CHAPTER 3.0

EVALUATION OF EFFECTS OF HERBICIDE COMBINATIONS ON WEED CONTROL AND CROP TOLERANCE IN SETHOXYDIM-TOLERANT CORN (ZEA MAYS)

3.1 ABSTRACT

Field experiments were conducted in 1996 and 1997 to evaluate the efficacy of sethoxydim combinations with broadleaf herbicides when used on sethoxydim-tolerant corn. The specific objectives of this research were: (1) to evaluate sethoxydim-based herbicide programs for the control of annual grass and broadleaf weeds; (2) and to evaluate crop response to these treatments. Experimental treatments included broadcast applications of sethoxydim alone and in combination with atrazine plus bentazon, dicamba, 2,4-D amine, atrazine plus dicamba, bromoxynil, nicosulfuron, primisulfuron, halosulfuron, primisulfuron plus prosulfuron, flumiclorac, pyridate, and bentazon. Combinations of sethoxydim with broadleaf herbicides generally provided broad-spectrum control of annual broadleaf species including redroot pigweed, common lambsquarters, ivyleaf morningglory, jimsonweed, and prickly sida. Antagonistic effects of broadleaf herbicides on sethoxydim activity on large crabgrass and giant foxtail were observed. Nomenclature: atrazine, 6-chloro-N²-ethyl-N⁴-isopropyl-1,3,5-triazine-2,4-diamine; bentazon, 3-isopropyl-1H-2,1,3-benzothiaziazin-4(3H)-one 2,2-dioxide; bromoxynil, (phenol): 3,5-dibromo-4-hydroxybenzonitrile; dicamba, 3,6-Dichloro-2-methoxybenzoic
acid, or 3,6-dichloro-anisic acid; 2,4-D, 2,4-dichlorophenoxyacetic acid; flumiclorac, [2-
chloro-4-fluoro-5-(1,3,4,5,6,7-hexahydro-1,3dioxo-2H-isoindol-2-yl]phenoxy]acetic acid;
halosulfuron-methyl, methyl 5-[(4,6-dimethoxy-2-
pyrimidinyl)amino]carbonylaminosulfonfonyl]-3-chloro-1-methyl-1H-pyrazole-4-carboxylate;
nicosulfuron, 2-[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonfonyl]-N,N-
dimethyl-3-pyridinecarboxamide; primisulfuron, 2-[[[[4,6-bis(difluoromethoxy)-2-
pyrimidinyl]amino]carbonyl]amino]sulfonfonyl]benzoic acid; prosulfuron, 1-(4-methoxy-6-
 methyl-triazin-2-yl)-3-[2-(3,3,3-trifluoropropyl)-phenylsulfonfonyl]-urea; pyridate, O-(6-
chloro-3-phenyl-4-pyridazinyl) S-octyl carbonothioate; sethoxydim, 2-[1-
(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one; common
lambsquarter, Chenopodium album L., #1 CHEAL; giant foxtail, Setaria faberi Herrm., #
SETFA; ivyleaf morningglory, Ipomoea hederacea (L.) Jacq., #IPOHE; jimsonweed,
Datura stramonium L., #DATST; large crabgrass, Digitaria sanguinalis L., #DIGSA;
prickly sida, Sida spinosa L., #SIDSP; redroot pigweed, Amaranthus retroflexus L., #
AMARE; corn, Zea mays L.

Additional Index Words: Amaranthus retroflexus, AMARE, CHEAL, Chenopodium
album, DATST, Datura stamonium, Digitaria sanguinalis, DIGSA, Cyperus esculentus,
CYPES, IPOHE, Ipomoea hederacea, Sida spinosa, SIDSP.

Abbreviations: DAT, days after treatment.

“1 Letters following this symbol are a WSSA-approved computer code from Composite
List of Weeds, Revised 1989. Available from WSSA, 810 East 10th Street, Lawrence, KS
66044-8897.”
3.2 INTRODUCTION

In the last 15 years, several herbicides, members of the aryloxyphenoxy propionates and the cyclohexanedione families of chemistry, have been developed and registered. They provide selective, postemergence control of annual and perennial grass weeds in broadleaf crops (Ware 1994). These herbicides, which are collectively referred to as graminicides due to their specificity for grass weeds, act on the lipid synthesis pathway by inhibiting acetyl-CoA carboxylase (ACCase) (Ahrens 1996). Both classes of chemistry afford high activity against many grasses at economical rates, and can be applied to most broadleaf crops with little risk of injury (Meister 1996).

Recently, sethoxydim tolerant corn plants have been regenerated from tissue cultures selected for callus growth in the presence of sethoxydim (Parker et al. 1990a; Parker et al. 1990b). These plants exhibited a 40-fold increase in tolerance to sethoxydim relative to plants regenerated from tissue not exposed to the herbicide. The resistance originates from a nuclear mutation resulting in an altered form of the ACCase enzyme (Marshall et al. 1992). Sethoxydim applied at 0.88 kg/ha, approximately four times the field use rate, was non-injurious to the sethoxydim-resistant (SR) corn line in field studies (Dotray et al. 1993).

Potential benefits of developing herbicide tolerant crops include an increased margin of safety with respect to herbicide injury, reduced risk of crop damage from residual herbicides from rotational crops, and introduction of new herbicides for use on normally susceptible crops (Harrison 1992). Other potential advantages include the use of environmentally-sound herbicides, superior weed control for specific weed problems,
better or more options for herbicide use in minor acreage crops, more weed control options and greater flexibility in both timing and in varying cropping systems, and management tools for resistant weeds (Giaquinta 1992; Kishore et al. 1992; Wyse 1992).

The introduction of herbicide-resistant row crops could have several consequences on crop production as a whole, and on weed control in particular, such as cheaper production costs, and greater public acceptance of modern day agriculture (Shaw 1995). Giaquinta (1992) suggests that just because herbicide-tolerant crop technology is available does not mean it will be readily adopted. The adoption of herbicide resistant crops into agriculture and the concomitant market success will be determined by value added weed control, environmental and safety attributes of the herbicide, quality and acceptability of germplasm which carries the herbicide-tolerant trait, availability of seed, economic benefit, regulatory framework, management of product and environmental stewardship issues, and public acceptance.

The benefit of weed control in corn has been studied and documented. Stoller et al. (1979) investigated yellow nutsedge (Cyperus esculentus L. # CYPES) competition in corn and found that when no control was practiced, yields were reduced 17% in a moderate infestation (initially infested with 300 tubers/m$^2$) and 41% in a heavy infestation (initially infested with 1200 tubers/m$^2$). Young et al. (1984) conducted field studies to determine the competitive nature of quackgrass (Elytrigia repens (L.) Nevski # AGRRE) in corn and found densities of 745 shoots/m$^2$ reduced corn yields an average of 37% and significantly reduced corn height and ear length. Giant foxtail (Setaria faberi Herrm.) has been reported to cause yield losses of as much as 26% in corn, and shattercane (Sorghum
bicolor (L.) Moench. # SORVU) has been shown to reduce corn yield by 75% (Beckett et al. 1988).

The development and commercialization of sethoxydim-tolerant corn would provide significant new options for postemergence control of grass weeds in corn. Sethoxydim has the potential to be used as a supplement to preemergence herbicides for control of escaped grass weeds, or as a total postemergence treatment in combination with broadleaf herbicides (E. S. Hagood, personal communication, 1998; Young et al. 1996).

The objectives of this research were: (1) to evaluate sethoxydim-based herbicide programs for the control of annual grass and broadleaf weeds; and (2) to evaluate crop response to these treatments.
3.3 MATERIALS AND METHODS

Field experiments to evaluate the effects of postemergence applications of sethoxydim and broadleaf herbicides on sethoxydim-tolerant corn vigor and weed control were conducted in Montgomery County, Va. in 1996 and 1997. Experiments were conducted on a Ross silt loam soil (fine-loamy, mixed, mesic cumulic Hapludolls) with 2% organic matter and pH 6.1. The experimental area contained natural and supplemented infestations of grass and broadleaf weed species, as well as a natural infestation of yellow nutsedge in the 1996 experiment.

Corn (*Zea mays* L. ‘Dekalb 592’) was grown using conventional tillage methods and a commercial planter delivering approximately 76,800 seeds/ha. Experimental areas were planted May 17, 1996 and May 12, 1997. In both experiments, individual plots consisted of two 76-cm corn rows 7.6-m in length. Herbicide applications were made to an area 1.8 m wide centered over the two treated rows. Two corn rows which did not receive treatment were located between each treated experimental unit, and served as buffers.

Herbicide applications were made using a CO$_2$-pressurized backpack sprayer delivering 210 L/ha of water at 220 kPa through flat fan spray tips$^2$. All herbicide treatments included crop oil concentrate$^3$ at 1.0 % (v/v). In the 1996 experiment

$^2$Teejet 8003 flat fan spray tips. Spraying Systems Co., North Ave., Wheaton, IL 60287
$^3$Crop-Surf Oil Concentrate, 83% Parrafin Base Oil. Marketed by Universal Cooperatives, Inc., 7801 Metro Pkwy., Minneapolis, MN 55440.
applications were made to 5 to 7-leaf corn, 20 to 26-cm in height and 2.5 to 4-cm redroot pigweed, 1.3 to 4-cm common lambsquarters, 8 to 10.5-cm yellow nutsedge, 4 to 5.5-cm jimsonweed, 6 to 9-cm large crabgrass, 4 to 5.5-cm ivyleaf morningglory, and 14 to 20-cm fall panicum. In 1997 experiments, applications were made to 4 to 6-leaf corn, 18 to 24 cm in height and 5 to 8-cm large crabgrass, 3 to 6-cm ivyleaf morningglory, 13 to 19 cm- giant foxtail, and 2 to 3-cm prickly sida.

Both experiments were arranged in a randomized complete block design with four replications. The dependent variables evaluated included corn vigor reduction, weed control by species, and corn yield. Observations were made at 7 day intervals and utilized visual estimates of crop injury and weed control. Visual estimates used a 0 to 100 scale, where 0 signifies no crop injury or weed response and 100 signifies death of the crop or complete weed control. For each experiment, data from two evaluation dates are presented, including representative data from one early and one late-season evaluation. For all studies, crop response and weed control data taken at harvest did not differ with data from the later evaluation presented. Corn yields were obtained by hand harvesting treated rows and yields were adjusted to 15.5 % moisture content. All data were subjected to analysis of variance and means separated using Fishers Protected LSD with a significance level of $\alpha = 0.05$. 
3.4 RESULTS AND DISCUSSION

Significant effects of herbicide combinations for yellow nutsedge, annual grass and broadleaf control, corn vigor, and corn yield were observed in all experiments (Tables 3.1-3.4). In 1996, in observations taken at 19 DAT, neither sethoxydim nor combinations including sethoxydim and atrazine plus bentazon, bromoxynil, primisulfuron, halosulfuron, primisulfuron plus prosulfuron, flumiclorac, pyridate or bentazon caused significant injury to the crop (Table 3.1). Broadcast applications of sethoxydim plus 2,4-D amine, sethoxydim plus atrazine plus dicamba, sethoxydim plus dicamba, and sethoxydim plus nicosulfuron caused crop damage of 15%, 16%, 18%, and 29% respectively. Sethoxydim alone caused the least injury. By 47 DAT, however, recovery from this injury was apparent with all combination treatments (Table 3.2).

Control of yellow nutsedge was 86%, 89%, and 85% with sethoxydim in combination with atrazine plus bentazon, halosulfuron, and bentazon respectively (Table 3.1). Sethoxydim combinations with atrazine plus dicamba, nicosulfuron, primisulfuron, and primisulfuron plus prosulfuron also provided partial control of this species. Similar results were observed at 47 DAT, where 90 to 100% yellow nutsedge control was observed in combination treatments containing atrazine plus bentazon, halosulfuron, or bentazon (Table 3.2).

All combination treatments provided redroot pigweed control at 19 DAT with control levels ranging from 84 to 100% (Table 3.1). Control of this species also varied from 84 to 100% at 47 DAT (Table 3.2). Commercially acceptable common lambsquarter control was also provided by all combination treatments at 19 DAT except sethoxydim
plus halosulfuron, where only 44% control was observed (Table 3.1). Common lambsquarters control varied from 86 to 100% at 47 DAT with all treatments except sethoxydim alone and combinations of sethoxydim with nicosulfuron, halosulfuron, flumiclorac, and bentazon (Table 3.2).

At 19 DAT, all treatments except sethoxydim alone and sethoxydim plus bentazon provided control of ivyleaf morningglory (Table 3.1). Control with these treatments ranged from 80 to 100%, where sethoxydim plus bentazon provided only 54% control. At 47 DAT, ivyleaf morningglory control of 80% or greater was provided by all treatments except sethoxydim plus halosulfuron, flumiclorac, pyridate, or bentazon (Table 3.2). All combination treatments of sethoxydim plus broadleaf herbicides provided control of jimsonweed at both 19 and 47 DAT (Tables 3.1 and 3.2). Control values for this species ranged from 86 to 100%.

Excellent control of the annual grass species fall panicum and large crabgrass was provided by sethoxydim alone at both 19 and 47 DAT. No antagonistic effects of broadleaf herbicides on fall panicum control with sethoxydim were noted at either 19 or 47 DAT, where control ranged from 88 to 100% and 90 to 100% at 19 and 47 DAT, respectively. Large crabgrass control was reduced to 79% by the addition of nicosulfuron to sethoxydim at 19 DAT, and to 83% by the addition of primisulfuron plus prosulfuron (Table 3.1). At 47 DAT, these treatments also caused slight reductions in large crabgrass control relative to control with sethoxydim applied alone.

Corn yields in the 1996 experiment generally reflected adequate weed control provided by combination treatments and the lack of crop injury exhibited by the treatments (Table 3.2). All treatments provided yields significantly greater than that of control plots.
Four primary weed species were present in the 1997 experimental area, and included giant foxtail, large crabgrass, ivyleaf morningglory, and jimsonweed. At 7 DAT, highest crop injury was observed from sethoxydim in combination with 2,4-D amine, atrazine plus dicamba, and nicosulfuron (Table 3.3). By 54 DAT, however, no injury was apparent with any of the combination treatments (Table 3.4).

At 22 DAT, all treatments except sethoxydim plus bromoxynil, halosulfuron, flumiclorac, pyridate and bentazon provided control of ivyleaf morningglory (Table 3.3). Control with these treatments ranged from 81 to 94%, where sethoxydim plus bromoxynil provided 71% control, sethoxydim plus halosulfuron 68% control, sethoxydim plus flumiclorac 44% control, sethoxydim plus pyridate 59% control, and sethoxydim plus bentazon 56% control. At 54 DAT only sethoxydim plus atrazine plus bentazon, sethoxydim plus dicamba, and atrazine plus dicamba provided ivyleaf morningglory control of 90% or greater. Other treatments provided control of 78% or less.

All treatments provided control of prickly sida at 22 DAT except sethoxydim in combination with bromoxynil, nicosulfuron, halosulfuron, and flumiclorac (Table 3.3). Control with these treatments ranged from 81 to 100%. Sethoxydim plus bromoxynil, nicosulfuron, halosulfuron, and flumiclorac provided 73%, 78%, 53%, and 68% control respectively. At 54 DAT control of prickly sida ranged from 55 to 98 %, with sethoxydim plus atrazine plus bentazon providing control of 98%. The treatments sethoxydim plus dicamba, atrazine plus dicamba, pyridate, bentazon, 2,4-D amine, and prosulfuron afforded control of 88%, 89%, 84%, 85%, 80%, and 78%, respectively (Table 3.4). Reduced control of prickly sida was observed when sethoxydim was used in combination with 2,4-D amine, bromoxynil, nicosulfuron, primisulfuron, halosulfuron, primisulfuron
plus prosulfuron, and flumiclorac at levels of 69%, 66%, 64%, 60%, and 55%
respectively.

At 22 DAT in 1997, control of the annual grasses giant foxtail and large crabgrass
varied from 86 to 98%, where sethoxydim alone provided 98 and 96% control of these
species, respectively (Table 3.3). Slight reductions in control of giant foxtail with
combinations relative to the control with sethoxydim alone were noted, particularly with
primisulfuron, primisulfuron and prosulfuron, and pyridate. The addition of primisulfuron
or primisulfuron plus prosulfuron also caused slight reductions in large crabgrass control
relative to control with sethoxydim alone. Similar results were observed at 54 DAT, where
giant foxtail control ranged from 73 to 93% with combination treatments. Giant foxtail
control was reduced significantly by the addition of primisulfuron to sethoxydim, and
slightly by the addition of nicosulfuron, pyridate, and primisulfuron plus prosulfuron. All
treatments provided excellent control of large crabgrass at 54 DAT.

All combination treatments in the 1997 experiments resulted in increased corn
yields compared to the control plots. In the treatment where sethoxydim was applied alone
yield was the same as the control, indicating that the annual grass control provided by
sethoxydim was masked by the competitive effects of the broadleaf weed species.

The overall results of these studies indicate that combinations of sethoxydim with
broadleaf herbicides generally provided broad-spectrum control of annual broadleaf
species including redroot pigweed, common lambsquarters, ivyleaf morningglory,
jimsonweed, and prickly sida. Broadleaf herbicides combined with sethoxydim reduced
sethoxydim activity on large crabgrass and giant foxtail.
3.5 LITERATURE CITATIONS


Willoughby, OH.


