

Chapter V

Control of Italian Ryegrass (*Lolium multiflorum*)

in Wheat (*Triticum aestivum*) with Several Postemergence Herbicides

Abstract. Field experiments were conducted in Virginia in 2000 and 2001 to investigate responses of wheat and diclofop-methyl-sensitive and -resistant Italian ryegrass to POST applications of several experimental and registered herbicides. The experimental herbicide combination AE F130060 03 was as effective as diclofop-methyl and more effective than chlorsulfuron plus metsulfuron, chlorsulfuron plus metribuzin, MON 37560, ICIA 0604, and CGA 184927 for control of diclofop-methyl-sensitive Italian ryegrass. AE F130060 03 also controlled diclofop-methyl-resistant Italian ryegrass better than all other herbicides applied. AE F130060 03 also reduced late-season inflorescence emergence of diclofop-methyl-sensitive and -resistant Italian ryegrass by 91 to 100%. Although 10 to 24% wheat injury from AE F130060 03 was greater than from the other herbicides, wheat recovered and injury did not influence grain yield. Grain yield from wheat treated with AE F130060 03 was similar to or greater than yield from wheat treated with the other herbicides. Italian ryegrass control, inflorescence emergence, and grain yield was not influenced by AE F130060 03 rate or the addition of methylated seed oil. In these experiments, AE F130060 03 was comparable to diclofop-methyl for control of diclofop-methyl-sensitive Italian ryegrass and more effective than all other herbicides for control of diclofop-resistant Italian ryegrass.

Nomenclature: AE F130060 03 {8.3:1.7 mixture of AE F130060 00, proposed common name mesosulfuron-methyl, 2-[(4,6-dimethoxypyrimidin-2-yl carbamoyl)sulfamoyl]-4-methanesulfonamido)-*p*-toluic acid, plus AE F115008 00, proposed common name iodosulfuron-methyl-sodium, 4-iodo-2-[3-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)ureidosulfonyl]benzoic acid}; AE F107892, proposed common name mefenpyr

diethyl, 1-(2,4-dichlorophenyl)-4,5-dihydro-5-methyl-1*H*-pyrazole-3,5-dicarboxylic acid; CGA 184927, proposed common name clodinafop-propargyl, (*R*)-2-[4-[(5-chloro-3-fluoro-2-pyridinyl)oxy]phenoxy]propanoic acid 5-chloro-8-quinolinoxyacetic acid-1-methylester; chlorsulfuron; diclofop-methyl; ICIA 0604, proposed common name tralkoxydim, 2-[1-(ethoxyamino)propyl]-3-hydroxy-5-(2,4,6-trimethylphenyl)-2-cyclohexen-1-one; metribuzin; metsulfuron; MON 37560, proposed common name sulfosulfuron, 1-(4,6-dimethoxypyrimidin-2-yl)-3-[(ethanesulfonyl-imidazo{1,2-*a*}-pyridine-3-yl)sulfonyl]urea; Italian ryegrass, *Lolium multiflorum* Lam. LOLMU #⁷; winter wheat, *Triticum aestivum* L. 'Pioneer 2643', 'Pioneer 26R24', 'Pocohontas'.

Additional index words: diclofop-methyl resistance, resistance management.

Abbreviations: ACCase, acetyl coenzyme A carboxylase (EC 6.4.1.2); ALS, acetolactate synthase (EC 4.1.3.18); MSO, methylated seed oil; POST, postemergence; WBT, wk before treatment; WAP, wk after planting; WAT, wk after treatment.

INTRODUCTION

Winter wheat is an economically important crop throughout much of the U.S. However, winter wheat production has declined during the past 11 yr from 49.7 million ha harvested in 1990 at a value of \$5.4 billion to 31.3 million ha harvested in 2001 at a value of \$3.8 billion (Anonymous 2002a). Low wheat prices and other production concerns have led to this decline in production.

Weeds are a major production concern in winter wheat. Producers typically encounter several winter annual broadleaf and grass weeds that compete with wheat. Italian ryegrass is ranked as one of the top ten most common and troublesome weeds in wheat in all nine Southern states (Webster 2000). Wheat

⁷Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

grain yield reductions as high as 92% have been observed due to competition with Italian ryegrass (Appleby et al. 1976; Hashem et al. 1998). Liebl and Worsham (1984) reported a 5% yield loss for every 10 Italian ryegrass plants/m². The competitive ability of Italian ryegrass with wheat is related to the ability of ryegrass to reduce wheat tillering (Appleby et al. 1976; Ketchersid and Bridges 1987) and deplete soil nitrogen and phosphorus resources intended for wheat (Liebl and Worsham 1987; Perez-Fernandez and Coble 1998). In addition, Italian ryegrass has a faster leaf expansion rate than wheat (Ball et al. 1995). Severe infestations of Italian ryegrass are not uncommon in North Carolina and Virginia wheat fields and often result in field abandonment⁸.

Several researchers have reported that Italian ryegrass control programs which utilize cultural practices such as wheat seeding arrangement and seeding density, and the use of more competitive wheat varieties, were ineffective in reducing Italian ryegrass competition with wheat (Appleby and Brewster 1995; Hashem et al. 1998). Therefore, chemical weed management strategies are the only practical means of controlling Italian ryegrass in wheat.

Diclofop-methyl was registered for selective control of Italian ryegrass in wheat in North Carolina and Virginia in the early 1980's. Diclofop-methyl is an aryloxyphenoxypropanoate herbicide that inhibits acetyl coenzyme A carboxylase (ACCase, EC 6.4.1.2), a chloroplastic enzyme essential to fatty acid biosynthesis in susceptible monocot species (Kocher 1984; Bravin et al. 2001). Diclofop-methyl has controlled Italian ryegrass since its registration. However, repeated use of this herbicide has selected Italian ryegrass biotypes resistant to diclofop-methyl. Currently, diclofop-methyl-resistant Italian

⁸A. C. York, North Carolina State University; E. S. Hagood, Virginia Tech, personal communication.

ryegrass biotypes infest more than 50% of the wheat hectareage in Virginia and result in annual net losses in excess of \$3.2 million⁹.

Since the initial discovery of Italian ryegrass biotypes resistant to diclofop-methyl, several other ACCase-inhibitor and non-ACCase-inhibitor herbicides have been registered for control of Italian ryegrass in wheat. ICIA 0604 (proposed common name tralkoxydim) is an ACCase-inhibiting herbicide similar to diclofop-methyl that is registered for Italian ryegrass control in wheat (Anonymous 2001a). In spring wheat, ICIA 0604 applied at 202 g/ha controlled one-leaf to fully-tillered Italian and perennial ryegrass (*Lolium perenne* L.) 86 to 95% (Yenish and Eaton 1999). Stevenson et al. (2000) found that ICIA 0604 also controlled wild oat (*Avena fatua* L.), another problematic grass species in wheat. CGA 184927 (proposed common name clodinafop-propargyl) is another ACCase-inhibiting herbicide registered for Italian ryegrass control in wheat (Anonymous 2001b) that has controlled wild oat and ryegrass species (Driver et al. 1999; Blackshaw and Harker 1996; Kirkland et al. 2001).

Although these ACCase-inhibiting herbicides may be effective on Italian ryegrass and wild oat biotypes that have not developed resistance to diclofop-methyl, diclofop-methyl-resistant biotypes of many grass species are often cross resistant to other herbicides with the same mode-of-action (Cocker et al. 2001; Bourgeois et al. 1997; Bravin et al. 2001; Kuchuran and Beckie 2000). For these reasons, introduction of herbicides with alternative modes-of-action are essential for wheat production in areas where diclofop-methyl-resistant Italian ryegrass populations persist.

Sulfonylurea herbicides differ from ACCase-inhibiting herbicides by inhibiting acetolactate synthase (ALS, EC 4.1.3.18), the enzyme that catalyzes the first parallel reaction in the biosynthesis of the branched chain amino

⁹Hagood, E. S., Jr. 2000. Application for specific exemption in accordance with section 18 of FIFRA to use Axiom herbicide to control annual ryegrass in wheat.

acids valine, leucine, and isoleucine (Ray 1984). Several ALS-inhibiting herbicides have been registered for control of diclofop-methyl-resistant Italian ryegrass. Chlorsulfuron was the first ALS-inhibiting herbicide registered for Italian ryegrass control in wheat. With adequate rainfall, preemergence (PRE) applications of chlorsulfuron at 18 to 35 g ai/ha have controlled Italian ryegrass (Griffin 1985; Klingaman and Peeper 1989), but chlorsulfuron has not been as effective postemergence (POST) (Justice et al. 1994). A prepackaged mix of chlorsulfuron plus metsulfuron (5:1 w/w) applied PRE at 26 g ai/ha is also registered for suppression of Italian ryegrass (Anonymous 2001c). This herbicide mixture may also control Italian ryegrass in POST applications (Wilson and Hines 1997). However, insufficient control has been observed from this herbicide mixture in Virginia (Bailey et al. 2001). MON 37560 (proposed common name sulfosulfuron) is another ALS-inhibiting herbicide that was registered in some regions of the U.S. in 1999 to control Italian ryegrass and other weeds in spring and winter wheat (Anonymous 2001d). Similar to chlorsulfuron or chlorsulfuron plus metsulfuron, however, Italian ryegrass control by MON 37560 has not been consistent (Rauch and Thill 1999; Brewster et al. 1997).

AE F130060 03 is an 8.3:1.7 mixture of the two experimental sulfonylurea herbicides AE F130060 00 and AE F115008 00. AE F130060 00 (proposed common name mesosulfuron-methyl) has activity primarily against monocotyledonous weed species while AE F115008 00 (proposed common name iodosulfuron-methyl-sodium) acts primarily against dicotyledonous weed species (Anonymous 2002b; Anonymous 2002c). This sulfonylurea mixture has controlled Italian ryegrass and several winter annual dicotyledonous weed species and can be applied to wheat when used with the crop safener and adjuvant AE F107892 (proposed common name mefenpyr diethyl) (Anderson et al. 2002; Bailey et al. 2002; Crooks et al. 2002; Hand et al. 2002). AE F107892 was developed in 1993 as a crop safener for fenoxaprop-P-ethyl, but is also an effective safener for certain other chemical classes (Hopkins 1997). In addition, foliar absorption of this herbicide combination in

Italian ryegrass may be enhanced with the addition of methylated seed oil (MSO) (Anonymous 2002b).

To date, no studies have been reported in which all of the herbicides discussed above have been compared for control of Italian ryegrass. For this reason, research was conducted to investigate wheat response and control of diclofop-methyl-sensitive and -resistant Italian ryegrass with several ACCase-inhibiting and ALS-inhibiting herbicides. Of special interest was a determination of the activity of AE F130060 03 against Italian ryegrass and the effect of MSO on wheat injury and Italian ryegrass control by this herbicide combination.

MATERIALS AND METHODS

Field experiments were conducted at the Eastern Shore Agricultural Research and Extension Center near Painter, VA as well as in private grower fields near Cape Charles, VA in 2000 and near Pungoteague, VA in 2001. Identification of resistance patterns to diclofop-methyl, timing of important field operations, and rainfall at experimental locations are listed in Table 1. Experiments conducted at Painter contained a commercially-available diclofop-methyl-sensitive Italian ryegrass cultivar¹⁰. To insure uniform infestations of diclofop-methyl-sensitive Italian ryegrass at Painter, this commercial cultivar was broadcast onto each plot at 36 kg/ha on November 27, 2000 and 40 kg/ha on October 16, 2001 prior to wheat seeding. Italian ryegrass seed were lightly incorporated with an S-tine cultivator with double rolling baskets after seeding. Two wk after seeding, Italian ryegrass densities at Painter were 108 and 129 plants/m² in 2000 and 2001, respectively.

Duplicate experiments with diclofop-methyl-resistant Italian ryegrass were conducted at a site near Cape Charles, VA in 2000 and at two sites near

¹⁰Oregon Grown Premium Quality Grass Seed. Italian ryegrass, cultivar not stated. Wetsel, Inc., 1345 Diamond Springs Road, Virginia Beach, VA 76618.

Pungoteague, VA in 2001. Natural infestations of diclofop-methyl-resistant Italian ryegrass were prevalent at Cape Charles and Pungoteague sites and resistance levels of at least two-fold were confirmed at each site (Table 5.1). At Cape Charles, the experimental site had a history of diclofop-methyl use since at least 1990, and decreased control from diclofop-methyl was observed in 1996. Preliminary greenhouse screens indicated diclofop-methyl resistance levels of at least two-fold (1680 g ai/ha diclofop-methyl) in this population (data not presented). At Pungoteague, both sites had a history of diclofop-methyl use since 1995, and decreased control from diclofop-methyl was observed in 2000. In preliminary rate response studies conducted at each of these sites, Italian ryegrass populations had at least four-fold resistance levels to diclofop-methyl (3360 g ai/ha diclofop-methyl) (data not presented). Italian ryegrass densities present at the initiation of experiments were 5 plants/m² at Cape Charles in 2000 and 194 and 237 plants/m² at sites 1 and 2, respectively, at Pungoteague in 2001.

Two to 3 d after seeding diclofop-methyl-sensitive Italian ryegrass at Painter, 'Pocohontas' soft red winter wheat was planted at 168 kg/ha on November 30, 2000 and October 18, 2001 using a grain drill equipped with disk openers and press wheels on 17-cm row spacing. Soil type at Painter was a Bojac sandy loam (mixed, thermic Typic Hapludult) with pH 6.2 and <1% organic matter. 'Pioneer 2643' soft red winter wheat was planted at approximately 180 kg/ha using a grain drill with 18-cm row spacing at Cape Charles in late October 2000 and 'Pioneer 26R24' soft red winter wheat was planted at 150 kg/ha using a grain drill at both Pungoteague sites in early November 2001. Plot size at all locations was 2 by 6.1 m. The experimental design at all locations was a randomized complete block with three replications. Herbicides were applied at Painter with a tractor-mounted plot sprayer that was calibrated to deliver 236 L/ha at 207 kPa

through flat fan spray tips¹¹. At Cape Charles and Pungoteague, herbicides were applied with a propane-pressurized backpack sprayer calibrated to deliver 195 L/ha at 207 kPa through flat-fan spray tips.

Treatments at all locations included ACCase-inhibiting herbicides as well as ALS-inhibiting herbicides. All herbicides were applied POST when Italian ryegrass was in the one-tiller growth stage. Treatments included the ACCase-inhibiting herbicides diclofop-methyl at 1680 g ai/ha, ICIA 0604 at 280 g ai/ha with the addition of a surfactant oil¹² specific to this herbicide at 0.25% v/v, and CGA 184927 applied at 71 g ai/ha with a surfactant-petroleum hydrocarbon blend¹³ as adjuvant at 0.25% v/v. ALS-inhibiting herbicide treatments included a prepackaged mixture of chlorsulfuron plus metsulfuron¹⁴ at 21.7 plus 4.3 g ai/ha with the addition of non-ionic surfactant¹⁵ at 0.25% v/v, a tank mixture application of chlorsulfuron at 26 g/ha plus metribuzin at 105 g ai/ha with non-ionic surfactant⁹ at 0.25% v/v, MON 37560 applied at 35 g ai/ha with non-ionic surfactant⁹ at 0.25% v/v, and AE F130060 03. AE F130060 03 was applied at 15 g/ha with the safener and adjuvant AE F107892 at 15 g/ha, at 18 g/ha with AE

¹¹TeeJet 8003 flat fan spray tips, Spraying Systems Co., North Ave., Wheaton, IL 60188.

¹²Supercharger™ adjuvant. Petroleum hydrocarbon oil:emulsifier blend:low MW alcohol solvent (50:40:10% by vol.) surfactant. Syngenta Crop Protection, P.O. Box 18300, Greensboro, NC 27419.

¹³Score™ adjuvant. 17% surfactant blend plus 83% petroleum hydrocarbon blend, Syngenta Crop Protection, P.O. Box 18300, Greensboro, NC 27419.

¹⁴Finesse™ herbicide. E. I. DuPont de Nemours and Company. Agricultural Enterprise. Walker's Mill, Banley Mill Plaza. Wilmington, DE 19898-0038.

¹⁵Induce™, a non-ionic low-foam wetter/spreader adjuvant with 90% principal functioning agents as a blend of alkyl aryl polyoxylkane ether free fatty acids. Setre Chemical Company, Memphis, TN 38137.

F107892 at 18 g/ha, or at 15 g/ha with AE F107892 at 15 g/ha plus MSO¹⁶ at 0.5% v/v. A nontreated control was included for comparison.

Wheat injury was visually estimated at all locations 4 wk after treatment (WAT) and Italian ryegrass control was visually estimated at all locations 1 to 2 wk prior to wheat harvest. Wheat injury and Italian ryegrass control were rated using a 0 to 100% scale where 0 = no visible wheat injury or Italian ryegrass control and 100 = complete wheat death or complete Italian ryegrass control (Frans et al. 1986). Also, at the time of Italian ryegrass control ratings, counts of Italian ryegrass inflorescences/m² were made at all locations except for Cape Charles. Wheat grain was harvested at Painter on Ju 20, 2001 and June 10, 2002, weighed, and grain yield was adjusted to 13.5% moisture. In 2002, one grain sample of approximately 100 g was collected as wheat was harvested from each plot at Painter. Grain samples were dried and percent moisture per plot was calculated. Samples were then cleaned using U.S. Standard No. 8 and No. 10 sieves¹⁷ and amounts of Italian ryegrass seed in harvested grain were determined as a percentage of grain sample weight. Grain was not harvested at the Cape Charles and Pungoteague locations.

All data were subjected to analyses of variance in SAS¹⁸ with mean separation based on Fisher's protected LSD at P=0.05. Data were combined over years or locations when appropriate. Analysis of data residual plots indicated heterogeneity of variance among wheat injury and Italian ryegrass control data. Therefore, data for wheat injury and Italian ryegrass control were arcsine transformed prior to analysis. Mean separation for wheat injury and Italian

¹⁶Meth Oil™ methylated seed oil. Methyl soyate blend. Riverside/Terra Corp. Terra Centre. 600 4th Street, Sioux City, IA 51101.

¹⁷U.S. Standard Testing Sieves. Fisher Scientific Company. Fair Lawn, NJ 07410.

¹⁸Statistical Analysis Systems (SAS) software, Version 7.0, SAS Institute, Inc., Box 8000, SAS Circle, Cary, NC 27513.

ryegrass control data are based on transformed data, although nontransformed means are presented for clarity.

RESULTS AND DISCUSSION

Diclofop-methyl-sensitive Italian ryegrass

Italian ryegrass control. Significant year by treatment interactions occurred for diclofop-methyl-sensitive Italian ryegrass control at Painter; therefore, data are presented separately by year. Diclofop-methyl-sensitive Italian ryegrass control by diclofop-methyl and AE F130060 03 was greater than or equal to 84% in 2000 or 2001 (Table 5.2). Italian ryegrass control from AE F130060 03 treatments was not influenced by rate or the addition of MSO. CGA 184927 controlled diclofop-methyl-sensitive Italian ryegrass 95% in 2000 but only 72% in 2001 when lower rainfall occurred before and after application (Table 5.1). In 2000, chlorsulfuron plus metsulfuron, chlorsulfuron plus metribuzin, and ICIA 0604 controlled diclofop-methyl-sensitive Italian ryegrass 76 to 77%. In 2001, Italian ryegrass control from these treatments ranged from 45 to 56%. MON 37560 was the least effective of the herbicides tested, controlling Italian ryegrass 71% in 2000 and only 35% in 2001.

Italian ryegrass inflorescence emergence. Significant year by treatment interaction occurred for Italian ryegrass inflorescence emergence data; therefore, data are presented separately by year. In general, trends in data for Italian ryegrass inflorescence emergence closely followed trends seen in Italian ryegrass control data. In 2000, all herbicides reduced Italian ryegrass inflorescence emergence. In addition, all herbicides except MON 37560 reduced inflorescence emergence to no more than 12 inflorescences/m² (Table 5.2). Italian ryegrass treated with MON 37560 produced 35 inflorescences/m² while nontreated plots contained 93 inflorescences/m².

In 2001, inflorescence emergence levels were higher than in 2000, reflecting higher Italian ryegrass populations and lower control. However, all herbicides

reduced Italian ryegrass inflorescence emergence. Lowest numbers of Italian ryegrass inflorescences occurred in plots treated with diclofop-methyl, CGA 184927, and AE F130060 03 at 15 or 18 g/ha or 15 g/ha with MSO. Italian ryegrass treated with CGA 184927 or any AE F130060 03 treatment produced 39 to 64 inflorescences/m² while Italian ryegrass treated with diclofop-methyl produced only 12 inflorescences/m² (Table 5.2). Italian ryegrass treated with chlorsulfuron plus metsulfuron, chlorsulfuron plus metribuzin, or MON 37560 produced 119, 135, and 149 inflorescences/m², respectively. Nontreated Italian ryegrass produced 199 Italian ryegrass inflorescences/m² in 2001.

Wheat response and grain yield. Due to lack of a treatment by year interaction for wheat injury, data for wheat injury at Painter were pooled over 2000 and 2001. Although AE F130060 03 controlled diclofop-methyl-sensitive Italian ryegrass and reduced inflorescence emergence, AE F130060 03 caused greater wheat injury than other herbicides. However, this injury was transitory and was not apparent by late season (data not presented). Wheat treated with AE F130060 03 exhibited a temporary stunting with some foliar discoloration (purpling), particularly when colder temperatures occurred at the time of and shortly after application. Diclofop-methyl, ICIA 0604, CGA 184927, chlorsulfuron plus metsulfuron or metribuzin, and MON 37560 injured Pocohontas wheat 3 to 8% at 4 WAT (Table 5.3). AE F130060 03 at 15 or 18 g/ha with or without MSO injured wheat 16 to 20%.

Treatment by year interaction occurred for wheat yield data; therefore, data are presented separately for 2000 and 2001. In 2000, wheat treated with any herbicide produced similar increases (13 to 24%) in grain yield compared to nontreated wheat (Table 5.3), and these yields were 5060 to 5540 kg/ha. In 2001, herbicide applications resulted in wheat grain yield increases of at least 40%. Highest yields occurred in wheat treated with diclofop-methyl, CGA 184927, or any AE F130060 03 treatment, which produced 4390 to 4680 kg/ha. Wheat treated with chlorsulfuron plus metsulfuron or metribuzin, or ICIA 0604 produced

3160 to 3450 kg/ha grain. Lowest grain yield from herbicide-treated wheat occurred in wheat treated with MON 37560 (2240 kg/ha) (Table 5.3). Although AE F130060 03 caused greater early-season injury to wheat than did other herbicides, yields from wheat treated with AE F130060 03 were similar to or greater than yields from wheat treated with other herbicides in either year.

Although herbicide treatment influenced Italian ryegrass control and subsequent inflorescence emergence in 2001, Italian ryegrass was sufficiently dry at the time of wheat harvest that moisture of harvested wheat grain was not affected. Percent moisture in collected grain samples was 9.2 to 9.5% in any treatment (data not presented). However, the percentage of sample dry weight attributed to Italian ryegrass seed in grain samples was influenced by herbicide treatment. Among herbicide-treated wheat samples, highest amounts of foreign matter attributed to Italian ryegrass seed were in samples collected from ICIA 0604 and MON 37560-treated plots (0.60 and 0.78% Italian ryegrass seed, respectively) (Table 5.3). In nontreated wheat, 1.19% of the weight of the collected grain sample was attributed to Italian ryegrass seed. Lowest amounts of Italian ryegrass seed in grain samples occurred in plots treated with diclofop-methyl, CGA 184927, or any AE F130060 03 treatment (0.21 to 0.31% Italian ryegrass seed). Similarly, amounts of Italian ryegrass seed in plots treated with chlorsulfuron plus metsulfuron or chlorsulfuron plus metribuzin were 0.36 to 0.39% of the harvested grain sample.

Although trends in Italian ryegrass control, inflorescence emergence, and wheat grain yield following herbicide applications were generally similar in the two years, control was higher and inflorescence emergence lower in 2000 compared to 2001. Decreased Italian ryegrass control and increased inflorescence emergence in 2001 compared to 2000 may be attributed to differences in the timing of field operations as well as environmental conditions at Painter during the two years of the experiment (Table 5.1). In 2000, wheat and Italian ryegrass were planted more than one month later than in 2001 and POST

applications were made almost three months later than in 2001. Also, slightly higher Italian ryegrass seeding rates resulted in higher densities of Italian ryegrass in 2001. Finally, there were differences in rainfall before and after POST applications in the two years. In 2000, cumulative rainfall in the 2 wk prior to POST applications was 3.05 cm, with an additional 1.35 cm of rainfall occurring in the 2 wk following POST applications. In 2001, however, no rainfall occurred in the 2 wk prior to applications and only 0.09 cm of rainfall occurred in the 2 wk following applications. Lack of rainfall and greater Italian ryegrass densities in 2001 resulted in plant stress that likely made Italian ryegrass more difficult to control. Other researchers have also noted lesser Italian ryegrass control from POST herbicides when weeds are under drought stress and at heavy densities (Burrill and Appleby 1978).

Diclofop-methyl-resistant Italian ryegrass

Wheat response. A treatment by location interaction occurred between data from Cape Charles and Pungoteague for wheat injury data; however, there was no treatment by location interaction for data from the two sites near Pungoteague. Therefore, data are presented separately for Cape Charles in 2000 and averaged over the two Pungoteague sites in 2001. Wheat injury at diclofop-methyl-resistant Italian ryegrass sites was generally similar to wheat injury at Painter. At Cape Charles, no injury occurred from diclofop-methyl at 4 WAT and injury from the other ACCase-inhibiting herbicides ICIA 0604 and CGA 184927 was no more than 3% (Table 5.4). Wheat injury from chlorsulfuron plus metsulfuron was 2% while injury from chlorsulfuron plus metribuzin or MON 37560 ranged from 6 to 7%. Greatest injury occurred from AE F130060 03 treatments and ranged from 10 to 11% when AE F130060 03 was applied at 15 or 18 g/ha and increased to 14% when AE F130060 03 was applied at 15 g/ha with MSO.

At Pungoteague, wheat injury from chlorsulfuron plus metsulfuron or metribuzin, diclofop-methyl, or MON 37560 was 3 to 5% and injury from ICIA 0604

or CGA 184927 caused 8% injury to wheat (Table 4). Similar to wheat injury at Painter and Cape Charles, highest injury occurred from AE F130060 03 treatments. Wheat injury 4 WAT from all AE F130060 03 treatments at Pungoteague ranged from 21 to 24%.

Italian ryegrass control. Significant treatment by location interactions occurred for Italian ryegrass control data; therefore, control data are presented separately by Cape Charles and Pungoteague locations. However, Pungoteague data are averaged over the two sites. Control of diclofop-methyl-resistant Italian ryegrass at Cape Charles and Pungoteague locations from several treatments was generally lower than control of diclofop-methyl-sensitive Italian ryegrass at Painter, particularly with ACCase-inhibiting herbicides.

Similar to data from diclofop-methyl-sensitive Italian ryegrass control at Painter, highest control at Cape Charles was from AE F130060 03 treatments. AE F130060 03 at 15 or 18 g/ha or at 15 g/ha plus MSO controlled the diclofop-methyl-resistant Italian ryegrass population at Cape Charles 97% (Table 5.5). Control of diclofop-methyl-resistant Italian ryegrass from chlorsulfuron plus either metsulfuron or metribuzin ranged from 85 to 89%. Lowest Italian ryegrass control occurred from diclofop-methyl or ICIA 0604 and was 22 to 23%, while control from CGA 184927 or MON 37560 was 35 to 38%.

Similar to diclofop-methyl-sensitive Italian ryegrass control at Painter and diclofop-methyl-resistant Italian ryegrass control at Cape Charles, highest control at Pungoteague occurred from AE F130060 03 treatments. When applied at either 15 or 18 g/ha or at 15 g/ha with MSO, AE F130060 03 controlled diclofop-methyl-resistant Italian ryegrass populations at both Pungoteague sites 90 to 94% (Table 5.5). Additionally, diclofop-methyl-resistant Italian ryegrass control from ACCase-inhibiting herbicides at Pungoteague was lower than control of diclofop-methyl-sensitive Italian ryegrass at Painter. Diclofop-methyl controlled Italian ryegrass 29% while control from ICIA 0604 or CGA 184927 was 43 to 47%. MON 37560 controlled diclofop-methyl-resistant Italian ryegrass only

26% and was similar to control from diclofop-methyl. Unlike control at Cape Charles, control of the diclofop-methyl-resistant Italian ryegrass populations at Pungoteague sites was 30 to 43% from chlorsulfuron plus metsulfuron and chlorsulfuron plus metribuzin, respectively.

Italian ryegrass inflorescence emergence. Relatively low Italian ryegrass densities (5 plants/m²) at Cape Charles did not warrant measurement of Italian ryegrass inflorescence emergence. However, diclofop-methyl-resistant inflorescence emergence was recorded at Pungoteague sites, where natural diclofop-methyl-resistant Italian ryegrass densities were nearly twice as great as the diclofop-methyl-sensitive population sown at Painter (Table 5.1).

Due to significant treatment by location interaction among data from the two Pungoteague sites, data for inflorescence emergence are presented by site. However, inflorescence emergence reflected Italian ryegrass control at both Pungoteague sites. At site 1, late-season Italian ryegrass inflorescence emergence in nontreated wheat plots was 257 inflorescences/m² 2 wk prior to wheat harvest (Table 5.5). Italian ryegrass treated with chlorsulfuron plus metsulfuron or MON 37560 resulted in 198 and 217 inflorescences/m², respectively, which was similar to nontreated Italian ryegrass. Diclofop-methyl reduced Italian ryegrass inflorescence emergence by 33% while chlorsulfuron plus metribuzin and ICIA 0604 reduced inflorescence emergence by 45 and 53%, respectively. CGA 184927 reduced inflorescence emergence by 63%. Highest reductions in inflorescence emergence were 91 to 98% (5 to 24 inflorescences/m²) from AE F130060 03 applications.

At the second site near Pungoteague, nontreated wheat plots contained 330 inflorescences/m² 2 wk prior to wheat harvest (Table 5.5). Although all herbicide treatments reduced inflorescence emergence, highest emergence occurred in Italian ryegrass treated with the ACCase-inhibitors diclofop-methyl (259 inflorescences/m²), ICIA 0604 (207 inflorescences/m²), and CGA 184927 (209 inflorescences/m²). Similarly, high inflorescence emergence occurred in Italian

ryegrass treated with MON 37560 (251 inflorescences/m²), chlorsulfuron plus metsulfuron (232 inflorescences/m²), and chlorsulfuron plus metribuzin (177 inflorescences/m²). Consistent with inflorescence emergence data from Painter in 2000 and 2001, and from the first site at Pungoteague, greatest reductions in Italian ryegrass inflorescence emergence occurred in plots treated with AE F130060 03. AE F130060 03 at 15 or 18 g/ha or at 15 g/ha plus MSO reduced inflorescence emergence 96 to 97% (11 to 13 inflorescences/m²).

In these experiments, AE F130060 03 controlled and reduced inflorescence emergence of both diclofop-methyl-sensitive and -resistant Italian ryegrass. The ACCase-inhibiting herbicides ICIA 0604 and CGA 184927 were ineffective in controlling diclofop-methyl-resistant Italian ryegrass and sometimes inconsistent in controlling diclofop-methyl-sensitive Italian ryegrass. Registered ALS-inhibiting herbicides were also inconsistent in many instances for control of diclofop-methyl-sensitive and -resistant Italian ryegrass. Inconsistent control from chlorsulfuron plus either metsulfuron or metribuzin, or MON 37560 has also occurred in other research (Bailey et al. 2001; Brewster et al. 1997; Rauch and Thill 1999). AE F130060 03 controlled diclofop-methyl-sensitive Italian ryegrass at Painter as well as diclofop-methyl and better than other herbicides. At diclofop-methyl-resistant Italian ryegrass locations, AE F130060 was more effective than all other herbicides. Italian ryegrass control and inflorescence reduction were not influenced by AE F130060 03 rate or the addition of MSO. Although early-season wheat injury was greatest from AE F130060 03, wheat recovered and grain yields were not reduced. AE F130060 03 was comparable to diclofop-methyl for control of diclofop-methyl-sensitive Italian ryegrass and more effective than all herbicides for control of diclofop-methyl-resistant Italian ryegrass.

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Table 5.1. Levels of diclofop-methyl resistance and densities of Italian ryegrass populations, and rainfall before and after herbicide applications in Accomack and Northampton Co., VA in 2000 and 2001.

Year	Location	Italian ryegrass		POST ^a date	Rainfall	
		Diclofop-methyl resistance	Density - plants/m ² -		2 WBT	2 WAT
					cm	
2000	Painter	0	108	2-20-01	3.05	1.35
2000	Cape Charles	≥2-fold	5	3-01-01	3.86	0.86
2001	Painter	0	129	11-19-01	0	0.09
2001	Pungoteague 1	≥4-fold	194	1-26-02	5.92	2.51
2001	Pungoteague 2	≥4-fold	237	1-31-02	4.47	2.51

^aAbbreviations: POST = postemergence; WBT = wk before treatment; WAT = wk after treatment.

Table 5.2. Late-season control and inflorescence emergence of diclofop-methyl-sensitive Italian ryegrass following postemergence herbicide applications in 2000 and 2001 at Painter, VA.

Herbicides	Herbicide application rate	Diclofop-methyl-sensitive Italian ryegrass ^e			
		Control ^f		Inflorescence emergence ^g	
		2000	2001	2000	2001
	g/ha	%		inflorescences/m ²	
Diclofop-methyl	1680	94 a	90 a	7 c	12 e
ICIA 0604 ^a	280	77 b	45 d	1 c	108 c
CGA 184927 ^b	71	95 a	72 b	3 c	53 d
Chlorsulfuron + metsulfuron ^c	21.7 + 4.3	76 b	55 c	12 c	119 bc
Chlorsulfuron + metribuzin ^c	26 + 105	77 b	56 c	4 c	135 bc
MON 37560 ^c	35	71 c	35 e	35 b	149 b
AE F130060 03 + AE F107892	15	96 a	84 a	0 c	39 de
AE F130060 03 + AE F107892	18	96 a	86 a	0 c	40 de
AE F130060 03 + AE F107892 + MSO ^d	15	97 a	87 a	0 c	64 d
Nontreated control		0 d	0 f	93 a	199 a

^aICIA 0604 applied with SuperchargerTM surfactant oil at 0.25% (v/v).

^bCGA 184927 applied with ScoreTM adjuvant, a surfactant-petroleum hydrocarbon blend at 0.25% (v/v).

^cHerbicide applied with InduceTM non-ionic surfactant at 0.25% (v/v).

^dAE F130060 03 applied with Meth Oil™ methylated seed oil (MSO) at 0.5% (v/v).

^eMeans followed by the same letter do not differ according to Fisher's protected LSD test at P=0.05.

^fItalian ryegrass control was visually estimated 1.5 wk prior to wheat harvest.

^gItalian ryegrass inflorescence counts taken 1 wk prior to wheat harvest.

Table 5.3. Early-season wheat injury, wheat grain yield, and percent Italian ryegrass seed in harvested grain samples following herbicide applications to diclofop-methyl-sensitive Italian ryegrass at Painter, VA.

Herbicides	Herbicide	Wheat	Wheat grain yield ^f		LOLMU seed ^g
	application rate	injury ^{ef}	2000	2001	
	g/ha	%	kg/ha		%
Diclofop-methyl	1680	3 e	5540 a	4600 a	0.60 bc
ICIA 0604 ^a	280	3 de	5500 a	3160 b	0.78 b
CGA 184927 ^b	71	6 cde	5430 a	4600 a	0.29 cd
Chlorsulfuron + metsulfuron ^c	21.7 + 4.3	7 cd	5420 a	3450 b	0.36 cd
Chlorsulfuron + metribuzin ^c	26 + 105	8 bc	5390 a	3370 b	0.39 cd
MON 37560 ^c	35	5 cde	5380 a	2240 c	0.25 cd
AE F130060 03 + AE F107892	15	16 ab	5060 a	4680 a	0.21 d
AE F130060 03 + AE F107892	18	18 a	5160 a	4590 a	0.31 cd
AE F130060 03 + AE F107892 + MSO ^d	15	20 a	5090 a	4390 a	0.30 cd
Nontreated control		0 f	4480 b	1600 d	1.19 a

^aICIA 0604 applied with Supercharger™ surfactant oil at 0.25% (v/v).

^bCGA 184927 applied with Score™ adjuvant, a surfactant-petroleum hydrocarbon blend at 0.25% (v/v).

^cHerbicide applied with Induce™ non-ionic surfactant at 0.25% (v/v).

^dAE F130060 03 applied with Meth Oil™ methylated seed oil (MSO) at 0.5% (v/v).

^eWheat injury pooled over 2000 and 2001.

^fMeans followed by the same letter do not differ according to Fisher's protected LSD test at P=0.05.

^gData for percent LOLMU (Italian ryegrass) seed in grain collected only in 2001. Values presented are percentage of grain sample weight (approximately 100 g) that was attributed to Italian ryegrass seed.

Table 5.4. Early-season wheat injury following herbicide applications for control of diclofop-methyl-resistant Italian ryegrass near Cape Charles, VA and at two sites near Pungoteague, VA.

Herbicides	Herbicide	Wheat injury ^e	
	application rate	Cape Charles	Pungoteague sites ^f
	g/ha	%	
Diclofop-methyl	1680	0 f	3 c
ICIA 0604 ^a	280	3 d	8 b
CGA 184927 ^b	71	2 de	8 b
Chlorsulfuron + metsulfuron ^c	21.7 + 4.3	2 de	4 c
Chlorsulfuron + metribuzin ^c	26 + 105	6 c	5 bc
MON 37560 ^c	35	7 c	3 c
AE F130060 03 + AE F107892	15	11 b	21 a
AE F130060 03 + AE F107892	18	10 b	23 a
AE F130060 03 + AE F107892 + MSO ^d	15	14 a	24 a
Nontreated control		0 f	0 e

^aICIA 0604 applied with SuperchargerTM surfactant oil at 0.25% (v/v).

^bCGA 184927 applied with ScoreTM adjuvant, a surfactant-petroleum hydrocarbon blend at 0.25% (v/v).

^cHerbicide applied with InduceTM non-ionic surfactant at 0.25% (v/v).

^dAE F130060 03 applied with Meth OilTM methylated seed oil (MSO) at 0.5% (v/v).

^eMeans followed by the same letter do not differ according to Fisher's protected LSD test at P=0.05.

^fWheat injury averaged over two experiment sites near Pungoteague, VA in 2001.

Table 5.5. Late-season inflorescence emergence and control of diclofop-methyl-resistant Italian ryegrass following postemergence herbicide applications near Cape Charles, VA in 2000 and Pungoteague, VA in 2001.

Herbicides	Herbicide application rate g/ha	Diclofop-methyl-resistant Italian ryegrass ^e			
		Control ^f		Inflorescence emergence ^g	
		Cape Charles	Pungoteague	Pungoteague	
		Site 1	Site 2		
		g/ha	%	inflorescences/m ²	
Diclofop-methyl	1680	22 d	29 c	172 bcd	259 b
ICIA 0604 ^a	280	23 d	43 b	122 cd	207 bc
CGA 184927 ^b	71	35 c	47 b	95 de	209 bc
Chlorsulfuron + metsulfuron ^c	21.7 + 4.3	85 b	30 c	198 abc	232 bc
Chlorsulfuron + metribuzin ^c	26 + 105	89 ab	43 bc	141 bcd	177 c
MON 37560 ^c	35	38 c	26 c	217 ab	251 b
AE F130060 03 + AE F107892	15	97 a	90 a	24 ef	13 d
AE F130060 03 + AE F107892	18	97 a	94 a	11 f	13 d
AE F130060 03 + AE F107892 + MSO ^d	15	97 a	92 a	5 f	11 d
Nontreated control		0 e	0 d	257 a	330 a

^aICIA 0604 applied with Supercharger™ surfactant oil at 0.25% (v/v).

^bCGA 184927 applied with Score™ adjuvant, a surfactant-petroleum hydrocarbon blend at 0.25% (v/v).

^cHerbicide applied with Induce™ non-ionic surfactant at 0.25% (v/v).

^dAE F130060 03 applied with Meth Oil™ methylated seed oil (MSO) at 0.5% (v/v).

^eMeans followed by the same letter do not differ according to Fisher's protected LSD test at P=0.05.

^fItalian ryegrass control was visually estimated 2 wk prior to wheat harvest.

^gItalian ryegrass inflorescence counts taken 2 wk prior to wheat harvest.