Weed Management Programs in Potato, Transplanted Tomato

and Transplanted Peppers with Rimsulfuron and Other Herbicides

By

John A. Ackley

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APPROVED:

Henry P. Wilson, Chairman

E. Scott Hagood

Kriton K. Hatzios

John Hess

Ronald D. Morse

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John Andrew Ackley

Dr. Henry P. Wilson, Chairman

(ABSTRACT)

Weed management programs in 'Superior' potato with PRE and POST rimsulfuron treatments were investigated during 1992, 1993, and 1994. Common ragweed control by PRE combinations of metolachlor with linuron or metribuzin was higher when treatments included PRE or POST rimsulfuron. Common lambsquarters control was 93 to 96% by treatments that included POST rimsulfuron. Applications of 35 g ai/ha rimsulfuron plus 280 g ai/ha metribuzin POST controlled weeds comparable to sequential applications. Potato recovered from occasional injury caused by rimsulfuron, rimsulfuron plus metribuzin, and organophosphate insecticides combined POST with rimsulfuron plus metribuzin.

Several acetolactate synthase (ALS)-inhibiting herbicides were evaluated for yellow nutsedge control in the greenhouse. Herbicides were applied POST to yellow nutsedge at actual or anticipated commercial rates. Yellow nutsedge control was 92 and 71% from halosulfuron and chlorimuron, respectively. Control ranged from 48 to 69% from primisulfuron, pyrithiobac, and rimsulfuron. Control from nicosulfuron and imazethapyr was 45 and 68%, respectively, while thifensulfuron and CGA-152005 had almost no activity on yellow nutsedge. Chlorimuron, imazethapyr, and halosulfuron were the only

herbicides which reduced yellow nutsedge regrowth.,

Rrimsulfuron was evaluated in tomato at 26 and 35 g ai/ha, sequentially at 26 g/ha, at 26 g/ha plus metribuzin at 280 g ai/ha, and metribuzin at 280 g/ha were evaluated POST for weed control in transplanted ‘Agriset’ tomato. Common lambsquarters was controlled by rimsulfuron at 35 g/ha. Rimsulfuron plus metribuzin gave consistent control of common ragweed but jimsonweed and goosegrass control was generally low. Rimsulfuron treatments caused < 12% injury to tomato. Tomato yield was consistently high in the metribuzin, metribuzin plus rimsulfuron, and rimsulfuron sequential treatments. In greenhouse studies, giant foxtail and large crabgrass control by rimsulfuron was above 95 and 85% respectively, but goosegrass was not controlled. Height of four tomato cultivars was not reduced, but dry weight of ‘Floradade’ and ‘Sunbeam’ was reduced by rimsulfuron.

In 1993, 1994 and 1995, PPI clomazone at 390 g ai/ha, POST rimsulfuron at 35 g ai/ha, and PPI trifluralin at 560 g ai/ha were evaluated for weed control in transplanted ‘Keystone RG3' bell pepper. Common lambsquarters and jimsonweed control was highest by clomazone treatments, while common ragweed control was low from all treatments. Keystone RG3 in the field and greenhouse and ‘Camelot’, ‘Jupiter’ and ‘Memphis’ in the greenhouse were injured by POST rimsulfuron and had lower height and dry weight than untreated controls. In the greenhouse, black nightshade control was below 23% and jimsonweed control was below 49% by rimsulfuron POST.

The absorption, translocation, and metabolism of rimsulfuron was investigated in three Solanaceous weed species. Rimsulfuron uptake did not differ between black nightshade and eastern black nightshade while less labeled herbicide was absorbed by hairy nightshade. Black and eastern black nightshade translocated up to 50% of the labeled herbicide out of the treated leaf with 40 to 50% of the herbicide being moved to the actively growing regions of the plant. In hairy nightshade, an average 40% of the labeled herbicide was moved out of the treated leaf and less than 30% of the translocated herbicide was moved basipetally. Most major metabolites were apparent at 24 and 48 hours however, there were no differences in metabolite composition. Rimsulfuron will be an effective herbicide for use in weed management programs in potatoand tomato, however rimsulfuron causes too much injury in pepper to be used.

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Table of Contents

		Page no.
Abstract		ii
Acknowledgments		v
List of Tables		ix
Chapter I	Introduction and Review of Literature	1
	-Objectives	7
	-Literature Cited	8
Chapter II	Weed Management Programs in Potato (*Solanum tuberosum*) with Rimsulfuron	16
	-Abstract	16
	-Introduction	16
	-Materials and Methods	18
	-Results and Discussion	22
	-Literature Cited	25
Chapter III	Yellow Nutsedge (*Cyperus esculentus*) Control Post With Acetolactate Synthase-Inhibiting Herbicides	33
	-Abstract	33
	-Introduction	33
	-Materials and Methods	35
	-Results and Discussion	36
	-Literature Cited	39
Chapter IV	Rimsulfuron and Metribuzin Efficacy in Transplanted Tomatoes (*Lycopersicum esculentum*)	43
	-Abstract	43

	-Introduction	43
	-Materials and Methods	45
	-Results and Discussion	48
	-Literature Cited	52
Chapter V	Weed Management in Transplanted Peppers (*Capsicum annum*)	58
	-Abstract	58
	-Introduction	58
	-Materials and Methods	60
	-Results and Discussion	63
	-Literature Cited	66
Chapter VI	Absorption, Translocation and Metabolism of Rimsulfuron in Black Nightshade (*Solanum nigrum*), Eastern Black Nightshade (*Solanum ptycanthum*) and Hairy Nightshade(*Solanum sarrachoides*)	71
	-Abstract	71
	-Introduction	72
	-Materials and Methods	73
	-Results and Discussion	77
	-Literature Cited	81
Chapter VII	Summary	87
	-Literature Cited	91
Vita		93

LIST OF TABLES

Chapter	Table	Title	Page
II	1	Common lambsquarters and common ragweed control, potato injury and height, and tuber yield from potato treated with rimsulfuron, in programs that included metolachlor, metolachlor plus linuron, and metolachlor plus metribuzin in 1992 and 1993.	28
	2	Common lambsquarters, common ragweed, and jimsonweed control, potato injury and height, and tuber yield from potato treated with rimsulfuron and metribuzin at different rates and application timings in 1993 and 1994.	30
	3	Injury, height and tuber yield from potatoes treated POST with combinations of organophosphate insecticides with rimsulfuron plus metribuzin in 1993 and 1994.	32
III	4	Yellow nutsedge control, height, dry weight, and regrowth following POST applications of acetolactate synthase-inhibiting herbicides in the greenhouse	42
IV	5	Common lambsquarters, common ragweed, jimsonweed, and goosegrass control in tomato treated with rimsulfuron and metribuzin POST in 1991, 1992 and 1993.	55
	6	Tomato injury and fruit yield from tomato treated with rimsulfuron and metribuzin POST in 1991, 1992, and 1993.	56

	7	Control, height and dry weight of giant foxtail, goosegrass, and large crabgrass by rimsulfuron POST in the greenhouse.	57
	8	Injury, height and dry weight of four tomato cultivars by rimsulfuron POST in the greenhouse	58
V	9	Pepper injury, common lambsquarters, common ragweed and jimsonweed control with rimsulfuron, clomazone, and trifluralin in 1993 1994, and 1995	68
	10	Control, height and dry weight of jimsonweed and black nightshade by POST rimsulfuron in the greenhouse	69
	11	Injury, height and dry weight of four bell pepper varieties by POST rimsulfuron in the greenhouse	70
VI	12	Absorption of ^{14}C-rimsulfuron applied to black, eastern black, and hairy nightshade.	84
	13	Translocation of ^{14}C-rimsulfuron applied to black, eastern black, and hairy nightshade.	85
	14	Percent of recovered herbicide from Black, Hairy, and Eastern Black nightshade treated with ^{14}C-Rimsulfuron and harvested after application	86

Chapter 1

Introduction and Literature Review

Rimsulfuron is a sulfonylurea herbicide that has been evaluated for broadleaf and grass weed control PRE and POST in potato (*Solanum tuberosum* L.) (Ackley et al. 1995; 1996a; 1996b; Blackshaw et al. 1995; Eberlein et al. 1994) and tomato (*Lycopersicum esculentum* L.) (Ackley et al. 1994b: Bewick et al. 1995). It controls many broadleaf and some grass species and has selectivity in these solanaceous crops, although some tomato cultivars may be injured (Bewick et al. 1995). Solanaceous weeds including jimsonweed and other nightshade species have been controlled by rimsulfuron treatments (Bewick et al. 1995; Eberlein et al. 1994). Rimsulfuron controls many broadleaf and some grass weeds including giant foxtail (Ackley et al. 1995; 1996b) and large crabgrass (Ackley et al. 1995b). PRE and POST rimsulfuron combinations with metribuzin controlled additional weed species and did not affect potato yields when compared to yields from potato treated with metribuzin alone or a hand-weeded check (Ackley et al. 1995; Eberlein et al. 1994). Rimsulfuron is most effective when applied POST with a nonionic surfactant at 0.25% (v/v) (Green and Green 1993) to actively growing weeds, and does not cause injury to rotational crops (Leep et al. 1991). The mode of action of the sulfonylurea herbicides is the inhibition of acetolactate synthase, a key enzyme in the biosynthetic pathway of branched-chain amino acids (Hawkes et al. 1989)

Only a few herbicides are registered for use in potato (Blackshaw et al. 1995; Dallyn, 1971; Eberlein et al. 1994; Wallace and Bellinder 1990). In Virginia, metolachlor, linuron, and metribuzin are often used in various combinations for annual broadleaf and grass weed control. However, these herbicides do not control all of the weeds which are important to potato growers in Virginia[1]. Further, metribuzin applied POST to potato may cause leaf chlorosis and necrosis and increase the occurrence of hollow heart (Freisen and Wall 1986; Gawronski et al. 1985; Henne 1975). Potato tuber yield has been reduced at 560 g/ha metribuzin (Hatterman-Valenti et al. 1994).

Organophosphate insecticides are used PRE and POST to control insect pests in several crops including potato. When organophosphate insecticides are applied in-furrow and followed by POST applications of certain sulfonylurea herbicides, injury and yield reductions have occurred in corn (*Zea mays* L.) and sweet corn (*Zea mays saccharata* L.) (Kapusta and Krausz 1992; Morton et al. 1991). Furthermore, organophosphate insecticides applied POST have increased injury and reduced fresh weight of soybean (*Glycine max* L. Merr.) when applied with thifensulfuron {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl] amino]sulfonyl]-2-thiophenecarboxylic acid} (Ahrens 1990). POST malathion (O,O-dimethyl phosphorodithioate of diethyl mercaptosuccinate) increased chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl]benzenesulfonamide} toxicity to a chlorsulfuron-resistant biotype of rigid ryegrass (*Lolium rigidum* Gaud.) by inhibiting herbicide metabolism (Christopher et al.

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[1] Wilson, H. P. 1995. Personal communication. Eastern Shore Agric. Res. and Ext. Ctr., Virginia Polytechnic Inst. and State Univ., Painter, VA.

1994). The combination of phorate {O,O-diethyl S-[(ethylthio)methyl]phosphoro dithioate} and metribuzin decreased potato vine growth and tuber yield (Cranshaw and Thornton 1988). Relationships between rimsulfuron and organophosphate insecticides and have not been reported in potato.

Yellow nutsedge is distributed throughout the world and is competitive in many crops. It reduces crop yield and quality by competing for light, water, and nutrients, and by interfering with pesticide applications and harvest operations (Holm et al. 1977). Yellow nutsedge is one of the 10 most troublesome weeds in Virginia[2]. Soil applications of two classes of herbicides, the carbamothioates and the chloroacetamides have partially controlled yellow nutsedge in many crops (Wilson et al. 1970). The carbamothioates must be incorporated to reduce losses due to volatility and control may not last long enough due to microbial degradation of these herbicides (Wilkinson 1988). Bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] selectively controls yellow nutsedge POST in several crops but two applications are frequently required (Richburg et al. 1993).

Several acetolactate synthase (ALS)[3]-inhibiting herbicides have activity on yellow nutsedge. Imazethapyr and imazaquin {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-

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[2]Hagood, E. S. 1995. Personal communication. Dept of Plant Pathol., Physiol. and Weed Sci., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061-0331.

[3]Abbreviations: ALS, acetolactate synthase.

oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic acid}, two imidazolinones, control yellow nutsedge from PRE and POST applications but may be most effective PRE (Grichar et al. 1992; Nandihalli and Benedixen 1988; Richburg et al. 1993b). The sulfonylurea herbicides, chlorimuron and Halosulfuron control yellow nutsedge in the field or greenhouse and are selective in soybean (*Glycine max* (L.) Merr.) and corn (*Zea mays* L.), respectively (Bhowmik et al. 1994; Frank et al. 1993; Vencill et al. 1995). Additional sulfonylurea herbicides such as nicosulfuron, primisulfuron, CGA-152005, and thifensulfuron are used commercially POST in corn and soybean but their effects on yellow nutsedge are largely unreported (Ackley et al. 1994a). Rimsulfuron controls weeds and some grasses in solanaceous vegetable crops (Ackley et al. 1993; Ackley et al. 1994b; Blackshaw et al. 1995; Eberlein et al. 1994) and the pyrimidinyl thiobenzoate, pyrithiobac, controls weeds in cotton (*Gossipium hirsutum* L.) (Dotray et al. 1994; Jordan et al. 1995a; Jordan et al. 1995b; Keeling et al. 1993); both rimsulfuron and pyrithiobac have effect on yellow nutsedge (Ackley et al. 1994a).

Tomato and bell pepper are economically important vegetable crops in Virginia and the northeastern United States. Efficient production of high yielding and high quality fruit is dependent upon implementation of an effective weed control program. Weeds can affect crop quality and yield directly by competing for water, essential nutrients, and photosynthetically active radiation, or indirectly by serving as a reservoir to insect pests and disease of tomato (Freisen 1979; McGiffen et al. 1992; Perez and Matsiunas 1990; Weaver et al. 1987; Weaver and Tan 1983), and pepper (Frank et al. 1988: 1991).

Tomato yields are highest when weeds are controlled prior to the initiation of flowering (Weaver et al. 1987). Pepper is a poor competitor with weeds and the lack of weed control may result in yield reduction (Frank et al.1988; 1991) However, weed control is difficult since few herbicides are registered for tomato (Ackley et al. 1994b; Beste et al. 1992; Bewick et al. 1995; Glaze 1990) and pepper (Ackley et al. 1992; Baltajar et al. 1984; Eshel et al. 1973; Lanini and LeStrange 1991; 1994; Schroeder 1992).

Metribuzin is the only selective herbicide registered for POST control of broadleaf weeds in tomato. However, metribuzin may injure tomato (Fortino and Splittstoesser 1974; Frank and Beste 1985; Henne 1974). Trifluralin is registered for use in many crops, including pepper and tomato, and is primarily effective for control of annual grasses (Ackley et al. 1992). Clomazone[4] is registered for use in cotton (*Gossypium hirsutum* L.), soybean [*Glycine max* (L.) Merr.], pepper (*Capsicum annum* L.), tobacco (*Nicotiana tobacum* L.), and succulent pea (*Pisum sativum* L.) for control of annual grasses and certain broadleaf weeds (Jordan et al. 1993; Westberg et al. 1989). In initial studies, clomazone was the only herbicide in transplanted peppers which controlled certain broadleaf weeds (Ackley et al. 1992). However, clomazone must be incorporated to reduce off-site movement and residual activity may affect sensitive crops planted after pepper harvest[4].

The lack of herbicides registered for use in tomato and pepper often results in,

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[4]Command herbicide label. FMC Copr. 1735 Market St. Philadelphia, PA 19103.

depending upon the weed species present, incomplete weed control. This failure to control many broadleaf weed species indigenous to the tomato and pepper producing regions of Virginia results in a need for additional POST herbicides for these crops.

Herbicide efficacy is generally influenced by absorption, translocation, and/or metabolism since these processes affect delivery of the herbicide to the site of action (Dodge 1989). Although absorption and translocation of sulfonylurea herbicides occur in both tolerant and sensitive plant species, selectivity is most often based on differential metabolism (Hawkes et al. 1989). The mechanisms of tolerance and sensitivity to rimsulfuron have not been thoroughly investigated.

The nightshades are a troublesome family of weed species associated with the production of many crops (McGiffen et al 1992: Perez and Matsiunas, 1990; Weaver et al. 1987). The nightshade species selected for this experiment represent a range in tolerance to rimsulfuron. Researchers have found that in field studies hairy nightshade is sensitive to applications of rimsulfuron (Eberlein et al. 1994), black nightshade is tolerant[5], but response of eastern black nightshade is largely unreported. Laboratory experiments would be helpful to characterize the mechanisms responsible for the differential response of these nightshade species at the whole plant level.

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[5]Wilson, H. P. 1994. Unpublished data. Eastern Shore Agric. Res. And Ext. Ctr., Virginia Polytechnic Inst. and State Univ., Painter, VA.

Objectives

The objectives of this research were to determine the potential for rimsulfuron to be an effective component of weed management programs in potato, tomato and pepper, and to determine the realtive effectiveness of several ALS-inhibiting herbicides for control of yellow nutsedge. In Potato, studies were conducted to determine if rimsulfuron would improve weed control from metolachlor, metolachlor plus linuron and metolachlor plus metribuzin, if single or sequential applications of rimsulfuron plus metribuzin would give higher weed control, and if combinations of organophosphate insecticides with POST rimsulfuron plus metribuzin would injure potato. Studies were also conducted to determine the activity of several ALS-inhibiting herbicides in the greenhouse to control yellow nutsedge POST. In tomato, studies were conducted to determine the potential of POST rimsulfuron alone, sequentially, and in combination with metribuzin for weed control in field transplanted tomato, and the response of four commercially available tomato cultivars and three annual grasses to rimsulfuron POST in the greenhouse.

In pepper, studies were conducted to determine the potential for clomazone and rimsulfuron for weed control in transplanted bell pepper, the efficacy of rimsulfuron in the greenhouse with respect to pepper cultivar, black nightshade, and jimsonweed. Three solanaceous nightshade species differ in sensitivity to rimsulfuron, therefore, studies were conducted to determine the absorption, translocation, and metabolic breakdown of rimsulfuron when applied foliarly to black, eastern black, and hairy nightshade, in order to determine the mechanism responsible for the differences in sensitivity.

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Chapter II

Weed Management Programs in Potato

(*Solanum tuberosum*) with Rimsulfuron

Abstract. Weed management programs in 'Superior' potato with PRE and POST rimsulfuron treatments were investigated during 1992, 1993, and 1994 in Virginia on a State sandy loam soil. Common ragweed control by PRE combinations of metolachlor with linuron or metribuzin was higher when treatments included PRE or POST rimsulfuron. Common lambsquarters control was 93 to 96% by treatments that included POST rimsulfuron. In the absence of PRE herbicides, POST applications of 35 g ai/ha rimsulfuron plus 280 g ai/ha metribuzin controlled weeds comparable to sequential applications of this combination and to sequential applications of 17 g/ha rimsulfuron plus 140 g/ha metribuzin. Potato recovered from occasional terminal leaf chlorosis caused by rimsulfuron, rimsulfuron plus metribuzin, and organophosphate insecticides combined POST with rimsulfuron plus metribuzin. These studies demonstrate that rimsulfuron can be a useful component of weed management programs that include metolachlor, linuron, and metribuzin.

INTRODUCTION

Rimsulfuron is a sulfonylurea herbicide for PRE and POST control of numerous weed species (Ackley et al. 1995a; Blackshaw et al. 1995; Eberlein et al. 1994). PRE and POST rimsulfuron combinations with metribuzin controlled additional weed species and did not affect potato yields when compared to yields from potato treated with metribuzin alone or a hand weeded check (Ackley et al. 1995a; Eberlein et al. 1994).

Only a few herbicides are registered for use in potato (Blackshaw et al. 1995; Dallyn, 1971; Eberlein et al. 1994; Wallace and Bellinder 1990). In Virginia, metolachlor, linuron, and metribuzin are often used in various combinations for annual broadleaf and grass weed control. However, these herbicides do not control all of the weeds indigenous to Virginia[1]. Further, metribuzin applied POST to potato may cause leaf chlorosis and necrosis and increase the occurrence of hollow heart (Freisen and Wall 1986; Gawronski et al. 1985; Henne 1975). Potato tuber yield has been reduced at 560 g/ha metribuzin (Hatterman-Valenti et al. 1994).

Organophosphate insecticides are used PRE and POST to control insect pests in several crops including potato. When organophosphate insecticides are applied in-furrow and followed by POST applications of certain sulfonylurea herbicides, injury and yield reductions have occurred in corn (*Zea mays* L.) and sweet corn (*Zea mays saccharata* L.) (Kapusta and Krausz 1992; Morton et al. 1991). Furthermore, organophosphate insecticides applied POST have increased injury and reduced fresh weight of soybean [*Glycine max* (L.) Merr.] when applied with thifensulfuron {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl] amino]sulfonyl]-2-thiophenecarboxylic acid} (Ahrens

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[1]Wilson, H. P. 1995. Personal communication. Eastern Shore Agric. Res. and Ext. Ctr., Virginia Polytechnic Inst. and State Univ., Painter, VA.

1990). POST malathion (O,O-dimethyl phosphorodithioate of diethyl mercaptosuccinate) increased chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl]benzenesulfonamide} toxicity to a chlorsulfuron-resistant biotype of rigid ryegrass (*Lolium rigidum* Gaud.) by inhibiting herbicide metabolism (Christopher et al. 1994). The combination of phorate {O,O-diethyl S-[(ethylthio) methyl] phosphorodithioate} and metribuzin decreased potato vine growth and tuber yield (Cranshaw and Thornton 1988). Relationships between rimsulfuron and organophosphate insecticides, have not been reported in potato.

The objectives of this research were to determine: 1) if rimsulfuron would improve weed control from metolachlor, metolachlor plus linuron and metolachlor plus metribuzin, 2) if single or sequential applications of rimsulfuron plus metribuzin would give higher weed control in potato, and 3) if combinations of organophosphate insecticides with POST rimsulfuron plus metribuzin would injure potato.

MATERIALS AND METHODS

General. Field studies were conducted in 1992, 1993 and 1994 on a State sandy loam (Typic Hapludults) at Painter, VA. Soil organic matter was 1% and pH was 5.7 to 6.0 at the separate, adjacent sites. The seedbed was prepared by moldboard plowing followed by tandem disking twice. Seed potato were cut commercially. ‘Superior’ potato cultivar was selected because it is the predominant cultivar in Virginia and is sensitive to POST metribuzin applications (Henne 1975). Potato seed pieces were planted on Mar. 4, 1992, Apr. 5, 1993, and Apr. 5, 1994 using a commercial two-row potato planter which formed a 10- to 12-cm ridge over the row during planting. Fertilizer was band-applied at planting according to Virginia Polytechnic Inst. and State Univ. recommendations[2]. Potato rows were 0.9 m apart and seed piece spacing was 0.3 m in the row. Approximately 3 wk after planting, potato were cultivated according to standard production practices. Two-row, 2 m by 7.6 m plots were established for herbicide treatments with an untreated row between plots. Herbicides were applied at 190 L/ha and 220 kPa through flat fan spray tips[3] by a backpack sprayer with an effective spray width of 1.8 m. Nonionic surfactant[4] was included with the spray mix at a concentration of 0.25% v/v in all POST and LPOST applications (Green and Green 1993). PRE herbicides were applied prior to potato or weed emergence on April 1, 1992, April 24, 1993, and April 20, 1994. POST herbicides were applied to actively growing weeds which were less than 8 cm tall and to 4- to 6-leaf potato on April 21, 1992, May 7, 1993 and May 3, 1994 and LPOST herbicides were applied to 8- to 10-leaf potato on May 25, 1993 and May, 20 1994. Two WAT with POST herbicides, potato were cultivated except the comparisons of single with sequential applications of rimsulfuron plus metribuzin.

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[2]Alexander, S. A., H. E. Holt, C. R. O'Dell, J. S. Speese, S. B. Sterrett, and H. P. Wilson. 1997. Commercial Vegetable Production Recommendations. Virginia Polytechnic Instit. and State Univ. Publication 456-420.

[3]Teejet 8003 flat fan spray tips, Spraying Systems Co., North Ave. Wheaton, IL 60188.

[4]X-77 Spreader, Loveland Industries Inc., P. O. Box 1289, Greely, CO 80632-1289. Nonionic surfactant with alkylarylpolyoxyethylene as the principal functioning agent.

Moisture was adequate to produce a good stand of potato and weeds. In 1992, 35 cm of rain was received during the growing season with 0.1 and 3.7 cm received within 10 DAT for PRE and POST herbicides, respectively. In 1993, 47 cm of rain was received during the growing season with 2.1 and 5.4 cm received within 10 DAT for PRE and POST herbicides, respectively. In 1994, 19 cm of rain was received within the growing season with 0, 2.4 and 2.8 cm received during the 10 DAT for PRE, POST, and LPOST herbicides, respectively. In addition, 2.5 cm irrigation were applied twice each yr during tuber development. Common lambsquarters and common ragweed were present in uniform populations of 20 to 30 plants/m^2 in all yr, while jimsonweed, (*Datura stramonium* L. # DATST) was present in 1993 and 1994 at a density of 3 to 5 plants/m^2.

Visual estimates of percent crop injury and weed control were determined using a 0 to 100% scale with 0 = no injury or control and 100% = crop death or complete weed control. Potato heights were recorded from three randomly selected plants in each plot and then averaged before analysis. Potato were harvested with a commercial potato harvester on July 15, 1992, June 28, 1993, and July 7, 1994, and were graded on a commercial potato grader according to the United States Department of Agriculture Standards for chipping potato (Anonymous 1991). Tubers which were larger than 4.8 cm in diameter (A-size) were weighed to permit yield determinations; tubers smaller than 4.8 cm in diameter were discarded.

Rimsulfuron programs. Studies in 1992 and 1993 investigated rimsulfuron in herbicide programs that included metolachlor, metolochlor plus linuron, and metolachlor plus metribuzin. Rimsulfuron was applied either with the PRE herbicides or POST following PRE applications of linuron and metolachlor. Rimsulfuron was also applied POST with metribuzin following PRE applications of metolachlor. Potato injury was estimated 2 WAT with POST herbicides and estimates of percent weed control and measurements of potato height were recorded 4 WAT.

Sequential applications. The effect of rimsulfuron plus metribuzin application method on weed control and potato growth was investigated in 1993 and 1994. Treatments included PRE, POST and sequential applications of 35 g/ha rimsulfuron plus 280 g/ha metribuzin and sequential applications of 17 g/ha rimsulfuron plus 140 g/ha metribuzin. Potato injury was recorded 2 WAT with POST herbicides. Estimates of weed control and potato height measurements were made 7 WAT with POST herbicides.

Foliar insecticides. Mixtures of organophosphate insecticides with rimsulfuron plus metribuzin were evaluated POST to potato in 1993 and 1994. Insecticide treatments included, azinphos-methyl {O,O-dimethyl S-[(4-oxo-1,2,3-benzotriazin-3 (4*H*)-yl)methyl]phosphorodithioate} applied at 840 g ai/ha, dimethoate [(O,O-dimethyl S-(methylcarbamoylmethyl phosphorodithioate] applied at 560 g ai/ha, and methamidophos (O, S - dimethyl phosphoramidothioate) applied at 1120 g ai/ha. Treatments included mixtures of each insecticide with rimsulfuron plus metribuzin as well as each insecticide and rimsulfuron plus metribuzin alone. Linuron (420 g ai/ha) plus metolachlor (1400 g ai/ha) were applied PRE to the entire study area to reduce weed competition. Potato injury was recorded 2 WAT and potato height was measured 7 WAT.

Data analysis. Experiments were conducted using a randomized complete block design with four replications. Data were analyzed statistically by analysis of variance and means were separated using Duncan's new multiple range test at the 0.05 significance level. Percent control and injury data were arcsine transformed to produce a near-normal distribution (Zar 1984). The data are presented in untransformed percentages while mean separation procedures reflect the differences found with the arcsine transformed data.

RESULTS AND DISCUSSION

Rimsulfuron programs. Common lambsquarters control was 72 to 88% for PRE combinations of metolachlor and linuron or metribuzin. Control did not increase by adding rimsulfuron to these combinations (Table 1). Common lambsquarters control was 95% in 1993 for metolachlor and linuron PRE followed by rimsulfuron POST and was 95% and 96% in 1992 and 1993 from metolachlor PRE followed POST by rimsulfuron plus metribuzin. Common ragweed control was lowest both yr from PRE applications of metolachlor alone and with linuron or metribuzin, and was improved with PRE and POST applications of rimsulfuron. Generally the higher common ragweed control in 1993 than in 1992 was associated with higher rainfall during the 10 DAT with PRE and POST herbicides in 1993. In other studies, yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.) were controlled by soil applications of ALS-inhibitor herbicides (Nandihalli and Benedixen 1988; Reddy and Benedixen 1989; Vencill et al. 1995), and it is likely that root uptake may contribute to weed control by POST applications that are followed by adequate rainfall or irrigation. Potato injury by rimsulfuron was present as leaf chlorosis in terminal growth and occasional decrease in internode elongation and leaf area and was highest from POST applications. Potato recovered from injury within 3 to 4 wk, (data not presented); however, potato treated POST with rimsulfuron plus metribuzin in 1992 were shorter than potato in all other treatments except linuron PRE plus rimsulfuron POST. Potato height was not affected by rimsulfuron in 1993. Yields of A-size potato in 1992 were highest from herbicide programs which contained rimsulfuron PRE or POST. In 1993, low tuber yields likely resulted from the reduced interval between planting and harvest; as a result, tuber yields from herbicide-treated potato were not always higher than those from the untreated control.

Sequential applications. All rimsulfuron plus metribuzin treatments provided 90% or higher control of common lambsquarters, common ragweed and jimsonweed except the PRE applications in 1994 (Table 2). Low control from the PRE application in 1994 was likely due to no rainfall during the 10 DAT; control was improved in 1993 when 2.1 cm rainfall occurred in the 10 DAT. Potato injury was highest from rimsulfuron plus metribuzin applications POST. The LPOST application of rimsulfuron plus metribuzin produced slight additional injury but potato recovered within 3 WAT (data not presented). Potato height was not affected by rimsulfuron plus metribuzin. Yields of A-size tubers were generally higher in 1994 than in 1993 likely as a result of a longer interval between planting and harvest in 1994. Rimsulfuron treatment did not affect potato yields in 1993 but in 1994 all potato treated POST with rimsulfuron plus metribuzin produced yields above the untreated control. High tuber yields from potato treated sequentially POST and LPOST with rimsulfuron plus metribuzin demonstrated the tolerance of Superior to this combination.

Foliar Insecticides. Potato were injured 22 to 25% in 1993 and 12 to 13% in 1994 when organophosphate insecticides were included with rimsulfuron plus metribuzin (Table3). Potato recovered from foliar injury in 3 WAT and heights of treated potato were similar to the controls in both yr. Tuber yields were similar from potato treated with organophosphate insecticides, rimsulfuron plus metribuzin, and the combinations in 1993 and 1994.

In summary, rimsulfuron improved weed control by metolachlor, metolachlor plus linuron, and metolachlor plus metribuzin. These benefits were dependent on weed species, application timing, and rainfall. Potato can tolerate two POST applications of 35g/ha rimsulfuron plus 280 g/ha metribuzin without reducing tuber yield. However, single POST applications of 35g/ha rimsulfuron plus 280 g/ha metribuzin and sequential applications of 17 g/ha rimsulfuron plus 140 g/ha metribuzin controlled weeds in these studies. Potato recovered rapidly from visible injury by combinations of organophosphate insecticides with rimsulfuron plus metribuzin and potato tuber yields were similar from all treatments. These studies confirm that rimsulfuron can be a useful component of weed management programs in Superior potato.

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Table 1. Common lambsquarters and common ragweed control, potato injury and height, and tuber yield from potato treated with rimsulfuron, in programs that included metolachlor, metolachlor plus linuron, and metolachlor plus metribuzin in 1992 and 1993.

			Weed control[a]				Potato					
			Common lambsquarter		Common ragweed		Injury[b]		Height[b]		Tuber yield[c]	
Treatment	Application	Rate	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
		g/ha	— % —		— % —		— % —		— cm —		— kg/ha x 1000 —	
Metolachlor[d]	PRE	1400	10 c[e]	20 d	0 d	20 d	0 c	5 b	39 b	29 ab	16.8 c	8.5 bc
Linuron	PRE	420	84 ab	88 bc	38 c	72 c	0 c	7 b	39 b	23 b	23.7 b	11.8 ab
Metribuzin	PRE	280	72 b	82 c	42 c	70 c	2 bc	7 b	39 b	27 ab	23.6 b	11.6 abc
Linuron + rimsulfuron	PRE	420 + 35	87 ab	93 ab	76 b	89 ab	3 b	7 b	38 b	25 ab	28.3 a	13.1 a
Metribuzin + rimsulfuron	PRE	280 + 35	89 ab	87 c	72 b	86 b	2 bc	8 b	40 b	24 ab	30.4 a	11.7 ab
Linuron + rimsulfuron	PRE + POST[f]	420 + 35	93 ab	95 a	84 ab	92 ab	16 a	17 a	37 bc	25 ab	30.6 a	11.4 abc
Metribuzin + rimsulfuron	POST	280 + 35	96 a	95 a	90 a	92 a	22 a	18 a	35 c	25 ab	31.4 a	11.4 abc
Untreated control			0 c	0 e	0 d	0 e	0 c	0 c	44 a	29 a	13.5 c	7.3 c

[a] Estimates of percent weed control were recorded 4 WAT with POST herbicides.
[b] Estimates of percent potato injury were recorded 2 WAT and measurements of potato height were recorded 4 WAT with POST herbicides.

[c]A-size potato tubers are 4.8 cm and larger in diameter.
[d]All treatments except the untreated control included metolachlor at 1400 g/ha PRE.
[e]Means followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.
[f]All POST treatments contained 0.25 % v/v nonionic surfactant.

Table 2. Common lambsquarters, common ragweed, and jimsonweed control, potato injury and height, and tuber yield from potato treated with rimsulfuron and metribuzin at different rates and application timings in 1993 and 1994.

			Weed control[a]						Potato					
			Common lambsquarter		Common ragweed		Jimsonweed		Injury[b]		Height[b]		Tuber yield[c]	
Treatment	Application	Rate	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
		g/ha	%		%		%		%		%		kg/ha x 1000	
Rimsulfuron +	PRE	35 +	93 a[d]	60 b	90 a	57 b	90 ab	62 b	3 c	0 c	24 a	34 ab	10.0 a	12.8 bc
metribuzin		280												
Rimsulfuron +	POST[e]	35 +	93 a	95 a	92 a	92 a	90 ab	95 a	22 a	10 a	29 a	36 a	13.6 a	20.3 a
metribuzin		280												
Rimsulfuron +	PRE fb[f]	17 +	95 a	95 a	92 a	90 a	92 ab	92 a	10 b	7 b	26 a	38 a	14.5 a	19.5 a
metribuzin		140 fb												
Rimsulfuron +	POST	17 +												
metribuzin		140												
Rimsulfuron +	POST fb	17 +	92 a	95 a	88 a	93 a	90 ab	93 a	10 b	5 b	25 a	35 ab	10.8 a	17.4 a
metribuzin		140 fb												
Rimsulfuron +	LPOST	17 +												
metribuzin		140												
Rimsulfuron +	POST fb	35 +	95 a	95 a	93 a	95 a	95 a	95 a	22 a	9 a	24 a	36 a	15.0 a	16.7 ab
metribuzin		280 fb												
Rimsulfuron +	LPOST	35 +												

metribuzin	280												
Untreated control		0 b	0 c	0 b	0 c	0 c	0 c	0 d	0 c	28 a	31 b	11.1 a	11.4 c

[a] Estimates of percent weed control were recorded 7 WAT with POST herbicides.
[b] Percent potato injury was recorded 2 WAT and measurements of potato height were recorded 4 WAT with POST herbicides.
[c] A-size potato tubers are 4.8 cm and larger in diameter.
[d] Means followed by the same letter do not differ at the significance level by Duncan's new multiple range test.
[e] All POST and LPOST treatments contained 0.25 % v/v nonionic surfactant.
[f] fb, followed by.

Table 3. Injury, height and tuber yield from potatoes treated POST with combinations of organophosphate insecticides with rimsulfuron plus metribuzin in 1993 and 1994.

		Injury		Height		Tuber yield[a]	
Treatment[b]	Rate	1993	1994	1993	1994	1993	1994
	g/ha	—— % ——		—— cm ——		—— kg/ha x 1000 ——	
Azinphos-methyl	840	3 c[c]	0 c	31 a	37 a	14.7 a	18.2 ab
Dimethoate	560	3 c	0 c	26 ab	36 a	13.0 a	20.3 ab
Methamidophos	1120	5 c	0 c	27 ab	33 ab	13.7 a	21.2 ab
Azinphos-methyl +	840 +	22 a	12 a	25 ab	35 a	12.0 a	18.8 ab
rimsulfuron +[d]	35 +						
metribuzin	280						
Dimethoate +	560 +	23 a	13 a	22 b	36 a	13.4 a	20.4 ab
rimsulfuron +	35 +						
metribuzin	280						
Methamidophos +	1120 +	25 a	12 a	26 ab	36 a	13.8 a	17.8 b
rimsulfuron +	35 +						
metribuzin	280						
Rimsulfuron +	35 +	12 b	5 b	26 ab	31 a	11.1 a	20.6 ab
metribuzin	280						
Control		2 c	0 c	25 ab	36 a	12.2 a	23.7 a

[a] A-size potatoes are 4.8 cm and larger in diameter.
[b] The entire area received 420 g/ha linuron and 1400 g/ha metolachlor PRE, and was cultivated twice.
[c] Means followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.
[d] All POST treatments with rimsulfuron plus metribuzin contained 0.25 % v/v nonionic surfactant.

Chapter III

Yellow Nutsedge (*Cyperus esculentus*) Control POST With Acetolactate Synthase-Inhibiting Herbicides

Abstract. Several acetolactate synthase (ALS)-inhibiting herbicides were evaluated for yellow nutsedge control in the greenhouse. Herbicides were applied POST to yellow nutsedge at actual or anticipated commercial rates. Yellow nutsedge control was 92 and 71% from halosulfuron and chlorimuron, respectively. Control ranged from 48 to 69% from primisulfuron, pyrithiobac, and rimsulfuron. Control from nicosulfuron and imazethapyr was 45 and 68%, respectively, while thifensulfuron and CGA-152005 had almost no activity on yellow nutsedge. Chlorimuron, imazethapyr and halosulfuron were the only herbicides which reduced yellow nutsedge regrowth, after the initial harvest, while regrowth from yellow nutsedge treated with other herbicides was similar to or higher than regrowth in the untreated control.

INTRODUCTION

Yellow nutsedge is distributed throughout the world and is competitive in many crops. It reduces crop yield and quality by competing for light, water, and nutrients, and by interfering with pesticide applications and harvest operations (Holm et al. 1977). Yellow nutsedge is one of the 10 most troublesome weeds in Virginia[1]. Soil applications of two

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[1]Hagood, E. S. 1995. Weed Survey - Southern States. Proc. Southern Weed Sci. Soc. 48:297

classes of herbicides, the carbamothioates and the chloroacetamides have partially controlled yellow nutsedge in many crops (Wilson et al. 1970). The carbamothioates must be incorporated to reduce losses due to volatility and control may not last long enough due to microbial degradation of these herbicides (Wilkinson 1988). Bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] selectively controls yellow nutsedge POST in several crops but two applications are frequently required (Richburg et al. 1993).

Several acetolactate synthase (ALS)[2]-inhibiting herbicides have activity on yellow nutsedge. Imazethapyr and imazaquin {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic acid}, two imidazolinones, control yellow nutsedge from PRE and POST applications but may be most effective PRE (Grichar et al. 1992; Nandihalli and Benedixen 1988; Richburg et al. 1993). The sulfonylurea herbicides, chlorimuron and halosulfuron control yellow nutsedge in the field or greenhouse and are selective in soybean (*Glycine max* (L.) Merr.) and corn (*Zea mays* L.), respectively (Bhowmik et al. 1994; Frank et al. 1993; Vencill et al. 1995). Additional sulfonylurea herbicides such as nicosulfuron, primisulfuron, CGA-152005, and thifensulfuron are used commercially POST in corn and soybean but their effects on yellow nutsedge are largely unreported (Ackley et al 1994b). Rimsulfuron controls weeds and some grasses in solanaceous vegetable crops (Ackley et al. 1993; Ackley et al. 1994a; Blackshaw et al.

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[2]Abbreviations: ALS, acetolactate synthase.

1995; Eberlein et al. 1994) and the pyrimidinyl thiobenzoate, pyrithiobac, controls weeds in cotton (*Gossipium hirsutum* L.) (Dotray et al. 1994; Jordan et al. 1995; Jordan et al. 1995; Keeling et al. 1993); both of these herbicides have effects on yellow nutsedge (Ackley et al. 1994b). The objective of these studies was to evaluate the activity of several ALS-inhibiting herbicides in the greenhouse to control yellow nutsedge POST.

MATERIALS AND METHODS

Yellow nutsedge tubers were collected in early February, 1994 from a field without history of ALS-inhibitor herbicide applications. Uniform-size tubers were first washed, then tubers were planted 2 cm deep in 0.5-L cups in a mixture of sandy loam soil, sand, and peat (23:13:1 by wt). The pH of the final mix was 5.8. Studies were conducted during March and April, 1994 under natural sunlight supplemented with metal halide lamps. After yellow nutsedge emerged, plants were thinned to five uniform plants per cup and grown to a height of 5 to 6 cm; plants were watered daily. Cups were then removed from the greenhouse, placed in rows on the ground and herbicides were applied with a tractor-mounted plot sprayer delivering 190 L/ha at 220 kPa through flat fan tips[3] and cups were returned to the greenhouse for an additional 3 wk. Nonionic surfactant[4] was

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[3]Teejet 8003 flat fan tips, Spraying Systems Co., North Ave. Wheaton, IL. 60188.

[4]X-77 Spreader, Loveland Industries Inc., P.O. Box 1289 Greely, CO 80632-1289. Nonionic surfactant with alkylarylpolyoxyethylene as the principle functioning agents.

included in all spray mixes at 0.25% (v/v). Three WAT, estimates of percent control were made. Heights of surviving plants were recorded and averaged before data were analyzed and yellow nutsedge shoots were harvested and dried to constant weight. Cups were maintained for an additional 4 wk when yellow nutsedge shoot growth was harvested and dried to constant weight to compare regrowth.

Data analysis. Greenhouse studies were conducted using a randomized complete block design with three replications and were repeated. No treatment by repetition interaction occurred for any dependent variable and data were combined prior to analysis. Data were analyzed statistically by analysis of variance and means were separated using Duncan's new multiple range test at the 0.05 significance level. Percent control data were arcsine transformed to produce a near normal distribution (Zar 1984). The data are presented in untransformed percentages while mean separation procedures reflect differences found with the arcsine transformed data.

RESULTS AND DISCUSSION

Yellow nutsedge did not respond to all ALS-inhibitor herbicides but where responses occurred, symptoms included cessation of growth and development of chlorosis, and often progressed to terminal leaf or whole plant necrosis. Percent yellow nutsedge control from halosulfuron was higher than from chlorimuron although reductions of yellow nutsedge heights and dry weights were similar from these two herbicides (Table 1). Imazethapyr was more active in the greenhouse than in the field (Ackley et al. 1994b) as reflected by yellow nutsedge control, height, and dry weight, which may result from the continuous high soil moisture in the greenhouse (Richburg et al. 1993; Vencill et al. 1995). Ample soil moisture promotes herbicide activity through root uptake. Chlorimuron, halosulfuron, and imazethapyr were the only herbicides to reduce or prevent yellow nutsedge regrowth in the greenhouse. Primisulfuron and rimsulfuron gave 64 and 69% control respectively, and reduced yellow nutsedge height an average 61% and dry weight 58% but permitted more regrowth than the untreated control. Nicosulfuron gave 45% control and reduced yellow nutsedge height 48% and dry weight 44% but permitted regrowth comparable to the untreated control. Yellow nutsedge control and height reduction by 35 and 70 g/ha pyrithiobac were comparable although plant dry weight and regrowth were lower at 70 g/ha than at 35 g/ha. Yellow nutsedge was not controlled by CGA-152005 or thifensulfuron and, although both herbicides reduced yellow nutsedge height, they did not reduce dry weight or regrowth.

Good to excellent yellow nutsedge control is obtained from halosulfuron and chlorimuron in the greenhouse and these herbicides should be useful in corn and soybean, respectively. Imazethapyr was more active in the greenhouse than in the field as reflected by yellow nutsedge control, height, dry weight and dry weight of regrowth which may result from the continuous high soil moisture in the greenhouse (Ackley et al. 1994b; Richburg et al. 1993). Although control was lower, rimsulfuron and pyrithiobac should improve yellow nutsedge management in solanaceous vegetable crops and cotton, respectively, since crop competition, tillage, and herbicides such as metolachlor, [*2*-

chloro-*N*-(2-ethyl-6-methyl phenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] PRE also provide partial control in these crops. Since yellow nutsedge is controlled by soil applications of some ALS-inhibitors (Nandihalli and Benedixen 1989; Reddy and Benedixen 1989; Richburg et al. 1993; Vencill et al. 1995), it is likely that root uptake may contribute to yellow nutsedge control by POST applications that are followed by adequate rainfall or irrigation. This would explain the good initial control and regrowth control by chlorimuron, halosulfuron, and imazethapyr under the high soil moisture in the greenhouse.

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Table4. Yellow nutsedge control, height, dry weight, and regrowth following POST applications of acetolactate synthase-inhibiting herbicides in the greenhouse.[abc]

		Yellow nutsedge			
Herbicide	Rate	Control	Height	Dry weight	Regrowth dry weight
	g/ha	%	cm	g	g
CGA-152005	31	0 f	17.5 b	2.55 a	0.94 b
Chlorimuron	9	71 b	8.7 cd	0.91 c	0.08 d
Imazethapyr	70	68 bc	8.6 cd	0.73 c	0.15 d
Halosulfuron	35	92 a	7.0 d	0.59 c	0.00 d
Nicosulfuron	35	45 e	10.3 c	1.49 b	1.02 b
Primisulfuron	40	64 bc	7.0 d	0.84 c	1.51 a
Pyrithiobac	35	48 de	9.8 c	1.54 b	1.02 b
Pyrithiobac	70	59 cd	8.3 cd	0.99 c	0.61 c
Rimsulfuron	35	69 bc	8.4 cd	0.84 c	1.42 a
Thifensulfuron	4	3 f	17.7 b	2.37 a	0.87 bc
Untreated		0 f	19.7 a	2.63 a	0.91 bc

[a] All treatments contained 0.25 % v/v nonionic surfactant.

[b] Means are the average of two studies.

[c] Means followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.

ChapterIV

Rimsulfuron and Metribuzin Efficacy in Transplanted Tomato (*Lycopersicon esculentum*)

Abstract. In field studies in 1991, 1992, and 1993, rimsulfuron at 26 and 35 g ai/ha, sequentially at 26 g/ha, at 26 g/ha plus metribuzin at 280 g ai/ha, and metribuzin at 280 g/ha were evaluated POST for weed control in transplanted ‘Agriset’ tomato. Common lambsquarters was controlled by rimsulfuron at 35 g/ha. Rimsulfuron plus metribuzin gave consistent control of common ragweed but jimsonweed control was inconsistent and goosegrass control was generally low. Rimsulfuron treatments caused slight (< 12%) temporary injury to new terminal growth of tomato. Yield of tomato fruit was consistently high in the metribuzin, metribuzin plus rimsulfuron, and rimsulfuron sequential treatments. In greenhouse studies, giant foxtail and large crabgrass control by rimsulfuron was above 95 and 85% respectively, but goosegrass was not controlled. Height of four tomato cultivars was not reduced, but dry weight of ‘Floradade’ and ‘Sunbeam’ was reduced by rimsulfuron.

INTRODUCTION

Tomato is an economically important vegetable crop in Virginia. Efficient production of high yielding tomato with high quality fruit is dependent upon implementation of an effective weed control program. Weeds can affect tomato quality and yield directly by competing for water, essential nutrients, and photosynthetically active radiation, or indirectly by serving as a reservoir to insect pests and disease of tomato (Freisen 1979;

McGiffen et al. 1992; Perez and Matsiunas 1990; Weaver et al. 1987; Weaver and Tan 1983). Tomato yields are highest when weeds are controlled prior to the initiation of flowering (Weaver et al. 1987). However, weed control is difficult since few herbicides are registered for tomato. (Ackley et al. 1994; Beste et al. 1992; Bewick et al. 1995; Glaze 1990). Metribuzin is the only selective herbicide registered for POST control of broadleaf weeds in tomato. However, metribuzin may injure tomato (Fortino and Splittstoesser 1974; Frank and Beste 1985; Henne 1974), and the failure to control many broadleaf weed species indigenous to the tomato producing regions of Virginia results in a need for additional POST herbicides for this crop.

Rimsulfuron, a sulfonylurea herbicide, has been evaluated for broadleaf and grass weed control in potato (*Solanum tuberosum* L.) (Ackley et al. 1996a; 1996b) and tomato (Ackley et al. 1994; Bewick et al. 1995). Rimsulfuron controls many broadleaf and some grass weeds including giant foxtail (Ackley et al. 1995; 1996b) and large crabgrass (Ackley et al. 1995) while giving little injury to these solanaceous crops. However, some tomato cultivars are sensitive to rimsulfuron (Bewick et al. 1995). Rimsulfuron is most effective when applied POST with a nonionic surfactant at 0.25% (v/v) (Green and Green 1993) to actively growing weeds, and does not cause injury to rotational crops (Leep et al. 1991). The objectives of these studies were to evaluate: 1) POST rimsulfuron alone, sequentially, and in combination with metribuzin for weed control in field transplanted tomato, and 2) to determine response of four commercially available tomato cultivars and three annual grasses to rimsulfuron POST in the greenhouse.

MATERIALS AND METHODS

Field studies. Studies were conducted in 1991, 1992, and 1993 at Painter, VA on a State sandy loam (Typic Hapludults) with 1% organic matter and pH 5.9 to 6.0. A conventional seedbed was prepared by moldboard plowing and tandem disking. Six- to 8-leaf Agriset tomato plants that were 15- to 20- cm tall were transplanted in the field on May 10, 1991, May 12, 1992, and May 25, 1993 with a commercial one-row mechanical transplanter. Plots consisted of one row of tomato and were 2.5 by 7.5 m long. Tomato plants were 45 cm apart in the row and 2.7 m between the rows.

Herbicide treatments included rimsulfuron applied POST 10 days after transplanting (DAP)[1] at 26 and 35 g/ha, sequential applications of 26 g/ha rimsulfuron at 10 DAP followed by 26 g/ha at 21 DAP (late POST), 26 g/ha rimsulfuron plus 280 g ai /ha metribuzin at 10 DAP, and metribuzin at 280 g/ha at 10 DAP (standard treatment) in 1992 and 1993; however, in 1991 metribuzin was applied PPI. Sethoxydim {2-[1-(ethoxyimino) butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one}at 17 g ai/ha was applied POST in 1991 to control grass in the metribuzin treatment. An untreated control was included each year. Herbicides were applied with a tractor-mounted plot sprayer which delivered 190 L/ha with a pressure of 220 kPa through flat fan nozzles[2].

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[1]Abbreviations: DAP, days after transplanting.

[2]Teejet 8003 flat fan spray tips, Spraying Systems Co., North Ave. Wheaton, IL 60188.

Nonionic surfactant[3] was included with the spray mix at a concentration of 0.25 % v/v in all POST and late POST applications. Seedling common lambsquarters, common ragweed and goosegrass were each present at 15 to 20 plants/m^2. Seedling jimsonweed was uniformly distributed in populations of 3 to 5 plants/m^2 in 1992 and 1993 and smooth pigweed (*Amaranthus hydridus* L.) was present at 6 to 8 plants/m^2 in 1991.

Visual estimates of percent crop injury and weed control were recorded on a scale of 0 to 100%, where 0% = no injury or weed control and 100% = complete plant death. Tomato injury was evaluated at 4 and 2 WAT for POST, and late POST applications, respectively. Weed control was evaluated 8 WAT which corresponded with end-of-season (preharvest) control. Tomato was hand-harvested in a once over harvest at 10 WAT in 1991 and 1992, and 11 WAT in 1993 by removing and weighing all mature and immature fruit. Moisture was adequate to produce a good stand of tomato and weeds in each year. In 1991, 15 cm of rain was received during the growing season with 3.2 and 0.1 cm received within the 10 DAT for POST and late POST herbicides, respectively. In 1992, 33 cm of rain was received during the growing season with 8.3 and 0.1 cm received during the 10 DAT with POST and late POST herbicides, respectively, and in 1993, 22 cm of rain was received during the growing season with 0.5 and 0.1 cm received during the 10 DAT with POST and late POST herbicides, respectively.

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[3]X-77 Spreader, Loveland Industries Inc. P.O. Box 1289, Greely, CO 80632-1289.

`Nonionic surfactant with alkylarylpolyoxyethelene as the principal functioning agent.

Greenhouse studies. Studies were conducted in the greenhouse in June and September 1994, and July, 1995 to evaluate the effect of rimsulfuron POST on four tomato cultivars and three annual grasses. Seed of tomato cultivars, giant foxtail, large crabgrass, and goosegrass were planted 0.8 cm deep in separate 0.5-L cups in a mixture of sandy loam soil, sand, and peat (23:13:1). The pH of the final mix was 5.8. Plants were grown under natural sunlight and were watered as needed. Greenhouse temperatures were between 20 and 33 C. Tomato plants were thinned 2 WAP to one plant per cup and grown to the 6- to 8-leaf stage (18- to 20-cm tall), which is commonly the growth stage for transplanting. After grass species emerged, plants were thinned to 5 plants per cup and grown to the 3- to 5-leaf stage or 12- to 14-cm in height. Cups were then removed from the greenhouse, placed on the ground, and rimsulfuron was applied POST at 17, 26, and 35 g/ha using a backpack sprayer delivering 190 L/ha with 220 kPa pressure through flat fan spray tips[2]. Nonionic surfactant was included with the spray mix at a concentration of 0.25 % (v/v)[3]. At 3 WAT, visual estimates of tomato injury and grass weed control were made and height from soil surface to growing point of surviving plants was recorded. Height of grasses were averaged for each cup before data were analyzed. Plant shoots were then harvested, dried to constant weight, and weighed.

Data analysis. Field and greenhouse studies were conducted using a randomized complete block design with four replications in the field and three replications in the greenhouse. Greenhouse studies were repeated six times. In the field studies, a significant ($p<0.05$) treatment by year interaction for weed control occurred. The differential response of weed species to herbicides between years resulted from differences in rainfall and the associated vigor of the weeds. No treatment by repetition interaction occurred for any dependent variable in the greenhouse studies and data were combined prior to analysis. Data were analyzed statistically by analysis of variance and means were separated using Duncan's new multiple range test at the 0.05 significance level.

RESULTS AND DISCUSSION

Field studies. Common lambsquarters control by 26 g/ha rimsulfuron averaged 71% from 1991 to 1993 (Table 1). Control was higher in 1991 and 1992 but not 1993 from 35 g/ha rimsulfuron, sequential applications of 26 g/ha rimsulfuron, metribuzin, and the combination of rimsulfuron plus metribuzin. Common ragweed control was influenced by rainfall during the 10 DAT and averaged 90% only from rimsulfuron plus metribuzin. Other treatments often gave lower common ragweed control, especially in 1993 when rainfall was 0.5 in the 10 DAT compared with 3.2 and 8.3 cm in 1991 and 1993, respectively. Jimsonweed control by rimsulfuron was generally low as reported previously (Ackley et al. 1995, 1996a). In 1992, all treatments gave 48 to 63% jimsonweed control except rimsulfuron plus metribuzin which gave 91% control. Control of jimsonweed by single and sequential rimsulfuron applications in 1993 was 18 to 31%, and was 53 to 75% by metribuzin treatments. Low rainfall following application in 1993 likely contributed to low jimsonweed control but tolerance to these treatments should not be surprising since jimsonweed is a Solanaceous species like tomato and might be expected to have natural tolerance. Smooth pigweed was present only in 1991 and all rimsulfuron treatments gave 92% or higher control (data not presented). This was similar to 91% smooth pigweed control by rimsulfuron in transplanted peppers (*Capsicum annum L.*) in 1993[4]. High smooth pigweed control by other sulfonylurea herbicides has also been reported previously (Manley et al. 1996). Goosegrass control by rimsulfuron was generally low each year. Highest goosegrass control by rimsulfuron was in combination with metribuzin in 1992 and was likely the result of high rainfall within 10 DAT. In 1991, only sethoxydim POST controlled goosegrass that was not controlled by metribuzin.

Tomato response to rimsulfuron consisted of chlorosis in new terminal growth. Visible response did not exceed 12% in 1991 and 1992 and was generally similar to response to metribuzin (Table 2). Where tomato were injured, recovery occurred within 2 to 3 wk. Tomato response was not observed in 1993.

Fruit yields from treated and untreated tomato varied between years and generally reflected seasonal rainfall, weed populations, and the degree of weed control (Table 2). Low rainfall in 1991 resulted in low yields overall and only tomato treated with metribuzin PPI followed by sethoxydim POST produced yields higher than the untreated control. In 1992, tomato yields were generally higher and all rimsulfuron- and metribuzin-treated plots produced yields which were above those in the untreated control. In 1993, the

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[4]Wilson, H. P. 1993. Personal communication. Eastern Shore Agric. Res. and Ext. Ctr., Virginia Polytechnic Inst. and State Univ., Painter, VA.

highest tomato yields were produced in plots treated with rimsulfuron sequentially, metribuzin, and rimsulfuron plus metribuzin. Tomato treated with rimsulfuron at 26 and 35 g/ha produced fruit yields which did not differ from the untreated control as a result of low weed control.

Greenhouse studies. Rimsulfuron controlled giant foxtail and large crabgrass but did not control goosegrass in the greenhouse (Table 3). Rimsulfuron gave higher than 96% control of giant foxtail at all rates and 85 to 89% control of large crabgrass. Rimsulfuron reduced height of all three grasses and dry weight of giant foxtail and large crabgrass but did not reduce goosegrass dry weight. Increase in dry weight of goosegrass treated with rimsulfuron at 26 g/ha is likely the result of variability associated with the study and is more apparent than real. Visible injury symptoms of rimsulfuron-treated tomato included mottled chlorosis in new growth which often appeared within 7 DAT. Tomato injury was low from all treatments, and did not exceed 11% in any cultivar (Table 4). In addition to low visible injury, height of all cultivars was not reduced by 35 g/ha rimsulfuron. Dry weights of Agriset and Mt. Spring were not reduced by rimsulfuron, but Floradade dry weight was reduced by 35 g/ha rimsulfuron and 17 to 35 g/ha rimsulfuron reduced dry weight of Sunbeam.

In summary, in field studies common lambsquarters control by POST rimsulfuron and metribuzin treatments was generally high, but common ragweed control was highest from rimsulfuron plus metribuzin. No treatment consistently controlled jimsonweed or goosegrass. Greenhouse studies support reports from field studies (Ackley et al. 1995;

1996a) that rimsulfuron will control giant foxtail and large crabgrass but not goosegrass. Field and greenhouse studies confirmed that the tomato cultivars Agriset and Mt. Spring were tolerant to rimsulfuron; however, dry weights of Floradade and Sunbeam were reduced by rimsulfuron. In these studies, values for percent tomato injury and weed control were often statistically different but these differences between rimsulfuron rates were small and may be viewed as having little practical significance. These studies substantiate that rimsulfuron can be a useful component of weed management programs in tomato. Additional field studies should investigate the initial response of additional tomato cultivars to rimsulfuron and determine if fruit yield or maturity is affected by rimsulfuron.

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Table 5. Common lambsquarters, common ragweed, jimsonweed, and goosegrass control in tomato treated with rimsulfuron and metribuzin POST in 1991, 1992 and 1993[a,b].

Herbicide	Rate	Common lambsquarters 1991	Common lambsquarters 1992	Common lambsquarters 1993	Common ragweed 1991	Common ragweed 1992	Common ragweed 1993	Jimsonweed 1992	Jimsonweed 1993	Goosegrass 1991	Goosegrass 1992	Goosegrass 1993
	g/ha	%										
Rimsulfuron	26	69 b[c]	64 b	78 a	61 b	63 bc	18 b	48 c	18 bc	60 b	57 bc	40 a
Rimsulfuron	35	89 a	88 a	81 a	79 ab	70 b	23 b	56 bc	31 bc	68 b	45 cd	48 a
Rimsulfuron fb[d] rimsulfuron	26 fb 26	92 a	87 a	69 a	86 a	73 b	28 b	61 b	28 bc	65 b	71 b	23 a
Metribuzin[e]	280	97 a	85 a	93 a	81 ab	51 c	88 a	63 b	75 a	98 a	30 d	28 a
Rimsulfuron+ metribuzin	26+ 280	97 a	95 a	93 a	89 a	91 a	91 a	91 a	53 ab	68 b	90 a	50 a
Untreated	0	0 c	0 c	0 b	0 c	0 c	0 c	0 c	0 c	0 c	0 e	0 b

[a] All treatments included 0.25 % v/v non-ionic surfactant.
[b] Estimates of weed control were recorded 8 WAT with POST herbicides.
[c] Means followed by the same letter within columns do not differ at the 0.05 significance level by Duncan's new multiple range test.
[d] fb, followed by.
[e] Metribuzin was applied PPI in 1991 and sethoxydim was applied POST at 17 g/ha in 1991 to control grasses. Metribuzin was applied POST in 1992 and 1993.

Table 6. Tomato injury and fruit yield from tomato treated with rimsulfuron and metribuzin POST in 1991, 1992, and 1993.[a]

Herbicide	Rate	Tomato injury[b] 1991	Tomato injury[b] 1992	Tomato injury[b] 1993	Tomato yield[c] 1991	Tomato yield[c] 1992	Tomato yield[c] 1993
	g/ha	%			kg/ha x 1000		
Rimsulfuron	26	6 b[d]	8 a	0 a	14.9 ab	20.1 a	5.7 b
Rimsulfuron	35	12 a	11 a	0 a	12.0 ab	24.2 a	7.7 b
Rimsulfuron fb[e] rimsulfuron	26 fb 26	5 b	11 a	0 a	15.1 ab	22.6 a	17.0 a
Metribuzin[f]	280	8 b	2 b	0 a	16.0 a	20.4 a	21.2 a
Rimsulfuron+ metribuzin	26+ 280	11 a	8 a	0 a	15.5 ab	19.4 a	21.7 a
Untreated	0	0 c	0 b	0 a	11.1 b	5.4 b	1.2 b

[a] All treatments except metribuzin PPI included 0.25 % v/v non-ionic surfactant.
[b] Estimates of tomato injury were recorded 4 WAT with POST herbicides.
[c] Tomato yield was determined by removing all mature and immature fruit 10 WAT in 1991 and 1992 and 11 WAT in 1993.
[d] Means followed by the same letter within columns do not differ at the 0.05 significance level by Duncan's new multiple range test.
[e] fb, followed by.
[f] Metribuzin was applied PPI in 1991 and sethoxydim was applied POST at 17 g/ha in 1991 to control grasses. Metribuzin was applied POST in 1992 and 1993.

Table 7. Control, height and dry weight of giant foxtail, goosegrass, and large crabgrass by rimsulfuron POST in the greenhouse[a,b,c,d].

Herbicide	Rate	Control[d]			Height			Dry weight		
		Giant foxtail	Goosegrass	Large crabgrass	Giant foxtail	Goosegrass	Large crabgrass	Giant foxtail	Goosegrass	Large crabgrass
	g/ha	%			cm			g /pot		
Rimsulfuron	17	96 b	0 a	85 b	3.0 b[c]	9.6 c	2.6 b	0.66 b[c]	2.66 b	0.21 b
Rimsulfuron	26	98 a	0 a	86 ab	2.3 b	9.5 c	2.4 b	0.38 b	3.51 a	0.19 b
Rimsulfuron	35	97 ab	0 a	89 a	2.3 b	11.4 b	2.3 b	0.39 b	2.84 ab	0.23 b
Untreated	0	0 c	0 a	0 c	34.5 a	12.9 a	17.1 a	3.0 a	2.67 b	3.39 a

[a] All treatments included 0.25 % v/v non-ionic surfactant.
[b] Means are the average of six repetitions with three replications.
[c] Means followed by the same letter within columns do not differ at the 0.05 significance level by Duncan's new multiple range test.
[d] Giant foxtail, large crabgrass, and goosegrass control, height, and dry weight was recorded 3 WAT with rimsulfuron.

Table 8. Injury, height and dry weight of four tomato cultivars by rimsulfuron POST in the greenhouse [abcd].

Herbicide	Rate	Injury				Height				Dry weight			
		Agriset	Floradade	Mt. Spring	Sunbeam	Agriset	Floradade	Mt. Spring	Sunbeam	Agriset	Floradade	Mt. Spring	Sunbeam
	g/ha	%				cm				g/plant			
Rimsulfuron	17	4 b	9 ab	7 b	10 a	19.4 a[c]	20.0 a	19.4 b	20.5 a	2.78 a[c]	2.34 a	3.19 a	2.51 b
Rimsulfuron	26	7 a	7 b	10 a	9 a	20.1 a	21.3 a	22.1 a	20.4 a	2.54 a	2.43 a	2.57 b	2.44 b
Rimsulfuron	35	7 a	10 a	7 b	11 a	19.7 a	20.5 a	19.1 b	20.6 a	2.77 a	1.96 b	2.56 b	2.22 b
Untreated	0	0 c	0 c	0 c	0 b	19.9 a	20.7 a	19.8 b	17.8 b	2.66 a	2.40 a	2.35 b	2.93 a

[a] All treatments contained 0.25 % v/v nonionic surfactant.
[b] Means are the average of six repetitions with three replications.
[c] Means within columns followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.
[d] Tomato injury, height and dry weight was recorded 3 WAT with rimsulfuron.

Chapter V

Weed Management in Transplanted Peppers (*Capsicum annum*) with Clomazone, Rimsulfuron, and Trifluralin

Abstract. In 1993, 1994, and 1995, PPI clomazone at 390 g ai/ha, POST rimsulfuron at 35 g ai/ha, and PPI trifluralin at 560 g ai/ha were evaluated for weed control in transplanted 'Keystone RG3' bell pepper. Common lambsquarters and jimsonweed control was highest by clomazone treatments; common ragweed control was low by all three herbicides. Keystone RG3 in the field and greenhouse and 'Camelot', 'Jupiter' and 'Memphis' in the greenhouse did not recover from injury by POST rimsulfuron and had lower height and dry weight than untreated controls. In the greenhouse, black nightshade control was below 23% and jimsonweed control was below 49% by 17 to 35 g/ha rimsulfuron POST.

INTRODUCTION

Bell pepper is an economically important vegetable crop in the northeastern United States. Pepper is a poor competitor with weeds and the lack of weed control may result in yield reduction (Franket al. 1988; Franket al. 1991). Weed control is essential for production of good quality and high yielding fruit. Presence of weeds can affect both quality and yield of pepper by competing for water, essential nutrients, and by serving as a reservoir to insect pests and diseases of pepper (Franket al. 1988; Frank et al. 1991). Currently, there are a limited number of herbicides registered for use in pepper (Ackley et al. 1992; Baltajar et al. 1984; Eshel et al. 1973; Lanini and LeStrange 1991; Lanini and LeStrange 1991, Schroeder 1992). This lack of herbicides often results in, depending upon the weed species present, incomplete weed control. Trifluralin is registered for use in many crops, including pepper, and is primarily effective for control of annual grasses (Ackley et al. 1992). Clomazone is registered for use in cotton (*Gossypium hirsutum* L.), soybean [*Glycine max* (L.) Merr.], pepper (*Capsicum annum* L.), tobacco (*Nicotiana tobacum* L.), and succulent pea (*Pisum sativum* L.) for control of annual grasses and certain broadleaf weeds (Jordan et al. 1993; Westberg et al. 1989)[1]. In initial studies, clomazone was the only herbicide in transplanted peppers which controlled certain broadleaf weeds (Ackley et al. 1992). However, clomazone must be incorporated to reduce off-site movement and residual activity may affect sensitive crops planted after pepper harvest[1].

Rimsulfuron is a sulfonylurea herbicide that has been evaluated for broadleaf and grass weed control in potato (*Solanum tuberosum* L.) (Blackshaw et al. 1995; Eberlein et al. 1994) and tomato (*Lycopersicum esculentum* L.) (Bewick et al. 1995). It controls many broadleaf and some grass species and has selectivity in these solanaceous crops, although some tomato cultivars may be injured (Bewick et al. 1995). Solanaceous weeds including jimsonweed and other nightshade species have been controlled by rimsulfuron treatments (Bewick et al. 1995; Eberlein et al. 1994). These studies were conducted to evaluate clomazone and rimsulfuron for weed control in transplanted bell peppers. In the

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[1]Command herbicide label. FMC Corp. 1735 Market St. Philadelphia, PA 19103.

greenhouse, pepper cultivar, black nightshade, and jimsonweed response to rimsulfuron was investigated.

MATERIALS AND METHODS

Field studies. Studies were conducted in 1993, 1994, and 1995 at Painter, VA on a State sandy loam (Typic Hapludults) with 1% organic matter and a pH of 5.8 to 6.0. A conventional seedbed was prepared by moldboard plowing and tandem discing while a field cultivator was used for herbicide incorporation. Keystone RG3 pepper plants were transplanted in the field on June 15, 1993, May 10, 1994, and May 23, 1995, with a commercial one-row transplanter. Plots consisted of two rows of pepper and were 2.5 by 7.5 m, with an untreated buffer row between plots. Pepper plants were 30 cm apart in the row and rows were spaced 45 cm apart.

Herbicides were applied PPI and POST. Treatments applied PPI included trifluralin at 560 g ai /ha, clomazone at 390 g ai/ha, and the combination. Additional treatments were rimsulfuron POST at 35 g ai/ha at 10 DAP[2] and rimsulfuron POST at 10 DAP following PPI applications of trifluralin and clomazone. Herbicides were applied with a tractor-mounted plot sprayer which delivered 190 L/ha with a pressure of 220 kPa through flat

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[2]Abbreviations: DAP, Days after transplanting.

fan tips[3]. Nonionic surfactant[4] was included with the spray mix at a concentration of 0.25%(v/v) in all POST applications. Common lambsquarters and common ragweed were present at 15 to 20 plants/m^2. Jimsonweed was uniformly distributed at of 3 to 5 plants/m^2. Pepper fruit were not harvested from these studies because high mid-summer temperatures, herbicide injury, weed competition, and uncontrolled insect pests resulted in low estimated fruit yields that would likely not differ between herbicide treatments.

Moisture was adequate to produce a good stand of pepper and weeds. In 1993, 7 cm of rain was received during the growing season with 0 and 3 cm received during the 10 DAT with PPI and POST herbicides respectively. In 1994, 17 cm of rain was received during the growing season with 1.8 and 3 cm received during the 10 DAT with PPI and POST herbicides, respectively. In 1995, 10 cm of rain was received during the growing season with 1.7 and 1.3 cm received during the 10 DAT with PPI and POST herbicides, respectively.

Visual estimates of percent crop injury and weed control were recorded on a scale of 0 to 100%, where 0% = no injury or weed control and 100% = complete plant death. Pepper injury was evaluated visually at 5, and 3 WAT for PPI and POST herbicides, respectively. Weed control was evaluated 10, and 6 WAT for PPI and POST herbicides, respectively, which represents end of season control.

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[3]Teejet 8003 flat fan spray tips, Spraying Systems Co., North Ave. Wheaton, IL. 60188.

[4]X-77 Spreader, Loveland Industries Inc. P.O. Box 1289, Greely, CO 80632-1289. Nonionic surfactant with alkylarylpolyoxyethylene as the principal functioning agent.

Greenhouse studies. Studies were conducted in June and Sept. 1994 and July 1995 to evaluate the effect of POST rimsulfuron on four pepper varieties, jimsonweed (*Datura stramonium* L.) and black nightshade (*Solanum nigrum* L.). Pepper, jimsonweed and black nightshade seed was planted 1 cm deep in 0.5-L cups in a mixture of sandy loam soil, sand, and peat (23:13:1). The pH of the final mix was 5.8. Plants were grown under natural sunlight and were watered as needed. Pepper plants were thinned 2 wk after planting to one plant per cup and grown to the 6- to 8-leaf stage (18- to 20-cm tall), which is commonly the growth stage for transplanting. After jimsonweed and black nightshade species emerged, plants were thinned to 1 and 5 plants per cup, respectively, and grown to the 3- to 5-leaf stage. Cups were then removed from the greenhouse, placed on the ground, and rimsulfuron was applied at 17, 23, and 35 g/ha using a backpack sprayer which delivered 190 L/ha with a pressure of 220 kPa through flat fan tips[6]. Nonionic surfactant[7] was included with the spray mix at a concentration of 0.25% (v/v). Cups were returned to the greenhouse. At 3 WAT, visual estimates of pepper injury, jimsonweed, and black nightshade control and height of surviving plants was recorded. Plants were harvested, dried to constant weight, and weighed.

Data analysis. Field and greenhouse studies were conducted using a randomized complete block design with 4 replications in the field and 3 replications in the greenhouse: greenhouse studies were repeated. In the field studies, a significant (0.05) treatment by year interaction for weed control occurred. The differential response of weed species to herbicides between years resulted from differences in rainfall and the associated vigor of the weeds. No treatment by repetition interaction occurred for any dependent variable in the greenhouse studies and data were combined prior to analysis. Data were analyzed statistically by analysis of variance and means were separated using Duncan's new multiple range test at the 0.05 significance level.

RESULTS AND DISCUSSION

Field studies. Control of common lambsquarters, common ragweed and jimsonweed was better by clomazone than by trifluralin except in 1993 when common lambsquarters and common ragweed control was similar by both herbicides (Table 1). Common ragweed control would likely be improved by higher rates of clomazone and pepper would not be injured[5]. Jimsonweed control by clomazone and clomazone plus trifluralin was 82 to 95% during the three year of the study; no other herbicide is registered for control of jimsonweed in pepper. Pepper was not injured by trifluralin and clomazone treatments.

Rimsulfuron POST did not adequately control broadleaf weeds unless trifluralin or clomazone was applied PPI to the same plot. Where rimsulfuron was applied sequentially to PPI trifluralin or clomazone, control of individual species was occasionally higher than by one or both of the components alone.

Visible injury to pepper from POST rimsulfuron treatments was 19 to 47% (Table 1).

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[5]Majek, B. A. 1993. Personal communication. Dept of Crop Science, Rutgers University, Bridgeton, NJ 08302.

Pepper injury from rimsulfuron was present as a general leaf chlorosis and plants were more compact than those in the untreated controls or trifluralin- or clomazone-treated plots. The compact appearance resulted from a lack of internode elongation. This injury was more extensive than that reported in potato (Ackley et al. 1996b; Blackshaw et al. 1995; Eberlein et al. 1994) and tomato (Bewick et al. 1995) and unlike those crops, pepper did not recover by 10 WAT when percent weed control were recorded.

Greenhouse studies. In the greenhouse POST rimsulfuron generally gave low black nightshade and jimsonweed control, and had little effect on height or dry weight of both weeds (Table 2). Black nightshade control was 14 to 22% and jimsonweed control was 30 to 48% from 17 to 35 g/ha rimsulfuron. Height of black nightshade was not reduced by rimsulfuron and jimsonweed height was not reduced by rimsulfuron except at 26 g/ha. Dry weight of black nightshade was reduced by 35 g/ha rimsulfuron but dry weight of jimsonweed was not affected by any rimsulfuron rate.

Rimsulfuron injured all four pepper cultivars (Table 3). Pepper did not recover from rimsulfuron injury during the 3 WAT that the study was maintained. Pepper height and dry weight were reduced by 17 to 35 g/ha rimsulfuron and were in agreement with the field studies where peppers also failed to recover from rimsulfuron injury.

In summary, in field studies common lambsquarters and jimsonweed control by PPI clomazone at 390 g/ha and trifluralin at 560 g/ha was generally high but this clomazone rate was not sufficient to control common ragweed. Transplanted peppers were not injured by clomazone treatments and this herbicide should be useful for control of susceptible broadleaf weeds in peppers. Low jimsonweed control in the field and greenhouse by rimsulfuron agrees with previous studies which report higher jimsonweed control by combinations of rimsulfuron with metribuzin (Ackley et al. 1996a; .1996b). Black nightshade control in the greenhouse by rimsulfuron was lower than control of other nightshade species in field studies (Bewick et al. 1995; Eberlein et al. 1994) but was similar to control of jimsonweed in these studies. These results confirm that not all solanaceous weeds can be controlled by rimsulfuron. Further, based on these field and greenhouse studies 17 to 35 g/ha rimsulfuron is not tolerated sufficiently by bell peppers to permit use in this crop.

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Table 9. Pepper injury, common lambsquarters, common ragweed and jimsonweed control with rimsulfuron, clomazone, and trifluralin in 1993 1994, and 1995[a,b] .

			Pepper Injury			Common lambsquarters			Common ragweed			Jimsonweed		
Herbicide[b]	Rate	Timing	1993	1994	1995	1993	1994	1995	1993	1994	1995	1993	1994	1995
	g/ha		%											
Trifluralin	560	PPI	0 d[c]	0 c	0 c	86 a	68 b	53 b	13 c	50 b	10 d	21 c	50 b	17 c
Clomazone	390	PPI	0 d	0 d	0 c	90 a	77 a	95 a	13 c	78 a	42 c	90 a	82 a	95 a
Trifluralin+[d]	560+	PPI	1 d	0 d	0 c	89 a	78 a	95 a	10 c	80 a	58 abc	91 a	82 a	93 a
clomazone	390	PPI												
Rimsulfuron	35	POST	19 d	-	47 a	41 b	-	88 a	54 ab	-	50 bc	48 b	-	42 b
Trifluralin fb[e]	560 fb	PPI	29 b	30 a	45 a	85 a	75 a	93 a	51 ab	78 a	63 abc	53 b	68 a	47 b
rimsulfuron	35	POST												
Clomazone fb	390 fb	PPI	38 a	23 ab	30 ab	81 a	77 a	95 a	66 a	77 a	73 a	85 a	78 a	93 a
rimsulfuron	35	POST												
Untreated	0		0 d	0 d	0 c	0 c	0 c	0 c	0 d	0 c	0 d	0 d	0 c	0 d

[a]All POST treatments contained 0.25 % v/v nonionicsurfactant.
[b]Pepper injury was recorded 21 DAT and estimates of weed control were recorded 10 and 6 WAT with PPI and POST herbicides respectively.
[c]Means within columns followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.
[d]Standard treatment in Virginia.
[e]fb, followed by.

Table 10. Control, height and dry weight of jimsonweed and black nightshade by POST rimsulfuron in the greenhouse[a,b,c,d].

		Black nightshade			Jimsonweed		
Herbicide	Rate	Control	Height	Dry weight	Control	Height	Dry weight
	g/ha	%	cm	g	%	cm	g
Rimsulfuron	17	14 b	22.9 ab	2.52 ab	30 b	10.5 ab	1.98 a
Rimsulfuron	26	12 b	23.8 a	2.50 ab	31 b	8.8 b	3.0 a
Rimsulfuron	35	22 a	20.8 b	2.06 b	48 a	9.6 ab	2.6 a
Check	0	0 c	22.8 ab	3.22 a	0 c	13.0 a	2.4 a

[a] All treatments contained 0.25 % v/v nonionic surfactant.
[b] Means are the average of six repetitions with three replications.
[c] Means within columns followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.
[d] Black nightshade and jimsonweed control height and dry weight were recorded 3 WAT with rimsulfuron.

Table 11. Injury, height and dry weight of four bell pepper varieties by POST rimsulfuron in the greenhouse[a,b,c,d].

		Injury				Height				Dry weight			
Herbicide	Rate	Camelot	Jupiter	Keystone	Memphis	Camelot	Jupiter	Keystone	Memphis	Camelot	Jupiter	Keystone	Memphis
	g/ha	%				cm				g			
Rimsulfuron	17	56 b	50 b	44 b	51 a	9.0 b[c]	7.5 b	7.9 b	7.8 b	1.58 b[c]	1.05 b	1.49 c	2.06 b
Rimsulfuron	23	60 a	53 ab	51 ab	53 a	8.6 b	7.2 b	7.0 b	8.1 b	1.52 b	1.14 b	1.95 b	2.16 b
Rimsulfuron	35	62 a	60 a	57 a	55 a	7.6 b	6.4 c	6.8 b	7.4 b	1.34 b	1.09 b	1.70 c	1.56 c
Untreated	0	0 b	0 c	0 c	0 b	12.6 a	11.0 a	11.2 a	11.8 a	2.80 a	1.89 a	2.54 a	2.96 a

[a] All treatments contained 0.25 % v/v nonionic surfactant.

[b] Means are the average of six repetitions with three replications.

[c] Means within columns followed by the same letter do not differ at the 0.05 significance level by Duncan's new multiple range test.

[d] Black nightshade and jimsonweed control height and dry weight were recorded 3 WAT with rimsulfuron.

Absorption, Translocation, and Metabolism of Rimsulfuron in Black Nightshade (*Solanum nigrum*), Eastern Black Nightshade (*Solanum ptycanthum*), and Hairy Nightshade (*Solanum sarrachoides*).

Abstract. The absorption, translocation, and metabolism of rimsulfuron was investigated in three solanaceous weed species which were differentially sensitive to this herbicide. Four- to 6-leaf nightshade seedlings were exposed to foliar-applied ^{14}C-labeled rimsulfuron for 3, 6, 24, and 48 h. Rimsulfuron absorption did not differ between black nightshade and eastern black nightshade while less labeled herbicide was absorbed by hairy nightshade in 6 and 24 h. Translocation was rapid by all three nightshade species. Black and eastern black nightshade translocated up to 50% of the absorbed radioactivity out of the treated leaf with 40 to 50% of it moving to the actively growing regions of the plant. In hairy nightshade, an average 40% of the labeled herbicide was moved out of the treated leaf and less than 30% of the translocated herbicide moved basipetally. Metabolism of ^{14}C-rimsulfuron was also rapid. Most major metabolites were apparent at 24 and 48 h however, there were no differences in metabolite composition between the three nightshade species. Differential resistance to rimsulfuron between these three species is not due to one physiological mechanism. Differential early uptake, translocation and subtle differences in metabolism all account for differences in sensitivity in these nightshade species.

INTRODUCTION

Rimsulfuron, a sulfonylurea herbicide, controls numerous weed species and is under development for use in potato (*Solanum tuberosum*) and tomato (*Lycopersicum esculentum*) (Ackley et al.1994; 1996a; 1996b; Bewick et al. 1995; Eberlein et al. 1994). The mode of action of the sulfonylurea herbicides is the inhibition of acetolactate synthase, a key enzyme in the biosynthetic pathway of branched-chain amino acids (Hawkes et al. 1989)

Potato and tomato are economically important crops in Virginia and in many areas of the US. Weed control is essential to obtain optimum harvest efficiency and produce high crop yields and quality . Since a limited number of herbicides are labeled for potato and tomato, control of broadleaf weeds in these crops is difficult to achieve (Ackley et al 1994; 1996a; 1996b).

Herbicide efficacy is generally influenced by absorption, translocation, and/or metabolism since these processes affect delivery of the herbicide to the site of action (Dodge 1989). Although absorption and translocation of sulfonylurea herbicides occur in both tolerant and sensitive plant species, selectivity is most often based on differential metabolism (Hawkes et al. 1989; Brown et al. 1990; 1991). The mechanisms of tolerance and sensitivity to rimsulfuron have not been thoroughly investigated.

The nightshades are a troublesome family of weed species associated with the production of many crops (McGiffen et al 1992: Perez and Matsiunas, 1990; Weaver et al. 1987). The nightshade species selected for this experiment represent a range in tolerance to rimsulfuron. Researchers have found that in field studies hairy nightshade is sensitive to recommended applications of rimsulfuron (Eberlein et al. 1994), black nightshade is tolerant (Ackley et al. 1995), but response of eastern black nightshade is largely unreported. Objectives of this research were to evaluate absorption, translocation, and metabolic breakdown of rimsulfuron when applied foliarly to these three nightshade species. Results should assist in explanation of differential sensitivity to the selected plant species.

MATERIALS AND METHODS

Radiolabelled chemicals. Formulated, technical, and radiolabelled samples of rimsulfuron were provided by the DuPont Agricultural Chemical Company. The specific activity of [pyrimidine-2-^{14}C]-rimsulfuron was 1302 kBq/mg, and the radiochemical purity was 98%.

Absorption and translocation. Black nightshade, eastern black nightshade , and hairy nightshade seed were planted in a commercial potting medium[1] in 0.5 L styrofoam cups. The seed was germinated and grown under natural sunlight supplemented with metal halide lamps with a photoperiod of at least 14 h, and were watered as needed. After

[1]Metro Mix 360, the Wetsel Seed Co. Inc., 1345 Diamond Springs Rd., Virginia Beach, VA 23455.

emergence, plants were thinned to one plant per cup, and a complete fertilizer[2] was applied weekly. Commercially formulated rimsulfuron was applied at 17 g ai/ha. Rimsulfuron was applied with a greenhouse bench sprayer calibrated to deliver 234 L/ha of water at 221 kPa pressure through a flat fan spray tip[3] and included a non-ionic surfactant[4] at 0.25% v/v. Application of radiolabeled rimsulfuron was by the method described by Wilcut et al (1989). Immediately following application of the commercially formulated herbicides, 10 :l of ^{14}C-labeled-rimsulfuron was applied as a circular swipe on the third youngest leaf of each plant. The 10 :l solution contained approximately 2.63 kBq of ^{14}C-rimsulfuron in EtOH:H_20 (80/20, v/v) with a non-ionic surfactant[5] at 0.25% v/v.

Plants were removed from the soil 3, 6, 24, and 48 h after application (HAA)[5] of the radiolabeled herbicide, and the roots were rinsed and blotted dry. The plants were then divided into treated leaf, shoot above the treated leaf, shoot below the treated leaf, and roots. The treated leaves were rinsed in 20 ml of MeOH:H_20 (1:9, v/v) for 30 s to remove unabsorbed radioactivity. A 1 ml aliquot of the leaf rinse was added to 15 ml of

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[2]Peters 20-20-20 general purpose fertilizer, The Wetsel Seed Co. Inc., 1345 DiamondSprings Rd., Virginia Beach, VA 23455.

[3]Teejet 8001E flat fan spray tip, Spraying Systems Co. North Ave. Wheaton, IL 60188.

[4]X-77 Spreader, Loveland Industries Inc., P.O. Box 1289, Greely, CO 80632-1289. Nonionic surfactant with alkyarylpolyoxyethylene as the principal functioning agent.

[5]Abbreviations: HAA, Hours after application; LSS, Liquid scintillation spectrometry; TLC, Thin layer chromatography; Rf, Ratio of front.

scintillation fluid and radioactivity was quantified with liquid scintillation spectrometry[6] (LSS)[6]. Herbicide absorption was calculated by subtracting the amount of ^{14}C recovered in the leaf rinse from the amount applied. The plant parts were weighed and dried for at least 48 h at 50 C and weighed again. Translocation of ^{14}C out of the treated leaf was measured by combusting the parts in a biological sample oxidizer[7] and counting the radioactivity, trapped as $^{14}C0_2$, by LSS. Radioactivity in plant parts other than the treated leaf was totaled and translocation out of the treated leaf was expressed as a percent of absorbed ^{14}C.

Metabolism studies. Plants were grown and treated with commercially formulated and radiolabeled herbicides as described for absorption and translocation studies. Since little radioactivity was translocated to the roots, only shoots were harvested at 3, 24 and 48 HAA of the radiolabeled rimsulfuron, separated into parts, and the treated leaf rinsed as described earlier. Since similar amounts of radioactivity were present in the treated leaf, shoot above the treated leaf, and shoot below the treated leaf, only the treated leaf was extracted for use in metabolism analysis. Metabolite and parent herbicide extraction was done with minor modifications of Schneiders et al (1993). Treated leaves were frozen with liquid nitrogen, pulverized with morter and pestle and homogenized in 10 ml of MeOH:H_20 (80:20, v/v). The homogenates were centrifuged at 2,000 x *g* for 30 min and

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[6]LS-5800TA Model, Beckman Instrument Co., Fullerton, CA 92634.

[7]B0306 Biological Sample Oxidizer, Packard Instrument Co. Downer Grove, IL. 60515.

the supernatant was saved. The solid portion was extracted two more times with 10 ml of MeOH:H_2O (80:20, v/v). The combined supernatants were concentrated to 0.5 ml by evaporation. The concentrated supernatant was filtered through 2 :m nylon disposable filters[8]. Thirty :l of standard ^{14}C-rimsulfuron and 30 :l of each sample were loaded on silica gel thin layer chromatography (TLC)[6] plates[9]. Plates were developed in chloroform:methanol: acetate (190:10:2, v/v/v) solvent system.

Developed TLC plates were exposed to X-ray film[10] for 21 d, and the film was developed to reveal position of radioactive bands on the plates. The radioactive bands were then scraped from the plate and the amount of radioactivity was determined by LSS. Metabolites were separated by their RF[6] values and the radioactivity recovered during the TLC analysis.

Statistical analysis. Absorption, translocation, and metabolism studies were completely randomized designs with two replications of each treatment. Absorption and translocation data are from three studies, and metabolism data are from two studies. Data from separate studies were combined and analyzed statistically by ANOVA and means were separated using Fisher's LSD at the 0.05 significance level.

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[8]Acrodisc disposable filters, Gelman Sciences, Ann Arbor, MI 48106.

[9]Silica Gel 60 F_{254} precoated TLC plates, EM Science, 480 Democrat Rd., Gibbstown, NJ 08027.

[10]Kodak X-OMAT AR film, Eastman Kodak Co., Rochester, NY 14650.

RESULTS AND DISCUSSION

Absorption and translocation. Hairy nightshade absorbed less rimsulfuron than black and eastern black nightshade at 6 and 24 HAA, however there were no differences at 3 and 48 HAA (Table 1). Rimsulfuron was absorbed rapidly with 40% of the applied ^{14}C absorbed by hairy nightshade and an average of 50% for black and eastern black nightshade at 3 HAA of the radiolabeled rimsulfuron. Rimsulfuron absorption continued to increase with time to 54% for hairy nightshade and 74% for black and eastern black nightshade of the applied ^{14}C at 48 HAA. Absorption for black and eastern black nightshade were similar at all harvest timings.

Translocation of rimsulfuron out of the treated leaf was variable and did not increase from 3 to 48 HAA (Table 2). ^{14}C in the treated leaf averaged 62% for hairy nightshade and was similar for black and eastern black nightshade where an average of 38% of the applied ^{14}C remained from 3 to 48 HAA. Hairy nightshade retained more of the applied rimsulfuron in the treated leaf than eastern black nightshade at 3 and 6 HAA, however similar amounts remained at 24 and 48 HAA in all three nightshade species. Translocation was symplastic however, movement to the above the treated leaf portion of the plant was prevalent. Similar quantities of ^{14}C-rimsulfuron were recovered in the above the treated leaf portion of the plant for black and eastern black nightshade at 3, 6, and 48 HAA. Hairy nightshade translocated less herbicide upward than black or eastern black at 3, 6, and 48 HAA. Translocation of ^{14}C-rimsulfuron upward for eastern black nightshade did not increase over time. The low amount of 14% ^{14}C-rimsulfuron in the above the treated leaf portion of the plant for eastern black nightshade at 24 HAA is due to variability and may not be real. In light of this outlier, the differences are more apparent between hairy nightshade and the other nightshade species black and eastern black, where less radioactivity was translocated above the treated leaf in hairy nightshade then in black and eastern black nightshade. Translocation in the symplast accounts for less than an average of 28% of the total amount moved out of the treated leaf in all three nightshade species. There were no differences in the amount translocated to the region below the treated leaf between the nightshade species at 3 to 48 HAA. Less than 3% of the recovered radioactivity was located in the roots and there were no differences among the means (data not presented).

Metabolism studies. Since the majority of the radioactivity was found in the treated leaf, metabolism of ^{14}C-rimsulfuron represents only that radioactivity found in the treated leaf in all three nightshade species. Metabolites of rimsulfuron were not identified.

Standard unmetabolized rimsulfuron had an Rf value of 0.56 in the solvent system used. Generally, metabolism increased from 3 to 24 HAA but unexplainably decreased from 24 to 48 HAA. In these studies, two major metabolites of rimsulfuron were observed with Rf values of 0.66 and 0.78, and two minor metabolites were found to have Rf values of 0.26 and 0.91. According to Schneiders et al. (1995) the metabolites located at Rf value of 0.26 may correspond with the pyridine sulfonamide of rimsulfuron, while the metabolites with an Rf value of 0.66 and 0.78 may correspond with the pyrimidine urea and the pyrimidine amine of rimsulfuron. These metabolites were found in other plant species;

however, since rimsulfuron may be metabolized similarly in different plants the same metabolites may be present in these nightshade species. There was little difference in metabolite composition between the species however, differences were variable and were not consistent over time. Based on our research it is likely that metabolism of rimsulfuron to inactive metabolites is not a major reason for differences of control of the three nightshades species at the greenhouse or field level.

In summary, in previously conducted greenhouse studies, black and eastern black nightshade were more tolerant to rimsulfuron than hairy nightshade. In these studies, hairy nightshade absorbs less, translocates less out of the treated leaf and moves less rimsulfuron above the treated leaf than black and eastern black nightshade. Although there are differences, it is likely that absorption and translocation are not the main reasons for control differences of these nightshade species. Metabolism and metabolite composition appear similar for black, eastern black and hairy nightshade. Therefore, metabolism is likely not a cause for control differences. These studies have shown little reason for differential control of black, eastern black, and hairy nightshade. However, according to Robinson et al. (1997), slight differences in absorption, translocation, and metabolism were responsible for differences in activty of rimsulfuron at the field level to tomato and eastern black nightshade. According to Manley (1996) there is an altered acetolactate synthase enzyme which is tolerant to the imidazolinone herbicides in smooth pigweed (*Amaranthus hybridus* L.). While the resistant pigweed species was selected for by use of imazaquin {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-

yl]-3-quinolinecarboxylic acid} for a period of more than 5 yr, it is possible that the nightshade species may differ in acetolactate synthase, which differs in response to rimsulfuron.

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Table 12. Absorption of ^{14}C-rimsulfuron applied to black, eastern black, and hairy nightshade.[ab].

	3 HAA	6 HAA	24 HAA	48 HAA
Herbicide	% of appl	% of appl	% of appl	% of appl
Black nightshade	52 a	63 a	73 a	74 a
Eastern black nightshade	52 a	68 a	72 a	74 a
Hairy nightshade	40 a	38 b	56 b	54 a

[a] All treatments contained 0.25 % v/v nonionic surfactant.
[b] Means are the average of two studies.
[c] Means followed by the same letter across do not differ at the 0.05 significance level by Duncan's new multiple range test.

Table 13. Translocation of ^{14}C-rimsulfuron applied to black, eastern black, and hairy nightshade.[ab]

Species	Treated leaf	Above treated leaf	Below treated leaf
	% of appl	%	%
	3 hours after application		
Black	49 ab	32 a	19 a
Hairy	65 a	18 b	17 a
Eastern	34 b	44 a	23 a
	6 hours after application		
Black	42 ab	42 a	16 a
Hairy	60 a	20 b	20 a
Eastern	24 b	51 a	24 a
	24 hour after application		
Black	29 b	43 a	28 a
Hairy	69 a	29 a	17 a
Eastern	51 ab	14 b	19 a
	48 hours after application		
Black	37 a	39 a	23 a
Hairy	55 a	21 b	24 a
Eastern	41 a	45 a	14 a

[a] All treatments contained 0.25 % v/v nonionic surfactant.
[b] Means are the average of two studies.
[c] Means followed by the same letter within columns do not differ at the 0.05 significance level by Duncan's new multiple range test.

Table 14. Percent of recovered herbicide from Black, Hairy, and Eastern Black nightshade treated with ^{14}C-Rimsulfuron and harvested after application.[abc]

	Top of plate		Metabolites		*Bottom of plate*	
Species	0.91	0.78	0.66	0.56	0.26	0
			3 Hours After Application			
Black	3 a[d]	18 a	16 b	56 b	3 a	4 a
Hairy	3 a	11 b	19 b	57 b	3 a	5 a
Eastern	3 a	12 b	26 a	50 c	3 a	6 a
			24 Hours After Application			
Black	2 a	15 a	26 a	44 b	4 a	8 b
Hairy	2 a	9 b	31 a	48 b	3 ab	6 b
Eastern	2 a	12 a	24 a	43 b	5 a	13 a
			48 Hours After Application			
Black	13 a	4 ab	13 ab	62 b	3 b	6 a
Hairy	13 a	5 ab	15 a	61 b	2 b	4 ab
Eastern	13 a	8 a	13 ab	49 c	8 a	9 a

[a] All treatments contained 0.25 % v/v nonionic surfactant.
[b] Means are the average of two studies.
[c] The Parent rimsulfuron migrated mainly to an Rf value of 0.56.
[d] Means followed by the same letter within columns do not differ at the 0.05 significance level by Duncan's new multiple range test

Chapter VII

SUMMARY

In summary, rimsulfuron improved weed control by metolachlor, metolachlor plus linuron, and metolachlor plus metribuzin in potato. These benefits were dependent on weed species, application timing, and rainfall. Potato can tolerate two POST applications of 35g/ha rimsulfuron plus 280 g/ha metribuzin without reducing tuber yield. However, single POST applications of 35g/ha rimsulfuron plus 280 g/ha metribuzin and sequential applications of 17 g/ha rimsulfuron plus 140 g/ha metribuzin controlled weeds in these studies. Potato recovered rapidly from visible injury by combinations of organophosphate insecticides with rimsulfuron plus metribuzin and potato tuber yields were similar from all treatments. These studies confirm that rimsulfuron can be a useful component of weed management programs in Superior potato.

Good to excellent yellow nutsedge control is obtained from halosulfuron and chlorimuron in the greenhouse and these herbicides are useful in corn and soybean, respectively. Imazethapyr was more active in the greenhouse than in the field as reflected by yellow nutsedge control, height, dry weight and dry weight of regrowth which may result from the continuous high soil moisture in the greenhouse (Ackley et al 1994; Richburg et al. 1993). Although control was lower, rimsulfuron and pyrithiobac should improve yellow nutsedge management in potato, tomato, and cotton, respectively, since crop competition, tillage, and herbicides such as metolachlor, [*2*-chloro-*N*-(2-ethyl-6-methyl phenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] PRE also provide partial control in these crops. Since yellow nutsedge is controlled by soil applications of some ALS-inhibitors (Nandihalli and Benedixen 1989; Reddy and Benedixen 1989; Richburg et al. 1993; Vencill et al. 1995), it is likely that root uptake may contribute to yellow nutsedge control by POST applications that are followed by adequate rainfall or irrigation. This would explain the good initial control and regrowth control by chlorimuron, Halosulfuron, and imazethapyr under the high soil moisture in the greenhouse.

In tomato field studies common lambsquarters control by POST rimsulfuron and metribuzin treatments was generally high, but common ragweed control was highest from rimsulfuron plus metribuzin. No treatment consistently controlled jimsonweed or goosegrass. Greenhouse studies support reports from field studies (Ackley et al. 1995; 1996a) that rimsulfuron will control giant foxtail and large crabgrass but not goosegrass. Field and greenhouse studies confirmed that the tomato cultivars Agriset and Mt. Spring were tolerant to rimsulfuron; however, dry weights of Floradade and Sunbeam were reduced by rimsulfuron. In these studies, values for percent tomato injury and weed control were often statistically different but these differences between rimsulfuron rates were small and may be viewed as having little practical significance. These studies substantiate that rimsulfuron can be a useful component of weed management programs in tomato. Additional field studies should investigate the initial response of additional tomato cultivars to rimsulfuron and determine if fruit yield or maturity is affected by rimsulfuron.

In pepper field studies common lambsquarters and jimsonweed control by PPI clomazone at 390 g/ha and trifluralin at 560 g/ha was generally high but this clomazone rate was not sufficient to control common ragweed. Transplanted pepper was not injured by clomazone treatments and this herbicide should be useful for control of susceptible broadleaf weeds in pepper. Low jimsonweed control in the field and greenhouse by rimsulfuron agrees with previous studies which report higher jimsonweed control by combinations of rimsulfuron with metribuzin (Ackley et al.1996a; 1996b). Black nightshade control in the greenhouse by rimsulfuron was lower than control of other nightshade species in field studies (Bewick et al.. 1995; Eberlein et al. 1994) but was similar to control of jimsonweed in these studies. These results confirm that not all solanaceous weeds can be controlled by rimsulfuron. Further, based on these field and greenhouse studies 17 to 35 g/ha rimsulfuron is not tolerated sufficiently by bell pepper to permit use in this crop.

In previously conducted studies, black and eastern black nightshade were more tolerant to rimsulfuron than hairy nightshade and may be due to absorption, translocation and/or metabolism. In these studies, hairy nightshade absorbs less, translocates less out of the treated leaf and moves less rimsulfuron above the treated leaf than black and eastern black nightshade. Although there are differences, it is likely that absorption and translocation are not the main reasons for control differences of these nightshade species. Metabolism and metabolite composition appear similar for black, eastern black and hairy nightshade. Therefore, metabolism is likely not a cause for control differences. These studies have shown little reason for differential control of black, eastern black, and hairy nightshade.

According to Manley (1996) there is an altered acetolactate synthase enzyme which is tolerant to the imidazolinone herbicides in smooth pigweed (*Amaranthus hybridus* L.). While the resistant pigweed species was selected for by use of imazaquin {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic acid} for a period of more than 5 yr, it is possible that the nightshade species may differ in acetolactate synthase composition which range in tolerance to rimsulfuron.

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VITA

John Andrew Ackley was born to John J. and Barbara C. Ackley on July 8, 1968 in Elmer NJ. He was raised in a family that owned Massey Ferguson dealership where he was first employed as a farm machinery mechanic. In the summers of 1989 and 1990 he held a position as a summer intern with the Rhone Poulenc Agricultural Company where his responsibilities included pesticide research. He received his Bachelor of Science degree, in Agribusiness from Delaware Valley College of Science and Agriculture in 1990. He received his Master of Science degree, majoring in Weed Science from Virginia Polytechnic Institute and State University in 1994 under the guidance of Dr. Henry P. Wilson.

John Andrew Ackley