3,5-dichloro-6-fluoro-pyridyl)oxy]acetic acid (fluroxypyr).**

Ground ivy (*Glechoma hederacea* L.) is a creeping perennial weed in turf in the cooler climates of northeastern and midwestern United States (Mitich, 1994). During summer and fall, populations rapidly increase in size through vegetative propagation of new ramets along stolons. Eventually the turf site is populated with patches of ground ivy, resulting in a nonuniform turf stand. Once established, controlling ground ivy is challenging for the lawn care industry. In a survey of lawn care operators (LCOs) in Indiana, 49% of respondents reported poor or fair control of ground ivy and 40% reported nonuniform control (Table 1). Additionally, 86% indicated repeated herbicide applications were necessary for successful ground ivy control, further suggesting chemical control of ground ivy is challenging. Time, money, and effort spent on controlling ground ivy is considerable since 31% of the LCO customers had ground ivy on their property. However, there has been little research focusing on ground ivy control using herbicides common to LCOs (Hatterman-Valenti et al., 1996). Furthermore, of those reports that evaluated herbicides commonly used by LCOs (Czarnota et al., 2001; Olson and Hall, 1988; Vrabel, 1987), application was done in spring rather than fall when broadleaf weed control is often performed (Kohler, 2002).

Ground ivy stolons creep beneath the turf canopy when colonizing new areas (Birch and Hutchings, 1994; Hutchings and Price, 1999). Extensive rooting from these stolons makes mechanical control difficult. Nitrogen application (Dernoeden et al., 1993; Lowe et al., 2000), irrigation (Gaussoin and Branham, 1989; Jiang et al., 1998), and mowing (Brede, 1992; Dernoeden et al., 1993) have been studied to limit encroachment of weeds other than ground ivy, but there are no reports of cultural control of ground ivy. Both preemergence (Turgeon, 1996) and postemergence (Monaco et al., 2002; Sterling and Hall, 1997) herbicides have been used successfully for decades to control grassy or other broadleaf weeds, but ground ivy control is challenging and inconsistent (Hatterman-Valenti et al., 1996). The objectives of this research were to evaluate nitrogen fertility programming, preemergence herbicides, and postemergence herbicides for ground ivy control.

Materials and Methods

Conditions common to experiments. All experiments were conducted for 1 year at the W.H. Daniel Turfgrass Research Center in West Lafayette, Ind. Experiments were repeated the following year on different but adjacent sites. Field plots (1.5 × 1.5 m) were located in full sun in a low-maintenance stand of kentucky bluegrass (*Poa pratensis* L. 'America') that had not been fertilized during the experiments or during the previous 2 years. The soil was a Chalmers silt loam (fine silty mixed mesic Typic Haplaquoll) with a 7.0 pH, 0.133 meq·g^{-1} CEC, 4.7% organic matter, 219 kg·ha^{-1} P, and 510 kg·ha^{-1} K. Plots were irrigated as needed to prevent drought stress and mowed three times per week at 6.4 cm with clippings returned. All herbicide treatments were applied in 374 L·ha^{-1} water with a CO_2-pressurized backpack sprayer using a three-nozzle (TeeJet XR8002VS, Spraying Systems Co., Wheaton, Ill.) boom at 207 kPa.

Nitrogen fertility study. Fertilizer treatments were applied to plots containing uniform stands of ground ivy beginning on 15 May 2000 and 14 May 2001. Average initial ground ivy cover was 32% in 2000 and 45% in 2001. Treatments were a three by three factorial with three annual nitrogen rates (98, 196, or 293 kg·ha^{-1}) and three application schedules (heavy spring, heavy fall, or equal spring, summer, and fall), and an untreated control was included for comparison. Fertilizer and scheduled rates are given in Table 2. Fertilizer application dates were 15 May ±1, 25 July ±2, 18 Sept. ±2, 17 Oct. ±2, 15 Nov. ±2, 23 Mar. ±2, and 23 Apr. ±1. On each application date, total nitrogen was applied as 50% (by N content) urea (46N–0P–0K) (Shaw's, Knox, Ind.) and 50% sulfur-coated urea (32N–0P–0K) (Shaw's, Knox, Ind.). The experiment was a randomized complete block design with three replications. While percent ground ivy cover was visually estimated every 4 weeks for 1 year during each experiment, only data collected 12 months after initial treatment (MAIT) for each experiment are presented.

Preemergence herbicide study. Three 10.2-cm-diameter × 8-cm-deep plugs of ground ivy were transplanted into plots on 14 May 1999 and 10 May 2000. One week later, the following preemergence herbicides were applied at the highest-labeled rate or at one-half the highest-label rate for kentucky bluegrass (Vencill, 2002): prodiamine (2,4-dinitro-N^3,N^3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine) (Syngenta, Wilmington, Del.) at 1.7 or 0.9 kg·ha^{-1}, dithiopyr (*S*,*S*-dimethyl 2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-3,5-pyridinedicarbothioate) (Dow Agro Sciences, Indianapolis) at 0.6 or 0.3 kg·ha^{-1}, isoxaben (Dow AgroSciences, Indianapolis) at 1.1 or 0.6 kg·ha^{-1}, or pendimethalin (*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) (BASF, Research Triangle Park, N.C.) at 3.3 or 1.7 kg·ha^{-1}. Percent ground ivy cover was rated visually at 6, 12, and 26 weeks after treatment (WAT). Treatments were a 2 × 4 factorial with two rates and four herbicides, and an untreated control was included for comparison. The experiment was a randomized complete block design with three replications.

Postemergence herbicide study. Ten postemergence herbicide combinations were sprayed at the highest-labeled rate or at one-half the highest-labeled rate for kentucky bluegrass on plots containing dense, uniform stands of ground ivy on 30 Oct. 1999 and 15 Oct. 2000 (Table 3) (Vencill, 2002). Average initial

Received for publication1 Apr. 2003. Accepted for publication 9 Sept. 2003.
[1]Graduate research assistant.
[2]Director of research.
[3]Associate professor; to whom reprint requests should be addressed; e-mail zreicher@purdue.edu.

Table 1. Questions and answers from a survey of Indiana lawn care operators in January 2000. N = 66.

Question	Answer
1) How many customers do you provide weed control service for?	Range: 3–10,000
	Mean: 847
	Median: 160
2) Of this number, how many have ground ivy in their turf stand?	Tange: 1–7500
	Mean: 266 (31%)
	Median: 22
3) What chemicals do you use to control ground ivy? (percent of respondents)	Triclopyr + clopyralid (20%)
	2,4-D + triclopyr + clopyralid (18%)
	2,4-D + MCPP + dicamba (18%)
	2,4-D + clopyralid + dicamba (12%)
	2,4-D + triclopyr (8%)
	2,4-D + diclorprop + dicamba (8%)
	2,4-D + diclorprop + MCPP (3%)
	2,4-D + MCPP + dicamba + triclopyr + clopyralid (2%)
	2,4-D (2%)
	Dicamba (2%)
	2,4-D + dicamba (2%)
	Triclopyr (2%)
	Triclopyr + clopyralid + MCPA (2%)
	Miscellaneous (3%)
4) What time of the year do you usually apply herbicides for ground ivy control?	Spring and fall = 52% fall = 18%
	Spring = 11%
	Spring and summer and fall = 6%
	Miscellaneous = 13%
5) Are repeat applications necessary?	Yes = 86%
	No = 10%
	Miscellaneous = 4 %
6) How successful are the chemicals that you use for controlling ground ivy?	Excellent = 11%
	Good = 38%
	Fair = 43%
	Poor = 6%
	Miscellaneous = 2%
7) Have you seen a fairly uniform response from the herbicides you use to control ground ivy?	Yes = 56%
	No = 40%
	Miscellaneous = 4%

ground ivy cover was 42% in 1999 and 76% in 2000. Ground ivy cover was rated visually at 3, 6, and 30 WAT. Treatments were a 2 × 10 factorial with 2 rates and 10 herbicides, and an untreated control was included for comparison. The experiment was a randomized complete block design with three replications.

Statistical analysis. All data were analyzed using SAS (Statistical Analysis Systems Institute Inc., Cary, N.C.). Box-Cox analysis determined if transformation of the data was necessary (Box and Cox, 1964). Percent ground ivy cover was arcsin transformed where appropriate. Error variances were homogeneous over both years of each experiment, so data were combined over years. The exception to this was the postemergence herbicide study, which is presented by year due to nonhomogeneous error variances (Steel and Torrie, 1980). Treatment means were compared using Fisher's protected least significant difference at $P \leq 0.05$ ($\text{LSD}_{0.05}$) (Steel and Torrie, 1980). On transformed data, backtransformed values are presented where appropriate.

Results and Discussion

Nitrogen fertility study. There was no nitrogen application schedule × rate interaction for ground ivy cover so data presented are averaged over the main effects (Table 4). Nitrogen application schedule had no effect on percent ground ivy cover when measured 12 MAIT. There was no difference in ground ivy cover from spring, summer, or fall application schedules, though all nitrogen schedules reduced ground ivy cover compared to the unfertilized control. Therefore, nitrogen application at any time of the year will help reduce ground ivy cover. However, cool season turf benefits most from fall-applied nitrogen, which results in better foliar color retention in the late fall (Wehner et al., 1988) as well as increased shoot density (Beard, 1973) and root growth (Hanson and Juska, 1961).

Annual nitrogen rates above 98 $kg \cdot ha^{-1}$ decreased ground ivy cover (Table 4). Raising nitrogen rates from 0 to 293 $kg \cdot ha^{-1} \cdot year^{-1}$ decreased ground ivy cover by 32%. However, 293 $kg \cdot ha^{-1} \cdot year^{-1}$ nitrogen for kentucky bluegrass would be excessive, potentially reducing stress tolerance (Turgeon 1996), increasing mowing requirements (Markland and Roberts, 1969), and increasing susceptibility to certain diseases (Cheeseman et al., 1965; Freeman 1964). However, increasing nitrogen from 0 to 196 $kg \cdot ha^{-1} \cdot year^{-1}$ reduced ground ivy cover 24%, which would be an acceptable nitrogen rate for most home lawns.

Increasing nitrogen rates in turf reduces the cover of crabgrass (*Digitaria* spp.) (Dernoeden et al., 1993; Johnson and Bowyer, 1982; Murray et al., 1983) and dandelion (*Taraxacum officinale* L.) (Johnson and Bowyer, 1982; Murray et al., 1983). However, higher fertilization rates can increase bermudagrass (*Cynodon dactylon* L. 'Guymon') cover (Brede, 1992) and broadleaved dock (*Rumex obtusifolius* L.) growth (Niggli et al., 1993). Therefore, the effects of increased nitrogen rates on weed-turf competition are dependent on the specific weed and turf species involved. Increasing nitrogen likely improved the competitiveness of kentucky bluegrass in our study, thus reducing ground ivy. Price and Hutchings (1996) reported competition from perennial

Table 2. Annual nitrogen rate and application schedule for the nitrogen fertility study.

Annual N rate	Application schedule (% total annual N)			N application rate ($kg \cdot ha^{-1}$) and schedule						
($kg \cdot ha^{-1}$)	Spring	Summer	Fall	Mar.	Apr.	May	July	Sept.	Oct.	Nov.
0	---[z]	---	---	---	---	---	---	---	---	---
98	67	---	33	22	22	22	---	33	---	---
98	33	33	33	---	---	33	33	33	---	---
98	33	---	67	---	---	33	---	22	22	22
196	67	---	33	44	44	44	---	65	---	---
196	33	33	33	---	---	65	65	65	---	---
196	33	---	67	---	---	65	---	44	44	44
293	67	---	33	65	65	65	---	98	---	---
293	33	33	33	---	---	98	98	98	---	---
293	33	---	67	---	---	98	---	65	65	65

[z]Nitrogen not applied.

Table 3. Postemergence herbicides and application rates used in the postemergence herbicide study to control ground ivy.

	Rate (kg·ha^{-1})	
Herbicide[z]	Full	Half
Triclopyr + clopyralid	0.6 + 0.2	0.3 + 0.1
Triclopyr	1.1	0.6
Clopyralid	0.6	0.3
MCPP + 2,4-D (amine) + dicamba	0.8 + 0.3 + 0.1	0.4 + 0.1 + 0.1
MCPP + 2,4-D (amine) + dicamba	0.6 + 1.1 + 0.1	0.3 + 0.6 + 0.1
Dicamba	1.1	0.6
2,4-D (amine)	2.1	1.1
2,4-D (ester)	2.1	1.1
Quinclorac	0.8	0.4
Fluroxypyr[y]	0.3	0.1

[z]Triclopyr + clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) (Dow AgroScience, Indianapolis), triclopyr (Dow AgroScience, Indianapolis), clopyralid (Dow AgroScience, Indianapolis), MCPP [2-(4-chloro-2-methylphenoxy)propanoic acid] + 2,4-D + dicamba (3,6-dichloro-2-methoxybenzoic acid) (PBI Gordon, Kansas City, Mo.), dicamba (Sandoz, Des Plaines, Ill.), 2,4-D-amine (Rhône-Poulenc, Research Triangle Park, N.C.), 2,4-D-ester (Rhône-Poulenc, Research Triangle Park, N.C), quinclorac (3,7-dichloro-8-quinolinecarboxylic acid) (BASF, Research Triangle Park, N.C.), and fluroxypyr (Dow AgroScience, Indianapolis).
[y]Fluroxypyr is currently not labeled for use in turf.

Table 4. Effect of annual nitrogen application schedule and rate on ground ivy cover in kentucky bluegrass turf 12 months after initial treatment.

Parameter	Ground ivy cover[z] (%)
Nitrogen application schedule	
Untreated	72 b
Spring	50 a
Summer	51 a
Fall	46 a
Nitrogen rate (kg·ha^{-1})	
0	72 b
98	59 b
196	48 a
293	40 a
ANOVA	
Nitrogen application schedule (S)	**
Nitrogen rate (R)	**
S × R	NS

[z]Within variables, means followed by the same letter are not significantly different according to Fisher's $LSD_{0.05}$ test. Data are averaged over 2 years. [NS,**]Nonsignificant or significant at $P \leq 0.01$, respectively.

ryegrass (*Lolium perenne* L.) reduced the number of ground ivy ramets produced and mean leaf area of ground ivy. Reducing ground ivy cover with 196 kg·ha^{-1}·year^{-1} nitrogen is simple, inexpensive, and can be an effective cultural control tool in an integrated ground ivy control program.

Preemergence herbicide study. Isoxaben prevented the growth and development of ground ivy stolons throughout our studies (Table 5). At 26 WAT, ground ivy cover was reduced to 8% by 1.1 kg·ha^{-1} isoxaben and 26% by 0.6 kg·ha^{-1} isoxaben compared to the control plots at 42%. Neal and Senesac (1991) also found that isoxaben can control ground ivy. In our study, ground ivy stolons in plots treated with 1.1 kg·ha^{-1} isoxaben developed roots that were short, stubby, black, and had not penetrated the soil. Prodiamine, pendimethalin, and dithiopyr had no effect on ground ivy cover, and the rooting behavior of ground ivy in these treatments was similar to that of the untreated control. It is not surprising that most of the treatments did not have an effect on ground ivy cover. Prodiamine, dithiopyr, and pendimethalin are typically regarded as preemergence herbicides for annual grassy weed control (Dernoeden, 1998; Gardner et al., 1997; Johnson, 1996; Turgeon, 1996) even though their labels indicate that certain annual broadleaf weeds germinating from seed can also be controlled. Ground ivy is a perennial and little effect would be expected on rooting and spread from preemergence annual grass herbicides like prodiamine, dithiopyr, and pendimethalin. However, since the herbicides are often used on lawns, it is important to understand their potential positive or negative effects on ground ivy.

Ground ivy is difficult to control in part due to its ability to quickly reestablish after postemergence herbicide treatment. If all ramets along a stolon are not controlled, the surviving ramets have the potential to produce new roots and stolons. Complete postemergence herbicide coverage of ground ivy is impossible since ramets near the apical meristem exist that have rooted but have not yet pushed leaves above the turf canopy. Isoxaben could limit these developing ramets' rooting ability, reducing reestablishment and improving control from both cultural methods and postemergence herbicides.

Postemergence herbicide study. There was no herbicide × rate interaction for ground ivy cover in either year of this study, so data are presented as means of the main effects (Table 6). As expected, the full-labeled rate provided better control than the half-labeled rate on four of six rating dates. At 30 WAT, the full-labeled rate provided 11% and 20% less ground ivy cover than the half-labeled rate in 1999 and 2000, respectively. Therefore to maximize ground ivy control, application of the full-labeled rate of the herbicide is necessary.

Triclopyr + clopyralid, triclopyr, MCPP + 2,4-D + dicamba (5:10:1), both formulations of 2,4-D, and fluroxypyr reduced ground ivy compared to the control on four of the six rating dates. MCPP + 2,4-D + dicamba (8:2:1),

Table 5. The effect of herbicide and rate on ground ivy cover in kentucky bluegrass at 6, 12, and 26 weeks after treatment.

	Ground ivy cover (%)								
	6 WAT[z]			12 WAT			26 WAT		
	Rate								
Herbicide	Half	Full	Mean	Half	Full	Mean	Half	Full	Mean
Prodiamine	9[y]	8	8	18	18	18	43	48	45
Dithiopyr	9	6	7	18	14	16	41	37	39
Isoxaben	5	2	3	11	4	7	26	8	17
Pendimethalin	9	6	7	16	17	16	40	41	40
Mean	8	5		16	13		38	33	
Control[x]	8			19			42		
ANOVA									
Herbicide (H)		**			**			**	
Rate (R)		**			NS			NS	
H × R		NS			NS			*	
$LSD_{(0.05)}$ for comparing H means		2			4			6	
$LSD_{(0.05)}$ for comparing R means		1			NS			NS	
$LSD_{(0.05)}$ for comparing H × R means		NS			NS			5	

[z]WAT = weeks after treatment.
[y]Means of six replications. Data averaged over 2 years.
[x]For comparison.
[NS,*,**]Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

Table 6. Ground ivy cover in kentucky bluegrass turf after treatment in October with postemergence herbicides.

Parameter	Ground ivy cover[z] (%) 1999 3 WAT	1999 6 WAT	1999 30 WAT	2000 3 WAT	2000 6 WAT	2000 30 WAT
Herbicide						
Triclopyr + clopyralid	41 bc	46 d	29 b	53 c–e	48 de	10 bc
Triclopyr	42 c	43 bc	27 ab	44 b–d	26 b–d	3 ab
Clopyralid	32 bc	34 ab	44 cd	75 f	79 f	66 de
MCPP + 2,4-D (amine) + dicamba (8:2:1)	40 a–c	43 c	47 cd	73 ef	72 f	53 d
MCPP + 2,4-D (amine) + dicamba (5:10:1)	39 a–c	35 a–c	35 bc	51 cd	40 cd	16 c
Dicamba	31 a	36 a–c	37 bc	76 f	65 ef	60 de
2,4-D (amine)	34 a–c	37 a–c	32 b	27 ab	12 ab	5 a–c
2,4-D (ester)	34 a–c	33 a	18 a	15 a	4 a	1 a
Quinclorac	35 a–c	39 a–c	38 bc	64 d–f	70 f	61 de
Fluroxypyr	35 a–c	38 a–c	29 b	37 bc	25 bc	10 bc
Control	36 a–c	37 a–c	54 d	73 ef	85 f	76 e
Application rate						
Full-labeled rate	36 a	38 a	28 a	42 a	31 a	14 a
Half-labeled rate	36 a	39 a	39 b	61 b	56 b	34 b
Control	36 a	37 a	54 c	73 c	85 c	76 c
ANOVA						
Herbicide (H)	**	**	**	**	**	**
Rate (R)	NS	NS	**	**	**	**
H × R	NS	NS	NS	NS	NS	NS

[z]WAT = weeks after treatment. Within variables, means followed by the same letter are not significantly different according to Fisher's $LSD_{.05}$ test.

NS,**Nonsignificant or significant at $P \leq 0.01$, respectively.

Table 7. Total precipitation, average high and low temperature for West Lafayette, Ind., during the postemergence herbicide experiments. Application dates were 30 Oct. 1999 and 15 Oct. 2000.

Interval	1999–2000 Precipitation (cm)	1999–2000 Temp (°C) High	1999–2000 Temp (°C) Low	2000-2001 Precipitation (cm)	2000-2001 Temp (°C) High	2000-2001 Temp (°C) Low
1 WAT[z]	1.8	19	4	1.0	21	9
2 WAT	0.0	19	6	0.2	24	13
3 WAT	0.4	15	0	0.1	20	7
4 WAT	0.5	12	2	4.9	14	4
5 WAT	0.0	9	–2	1.2	6	–3
6 WAT	2.3	10	0	0.0	3	–8
December	4.8	4	–4	5.2	–4	–13
January	5.1	1	–9	2.4	–1	–8
February	5.8	6	–4	8.6	4	–5
March	3.4	13	0	1.0	7	–3
April	2.9	17	4	6.1	19	7
May	13.3	23	13	11.1	24	12

[z]WAT = weeks after treatment.

dicamba, and quinclorac reduced ground ivy cover on only one of the six rating dates. Thought it is commonly stated in textbooks and extension publications that ground ivy is susceptible to dicamba (Beard, 1973; Pound and Street, 2003; Shurtleff et al., 1987), we found only one instance in the literature of dicamba used for ground ivy control. Olson and Hall (1988) observed dicamba had little effect on ground ivy when applied either alone or tank-mixed with other herbicides. Considering how little control resulted from dicamba in our study, there appears to be little benefit from using dicamba alone or in a tank mix with other herbicides for ground ivy control. In contrast to our results, Czarnota et al. (2001) found 0.8 kg·ha^{-1} quinclorac provided >70% control of ground ivy at 6 WAT. While our treatments were applied in the fall, Czarnota et al. (2001) applied in the spring, which may explain the difference in ground ivy response to quinclorac. Clopyralid had no effect on ground ivy throughout our study, similar to results from Olson and Hall (1988). Herbicide combinations that include triclopyr, 2,4-D, or fluroxypyr provided maximum ground ivy control.

There was less ground ivy control in 1999 than in 2000. The variation in response by year to the herbicide treatments may be due to weather differences after herbicide application (Table 7). Treatments were applied at the end of October in 1999 and mid-October in 2000. Average high and low temperatures for the 4 WAT were consistently higher in 2000 than in 1999. Generally herbicide absorption and translocation are greater under higher temperatures (Devine et al., 1993), which may have lead to a more rapid and higher increase in ground ivy control during the second year. Other researchers have reported variable ground ivy control as well, which was possibly due to weather conditions (Hatterman-Valenti et al., 1996).

Ground ivy control generally improved between fall and the following spring. For instance, at 3 WAT in 2000, triclopyr reduced ground ivy slightly compared to the untreated control and significantly less than 2,4-D-ester. However, triclopyr reduced ground ivy cover to 3% by the following spring (30 WAT), and this cover was similar to that produced by 2,4-D-ester. Thus, the efficacy of slower-acting herbicides such as triclopyr might not become apparent until the following spring (Hanson and Branham 1988).

Textbooks and extension publications state that 2,4-D does not provide good ground ivy control (Calhoun, 2002; Shurtleff et al., 1987; Turgeon 1996), yet it performed well in our study. At 30 WAT in both years, 2,4-D reduced ground ivy cover by up to 75% compared to the untreated control. Lowering the MCPP:2,4-D ratio from 8:2 to 5:10 improved ground ivy control, especially in the second year, also suggesting that 2,4-D is highly active on ground ivy. Likewise, work by Olson and Hall (1988) implies that 2,4-D is highly active on ground ivy. Our LCO survey found a majority use 2,4-D for ground ivy control. However, half the respondents reported fair or poor ground ivy control while the other half reported excellent or good ground ivy control. The discrepancy between our 2,4-D findings and the results of the survey may be due to differences in herbicide application timing, rate, formulation, or ground ivy ecotype (Kohler, 2002).

Based on the results of our experiments, a ground ivy control strategy can be developed for cool-season turf. First, the turf site should receive an annual nitrogen application of 196 kg·ha^{-1} to improve or maintain turf density. Second, applying 1.1 kg·ha^{-1} isoxaben with or after a postemergence herbicide application in the fall will severely curtail regrowth from uncontrolled stolons. Third, a postemergence herbicide product containing 2,4-D, fluroxypyr, or triclopyr should be applied in the fall at the highest labeled rate for a given turfgrass species. Proper nitrogen fertility programming, preemergence herbicide application, and postemergence herbicide application can improve ground ivy control.

Literature Cited

Beard, J.B. 1973. Turfgrass science and culture. Prentice Hall, Englewood Cliffs, N.J.

Birch, C.P.D. and M.J. Hutchings. 1994. Exploitation of patchily distributed soil resources by the clonal herb *Glechoma hederacea*. J. Ecol. 82:653–664.

Box, G.E.P. and D.R. Cox. 1964. An analysis of transformations. J.R. Stat. Soc. B26:211–252.

Brede, A.D. 1992. Cultural factors for minimizing bermudagrass invasion into tall fescue turf. Agron. J. 84:919–922.

Calhoun, R. 2002. Turf tips for the homeowner: Ground ivy in lawns. Mich. State Univ. Ext. Bul. E06TURF.

Cheeseman, J.H., E.C. Roberts, and L.H. Tiffany. 1965. Effects of nitrogen level and osmotic pressure of the nutrient solution on incidence of *Puccinia graminis* and *Helminthosporium sativum* infection in Merion kentucky bluegrass. Agron. J. 57:599–602.

Czarnota, M.A., J.N. Barney, and L.A. Weston. 2001. The control of ground ivy (*Glechoma hederacea*) in turfgrass with quinclorac. Proc. N.E. Weed Sci. Soc. 55:96.

Dernoeden, P.H. 1998. Use of prodiamine as a preemergence herbicide to control annual bluegrass in kentucky bluegrass. HortScience

33:845–846.
Dernoeden, P.H., M.J. Carroll, and J.M. Krouse. 1993. Weed management and tall fescue quality as influenced by mowing, nitrogen, and herbicides. Crop Sci. 33:1055–1061.
Devine, M.D., S.O. Duke, and C. Fedtke. 1993. Physiology of herbicide action. Prentice Hall, Englewood Cliffs, N.J.
Freeman, T.E. 1964. Influence of nitrogen on severity of *Piricularia grisea* infection of st. augustine grass. Agron. J. 54:1187–1189.
Gardner, D.S., N.E. Christians, and B.R. Bingaman. 1997. Pendimethalin and corn gluten meal combinations to control turf weeds. Crop Sci. 37:1875–1877.
Gaussoin, R.E. and B.E. Branham. 1989. Influence of cultural factors on species dominance in a mixed stand of annual bluegrass/creeping bentgrass. Crop Sci. 29:480–484.
Hanson, A.A. and F.V. Juska. 1961. Winter root activity in kentucky bluegrass (*Poa pratensis* L.) Agron. J. 53:372–374.
Hanson, K.V. and B.E. Branham. 1988. Broadleaf weed control research update: II. Late fall weed control. Proc. 58th Annu. Mich. Turfgrass Conf. 17:44–51.
Hatterman-Valenti, H., M.D.K. Owen, and N.E. Christians. 1996. Ground ivy (*Glechoma hederacea* L.) control in a kentucky bluegrass turfgrass with borax. J. Environ. Hort. 14:101–104.
Hutchings, M.J. and E.A.C. Price. 1999. *Glechoma hederacea* L. (*Nepeta glechoma* Benth., *N. hederacea* (L.) Trev.). J. Ecol. 87:347–364.
Jiang, H., J. Fry, and N. Tisserat. 1998. Assessing irrigation management for its effects on disease and weed levels in perennial ryegrass. Crop Sci. 38:440–445.
Johnson, B.J. 1996. Effect of reduced dithiopyr and prodiamine rates on large crabgrass (*Digitaria sanguinalis*) control in common bermudagrass (*Cynodon dactylon*) and tall fescue (*Festuca arundinacea*) turf. Weed Technol. 10:322–326.
Johnson, B.J. and T.H. Bowyer. 1982. Management of herbicide and fertility levels on weeds and kentucky bluegrass turf. Agron. J. 74:845–850.
Kohler, E.A. 2002. Chemical and cultural control of ground ivy populations: Evidence of a 2,4-D-tolerant biotype and its mechanism of tolerance. PhD diss. Purdue Univ., West Lafayette, Ind.
Lowe, D.B., T. Whitwell, L.B. McCarty, and W.C. Bridges. 2000. Mowing and nitrogen influence green kyllinga (*Kyllinga brevifolia*) infestation in tifway bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) turf. Weed Technol. 14:471–475.
Markland, F.E. and E.C. Roberts. 1969. Influence of nitrogen fertilizers on Washington creeping bentgrass, *Agrostis paulustris* Huds. I. Growth and mineral composition. Agron. J. 61:698–700.
Mitich, L.W. 1994. Ground ivy. Weed Technol. 8:413–415.
Monaco, T.J., S.C. Weller, and F.M. Ashton. 2002. Weed science principles and practices. 4th ed. Wiley, New York.
Murray, J.J., D.L. Klingman, R.G. Nash, and E.A. Woolson. 1983. Eight years of herbicide and nitrogen fertilizer treatments on kentucky bluegrass (*Poa pratensis*) turf. Weed Sci. 31:825–831.
Neal, J.C. and A.F. Senesac. 1991. Ground ivy and healall control in turf. Proc. N.E. Weed Sci. Soc. 45:120.
Niggli, U., J. Nosberger, and J. Lehmann. 1993. Effects of nitrogen fertilization and cutting frequency on the competitive ability and the regrowth capacity of *Rumex obtusifolius* L. in several grass swards. Weed Res. 33:131–137.
Olson, B.D. and A.B. Hall. 1988. Postemergence broadleaf weed control in turf with nonphenoxy herbicide combinations. Proc. N.E. Weed Sci. Soc. 42:185–186.
Pound, W.E. and J.R. Street. 2003. Broadleaf weed control for home lawns. Ohio State Univ. Ext. Bul. AGF-402-95.
Price, E.A.C. and M.J. Hutchings. 1996. The effects of competition on growth and form in *Glechoma hederacea*. Oikos 75:279–290.
Shurtleff, M.C., T.W. Fermanian, and R. Randell. 1987. Controlling turfgrass pests. Prentice Hall, Englewood Cliffs, N.J.
Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach. 2nd ed. McGraw Hill, New York.
Sterling, T.M. and J.C. Hall. 1997. Mechanism of action of natural auxins and the auxinic herbicides, p. 111–141. In: R.M. Roe, J.D. Burton, and R.J. Kuhr (eds.). Herbicide activity: Toxicology, biochemistry and molecular biology. IOS Press, Amsterdam, Netherlands.
Turgeon, A.J. 1996. Turfgrass management. 4th ed. Prentice Hall, Upper Saddle River, N.J.
Vencill, W.K. (ed.). 2002. Herbicide handbook. 8th ed. Weed Sci. Soc. Amer., Champaign, Ill.
Vrabel, T.E. 1987. Wild violet control in cool season turf. Proc. N.E. Weed Sci. Soc. 41:237.
Wehner, D.J., J.E. Haley, and D.L. Martin. 1988. Late fall fertilization of kentucky bluegrass. Agron. J. 80:466–471.