8-2000

Influence of incorporation on sulfentrazone performance in tobacco

Gregory K. Breeden

To the Graduate Council:

I am submitting herewith a thesis written by Gregory K. Breeden entitled "Influence of incorporation on sulfentrazone performance in tobacco." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Thomas C. Mueller, Major Professor

We have read this thesis and recommend its acceptance:

Donald Fowlkes, G. Neil Rhodes Jr.

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Gregory K. Breeden entitled "Influence of Incorporation on Sulfentrazone Performance in Tobacco". I have examined the final copy of the thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Sciences.

Thomas C. Mueller, Major Professor

We have read this thesis
and recommend its acceptance.

Accepted for the Council:

Associate Vice Chancellor and
Dean of the Graduate School

Influence of Incorporation on Sulfentrazone Performance in Tobacco

A Thesis

Presented for

The Master of Science

Degree

The University of Tennessee, Knoxville

Gregory K. Breeden

August 2000

DEDICATION

This thesis is dedicated to my wife
Malisa Breeden
for her patience and encouragement.

ACKNOWLEDGMENTS

The author would like to express his appreciation to the following:

To God, for giving me strength and guidance.

To Dr. G. Neil Rhodes Jr., for his faith in me to get the job done, his assistance, guidance and friendship.

To Dr. Thomas C. Mueller, for his assistance, encouragement and friendship.

To Dr. Elmer Ashburn, for his encouragement, confidence in me and friendship.

To Dr. Don Fowlkes, for his assistance and friendship.

To Dr. Robert M. Hayes, for his assistance and friendship.

To Alice Harless, for her assistance, patience and friendship.

To the Black family for their love, support and the many lessons that I have learned by having the experience of life on their farm.

To my family, for their love and support.

To Chris Main and Anthony Carver, for the hard work and long hours that they put in with me.

To the Extension P&SS Staff, for being a great group to work with.

To the Extension Agents, for their aid in getting demonstration work and tours done.

To all the Weed Science Graduate Students, for their friendship and making the classes and studying for the weed contest fun.

ABSTRACT

Morningglories (*Ipomoea* spp.) have been persistent and difficult to control weeds in tobacco (*Nicotiana tabacum*) production. In 1997 sulfentrazone was labeled for use in tobacco. Sulfentrazone provides excellent control of morningglories and many other broadleaf weeds. It also provides partial control of annual grasses. Tobacco injury from sulfentrazone had not been noted during several years of research. In 1997, however, numerous producers using sulfentrazone experienced unexpected tobacco injury.

Studies were conducted at Greeneville and Springfield, TN to determine the influence of incorporation on tobacco injury and weed control. Treatments of sulfentrazone plus clomazone (352 g/ha + 840 g/ha) or sulfentrazone plus pendimethalin (352 g/ha + 1156 g/ha) were either surface applied or preplant incorporated to depths of 5 or 10 cm. Weed control was excellent at both locations and with all treatment combinations. Weed control was 90% or greater for smooth pigweed (*Amaranthus hybridus* L.), large crabgrass [*Digitaria sanguinalis* (L.) Scop.], goosegrass [*Eleusine indica* (L.) Gaertn.], Pennsylvania smartweed (*Polygonum pensylvanicum* L.), carpetweed (*Mollugo verticillata* L.) and yellow nutsedge (*Cyperus esculentus* L.). Weed control was not influenced by depth of incorporation.

Crop symptoms associated with sulfentrazone include stunting and chlorosis. In 1997 at Springfield, all injury was 20% or less at 14 days after treatment (DAT) with a slight increase in injury with both incorporation depths. At

64 DAT all treatments exhibited less than 10% injury. In 1998 and 1999 at Springfield, stunting and chlorosis were both less than or equal to 10% from 16 DAT to 27 DAT. No injury was observed later in the growing season. At Greeneville in 1997 stunting was less than 21% at 26 DAT and increased with depth of incorporation. By 59 DAT all stunting was less than 11%. Chlorosis in 1997 was 23% or less at 26 DAT and increased slightly with incorporation depth. Chlorosis had diminished to less than 15% by 59 DAT. At Greeneville in 1998 stunting injury was 13% at 33 and 69 DAT. Chlorosis was less than 21% at 33 DAT with no chlorosis evident at 69 DAT.

Tobacco injury was slight (less than 10%) in most cases and diminished as the season progressed. Injury from sulfentrazone + clomazone in both 1997 and 1998 increased with depth of incorporation. The influence of incorporation depth of sulfentrazone + pendimethalin was less clear. Injury was greater with the 5 cm incorporation depth than the 10 cm incorporation depth. In 1997 the 5 cm depth resulted in more injury than the other depths, and in 1998 the 0 and 5 cm resulted in more injury. The dark fire cured variety tended to exhibit less injury than the burley. Tobacco injury caused by incorporation depth of either herbicide combination did not affect tobacco yield or quality when compared to the untreated hand weeded check.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (-continued)

LIST OF FIGURES

Part I

Introduction

INTRODUCTION

As farm size and labor costs have increased, tobacco producers have increasingly relied on herbicides for improved weed control. Sulfentrazone is a selective soil-applied herbicide for the control of certain broadleaves, grasses and sedges (Anonymous 1998c). Some of the strengths of sulfentrazone are control of morningglories and nutsedge. The chemical name for sulfentrazone is `[2,4-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl]phenyl]methanesulfonamide (Anonymous 1998c). It is a member of the triazolinones and the mode of action is inhibition of protoporphyrinogen oxidase (PPO) (Hancock 1995).

Clomazone is a soil applied herbicide for the control of annual grass and broadleaf weeds (Anonymous 1998a). Weeds sensitive to clomazone include hairy galinsoga (*Galinsoga ciliata* (Raf.) Blake), fall panicum (*Panicum dichotomiflorum* Michx.), crabgrass and other grasses. The chemical name for clomazone is 2-(2-chlorophenyl)methyl-4, 4-dimethyl-3-isoxazolidinone (Anonymous 1998a). Its mode of action is not completely understood, but it apparently inhibits an enzyme in the isoprenoid pathway (WSSA 1994).

Pendimethalin controls most annual grasses and certain broadleaf weeds as they germinate (Anonymous 1998b). The strengths of pendimethalin are control of mainly the grass species. The chemical name for pendimethalin is (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) (Anonymous 1998b). Its chemical family is dinitroaniline and the mode of action of this herbicide is root growth inhibition (WSSA 1994).

Weed response to tillage is not consistent; it varies among species and also between years (Hayes et al. 1995). Uncertainty exists about the effect of incorporation of sulfentrazone on tobacco injury and weed control. Sulfentrazone was first labeled for use in tobacco in 1997. Prior research with sulfentrazone in tobacco had not suggested concerns about crop injury. However, producers encountered unexpected crop injury and this appeared in many cases to be related to incorporation.

In 1997 other factors also contributed to tobacco injury. Early season cool, wet weather likely enhanced this injury. Plant metabolism of sulfentrazone was likely delayed by poor growing conditions, increasing the potential for crop response. The early season rainfall may also have splashed sulfentrazone treated soil onto the transplanted tobacco seedlings, further increasing the risk of injury.

In some cases, crop injury from sulfentrazone in 1997 was also related to application problems. Factors that can affect application accuracy are excessive swath overlap, inadequate agitation, and poor calibration (Anonymous 1999). One cause of inaccurate application was spray overlap, which produced a double rate. Additionally, insufficient agitation could cause the herbicide to settle out of suspension, thereby creating an excessive rate when the application began. One also should not add concentrated chemicals to an empty tank (Wills 1993). The tank should be half full and agitation should be started. Improper sprayer calibration was another factor that often caused excessive application. The sprayer should be calibrated using field conditions (Wills 1993). The rate that was recommended on the label was 420 g a.i./ha (Anonymous 1997). This was often too high for the soils in Tennessee. Formulation inconsistencies and measurement problems also added to the problem.

University of Tennessee research and demonstration plots also exhibited some of this crop injury in 1997 (Walker et al. 1997). This was unexpected, since previous work had shown acceptable crop tolerance. Preplant incorporated (PPI) and post transplant (POST-T) applications were more injurious overall than the preemergence (PRE) application (Moore et al. 1994). Tobacco leaf yield and grade were not reduced by sulfentrazone application indicating tobacco's ability to recover from injury (Moore et al. 1994). Less than 6% tobacco stunting was observed in trials conducted in the Southeast (Bruff et al. 1996). Leaf necrosis at 21 days after planting (DAP) was rated less than 2% with 420 g a.i./ha and no tobacco injury was noted at the lower rates (Bruff et al. 1995). Bruff reported no differences in injury among varieties (Bruff et al. 1996). When sulfentrazone was tank mixed with a grass herbicide, tobacco stunting increased 4-5% with both PRE and PPI applications compared to sulfentrazone applied alone (Hancock 1998).

Researchers have consistently reported excellent weed control with sulfentrazone alone and in combination with a grass herbicide. Control of large crabgrass (*Digitaria sanguinalis* (L.) Scop), pigweed species (*Amaranthus* sp.), yellow nutsedge (*Cyperus esculentus* L.), pitted morningglory (*Ipomoea lacunosa* L.), common cocklebur (*Xanthium strumarium* L.) and common ragweed (*Ambrosia artemisiifolia* L.) was 90% or greater with 350 g a.i./ha plus 560 g a.i./ha clomazone applied PRE-Transplant (Bruff et al. 1995). Sulfentrazone provided greater than 97% pigweed control (Walker et al. 1997). Sulfentrazone provided 90% or greater control on the following weed species: entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray), prickly sida (*Sida spinosa* L.), purple moonflower (*Ipomoea turbinata* Lag.), smallflower morningglory (*Jacquemontia tamnifolia* (L.) Griseb.), smooth pigweed (*Amaranthus hybridus* L.), tall morningglory (*Ipomoea purpurea* (L.) Roth) and velvetleaf (*Abutilon theophrasti* Medik.) at 140 g a.i./ha or less; broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash), common cocklebur, seedling johnsongrass (*Sorghum halepense* (L.) Pers.) and pitted morningglory at 280 g a.i./ha; large crabgrass and hemp sesbania (*Sesbania exaltata* (Raf.) Rydb. ex A.W. Hill) at 420 g a.i./ha; and balloonvine (*Cardiospermum halicacabum* L.) at 560 g a.i./ha (Oliver et al.1995). Sulfentrazone also provided 88-100% control of lambsquarters (*Chenopodium album L.*), Pennsylvania smartweed (*Polygonum pensylvanicum* L.) and tropic croton (*Croton glandulosus* var. *septentrionalis* Muell.-Arg.) (Hancock 1998).

Part II

Influence of Incorporation on Sulfentrazone Performance in Tobacco[1]

[1] To be submitted for publication in Tobacco Science

INTRODUCTION

Tobacco (*Nicotiana tabacum*) is a high value crop that is important to Tennessee's economy. With this crop, as with others, optimum weed control is necessary to produce a high quality, high yielding crop. As farm size and labor costs have increased, tobacco producers have increasingly relied on herbicides for improved weed control. Unfortunately, few herbicides are labeled for use in tobacco. Over the past few years another herbicide has been added that fills an important niche. Sulfentrazone provides morningglory and nutsedge control. Morningglory is a troublesome weed in tobacco, causing leaf damage and loss at harvest and increasing market preparation. Other herbicides labeled for tobacco do not adequately control morningglories (Rhodes and Breeden 1998). Pebulate provides partial control of yellow nutsedge; however, it must be incorporated immediately (Rhodes and Breeden 1998). Sulfentrazone controls certain broadleaves, grasses and sedges, and does not require mechanical incorporation (Anonymous 1998c).

When sulfentrazone was first labeled in 1997, some producers experienced crop injury. This phenomenon was believed to be related to depth of sulfentrazone incorporation. This injury was unexpected, since previous work showed good crop tolerance. Less than 6% tobacco injury was observed in many trials (Bruff et al. 1995, Bruff et al. 1996). Many factors could have contributed to sulfentrazone injury. The early part of the1997 growing season was cool and wet, creating conditions that would increase the potential for injury from herbicides. Because sulfentrazone was a new product in 1997, growers had no experience with this herbicide, one which was very unlike other tobacco herbicides. Sprayer overlap, insufficient agitation and improper sprayer calibration were also factors associated with injury from sulfentrazone in 1997. The rate that was recommended on the label was 420 g a.i./ha (Anonymous 1997). This was often too high for many soils in Tennessee. Formulation inconsistencies and measurement problems added to the problem. This research was conducted to address the incorporation issue, and the objectives were: 1) To determine the influence of herbicide incorporation depth on tobacco injury and yield; 2) To determine if differential injury occurred due to the addition of a grass herbicide tank mix partner (clomazone or pendimethalin); and 3) To determine the influence of herbicide incorporation depth on weed control.

MATERIALS AND METHODS

Field experiments were established at Greeneville and Springfield, TN (Figure 1). All figures and tables are located in appendices. A burley variety (TN-90) was used at Greeneville in 1997 and 1998, and a dark fire cured variety (TN D950) was used at Springfield in 1997, 1998 and 1999. All trials were conducted using a randomized complete block (RCB) design with three or four replications. Plots were 4.3 m wide and 9.1 m long. Treatments with sulfentrazone at 350 g a.i./ha in combination with clomazone at 840 g a.i./ha or pendimethalin at 1200 g a.i./ha were replicated at three incorporation depths of 0 (no incorporation), 5 cm and 10 cm. An untreated, hand-weeded control was included. Herbicides were applied at 140 L/ha at 4.8 km/hr with a CO_2-pressurized 4-wheeler or tractor sprayer. Herbicides were incorporated mechanically within one hour using a tractor and a PTO driven roto-tiller. Visual estimates of weed control and tobacco injury were made at each location using a 0-100% scale, with 0 being no crop injury or weed control and 100 being total crop death or weed control. Three evaluations were taken; two early (within 30 d of treatment) and one late in the season (60-70 d). At approximately 4 wk after planting, all weeds were removed from the plots and they were maintained weed free by hand weeding until harvest.

Application dates and weeds evaluated varied by location and year (Table 1). Yield and grade indices were taken from the center two rows of a four row plot and were pooled over location. Grade indices are based on the United States Department of Agriculture Agricultural Marketing service official standard grades (Miller and Legg 1990). Numerical values are assigned to each level of the grade factors (Miller and Legg 1990; Bowman et al. 1989). These values are then used to calculate the grade index. Grade indices are independent of market demand and can be subjected to statistical analyses (Miller and Legg 1990). Data were subjected to analysis of variance and means were separated with LSD at the 5% level.

RESULTS AND DISCUSSION

Weed Control. In 1997 and 1998 at Greeneville all herbicide treatments provided greater than 89% control of seedling johnsongrass (*Sorghum halepense* (L.) Pers.); greater than 90% control of yellow nutsedge (*Cyperus esculentus* L.), crabgrass (*Digitaria sanguinalis* (L.) Scop), smooth pigweed (*Amaranthus hybridus* L.) and goosegrass (*Eleusine indica* (L.) Gaertn.)(Tables 2,3 and 4). In 1998 at Springfield, goosegrass, carpetweed (*Mollugo verticillata* L.) and Pennsylvania smartweed (*Polygonum pensylvanicum* L.) control was greater than 93% at each evaluation (Tables 5 and 6). In 1999 entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray) and jimsonweed (*Datura stramonium* L.) control at 19 days after treatment (DAT) was greater than 92% control (Table 7). The surface application of sulfentrazone + clomazone was 70% for entireleaf morningglory, and all other treatments provided greater than 89% control at 33 DAT (Table 8). All treatments provided 83% or better control of jimsonweed at 33 DAT in Springfield.

There were only seven weed control evaluations that were different from the other treatments within evaluations for an individual weed. These treatments were random and only one of them was below 89%. The majority of the evaluations were greater than 95%. Incorporation depth did not affect weed control. This was most likely due to the fact that adequate rainfall for herbicide activation occurred shortly after transplanting.

Tobacco Injury. Sulfentrazone injury symptoms were mainly stunting and chlorosis. Tobacco stunting was a general decrease in plant height. Chlorosis was a whitening/flecking of mainly the interveinal area of the leaf. Chlorosis was limited to mostly the older leaves from transplants with the bud usually not being affected. Some leaf crinkling occurred, and if injury was severe, some leaf necrosis was observed.

Tobacco stunting was less than 10% for all combinations of sulfentrazone + clomazone at Greeneville in 1997at both the 26 and 59 DAT evaluations (Table 9). Greater stunting was observed with the surface and 5 cm incorporation depths for sulfentrazone + pendimethalin. At 26 DAT, 15 and 21% stunting was observed for the surface and 5 cm depths, respectively. By 59 DAT injury from sulfentrazone + pendimethalin declined to less than 11%. The 10 cm incorporation depth caused less injury than the other sulfentrazone + pendimethalin treatments with 6% at 24 DAT and 5% at 59 DAT. In 1998 at Greeneville stunting caused by sulfentrazone + clomazone was less than 15% (Table 10). Stunting from the sulfentrazone + pendimethalin treatments was 21% or less at 26 DAT. Stunting declined for all treatments as the growing season progressed. Stunting in Springfield in 1998 was less than 11% for all treatment combinations with sulfentrazone + pendimethalin causing slightly more injury (Table 13). By 82 DAT all treatments had decreased to less than 3%. In 1999 at Springfield all stunting was less than 4% and had diminished by 65 DAT (Table 15).

In 1997 at Greeneville, tobacco chlorosis increased from 6 to 11% as incorporation depth increased for the sulfentrazone + clomazone treatments (Table 9). Chlorosis from sulfentrazone + pendimethalin at 26 DAT was 18 and 23% for the 0 and 5 cm incorporation depths, respectively, and 13% for the 10 cm depth. At 59 DAT chlorosis had declined to less than 15% for all treatments. In 1998 chlorosis ranged from 19% to 31% at 22 DAT (Table 11). At 33 DAT all treatments caused less than 21% chlorosis and, by 69 DAT, all chlorosis had diminished. At Springfield in 1998 chlorosis was less than 8% for all treatment combinations (Tables 14). This chlorosis had decreased to less than 5% by 27 DAT and had diminished by 82 DAT. In 1999 chlorosis was less than 6% for all treatment combinations at Springfield (Tables 16). All chlorosis had diminished by 33 DAT.

At Springfield in 1997 general tobacco injury was evaluated at 14, 42 and 63 DAT (Table 12). This injury evaluation took into account both the stunting and chlorosis caused by the treatments. Tobacco injury from the surface application of sulfentrazone + clomazone ranged from 18% to 12% and increased with depth of incorporation. By 63 DAT injury had decreased to less than 5%. Tobacco injury from the surface application of sulfentrazone + pendimethalin and the 10 cm sulfentrazone + pendimethalin was less than 10% at 14 DAT and had decreased to less than 4% by 63 DAT. The 5 cm incorporation of sulfentrazone + pendimethalin caused 20% injury at 14 DAT and had decreased to 10% by 63 DAT.

Early season weather was cool and wet in 1997 and 1998, creating adverse growing conditions (Tables 21 and 22). This may have contributed to greater tobacco injury in these two years compared to 1999. The growing season in 1999 was relatively good through early July (Tables 21 and 22). In 1997 and 1998, injury from sulfentrazone + clomazone increased with increased depth of incorporation. Injury diminished later in the growing season. The influence of sulfentrazone + pendimethalin was less clear. Injury was often greater with shallow placement. In 1997 the 5 cm incorporation depth caused more injury than the other depths, and in 1998 the surface application and 5 cm incorporation depth caused more injury. This may have been because the pendimethalin was concentrated in the root zone and inhibited root growth, which perhaps decreased sulfentrazone uptake into the tobacco plants thus masking the injury from sulfentrazone. In 1999 chlorosis and stunting was less than 6% for all treatments at 19 DAT and diminished as the season progressed. The dark fire cured variety tended to exhibit less injury than the burley variety. Transplants of the dark fire cured varieties have better vigor than those of the burley varieties. This difference in vigor may be one reason why less injury was observed for the dark fire cured variety than for the burley variety.

Tobacco Yield and Quality. Tobacco yield and grade indices were determined in Greeneville in 1997 and 1998 (Table 17 and 18). There were no differences in tobacco yield in 1997,1998 and when the data was pooled over the two years.

There were no differences among treatments for grade indices in 1997 at Greeneville (Table 18). In 1998, the surface application of sulfentrazone + pendimethalin was the lowest quality at 46.7 and the highest quality was 66.9 for the 5 cm incorporation depth of sulfentrazone + pendimethalin. When grade indices were pooled for the two years only the 10 cm incorporation depth of sulfentrazone + pendimethalin was better than the others.

At Springfield in 1997 only the 10 cm incorporation depth of sulfentrazone + pendimethalin had a higher yield than the others (Table 19). There were no differences in yield among the other years or when the data was pooled over the three years. In 1997 the grade indices for the surface application of sulfentrazone + pendimethalin and the 10 cm incorporation of sulfentrazone + pendimethalin were higher than the others (Table 20). There were no differences in 1998 at Springfield. In 1999 the surface application of sulfentrazone + clomazone and the 5 cm incorporation depth of sulfentrazone + pendimethalin were lower in quality. When the data was pooled over the three years the surface application of sulfentrazone + clomazone and the 5 cm incorporation depth of sulfentrazone + pendimethalin were lower in quality.

When the yield data were pooled over years, there were no differences among treatments. This result is in agreement with findings by Moore et al. 1994. This indicated that tobacco can recover from sulfentrazone injury. Differences in tobacco grade index were not likely caused by herbicides or depth of placement. These differences probably were due to field variability, weather and other factors that were uncontrollable. This is supported by the fact that the hand weeded check for the burley tended to be one of the lower quality treatments. To decrease the likelihood of injury one would apply the sulfentrazone + clomazone combination on the surface or lightly incorporate. Sulfentrazone + pendimethalin should be applied separately to have the least chance of injury. The pendimethalin should be applied then incorporated, then the sulfentrazone should be applied to the surface. However, the yield and quality data from these studies support the fact that tobacco can recover from early season injury which might occur.

LITERATURE CITED

Anonymous. 1998a. Command specimen label. FMC Corporation. Agricultural Products Group. Philadelphia, PA 19103.

Anonymous. 1998b. Prowl specimen label. American Cyanamid Company. Crop Protection Products Department. Parsippany, NJ

Anonymous. 1998c. Spartan specimen label. FMC Corporation. Agricultural Products Group. Philadelphia, PA 19103.

Anonymous. 1997. Spartan specimen label. FMC Corporation. Agricultural Products Group. Philadelphia, PA 19103.

Anonymous 1999. TeeJet Catalog 47A. Spraying Systems Co. Wheaton, IL 60189-7900

Bowman, D.T., Miller, R.D., Tart, A.G., Sasser, Jr, C.M., and Rufty, R.C. 1989. A Grade Index for Burley Tobacco. Tob. Sci. 33: 18-19

Bruff, S.A., and Hancock, H.G., 1995. Sulfentrazone a Promising New Herbicide for Tobacco. Proc. South. Weed Sci. Soc. 48: 10.

Bruff, S.A., Hancock, H.G., and Sims B.D. 1996. Utilization of Sulfentrazone and Clomazone Combinations in Tobacco. Proc. South. Weed Sci. Soc. 49: 15.

Hancock, H.G. 1995. Sulfentrazone: A Broad Spectrum Herbicide for Soybeans. Proc. South. Weed Sci. Soc. 48: 44-45.

Hancock, H.G. 1998. Spartan Performance in Tobacco. Proc. South. Weed Sci. Soc. 51: 34.

Hayes, R.M., Mueller, T.C. and Krueger W.A. 1995. Do Weeds Respond Differently to Tillage? Proc. South. Weed Sci. Soc. 48: 70-71.

Miller, R.D. and Legg, P.D. 1990. A grade Index for Type 22 and 23 Fire-cured tobacco. Tob. Sci. 32: 39-40.

Moore, J.M., Wilcut, J.W., Bridges, D.C., Richburg, J.S. III, and Hancock, H.G. 1994. Weed Control and Tobacco Tolerance with F-6285. Proc. South. Weed Sci. Soc. 47: 235-236.

Oliver, L.R.,Costello, R.W., and King, A.C. 1995. Weed Control Programs with Sulfentrazone in Soybeans. Proc. South. Weed Sci. Soc. 48: 73-74.

Rhodes, G.N. Jr. and Breeden, G.K. 1998 Weed Control Manual for Tennessee. The University of Tennessee Agricultural Extension Service. PB1580. pp.79-80, 111

Walker, E.R., Mueller, T.C., Rhodes, G.N. Jr. and Hayes, R.M. 1998. Spartan for Weed Control in Tobacco. Proc. South. Weed Sci. Soc. 51: 32-33

Weed Science Society of America. 1994. Herbicide Handbook. 7th ed. Weed Sci. Soc. Am., Champaign, IL. 64-66,230-232

Wills, J.B. Jr., 1993. Agricultural Chemical Sprayer Facts. The University of Tennessee Agricultural Extension Service. EC972. pp.29-37

APPENDICES

APPENDIX A

FIGURES

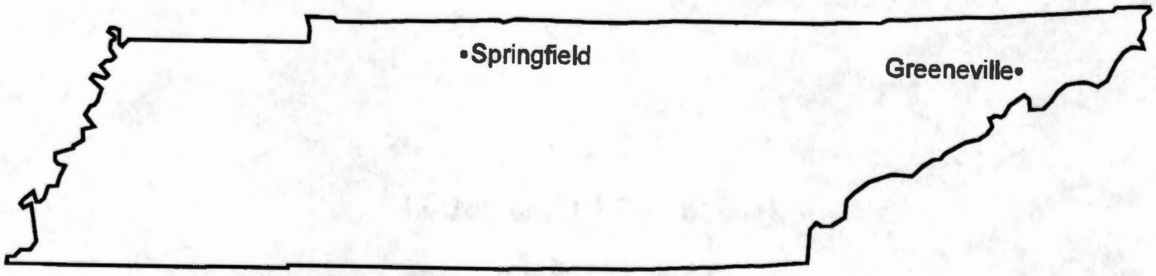

Figure 1. Field study locations in Tennessee.

APPENDIX B

TABLES

Table 1. Application dates, transplanting dates, varieties and weeds evaluated.

Location	Application Date	Transplant Date	Variety	Weeds Evaluated
Greeneville 1997	6-21	6-23	TN-90	seedling johnsongrass crabgrass yellow nutsedge smooth pigweed
Greeneville 1998	6-17	6-17	TN-90	crabgrass goosegrass pigweed sp.
Springfield 1997	6-23	6-24	TN-D950	-----
Springfield 1998	6-3	6-3	TN-D950	goosegrass carpetweed Pennsylvania smartweed
Springfield 1999	5-19	5-20	TN-D950	entireleaf morningglory jimsonweed

Table 2. Weed control 26 DAT[a] at Greeneville[b] 1997.

Treatment	Rate	Incorporation Depth	large crabgrass	seedling johnsongrass	smooth pigweed	yellow nutsedge
	g ai/ha	(cm)		%		
Sulfentrazone Clomazone	350 840	0	98 a	92 ab	99 a	97 a
Sulfentrazone Clomazone	350 840	5	99 a	91 ab	99 a	96 a
Sulfentrazone Clomazone	350 840	10	99 a	95 a	99 a	99 a
Sulfentrazone Pendimethalin	350 1200	0	99 a	89 b	99 a	96 a
Sulfentrazone Pendimethalin	350 1200	5	97 a	96 a	99 a	97 a
Sulfentrazone Pendimethalin	350 1200	10	98 a	93 ab	99 a	90 a
LSD (0.05)			NS	5	NS	NS

[a] DAT, days after treatment

[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 3. Weed control 22 DAT[a] at Greeneville[b] 1998.

Treatment	Rate	Incorporation Depth	crabgrass	goosegrass	pigweed species
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	98 a	96 a	99 a
Sulfentrazone Clomazone	350 840	5	98 a	97 a	99 a
Sulfentrazone Clomazone	350 840	10	96 a	98 a	99 a
Sulfentrazone Pendimethalin	350 1200	0	96 a	96 a	98 a
Sulfentrazone Pendimethalin	350 1200	5	96 a	98 a	99 a
Sulfentrazone Pendimethalin	350 1200	10	89 b	94 a	99 a
LSD (0.05)			5	NS	NS

[a] DAT, days after treatment

[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 4. Weed control 33 DAT[a] at Greeneville[b] 1998.

Treatment	Rate	Incorporation Depth	crabgrass	goosegrass	pigweed species
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	98 a	96 a	99 a
Sulfentrazone Clomazone	350 840	5	97 a	97 a	99 a
Sulfentrazone Clomazone	350 840	10	97 a	97 a	99 a
Sulfentrazone Pendimethalin	350 1200	0	96 a	95 a	99 a
Sulfentrazone Pendimethalin	350 1200	5	98 a	98 a	99 a
Sulfentrazone Pendimethalin	350 1200	10	91 b	95 a	98 a
LSD (0.05)			4	NS	NS

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 5. Weed control 16 DAT[a] at Springfield[b] 1998.

Treatment	Rate	Incorporation Depth	goosegrass	carpetweed	Pennsylvania smartweed
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	99 a	97 a	99 a
Sulfentrazone Clomazone	350 840	5	99 a	99 a	98 a
Sulfentrazone Clomazone	350 840	10	99 a	99 a	99 a
Sulfentrazone Pendimethalin	350 1200	0	94 a	96 a	98 a
Sulfentrazone Pendimethalin	350 1200	5	99 a	97 a	99 a
Sulfentrazone Pendimethalin	350 1200	10	99 a	97 a	99 a
LSD (0.05)			NS	NS	NS

[a] DAT, days after treatment

[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 6. Weed control 27 DAT[a] at Springfield[b] 1998.

Treatment	Rate	Incorporation Depth	goosegrass	carpetweed	Pennsylvania smartweed
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	99 a	99 a	99 a
Sulfentrazone Clomazone	350 840	5	99 a	99 a	99 a
Sulfentrazone Clomazone	350 840	10	99 a	98 a	99 a
Sulfentrazone Pendimethalin	350 1200	0	96 a	99 a	97 a
Sulfentrazone Pendimethalin	350 1200	5	98 a	99 a	99 a
Sulfentrazone Pendimethalin	350 1200	10	99 a	99 a	99 a
LSD (0.05)			NS	NS	NS

[a] DAT, days after treatment

[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 7. Weed control 19 DAT[a] at Springfield[b] 1999.

Treatment	Rate	Incorporation Depth	entireleaf morningglory	jimsonweed
	g ai/ha	(cm)	%	
Sulfentrazone Clomazone	350 840	0	92 a	94 a
Sulfentrazone Clomazone	350 840	5	97 a	99 a
Sulfentrazone Clomazone	350 840	10	99 a	99 a
Sulfentrazone Pendimethalin	350 1200	0	96 a	95 a
Sulfentrazone Pendimethalin	350 1200	5	99 a	98 a
Sulfentrazone Pendimethalin	350 1200	10	98 a	97 a
LSD (0.05)			NS	NS

[a] DAT, days after treatment

[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 8. Weed control 33 DAT[a] at Springfield[b] 1999.

Treatment	Rate	Incorporation Depth	entireleaf morningglory	jimsonweed
	g ai/ha	(cm)	%	
Sulfentrazone Clomazone	350 840	0	70 a	83 b
Sulfentrazone Clomazone	350 840	5	97 a	99 a
Sulfentrazone Clomazone	350 840	10	98 a	99 a
Sulfentrazone Pendimethalin	350 1200	0	89 a	96 a
Sulfentrazone Pendimethalin	350 1200	5	97 a	97 a
Sulfentrazone Pendimethalin	350 1200	10	97 a	94 a
LSD (0.05)			NS	9

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 9. Burley Tobacco Injury at Greeneville[b] 1997.

Treatment	Rate	Incorporation Depth	26 DAT[a] Stunting	26 DAT[a] Chlorosis	59 DAT[a] Stunting	59 DAT[a] Chlorosis
	g ai/ha	(cm)	%			
Sulfentrazone Clomazone	350 840	0	4 c	6 cd	7 ab	15 a
Sulfentrazone Clomazone	350 840	5	10 bc	9 bcd	9 a	9 a
Sulfentrazone Clomazone	350 840	10	10 bc	11 bc	10 a	11 a
Sulfentrazone Pendimethalin	350 1200	0	15 ab	18 ab	10 a	13 a
Sulfentrazone Pendimethalin	350 1200	5	21 a	23 a	11 a	10 a
Sulfentrazone Pendimethalin	350 1200	10	6 bc	13 bc	5 ab	11 a
Untreated	-----	------	0 c	0 d	0 b	0 b
LSD (0.05)			9	9	8	7

[a] DAT, days after treatment

[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 10. Burley Tobacco Stunting at Greeneville[b] 1998.

Treatment	Rate	Incorporation Depth	22 DAT[a]	33 DAT[a]	69 DAT[a]
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	8 bc	4 bc	4 ab
Sulfentrazone Clomazone	350 840	5	15 ab	11 a	8 ab
Sulfentrazone Clomazone	350 840	10	8 bc	9 ab	1 ab
Sulfentrazone Pendimethalin	350 1200	0	21 a	13 a	5 ab
Sulfentrazone Pendimethalin	350 1200	5	18 ab	10 ab	9 a
Sulfentrazone Pendimethalin	350 1200	10	16 ab	10 ab	6 ab
Untreated	-----	------	0 c	0 c	0 b
LSD (0.05)			9	7	7

[a] DAT, days after treatment

[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 11. Burley Tobacco Chlorosis at Greeneville[b] 1998.

Treatment	Rate	Incorporation Depth	22 DAT[a]	33 DAT[a]	69 DAT[a]
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	19 b	20 a	0 a
Sulfentrazone Clomazone	350 840	5	23 ab	14 a	0 a
Sulfentrazone Clomazone	350 840	10	19 b	18 a	0 a
Sulfentrazone Pendimethalin	350 1200	0	31 a	19 a	0 a
Sulfentrazone Pendimethalin	350 1200	5	26 ab	18 a	0 a
Sulfentrazone Pendimethalin	350 1200	10	24 ab	21 a	0 a
Untreated	-----	------	0 c	0 b	0 a
LSD (0.05)			10	10	NS

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 12. Dark Fire Cured Tobacco Injury at Springfield[b] 1997.

Treatment	Rate	Incorporation Depth	14 DAT[a]	42 DAT[a]	63 DAT[a]
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	12 ab	5 ab	2 ab
Sulfentrazone Clomazone	350 840	5	15 a	7 ab	5 ab
Sulfentrazone Clomazone	350 840	10	18 a	10 ab	4 ab
Sulfentrazone Pendimethalin	350 1200	0	8 ab	3 b	0 b
Sulfentrazone Pendimethalin	350 1200	5	20 a	15 a	10 a
Sulfentrazone Pendimethalin	350 1200	10	10 ab	10 ab	4 ab
Untreated	-----	------	0 b	0 b	0 b
LSD (0.05)			11	10	9

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 13. Dark Fire Cured Tobacco Stunting at Springfield[b] 1998.

Treatment	Rate	Incorporation Depth	16 DAT[a]	27 DAT[a]	82 DAT[a]
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	5 ab	5 bcd	0 b
Sulfentrazone Clomazone	350 840	5	5 ab	4 cd	0 b
Sulfentrazone Clomazone	350 840	10	10 a	11 a	3 a
Sulfentrazone Pendimethalin	350 1200	0	8 a	8 abc	0 b
Sulfentrazone Pendimethalin	350 1200	5	8 a	10 ab	0 b
Sulfentrazone Pendimethalin	350 1200	10	8 a	10 ab	1 ab
Untreated	-----	------	0 b	0 d	0 b
LSD (0.05)			5	5	2

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different (P≤ 0.05) according to the LSD test.

Table 14. Dark Fire Cured Tobacco Chlorosis at Springfield[b] 1998.

Treatment	Rate	Incorporation Depth	16 DAT[a]	27 DAT[a]	82 DAT[a]
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	4 ab	5 a	0 a
Sulfentrazone Clomazone	350 840	5	4 ab	1 a	0 a
Sulfentrazone Clomazone	350 840	10	5 ab	3 a	0 a
Sulfentrazone Pendimethalin	350 1200	0	8 a	4 a	0 a
Sulfentrazone Pendimethalin	350 1200	5	6 a	3 a	0 a
Sulfentrazone Pendimethalin	350 1200	10	5 ab	1 a	0 a
Untreated	-----	------	0 b	0 a	0 a
LSD (0.05)			5	NS	NS

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 15. Dark Fire Cured Tobacco Stunting at Springfield[b] 1999.

Treatment	Rate	Incorporation Depth	19 DAT[a]	33 DAT[a]	65 DAT[a]
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	1 a	0 a	0 a
Sulfentrazone Clomazone	350 840	5	1 a	0 a	0 a
Sulfentrazone Clomazone	350 840	10	4 a	1 a	0 a
Sulfentrazone Pendimethalin	350 1200	0	0 a	0 a	0 a
Sulfentrazone Pendimethalin	350 1200	5	1 a	1 a	0 a
Sulfentrazone Pendimethalin	350 1200	10	4 a	3a	0 a
Untreated	-----	------	0 a	0 a	0 a
LSD (0.05)			NS	NS	NS

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 16. Dark Fire Cured Tobacco Chlorosis at Springfield[b] 1999.

Treatment	Rate	Incorporation Depth	19 DAT[a]	33 DAT[a]	65 DAT[a]
	g ai/ha	(cm)		%	
Sulfentrazone Clomazone	350 840	0	5 a	0 a	0 a
Sulfentrazone Clomazone	350 840	5	5 a	0 a	0 a
Sulfentrazone Clomazone	350 840	10	6 a	0 a	0 a
Sulfentrazone Pendimethalin	350 1200	0	4 a	0 a	1 a
Sulfentrazone Pendimethalin	350 1200	5	5 a	0 a	0 a
Sulfentrazone Pendimethalin	350 1200	10	6 a	0 a	0 a
Untreated	-----	------	0 a	0 a	0 a
LSD (0.05)			NS	NS	NS

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 17. Burley Tobacco Yield (kg/ha) at Greeneville[b].

Treatment	Rate	Incorporation Depth	1997[a]	1998[a]	Two Year Average[a]
	g ai/ha	(cm)		kg/ha	
Sulfentrazone Clomazone	350 840	0	2420 a	2360 a	2420 a
Sulfentrazone Clomazone	350 840	5	2430 a	2660 a	2550 a
Sulfentrazone Clomazone	350 840	10	2410 a	2700 a	2540 a
Sulfentrazone Pendimethalin	350 1200	0	2410 a	2830 a	2620 a
Sulfentrazone Pendimethalin	350 1200	5	2380 a	2870 a	2420 a
Sulfentrazone Pendimethalin	350 1200	10	2620 a	2700 a	2760 a
Untreated	-----	------	2540 a	2930 a	2730 a
LSD (0.05)			NS	NS	NS

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 18. Burley Tobacco Grade Index at Greeneville[b].

Treatment	Rate g ai/ha	Incorporation Depth cm	1997[a]	1998[a]	Two Year Average[a]
Sulfentrazone Clomazone	350 840	0	55.5 a	56.4 abc	56.0 ab
Sulfentrazone Clomazone	350 840	5	58.7 a	60.5 ab	59.6 ab
Sulfentrazone Clomazone	350 840	10	58.2 a	49.7 bc	54.0 b
Sulfentrazone Pendimethalin	350 1200	0	58.9 a	46.7 c	52.8 b
Sulfentrazone Pendimethalin	350 1200	5	48.3 a	66.9 a	57.6 ab
Sulfentrazone Pendimethalin	350 1200	10	65.1 a	60.9 ab	63.0 a
Untreated	-----	------	52.5 a	53.3 bc	52.9 b
LSD (0.05)			NS	10	9

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different ($P \leq 0.05$) according to the LSD test.

Table 19. Dark Fire Cured Tobacco Yield (kg/ha) at Springfield[b].

Treatment	Rate	Incorporation Depth	1997[a]	1998[a]	1999[a]	Three Year Average[a]
	g ai/ha	(cm)	kg/ha			
Sulfentrazone Clomazone	350 840	0	2350 ab	3340 a	2420 a	2740 a
Sulfentrazone Clomazone	350 840	5	2190 b	3200 a	2400 a	2630 a
Sulfentrazone Clomazone	350 840	10	2740 ab	3040 a	2340 a	2700 a
Sulfentrazone Pendimethalin	350 1200	0	2690 ab	2930 a	2390 a	2660 a
Sulfentrazone Pendimethalin	350 1200	5	2490 ab	3000 a	2470 a	2670 a
Sulfentrazone Pendimethalin	350 1200	10	3060 a	3000 a	2570 a	2860 a
Untreated	-----	------	2700 ab	2850 a	2440 a	2660 a
LSD (0.05)			647	NS	NS	NS

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different (P≤ 0.05) according to the LSD test.

Table 20. Dark Fire Cured Tobacco Grade Index at Springfield[b].

Treatment	Rate g ai/ha	Incorporation Depth cm	1997[a]	1998[a]	1999[a]	Three Year Average[a]
Sulfentrazone Clomazone	350 840	0	54.4 c	53.0 a	43.3 c	49.9 c
Sulfentrazone Clomazone	350 840	5	54.3 c	54.9 a	49.4 abc	52.7 abc
Sulfentrazone Clomazone	350 840	10	56.7 bc	55.2 a	47.7 abc	52.9 abc
Sulfentrazone Pendimethalin	350 1200	0	64.0 ab	50.1 a	53.5 a	55.1 a
Sulfentrazone Pendimethalin	350 1200	5	58.2 abc	52.6 a	44.1 bc	51.1 bc
Sulfentrazone Pendimethalin	350 1200	10	67.1 a	54.2 a	45.5 abc	54.6 ab
Untreated	-----	------	62.9 abc	53.5 a	52.5 ab	55.7 a
LSD (0.05)			9	NS	8	4

[a] DAT, days after treatment
[b] Means followed by the same letter are not significantly different (P≤ 0.05) according to the LSD test.

Appendix C

Weather Data

Table 21. Rainfall at Greeneville in cm.

DAT	1997 (cm)	1998 (cm)
-5	0	0
-4	0	0.58
-3	1.91	0
-2	0.48	1.50
-1	0	0
0	0	0
1	0	0
2	0	0
3	0	0.25
4	0.1	0
5	0	0.64
6	1.91	3.35
7	0	0
8	0.05	0.18
9	0	0
10	1.09	0
11	2.29	0
12	0	0
13	0	0
14	0.66	2.29
15	0	0
16	0	0
17	0	0
18	0	0
19	0.1	0.18
20	0	0
21	0	0
22	0	1.12
23	0	1.22
24	0	0
25	0	0
26	0.03	0
27	0	0
28	0	0
29	0	0
30	0	0

Table 22. Rainfall at Springfield in cm.

DAT	1997 (cm)	1998 (cm)	1999 (cm)
-5	0.81	0	0.46
-4	0	0	0
-3	0	0	0
-2	0	0	0
-1	0.25	0.03	0
0	0.56	0	0.33
1	0	0	0
2	0	8.99	0
3	0	0.08	0
4	0.03	0	0
5	0	0	0
6	0.84	0.89	0
7	0.10	6.25	0.23
8	3.84	1.85	0
9	0	0	0
10	0	0	0
11	1.19	0.20	0
12	0	0.30	0
13	0	0	1.55
14	0	0	0.003
15	0	0	0.03
16	0	0.64	0
17	0.003	0	1.78
18	0	4.57	0
19	0	0.13	0.05
20	0	0	0
21	1.55	0	0
22	0.30	0	0
23	0	0	0
24	0	0	0
25	0	0	0
26	0	0	0.51
27	0	2.97	0.58
28	0.003	0	0
29	0	0	0
30	0	0	0

VITA

Gregory K. Breeden was born in Maryville, Tennessee, on March 5, 1973. He grew up on a small farm in Vonore, Tennessee and worked on a large row crop farm in Monroe County. The farm experience lead the author to a career in agriculture. He graduated from Vonore High School in May of 1991. He entered Cleveland State Community College in the Fall of 1991 and received a Associates Degree in May of 1993. In the Fall of 1993 he transferred to the University of Tennessee and completed a Bachelor of Science degree in Plant and Soil Science in May of 1996. In June 1996 he accepted his current position with the University of Tennessee Agricultural Extension Service. While working he started graduate school at the University of Tennessee in the Fall of 1997. He received a Master of Science degree with a concentration in Weed Science in August 2000.

The author is a member of the Southern Weed Science Society and the Tennessee Agricultural Production Association. Upon graduation he will continue working with the University of Tennessee Extension Weed Control Program.