CHAPTER 2

Response of Virginia Collections of Italian Ryegrass (*Lolium multiflorum*) to Selected Postemergence Herbicides

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Abstract. Biotypes of Italian ryegrass were collected from several locations in Virginia, where in some cases, diclofop had been used extensively for weed control. The objectives of this study were: (1) to evaluate the presence of diclofop resistance in Italian ryegrass biotypes collected across central and southeast Virginia and (2) to evaluate the efficacy of alternative herbicides for control of diclofop resistant Italian ryegrass biotypes. The evaluation of 32 biotypes collected across Virginia substantiated reports of diclofop resistance. At the label-recommended application rate (0.56 kg a.i./ha), diclofop controlled only one biotype. At a four times the application rate, only 50% of the biotypes previously exposed to diclofop in cropping systems were controlled versus 94% of the biotypes previously not treated. To evaluate alternative approaches in management of diclofop-resistant Italian ryegrass, five biotypes (A, L1, L2, L3, and M) were evaluated for susceptibility to several herbicides. Chlorsulfuron, chlorsulfuron plus metsulfuron, and sulfosulfuron did not result in visual injury in any of the five biotypes at any rate tested. Tralkoxydim provided the most effective control of four of the biotypes (L1, L2, L3, M). These studies confirm the development of diclofop resistance in Italian ryegrass in Virginia. Further research is needed to elucidate the mechanism of herbicide resistance as well as alternative methods of Italian ryegrass control for Virginia growers.

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Nomenclature: Chlorsulfuron, 2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide; clodinafop-propargyl, 2-propynyl (R)-2-[4-(5-chloro-3-fluoro-2-pyridinyloxy)phenoxy]-propionate; cloquintocet-methyl, safener, 5-chloro-8-quinolinoxyacetic acid-1-methylexyl-ester; diclofop, methyl ester of (±)-2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid; metsulfuron, methyl 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-benzoate; tralkoxydim, 2-[1-(ethoxyimino)propyl]-3-hydroxy-5-(2,4,6-trimethylphenyl)-(9Cl) 2 cyclohexen-1-one; sulfosulfuron, *N*-[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]-2-ethylsulfonyl-imidazo[1,2a]pyridine-3-sulfonamide; Italian ryegrass, *Lolium multiflorum* Lam. #[2] [LOLMU].

Additional index words: Herbicide resistance, aryloxyphenoxy herbicide, LOLMU.

Abbreviations: A biotype, Italian ryegrass biotype (Amelia County, VA); ACCase, acetyl-Coenzyme A carboxylase; ANOVA, analysis of variance; APP, aryloxyphenoxypropionates; DAT, days after treatment; L1 biotype, Italian ryegrass biotype [Lancaster County, VA (first location)]; L2 biotype, Italian ryegrass biotype [Lancaster County, VA (second location)]; L3 biotype, Italian ryegrass biotype [Lancaster County, VA (third location)]; LSD, least significant difference; M biotype, Italian ryegrass biotype (Mecklenburg County, VA).

INTRODUCTION

The continuous use of the same herbicide or herbicides with similar modes of action leads to the development of herbicide-resistant weed species, thus complicating farmers' decisions on weed management (Maxwell and Mortimer, 1994). Herbicide resistance reflects a plant's ability to withstand herbicide treatments and reproduce after an herbicide application rate that would

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

have been lethal to the wild type of the same species (Heap, 1997). Several Virginia growers have reported Italian ryegrass populations resistant to diclofop (Hagood[3], 2004).

Introduced from Europe as a forage crop, Italian ryegrass (*Lolium multiflorum* Lam.) is an upright annual, cool-season grass. Growing vigorously in winter and early spring, mature ryegrass plants reach up to 1.2 m in height (Whitson et al., 1996). Spreading extensively via seed, Italian ryegrass has become a competitive weed in small grains especially in northwestern and southeastern United States (Hall, 1996; Uva et al., 1997). Ryegrass infestations cause reductions in crop yield, field abandonment, and expense of cleaning seed (Mersie and Foy, 1985). Control of ryegrass is essential for successful crop production (Appleby and Brewster, 1992; Mersie and Foy, 1985; Stone et al., 1998).

The herbicide diclofop, or diclofop-methyl, has afforded effective control of Italian ryegrass. Introduced in 1979, diclofop became widely used in wheat-producing areas of Oregon and other northwestern United States. Currently marketed as Hoelon® 3 EC (Crop Protection Reference, 2004) and Illoxan® 3 EC (Turf and Ornamental Reference, 2004), it belongs to the herbicide subfamily of the aromatic carboxylic acid family, the aryloxyphenoxypropionates (APP). This herbicide family consists mainly of postemergence herbicides used to control grasses. Diclofop and some other members of the APP herbicide family inhibit acetyl-coenzyme A carboxylase (ACCase), an important enzyme in plant lipid synthesis (Betts et al., 1992; Burton et al., 1989; Gronwald et al., 1989).

Currently, over 25 weed species throughout the world have been confirmed to be resistant to ACCase-inhibiting herbicides (Heap, 2002). In most instances, the resistance to ACCase inhibitors was found to be due to the presence of an altered ACCase. Enzyme sensitivity differs among species, each conferring different patterns and levels of resistance. A plant sensitive to

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one APP herbicide may not be as sensitive to another APP herbicide, and not all tissues within the same plant are equally sensitive to the same herbicide (Egli et al., 1993; Nikolau et al., 1984).

The first incidence of diclofop-resistant Italian ryegrass was reported in 1987 (Stanger and Appleby, 1989). Diclofop-resistant biotypes of Italian ryegrass were found in wheat fields that had been treated annually with diclofop for at least seven years. Diclofop GR50 (rate required to reduce shoot weight by 50%) values varied among resistant biotypes and were 400 to 980 times higher than for susceptible biotypes (Stanger and Appleby, 1989).

Growers' reports of diclofop-resistant Italian ryegrass biotypes coupled with a reduction in diclofop efficacy for ryegrass control in some Virginia cropping systems prompted studies to confirm resistance as well as determine alternative control programs (Hagood[4], 2004). The objectives of this research were: (1) to determine the presence and evaluate the level of diclofop resistance in Italian ryegrass biotypes collected across central and southeast Virginia and (2) to evaluate the efficacy of alternative herbicides for control of diclofop-resistant Italian ryegrass biotypes.

MATERIALS AND METHODS

In order to carry out the two objectives, three experiments were conducted. The first experiment evaluated five biotypes for resistance to six application rates of diclofop. The second experiment evaluated resistance to three dic lofop rates in 32 Italian ryegrass biotypes. The third experiment evaluated the efficacy of alternative post-emergence herbicides on five Italian ryegrass biotypes.

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Herbicide treatments were applied using a spray table[5] calibrated to deliver 234 L/ha at 269 kPa. A TeeJet® 8001 EVS flat fannozzle tip[6] was used 30.5 cm above the plant canopy. Herbicides were applied to two- to three-leaf Italian ryegrass seedlings. Percent visual control ratings were taken at 15, 20, 25, 30, 35, and 40 days after treatment (DAT) in each experiment. Visible plant injury was rated from 0 (no injury) to 100 (plant death) in each experiment. The experiments were conducted in a greenhouse with temperatures ranging from 16° to 22°C.

Each experiment consisted of two repetitions. In each repetition, treatments were replicated four times. Experimental designs were randomized complete blocks with a factorial arrangement of treatments. For each experiment, data variance was tested for homogeneity prior to analysis of variance (ANOVA) by plotting residuals. Arcsine square-root transformation did not improve variance homogeneity for any experiment so actual data were used in each analysis. In each experiment, sums of squares were partitioned in ANOVA to test for the effects of repetition, biotype, and herbicide rate. Repetition was considered a random variable, and fixed effects were tested by the means square associated with the interaction of repetition (McIntosh 1985). Quantitative fixed effects were separated using Fischer's protected LSD ($\alpha = 0.05$). Where herbicide rate was significant for dose responses, regressions were used to explain measured responses.

Experiment 1. In July 1998, mature Italian ryegrass plants were collected from five locations in Virginia: Amelia County (biotype A), Mecklenburg County (biotype M), and three locations in Lancaster County (biotypes L1, L2, and L3). The Amelia and Mecklenburg locations were reported by growers to have had continuous diclofop applications, while the Lancaster County biotypes (L1, L2, L3) had received less frequent treatment (Hagood, 2004). The collected plants

[5] Stationary Track Sprayer. Allen Machine Works. 607 E. Miller Road, Midland, MI 48640.

[6] Spraying Systems Co.®, P.O. Box 7900, Wheaton, IL 60189.

were thrashed and seed stored at room temperature. Approximately 50 seed of each biotype collected in 1998 were sown 2.5 cm deep in a commercial potting medium[7] contained in 15-cm-diam plastic pots. Diclofop was applied at 0, 0.28, 0.56, 1.12, 2.24, 4.48, and 8.96 kg a.i./ha equivalent to 0, 0.5, 1, 2, 4, 8, and 16 times the normal use rate of diclofop, respectively.

Experiment 2. In early 1999, seed collections of Italian ryegrass from 27 other Virginia locations, primarily from central and southeast Virginia, were submitted for testing through the Virginia Tech Eastern Shore Agricultural Research and Extension Center. Seed preparation and treatment was conducted as described above. These biotypes were combined with A, L1, L2, L3, and M to create a total of 32 biotypes from fields with varying histories of diclofop use.

Approximately 30 seed from each of the 32 individual biotypes were sown 2.5 cm deep in commercial potting medium contained in 10-cm-diam plastic pots. Plants were treated for repetitions 1 and 2 in April and June of 1999. Diclofop was applied to Italian ryegrass seedlings at 0.56, 1.12, and 4.48 kg a.i./ha, equivalent to 1, 2, and 8 times the recommended rate, respectively. For repetitions 1 and 2, 2- to 2½-leaf and 3- to 3½-leaf plants were treated, respectively.

Field history for the 32 biotypes was categorized according to reported diclofop applications: (1) "treated" indicates a diclofop application the previous season; (2) "not treated" represents a field history with no diclofop application the previous season; and (3) "unknown" designates a cropping history in which the use of diclofop was not known for the previous season.

Experiment 3. Italian ryegrass biotypes A, L1, L2, L3, and M were evaluated for susceptibility to diclofop, chlorsulfuron, chlorsulfuron plus metsulfuron, clodinafop-propargyl, tralkoxydim, and sulfosulfuron. Rates and appropriate additives for each are listed in Table 2.2. For

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[7] 'General Purpose' Pro Mix BX peat-based growing medium. Premier Horticulture Inc., Red Hill, PA 18076.

repetitions 1 and 2, 3- to 3½-leaf and 2- to 2½-leaf plants were treated, respectively. A non-treated control for each biotype was included for each repetition.

RESULTS AND DISCUSSION

Homogeneity of variance analysis indicated that data in each of the three experiments could not be combined over repetition, and data for each repetition are therefore presented separately. For consistency in presentation, data for each experiment are presented for 35 DAT. This observation date accurately reflects the relative trends in biotype response and herbicide efficacy.

Experiment 1. Response to diclofop varied among the five Italian ryegrass biotypes in both repetitions of the experiment (Figures 2.1 and 2.2). In both repetitions, Italian ryegrass control increased with increasing herbicide rate for four of the five biotypes evaluated. However, diclofop did not provide above 70% control of any biotype except at the highest rates (8- and 16-times the label-recommended field rate). Most plants survived the label-recommended application rate (0.56 kg a.i./ha) at each observation date (data not shown).

At 35 DAT for repetitions 1 and 2 respectively, only 27 (L1) and 20% (L2) control was obtained for any biotype at the label-recommended application rate for diclofop. However, these two biotypes were the most susceptible to diclofop across all application rates and observation dates (data not shown). Leaf tissue in susceptible plants turned chlorotic, developed necrosis, and senesced. Leaf sheaths disintegrated at and just above the nodes. Maximum injury (> 90%) occurred to the L1 and L2 biotypes in both repetitions at the 16-times the label-recommended application rate. Greater than 80% control also occurred using 8-times the normal application rate on the L2 seedlings and 16-times the normal application rate on the L3 seedlings in repetition 2 (Figure 2.2). The high rates (4.48 and 8.96 kg a.i./ha) needed to achieve control in these biotypes confirm diclofop tolerance in Virginia Italian ryegrass populations as reported by Hagood[8].

The M biotype was partially resistant to all application rates at 35 DAT with control ranging from 5% to 48% and 0% to 55% for the 0.56 kg a.i./ha and 8.96 kg a.i./ha application rates for repetitions 1 and 2, respectively. Biotype M was not controlled above 60% at any observation date regardless of diclofop rate (data not shown). The L3 biotype responded similarly with some plants surviving across application rates at 35 DAT. Partial survival of plants within each of these two biotypes potentially reflects the existence of population heterogeneity within each biotype.

The A biotype appeared very resistant to diclofop, showing little injury from 1- to 16-times the recommended application rate in repetition 1 (Figure 2.1). In repetition 2, no response to any diclofop rate was recorded for this biotype at 35 DAT (Figure 2.2). Injury levels exhibited by biotype A did not exceed 12% regardless of application rate, identifying biotype A as the most resistant of the five evaluated.

Experiment 2. Resistance to diclofop varied among the 32 biotypes evaluated, the range of application rates, and showed a dependency on the growth stage of the plants at the time of herbicide application (Table 2.1). Significant interactions occurred across both biotypes and the range of application rates. Herbicide efficacy increased with increasing herbicide rate. In repetition 1, 94% percent of the biotypes collected from fields with no previous history of diclofop treatment, or "not treated," were controlled at acceptable levels ($\geq$ 80%) regardless of herbicide rate. At 1-, 2-, and 4-times the normal application rates, percent injury observed was 81, 94, and 94% and 6, 13, and 88%, for repetitions 1 and 2, respectively. This difference in

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control across repetitions is attributed to plant size (2- to 2½-leaf stage versus 3- to 3½-leaf stage, respectively, for repetitions 1 and 2).

At the recommended field-use rate, 21% and 0% of the "treated" biotypes and 81% and 6% of the "not treated" biotypes were effectively controlled in repetitions 1 and 2, respectively. At the 1.12 kg a.i./ha application rate in repetitions 1 and 2, respectively, 43% and 6% of "treated" versus 88% and 13% of "not treated" biotypes were effectively controlled. At the 4.48 kg a.i./ha rate, 50% and 43% of the "treated" and 94% and 88% of the "not treated" were effectively controlled. Generally, biotypes withstanding the 1.12 kg a.i./ha application rate originated in fields with known histories of diclofop applications.

The results of this experiment demonstrate varying degrees of resistance across a range of sources of Italian ryegrass. Partial survivability of some Italian ryegrass biotypes may indicate population heterogeneity among the populations where seed collections were made. The pattern of resistance development was more apparent in the biotypes previously treated with diclofop.

Experiment 3. To evaluate alternative approaches in management of diclofop-resistant Italian ryegrass, five biotypes (A, L1, L2, L3, and M) were tested for their susceptibility to diclofop, chlorsulfuron, chlorsulfuron plus metsulfuron, clodinafop-propargyl, tralkoxydim, and sulfosulfuron (Table 2.1). Chlorsulfuron, chlorsulfuron plus metsulfuron, and sulfosulfuron did not result in visual injury to any of the five biotypes regardless of rate or repetition. To stabilize variance, these data were removed prior to analysis. Significant interactions occurred across both biotypes and the range of application rates.

Highest levels of Italian ryegrass control were observed at 35 DAT, thus these data are shown to reflect the relative trends in herbicidal efficacy. Herbicide efficacy was generally higher in repetition 2 than in repetition 1. This observed difference in herbicide efficacy may be attributed to differences in plant size at the time of application in repetition 2.

In repetition 1, significant differences occurred between treatments; however, adequate control (≥ 80%) was not achieved with any treatment. Control ranged from 0 to 34% across all treatments and biotypes. In repetition two, adequate control of the L1 biotype was achieved with diclofop at 2X the recommended application rate.

Due to the lack of herbicide efficacy in controlling Biotype A, an LSD was not calculated. Biotype A was not controlled by any herbicide treatment and rate in either repetition, indicating the inefficiency of sulfonylureas and ACCase-inhibiting herbicides in control of this biotype. The ineffective control resulting from diclofop and tralkoxydim may indicate cross-resistance within different classes of ACCase inhibitors. All five biotypes showed no response in either repetition to chlorsulfuron, chlorsulfuron plus metsulfuron, and sulfosulfuron treatments. Moderate efficacy was achieved across all clodinafop-propargyl rates and the lowest rates of diclofop and tralkoxydim for the L1, L2, L3, and M biotypes. Tralkoxydim provided the most effective control of four biotypes (L1, L2, L3, M), ranging from 76 to 100% for the at 0.245 and 0.28 kg a.i./ha application rates. The remainder of the herbicide applications did not provide adequate control of any Italian ryegrass biotype regardless of application rate.

These experiments collectively substantiate the occurrence of diclofop-resistant Italian ryegrass biotypes in Virginia. Resistance to diclofop occurred using a 16-times the label-recommended rate of diclofop in some biotypes. Differences in absorption, translocation, and metabolism may contribute to differential expression of herbicide susceptibility across herbicides with similar modes of action and warrants further investigation.

Repeated herbicide use over an extended period of time may lead to a competitive advantage for resistant biotypes, especially as they develop in and/or spread into new areas. The resistant biotypes may not have a competitive advantage over wild types, as observed in *Lolium rigidum* species closely related to Italian ryegrass (Mortimer, 1993). However, this warrants further investigation. Small grain growers should be advised to impede the dispersion of herbicide-resistant Italian ryegrass biotypes via alternative control procedures, crop rotation, and equipment sanitation. Further study is warranted to determine the mode and method of diclofop resistance in Italian ryegrass.

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SOURCES OF MATERIALS

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Chlorsulfuron (Glean 75 DF®). DuPont Agricultural Products, 1007 Market St., Wilmington, DE 19898.

Diclofop-methyl (Hoelon® 3 EC). Bayer CropScience LP. P.O. Box 12014, 2 T.W. Alexander Drive, Research Triangle Park, NC 27709.

Sulfosulfuron (Maverick® 75 WDG). Monsanto Co., 800 N. Lindenbergh Blvd., St. Lois, MO 63167.

Tralkoxydim (Achieve® 40 DG). Zeneca Ag Products Inc., Wilmington, DE 19897.

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Table 2.1. Percent visual control of 32 Italian ryegrass biotypes with three application rates of diclofop at 35 days after treatment (DAT) in April and June 1999.

		Italian ryegrass control							
		Repetition 1[a]				Repetition 2			
		Diclofop rate (kg a.i./ha)				Diclofop rate (kg a.i./ha)			
Biotype	Field History[b]	0.56	1.12	4.48	LSD (0.05)	0.56	1.12	4.48	LSD (0.05)
		--------- (%) ---------				--------- (%) ---------			
Source 01	not treated	86	94	99	9	55	69	100	16
Source 02	not treated	83	96	99	8	49	74	99	9
Source 03	not treated	90	95	100	6	80	98	100	ns
Source 04	not treated	95	99	100	3	46	98	98	7
Source 05	not treated	98	100	100	ns	24	45	100	20
Source 06	not treated	88	90	100	ns	26	40	98	8
Source 07	not treated	96	100	100	ns	39	60	98	20
Source 08	not treated	85	95	100	10	10	23	83	16
Source 09	not treated	88	92	99	ns	36	71	95	6
Source 10	not treated	90	90	96	ns	8	13	88	16
Source 11	not treated	95	98	100	3	36	69	99	16
Source 12	not treated	95	96	100	ns	35	84	100	22
Source 13	not treated	69	86	98	14	16	33	94	5
Source 14	not treated	0[c]	0[c]	0[c]	--	0[c]	0[c]	0[c]	--
Source 15	not treated	74	85	91	13	8	15	86	11
Source 16	not treated	90	96	100	7	24	50	100	13
Source 17	treated	0[c]	0[c]	0[c]	--	4	5	10	ns

Source 18	treated	0[c]	0[c]	0[c]	--	1	3	4	ns
Source 19	treated	0[c]	0[c]	0[c]	--	1	4	9	ns
Source 20	treated	78	93	99	6	16	28	98	19
Source 21	treated	0[c]	0[c]	0[c]	--	0[c]	0[c]	0[c]	--
Source 22	treated	3	0	3	ns	0[c]	0[c]	0[c]	--
Source 23	treated	86	94	96	7	28	49	95	16
Source 24	treated	0[c]	0[c]	0[c]	--	0[c]	0[c]	0[c]	--
Source 25	treated	95	98	100	3	48	70	99	20
Source 26	treated	11	35	99	8	23	48	99	8
Source 27	treated	40	60	100	18	26	81	100	28
Source 28	treated	11	24	88	8	10	29	80	9
Source 29	treated	13	23	85	17	13	21	73	9
Source 30	treated	5	4	5	ns	0[c]	0[c]	0[c]	--
Source 31	unknown	5	8	13	ns	5	5	13	ns
Source 32	unknown	0[c]	0[c]	0[c]	--	0[c]	0[c]	0[c]	--
LSD (0.05)		10	8	4		15	15	9	

[a] Italian ryegrass was sprayed at 2 to 2 ½-leaf stage and 2 ½ to 3-leaf stage in repetitions 1 and 2, respectively.

[b] Reflects field history (i.e., previous treatments with diclofop at this particular location) from which a biotype was collected; a cropping situation is not implied.

[c] Deleted prior to analysis to stabilize variance.

Table 2.2. Percent control of five Italian ryegrass biotypes with diclofop, chlorsulfuron, chlorsulfuron plus metsulfuron, clodinafop-propargyl, tralkoxydim and sulfosulfuron at 35 days after treatment (DAT) in January and February 1999, respectively, in two repetitions.

		Italian ryegrass control											
		Repetition 1						Repetition 2					
Herbicide[b]	Rate	L1 [c]	L2	L3	M	A	LSD (0.05)	L1	L2	L3	M	A	LSD (0.05)
	kg a.i./ha	-- (%) --											
Chlorsulfuron	0.0157	0[d]	0[d]	0[d]	0[d]	0[d]	--	0[d]	0[d]	0[d]	0[d]	0[d]	--
Chlorsulfuron	0.0212	0[d]	0[d]	0[d]	0[d]	0[d]	--	0[d]	0[d]	0[d]	0[d]	0[d]	--
Chlorsulfuron	0.0258	0[d]	0[d]	0[d]	0[d]	0[d]	--	0[d]	0[d]	0[d]	0[d]	0[d]	--
Chlorsulfuron plus metsulfuron	0.0157	0[d]	0[d]	0[d]	0[d]	0[d]	--	0[d]	0[d]	0[d]	0[d]	0[d]	--
Chlorsulfuron plus metsulfuron	0.0212	0[d]	0[d]	0[d]	0[d]	0[d]	--	0[d]	0[d]	0[d]	0[d]	0[d]	--
Chlorsulfuron plus metsulfuron	0.0258	0[d]	0[d]	0[d]	0[d]	0[d]	--	0[d]	0[d]	0[d]	0[d]	0[d]	--
Clodinafop-propargyl	0.056	9	3	11	1	0[d]	ns	38	38	15	31	0[d]	ns
Clodinafop-propargyl	0.084	11	13	14	10	0[d]	ns	58	51	44	46	0[d]	ns
Clodinafop-propargyl	0.125	15	28	20	11	0[d]	10	76	66	54	58	3	16

Diclofop	0.56	26	29	18	4	0[d]	15	64	71	18	18	0[d]	8
Diclofop	1.12	28	29	15	4	0[d]	7	85	75	24	28	0[d]	13
Sulfosulfuron	0.035	0[d]	0[d]	0[d]	0[d]	0[d]	--	0[d]	0[d]	0[d]	0[d]	0[d]	--
Sulfosulfuron	0.07	0[d]	0[d]	0[d]	0[d]	0[d]	--	0[d]	0[d]	0[d]	0[d]	0[d]	--
Tralkoxydim	0.21	21	16	28	19	5	11	78	8	29	21	0[d]	28
Tralkoxydim	0.245	23	24	29	28	5	9	100	98	90	76	1	16
Tralkoxydim	0.28	34	28	34	30	3	8	100	96	91	76	0[d]	13
LSD (0.05)		10	11	6	8	ns		17	8	17	17	ns	

[a] Italian ryegrass plants were sprayed at 3 - 3 ½ leaf stage (January 1999) and 2 ½ - 3 leaf stage (February 1999).

[b] Chlorsulfuron and chlorsulfuron plus metsulfuron were applied with 0.5% (v/v) of 80% alkyl polyoxyethelene ether surfactant; clodinafop-propargyl was applied with 1% (v/v) cloquintocet-methyl safener; tralkoxydim was applied with 1% (v/v) petroleum distillate/polyoxethylene oleyl ether/n-alkyl alcohol adjuvant; sulfosulfuron was applied with 0.5% (v/v) of 80% alkyl polyoxyethelene ether surfactant.

[c] Denotes Italian ryegrass biotypes by location in Virginia: L1, Lancaster County ; L2, Lancaster County ; L3, Lancaster County ; M, Mecklenburg County; A, Amelia County.

[d] Deleted prior to analysis to stabilize variance.

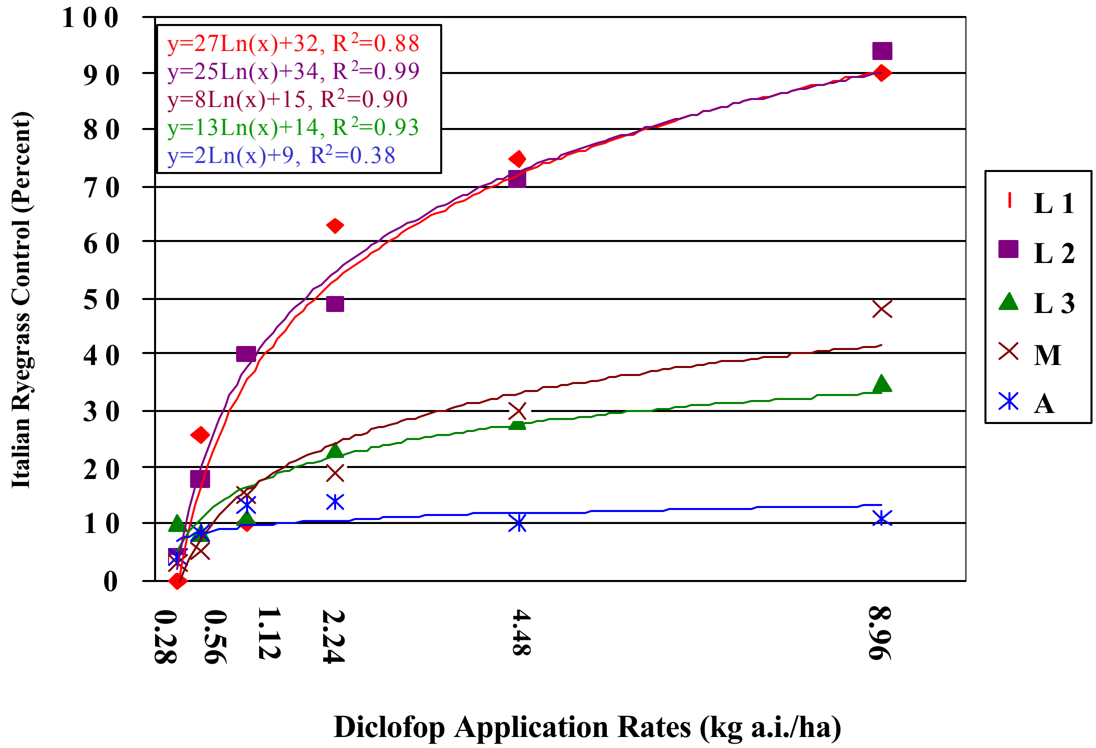

Figure 2.1. Estimated control at 35 days after treatment for repetition 1 evaluating Italian ryegrass biotypes[a] for susceptibility to six application rates of diclofop. [a] Denotes Italian ryegrass biotypes by location in Virginia: L1 (Lancaster County), L2 (Lancaster County), L3 (Lancaster County), M (Mecklenburg County), and A (Amelia County).

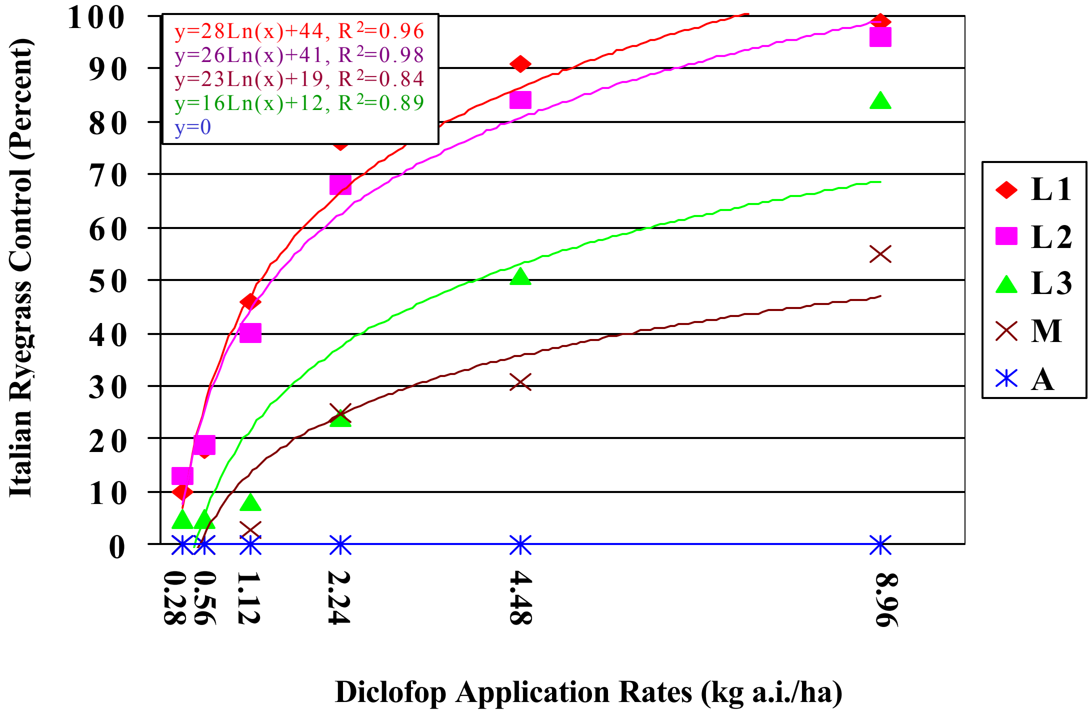

Figure 2.2. Estimated control at 35 days after treatment for repetition 2 evaluating Italian ryegrass biotypes[a] for susceptibility to six application rates of diclofop. [a] Denotes Italian ryegrass biotypes by location in Virginia: L1 (Lancaster County), L2 (Lancaster County), L3 (Lancaster County), M (Mecklenburg County), and A (Amelia County).