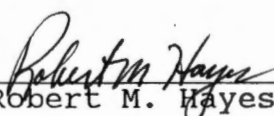
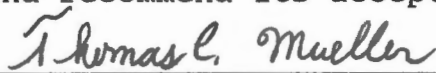
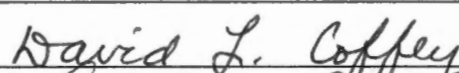
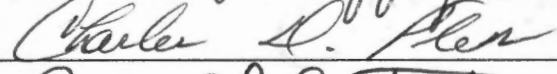
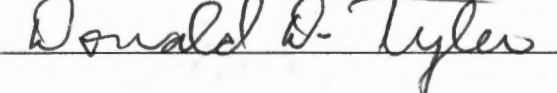


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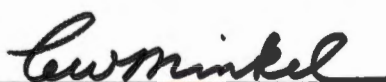
I am submitting herewith a dissertation written by Blake Alan Brown entitled "Effect of Cover Crop and Tillage on Fluometuron Bioavailability." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plant and Soil Science.


Robert M. Hayes, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:


Associate Vice Chancellor
and Dean of The Graduate
School

EFFECT OF COVER CROP AND TILLAGE ON
FLUOMETURON BIOAVAILABILITY

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Blake Alan Brown

May, 1993

~~NO VET MED~~

THESIS

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DEDICATION

To my wife, Lisa Hix Brown, whose many sacrifices made this effort a success, I dedicate this dissertation.

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ABSTRACT

Studies were conducted in 1991 and 1992 to determine the effects of long-term no-tillage and cover crops on efficacy and degradation of fluometuron in the field. Experiments were established on an area which had been planted no-till (NT) or conventional-till (CT) into either no cover crop (NC) or vetch (VE) continuously since 1981. The study utilized a two-by-two factorial arrangement of treatments in which the factors consisted of tillage systems (CT or NT) and cover crop (VE or NC).

Fluometuron was applied preemergence (PRE) at 1.7 kg ai ha⁻¹ broadcast. Soil samples were collected immediately after fluometuron application and at approximately 1, 2, 3, 4, 6, 8, and 12 wk after treatment (WAT). Fluometuron was quantified by High Pressure Liquid Chromatography (HPLC). Visual evaluations of weed control were made at approximately 3, 7, and 9 WAT.

Control of Palmer amaranth was lower in NT than in CT both years. Control of Palmer amaranth was not affected by cover crops.

Degradation of fluometuron did not differ among treatments in either surface soils (0 to 4 cm) or subsurface soils (4 to 8 and 8 to 15 cm). Therefore the differences in Palmer amaranth control could not be explained by differences in degradation of fluometuron among treatments.

Additional studies were conducted in 1992 to determine the effects of no-tillage and cover crops on adsorption and degradation of fluometuron in soil under controlled conditions. Soil from each treatment-by-depth combination in the previous study was collected prior to application of fluometuron. Adsorption of fluometuron on soil was determined using a slurry technique, and a distribution coefficient (K_d) was calculated for each treatment-by-depth combination.

Adsorption of fluometuron on soil was affected by tillage and cover crop. Adsorption was greatest in NT VE at a soil depth of 0 to 4 cm. At 4 to 8 cm adsorption in CT VE was higher than in NT VE.

Adsorption of fluometuron on soil correlated with various soil characteristics, with organic matter content being the most important. Cation exchange capacity was also highly correlated with adsorption of fluometuron.

Degradation of fluometuron under controlled conditions was determined for each treatment-by-depth combination by fortifying soil with fluometuron and incubating at 30 C. Fluometuron concentrations were quantified by HPLC.

First-order kinetics explained degradation of fluometuron at each soil depth ($r^2=0.99$). Degradation of fluometuron at 0 to 4 cm was more rapid in CT NC than in NT VE, although all treatments had half-lives >49 d. No differences in degradation of fluometuron were observed

between treatments at 4 to 8 or 8 to 15 cm soil depths.

Dissipation of fluometuron was slowest under NT VE at all soil depths. Dissipation also tended to be slower under NT than under CT at the 0 to 4 and 4 to 8 cm depths regardless of the cover crop effect. Soil under NT may adsorb more fluometuron rendering it unavailable for degradation or plant uptake.

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PART I

INTRODUCTION

ADVANTAGES OF NO-TILLAGE COTTON PRODUCTION

No-tillage cotton production is increasing in Tennessee due in part to federally mandated legislation which makes soil conservation a requirement for participation in federal farm programs.

No-tillage cotton production has several advantages over conventional tillage in addition to erosion control (1). Fuel consumption is reduced under no-tillage crop production since tillage operations are eliminated. Diesel fuel requirements for land preparation are 60 to 75% less for no-tillage than for conventional tillage. No-tillage provides greater flexibility in planting and harvesting due to less dependence on climatic conditions. Crops can be planted no-tillage before soils have dried sufficiently to be tilled, and untilled soil provides greater trafficability for planting and harvesting operations. No-tillage can also increase the intensity of land use. The Soil Conservation Service recommends upgrading class IIe, IIIe, and IVe land one class with no-tillage and incorporation of other conservation practices. Reduction in farm labor is another advantage associated with no-tillage crop production. No-tillage requires 50% less labor than conventional tillage for land preparation and planting. Soil moisture levels are sometimes greater under no-tillage than conventional tillage. This results from increased infiltration, reduced

runoff, and less evaporation, and creates a more favorable environment for increased yields, especially under dry conditions. An additional advantage of no-tillage is the reduced equipment requirement. No-tillage crop production requires a planter, a pesticide applicator, and harvest equipment. Tractor horsepower requirements are relatively low under no-tillage, and equipment life expectancy is increased as a result of decreased hours of operation.

WEED CONTROL IN NO-TILLAGE COTTON

A well-planned weed control program is essential to successful no-tillage cotton production (2). Without the option of mechanical cultivation, weed control must be accomplished with herbicides. Field selection is an important factor to consider. Fields heavily infested with perennial vines, bermudagrass [*Cynodon dactylon* (L.) Pers.], yellow nutsedge [*Cyperus esculentus* L.], and other difficult-to-control weeds should be avoided. Complete control of existing vegetation prior to cotton emergence is essential. Glyphosate applied 10 to 14 d prior to planting followed by paraquat plus residual herbicides at planting usually provides good control of existing vegetation. Fluometuron plus metolachlor or pendimethalin are needed to control common cocklebur [*Xanthium strumarium* L.], morningglory [*Ipomoea* spp.], pigweed [*Amaranthus* spp.],

seedling johnsongrass [*Sorghum halepense* (L.) Pers.], and annual grasses. Additional control of velvetleaf [*Abutilon theophrasti* Medik.], spurred anoda [*Anoda cristata* (L.) Schlecht], prickly sida [*Sida spinosa* L.], spurge [*Euphorbia* spp.], and grasses can be achieved by adding norflurazon to the tank-mixture at planting.

Post-directed herbicides are used to control weed escapes, provided that a height differential exists. Post-directing is very important under no-tillage due to the absence of cultivation and the lack of selective postemergence broadleaf herbicides in cotton.

EFFECTS OF NO-TILLAGE ON WEED BIOLOGY

Herbicides can be effectively used for weed control in no-tillage crop production; however, other factors must be considered. These factors include the effect that the lack of tillage has on weed seed distribution on the soil surface and within the soil profile in relation to weed seed viability and possible species shifts over time. Another factor to consider with no-tillage is the effect of the accumulated mulch on herbicide activity and persistence (3). Cussans reported that tillage had three basic effects (4). These effects were the burial of surface vegetation and weed seeds, inversion of the soil bringing previously buried weed seeds to the surface, and soil disturbances which shatter

rhizome and root systems. Under no-tillage conditions the inversion and disturbance phases are minimized.

EFFECTS OF NO-TILLAGE ON HERBICIDE ACTIVITY

Herbicide activity in no-tillage systems depends on many factors including chemical properties of the herbicide, application rate, soil pH, soil organic matter content, amount of surface plant residue, and environmental conditions (3). It is becoming increasingly important to know the fate of herbicides in the environment. For a herbicide to be effective, it must provide weed control for sufficient time until the crop can compete with the weeds or the weeds will not affect crop yields. If weed control declines too rapidly, crop yields will be reduced.

Problems are also encountered when herbicides persist longer than needed for weed control. Rotational crops can be affected, and herbicide residues can be moved from the site of application. A herbicide therefore, must last long enough to provide weed control without leaving potentially harmful residues.

The following sections of this dissertation will pertain to research conducted to determine the dissipation and bioavailability of fluometuron as affected by tillage and cover crop, and how these differences affect weed control with fluometuron under no-tillage cotton production.

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PART II

LITERATURE REVIEW

INTRODUCTION

Cotton ranks as Tennessee's second leading cash crop behind tobacco (2). Cotton production has increased from 117,000 ha planted in 1980 to 251,000 ha planted in 1991. In 1991 Tennessee cotton farmers produced 701,000 bales from 247,000 ha. The vast majority of cotton produced in Tennessee is in the western third of the state.

Western Tennessee has high soil erosion rates. In 1977 the United States Department of Agriculture Soil Conservation Service estimated the annual sheet and rill erosion of cultivated areas in Tennessee to be over 6 t ha⁻¹ yr⁻¹ (14). The 1985 Food and Security Act made soil conservation a qualification for participation in any federal farm program (15). This act required farmers to have a soil conservation plan for all highly erodible cropland by January 1, 1990 and also requires full implementation of the plan by 1995. As a result of this legislation, western Tennessee cotton growers have adopted conservation practices for their highly erodible cotton fields. No-tillage is one practice that is gaining popularity due to its ease of adoption and its ability to reduce soil losses.

Fluometuron. Fluometuron (N,N-dimethyl-N'-[3-(trifluoromethyl)phenyl]urea) is a substituted urea herbicide marketed under the trade names Cotoran and Meturon (Ciba Geigy,

Griffin Corp). Fluometuron was introduced in 1965 and is labeled for use on cotton and sugarcane (13). Fluometuron may be applied at rates from 1 to 4.5 kg ha⁻¹ preemergence (PRE) or postemergence (POST) for the control of annual grass and broadleaf weeds (1); however, application rates in Tennessee typically range from 1.1 to 2.2 kg ha⁻¹ (10). Fluometuron is a crystalline, white, odorless compound with a melting point of 163 to 164.5 C. Fluometuron has a low vapor pressure (5×10^{-7} mm Hg at 20 C) and is moderately soluble in water (90 mg L⁻¹ at 20 C).

Weed Control. Fluometuron is often the foundation of a cotton weed control program. Fluometuron has a relatively broad spectrum of weed control and has activity on both broadleaf and grass weed species. Fluometuron rates should be adjusted for soil texture with lower rates used on lighter soils which are low in organic matter (3). Phytotoxicity can occur if high rates are used on light textured soils. Fluometuron may be applied preemergence, postemergence, or post-directed.

Fluometuron may be applied to cotton plants at any growth stage from 7.6 cm high to lay-by. Fluometuron controls most annual grasses including crabgrass, fall panicum, foxtail, and goosegrass >80% (10). Fluometuron also controls many broadleaf weeds including common cocklebur, jimsonweed, common lambsquarters, pitted morningglory, pigweed, common ragweed, sicklepod, and

smartweed more than 80% (10).

Fluometuron Degradation. Fluometuron is degraded by step-wise demethylation to the metabolites, desmethyl-fluometuron (DMFM) and trifluoromethyl-phenyl urea (TFMPU), followed by hydrolysis to the aniline derivative trifluoromethyl-aniline (TFMA) as shown in Figure 1 (6,12). The half-life of fluometuron in soil is 30 to 70 d (1).

FLUOMETURON DISSIPATION PROCESSES

Fluometuron dissipation occurs due to many different processes including photodecomposition, volatilization, leaching, adsorption, chemical degradation. and microbial degradation.

Photodecomposition and volatilization. In 3 d exposure, natural sunlight decomposed 88% of a 10 ppm aqueous solution of fluometuron (1). However, fluometuron is normally applied to soil and losses due to photodecomposition are much less. Losses due to hydrolysis and volatilization are also minimal (1). Fluometuron is stable in water at pH 1 to 13 at 20 C. Fluometuron in aqueous solutions at pH 5 to 9 has a half-life between 730 and 1010 d. Volatilization is not expected to contribute to fluometuron dissipation due to the low vapor pressure of fluometuron (1).

Leaching. Fluometuron leaching into soil may be a significant dissipation process. Fluometuron has a leaching

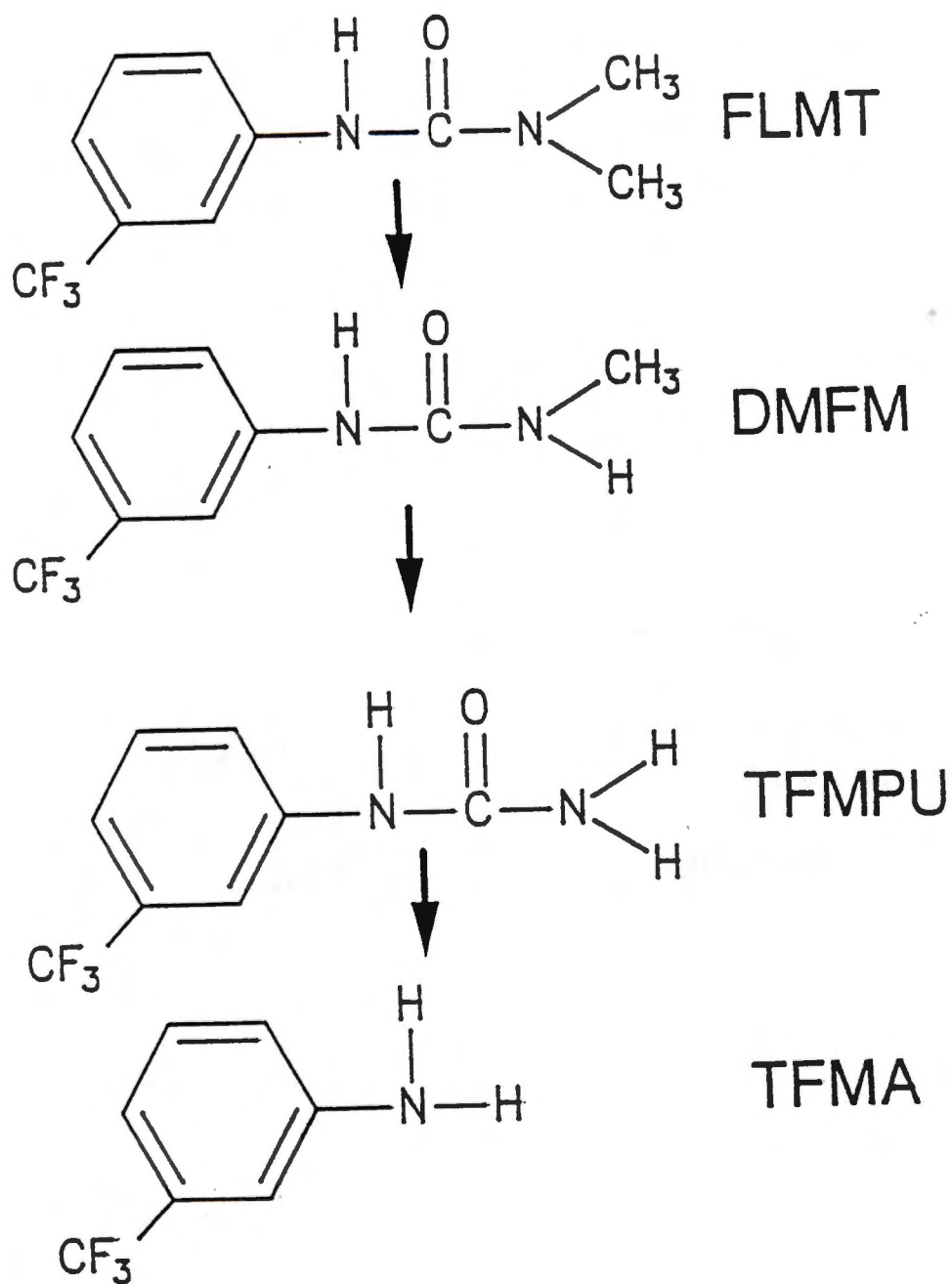


Figure 1. Degradation pathway of fluometuron.

index value of 12. An index value of 1 indicates low leaching potential and 20 indicates high leaching potential (1). Baldwin et al. (4) determined that leaching of fluometuron on a Teller sandy loam was affected by rainfall intensity and antecedent soil moisture. High rainfall intensity caused fluometuron to leach to greater depths at higher concentrations. Fluometuron leaching was also greater in soils with lower antecedent soil moisture levels. Soils which were dry prior to rainfall had less surface runoff than soils which were wet, resulting in more infiltration and more fluometuron leaching. No detectable fluometuron leached deeper than 10 cm. Studies were conducted in Puerto Rico to determine fluometuron leaching using field lysimeters (8). In these studies, fluometuron leached to a depth of 91 cm. The highest fluometuron concentration was determined in water samples taken 1 wk after fluometuron application. However the greatest total quantity of fluometuron lost from leaching occurred due to a 9.7 cm rain during the second week after application. Loss of fluometuron due to leaching was no longer detectable 20 wk after application. The total quantity of fluometuron lost during the study was determined by assuming that downward leaching of fluometuron occurred with little or insignificant lateral movement and that each lysimeter collected the herbicide applied directly above it. Using this approach it was determined that the total loss of

fluometuron due to leaching was 5.5% of the total applied.

Adsorption. Adsorption of fluometuron to soil colloids can result in the inactivation of a significant amount of fluometuron. Fluometuron adsorption was determined in Puerto Rico for 48 soils varying in texture, pH, and organic matter content (7). Fluometuron adsorption was significantly correlated with organic matter content, cation exchange capacity, calcium level, and clay content. There was no significant correlation between fluometuron adsorption and soil pH.

Soils from the 10 to 20 cm depth of a Taloka silt loam had higher fluometuron adsorption than soils from the 40 to 50 cm depth (5). The lower adsorptivity of soils from the 40 to 50 cm depth was consistent with lower organic matter content at those depths. Fluometuron is present in soil as a neutral molecule; however, non-uniform electron distribution in the molecules will cause them to be slightly polar. One proposed adsorption mechanism is that the carbonyl oxygen of fluometuron can form dipole-ion bonds with adsorbed cations and H-bonds with water molecules and carboxyl and hydroxyl groups of soil organic matter (5).

Microbial degradation. The primary mechanism of fluometuron dissipation is microbial degradation. Bouchard et al. (5) conducted laboratory studies to determine half-life values for fluometuron at different temperatures. After 16 wk incubation, no detectable fluometuron degradation occurred

in sterilized soil. Incubation studies were conducted with a Cahaba loamy fine sand which had been autoclaved, not autoclaved, or not autoclaved but amended with 1% glucose and 0.2% yeast extract (6). After 72 d incubation, 92, 56, and 16% of the fluometuron remained in the autoclaved, unamended, and amended soils, respectively. This indicates that microbial degradation is the predominant fluometuron degradation process, and that microbial degradation is enhanced by the addition of carbohydrates and nitrogen. Murray et al. (9) determined fluometuron degradation rates by three soil fungi at 5, 10, and 20 ppm in Eufala sand. *Aspergillus niger* was most effective in degrading fluometuron with 94, 73, and 92% fluometuron degradation occurring after 5 d at fluometuron concentrations of 5, 10, and 20 ppm, respectively. *Aspergillus tamarii* was a more effective degrader of fluometuron than was *Aspergillus sydowi*. Urea herbicide degradation occurred faster in soils amended with an organic matter source which was high in nitrogen. Rickard and Camper (11) studied the effects of two bacterial isolates and *Rhizoctonia solani* on soil degradation of fluometuron. After 35 d incubation, *Achromobacter* sp. degraded 4% of fluometuron into nine nonpolar products, and *Pseudomonas solani* degraded 3% of the herbicide into eight nonpolar products. *Rhizoctonia solani* degraded greater than 80% of fluometuron into seven metabolites. These data illustrate the importance of soil

microorganisms in fluometuron degradation.

Environmental effects. Environmental factors also affect fluometuron degradation rate. Fluometuron half-life in a Taloka silt loam incubated at different temperatures was studied (5). Soil from the 10 to 20 cm depth had half-life values of 21, 9, and 4 wk at 15, 23, and 37 C, respectively. Fluometuron half-life values for soils taken from the 40 to 50 cm depth were 25, 9, and 7 wk, respectively. At 7 C no detectable fluometuron degradation occurred in soil from either depth.

An additional study investigated the effect of soil depth and time of year, i.e. temperature, on fluometuron degradation (5). Soils were treated with fluometuron, placed in jars, and positioned in a horizontal orientation in the side of a freshly dug soil pit from the depth from which they were originally taken. Sets of treatments were buried in October and May. Treatments were collected at time intervals and analyzed for fluometuron. Degradation occurred more rapidly during summer than during winter. Soil from the 10 to 20 cm depth had fluometuron half-lives of 34 and 7 wk for treatments initiated in October and May, respectively. Half-life values for soil from the 40 to 50 cm depth were 52 and 13 wk for treatments initiated in October and May, respectively. Treatments initiated in May were exposed to warmer temperatures than treatments initiated in October; thus, half-life values were lower for

treatments initiated in May. Rogers et al. (13) studied fluometuron dissipation at three moisture levels and two temperatures on a Sharkey silty clay, a Dundee silt loam, and a Loring silt loam. Moisture levels were -1.0, -0.04 and -0.002 Mpa and incubation temperatures were 10 and 30 C. The treated soils were incubated for 90 d and were analyzed for fluometuron. Fluometuron degradation was greater at 30 C than at 10 C for all of the soils. Fluometuron degradation was also greater at higher moisture content.

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PART III

EFFECT OF COVER CROP AND TILLAGE ON FLUOMETURON
BIOAVAILABILITY. 1. EFFICACY AND FIELD DEGRADATION

ABSTRACT¹

The effects of tillage and vetch cover crop on fluometuron degradation were determined on a Lexington silt loam soil in 1991 and 1992. Fluometuron dissipation was initially rapid but gradually slowed throughout the sampling interval indicating a potential for biphasic fluometuron degradation. Fluometuron degradation was not affected by tillage or cover crop. Calculated initial half-lives of fluometuron ranged from 12 to 38 d. Tillage and cover crop do not affect fluometuron dissipation rates but may affect fluometuron bioavailability due to changes in soil chemical and physical properties, as evidenced by reduced control of Palmer amaranth in no-till treatments compared to conventional-tilled treatments. Nomenclature: Fluometuron, (N,N-dimethyl-N'-[3-(trifluoromethyl)phenyl]-urea); entireleaf morningglory, *Ipomoea hederacea* var. *integrifolia* Gray #² IPOHG; Palmer amaranth, *Amaranthus palmeri*, S.Wats. #AMAPA; spotted

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²Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

spurge, *Euphorbia maculata* L. #EPHMA; cotton, *Gossypium hirsutum* L.; rye, *Secale cereale* L. 'Balbo'; vetch, *Vicia villosa* L.

Additional index words. Persistence, no-till, cover crop.

INTRODUCTION

The adoption of no-tillage cotton production in Tennessee has spread rapidly since 1989. This trend is due in part to provisions of the 1985 Food and Security Act which made soil conservation a qualification for participation in any federal farm program (13). This act required farmers to have a soil conservation plan for all highly erodible soils by January 1, 1990, and also requires full implementation of the plans by 1995. This legislation mandated conservation practices for highly erodible cotton fields.

No-tillage is one practice that is gaining popularity due to its ease of adoption and its ability to reduce soil losses. In 1989 1% of the 197,000 ha of cotton in Tennessee was planted no-till (2). However no-till cotton accounted for 17% of Tennessee's 257,000 ha produced in 1992 (3).

Fluometuron is a substituted urea herbicide used for the control of annual grass and broadleaf weeds in cotton and sugarcane (1). Fluometuron may be applied PRE or POST at 1.1 to 2.2 kg ha⁻¹ (4). Dissipation of soil-applied

fluometuron is due to a combination of factors including removal through leaching by rainfall and irrigation water, adsorption to soil particles, volatilization, plant uptake and photochemical, chemical, and biochemical degradation (6).

Soil degradation of fluometuron has been studied extensively; however, fluometuron degradation under no-tillage situations has not been well documented. Herbicide persistence in no-tillage systems depends on many factors, including the chemical properties of the herbicide, application rate, soil pH, soil organic matter content, amount of surface plant residue, temperature, and rainfall (15).

The objectives of this study were to determine the effects of long-term no-tillage and cover crops on efficacy and degradation of fluometuron in the field.

MATERIALS AND METHODS

Weed control and phytotoxicity. Studies were initiated to determine the effects of tillage and presence of a vetch cover crop on soil degradation of fluometuron from a cotton field soil. A field study was conducted at Jackson, Tennessee, on a Lexington silt loam (fine-silty, mixed thermic Typic Paleudalf). Soil characteristics are listed in Table 1. The research was conducted on field plots

Table 1. Selected physical and chemical characteristics of soils from the various tillage and cover crop regimes in fluometuron dissipation experiments.

Trmt ^a	Depth	pH ^b	Organic Matter ^c	CEC ^d	Sand ^e	Silt ^e	Clay ^e
	cm		%	cmol kg ⁻¹	-----	%	-----
NT NC	0-4	5.1	2.0	8.8	6	79	15
NT NC	4-8	5.5	1.0	7.3	6	79	15
NT NC	8-15	6.5	0.9	7.3	6	78	16
CT NC	0-4	5.5	1.3	7.7	7	80	13
CT NC	4-8	5.7	1.3	7.5	6	80	14
CT NC	8-15	6.3	1.1	7.5	7	78	15
NT VE	0-4	4.7	2.5	9.6	7	78	15
NT VE	4-8	4.9	1.1	7.2	7	78	15
NT VE	8-15	5.7	0.9	7.2	7	78	15
CT VE	0-4	5.0	1.5	7.7	6	80	14
CT VE	4-8	5.0	1.5	7.5	6	79	15
CT VE	8-15	5.6	1.1	7.7	5	80	15

^a CT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

^b Soil pH was determined using a 1:1 soil to water suspension (10).

^c Soil organic matter content was determined by wet oxidation with potassium dichromate and sulfuric acid (11).

^d CEC, Cation exchange capacity was determined by extraction and subsequent calculation of exchangeable bases and acids (5).

^e Particle size analyses were performed using the hydrometer method (7).

established in 1981 to evaluate the effects of cover crop, nitrogen, and tillage on cotton (13). In the original study the experimental design was a randomized complete block with a split plot design using four replications. Nitrogen rates (0, 34, 67, or 101 kg ha⁻¹) were the main plots, cover crops (vetch [*Vicia villosa* L., variety not stated], rye [*Secale cereale* L., variety 'Balbo'], vetch plus rye, and no cover crop) were the sub-plots, and tillages (no-tillage and conventional tillage) were the sub-sub-plots. This research utilized a randomized complete block design with a two-by-two factorial arrangement of treatments. The factors consisted of conventional till (CT) or no-till (NT) and vetch (VE) or no cover (NC). Nitrogen was applied at 67 kg ha⁻¹ to each plot as in the past 10 yr and all treatments were replicated four times.

Approximately 4 wk prior to planting, the entire field plot was treated with glyphosate at 1.1 kg ai ha⁻¹ to kill existing vegetation. Cotton was planted on May 23, 1991 and May 12, 1992. Both years, fluometuron at 1.7 kg ai ha⁻¹ was applied to the entire test area the day after planting. Additional nonselective and preemergence herbicides that were applied each year as a tank-mixture with fluometuron are listed in Tables 2 and 3.

Soil samples (0 to 8 cm) were taken prior to herbicide application to determine residual fluometuron concentrations from the previous year. Additional soil samples were taken

Table 2. Summary of herbicide treatments applied to cotton in 1991.

Herbicide	Date	Rate	Application
			Type ^a
		kg ha ⁻¹	
Glyphosate	Apr 24	1.1	EPP
Glyphosate	May 1	1.1	EPP
Fluometuron	May 24	1.7	PRE
Pendimethalin	May 24	1.1	PRE
Paraquat	May 24	0.7	PRE
Norflurazon	May 24	1.7	PRE
Lactofen	Jul 8	0.2	PD
MSMA	Jul 8	2.2	PD

^aEPP, early pre-plant; PRE, preemergence; PD, post-directed.

Table 3. Summary of herbicide treatments applied to cotton in 1992.

Herbicide	Date	Rate	Application
			Type ^a
		kg ha ⁻¹	
Glyphosate	Apr 22	0.8	EPP
Fluometuron	May 13	1.7	PRE
Metolachlor	May 13	0.8	PRE
Paraquat	May 13	0.5	PRE
Lactofen	Jun 24	0.2	PD
Oxyfluorfen	Jul 2	0.2	PD
Fluazifop	Aug 5	0.2	POST

^aEPP, early pre-plant, PRE, preemergence, PD, post-directed, POST, postemergence

immediately after fluometuron application (0 days after treatment (DAT)³) and at 7, 14, 21, 28, 42, 56, and 84 DAT in 1991, and at 0, 7, 14, 28, 42, 55, and 89 DAT in 1992. Samples were taken with a tractor-mounted hydraulic probe equipped to extract 4.5 cm diameter soil cores to a depth of 15 cm. Acetate tubes were placed in the probe prior to each soil sampling and the soil samples were exhumed from the ground enclosed in the acetate tube. Three cores per plot were collected, capped, frozen immediately and stored at -10 C to prevent herbicide degradation. Vetch residue was collected from the NTVE plots to determine the amount of fluometuron intercepted by the vetch residue. Vetch samples were collected on the same dates as the soil samples, and were collected through 42 DAT in 1991 and 28 DAT in 1992. Vetch was collected from a 0.25 m² area in each plot, placed in a plastic bag and frozen immediately at -10 C to prevent herbicide degradation. Visual evaluations of weed control were made at 22, 45, and 65 DAT in 1991, and at 23, 67, and 99 DAT in 1992.

Chemical analysis.

Sample preparation. Soils were removed from the freezer and thawed at room temperature. The three cores from each plot

³Abbreviations: DAT, days after treatment; HPLC, high pressure liquid chromatography; NT, no-till; VE, vetch; CT, conventional-till; NC, no cover crop;

were removed from the acetate tubes, sectioned into two depths in 1991 (0 to 8 and 8 to 15 cm) and three depths in 1992 (0 to 4, 4 to 8, and 8 to 15 cm) and combined into a composite sample. The composite samples were homogenized by hand and thoroughly mixed by shaking. Each field plot was sampled and analyzed separately to maintain the field plot replication effect.

Sample extraction. Soil extractions and chemical analyses were conducted as described by Mueller and Moorman (8). A 40 g subsample of moist soil or 5 g of vetch were weighed and placed into 250 ml polyethylene bottles with screw-top caps (Nalgene, Rochester, NY). The samples were extracted with 80 ml of methanol by shaking 16 h on a reciprocating shaker at 200 cycles per minute. The extracts were filtered into 4 ml vials through two Whatman No. 1 filter papers (Whatman, Clinton, NJ) to remove particulates. Fluometuron concentrations were determined by high pressure liquid chromatography (HPLC)³ as previously described (8).

Analytical fluometuron (Ciba-Geigy, Raleigh, NC) was >95% pure and was used without further purification. Retention time for fluometuron was 10.3 min. A preliminary study indicated fluometuron recovery in this soil was >90% for all treatments.

Data Analysis. The visual evaluation data means were separated using an LSD at the 0.05 significance level. The dissipation data were fit to first-order kinetics using the

PCSAS NLIN procedure⁴. The fluometuron concentration in ng per g⁻¹ soil was converted to the natural logarithm and then linearly regressed against time in days. The NLIN procedure outputted the first-order dissipation rate and the 95% confidence interval. Half-lives ($t_{1/2}$) were then calculated by the equation $t_{1/2} = 0.693/k$ where k is the first-order dissipation rate constant (14).

RESULTS AND DISCUSSION

Weed Control and Phytotoxicity. Some interveinal chlorosis to cotton was observed in 1991 (Table 4). The observed injury symptoms were typical for substituted urea herbicides, and did not differ among treatments.

Cotton stunting was also observed in 1991 (Table 4). Cotton stunting was evaluated separately from chemical injury to provide an estimate of the reduction in cotton vigor. Cotton stunting was thought to be due to environmental rather than chemical factors. The highest level of stunting was observed in the NT VE treatment. Stunting in this treatment was greater than in the CT VE treatment but did not differ from treatments with NC. The presence of the vetch cover crop likely increased moisture retention which resulted in a cooler micro-climate. Under

⁴SAS Institute, Cary, NC.

Table 4. Herbicide injury and cotton stunting observed in various tillage-cover regimes on June 14, 1991.

Regime ^a	Cotton Injury	Cotton Stunting
-----%-----		
NT NC	14	15
CT NC	21	15
NT VE	16	24
CT VE	18	10
LSD (0.05)	8	10

^aCT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

these cooler conditions cotton growth would be less vigorous.

Fluometuron injury was possibly worsened by a 5.2 cm rainfall received in the first 4 d after planting. Rainfall transported the fluometuron into the soil with little chance for fluometuron dissipation. Total precipitation each year is shown in Table 5. Selectivity of substituted urea herbicides is due to differential translocation and metabolism as well as placement in the soil (12). The presence of fluometuron in the rooting zone combined with cool, cloudy conditions may have limited the ability of the cotton to detoxify the fluometuron. However, the injury was not evident by 35 DAT. No significant phytotoxicity was observed in 1992.

Visual weed control evaluations were made at 22, 45, and 65 DAT in 1991 (Table 6). The primary weed species was Palmer amaranth (*Amaranthus palmeri*). At 22 DAT there was no difference in Palmer amaranth control. At 45 DAT Palmer amaranth control was lower in NT NC treatment than in either CT treatments. At 65 DAT Palmer amaranth control was lower in NT treatments than in CT treatments.

Weed control ratings were made in 1992 at 22, 67, and 99 DAT. At 22 DAT no differences in control of entireleaf morningglory (*Ipomoea hederacea*) were observed (Table 7). Control of Palmer amaranth was lower in NT treatments than in CT treatments. At 67 DAT Palmer amaranth control was

Table 5. Monthly rainfall during the growing season at Jackson.

Month	Rainfall	
	1991	1992
	-----cm-----	
April	20	6
May	26	6
June	16	28
July	6	13
August	3	8
September	9	10

Table 6. Palmer amaranth control from soil residual herbicides under selected tillage-cover regimes in 1991.

Regime ^a	Palmer Amaranth Control		
	22 DAT	45 DAT	65 DAT
	-----§-----		
NT NC	90	64	81
CT NC	98	96	98
NT VE	97	81	90
CT VE	98	96	98
LSD (.05)	NS	18	7

^aCT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

Table 7. Control of entireleaf morningglory and Palmer amaranth at 22 DAT from fluometuron and metolachlor under selected tillage-cover regimes in 1992.

Regime ^a	Weed Control	
	IPOHG ^b	AMAPA ^b
-----§-----		
NT NC	99	86
CT NC	98	99
NT VE	99	90
CT VE	99	99
LSD (0.05)	NS	9

^aCT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

^bIPOHG, entireleaf morningglory; AMAPA, Palmer amaranth.

less in NT treatments than in CT treatments (Table 8). At 99 DAT control of Palmer amaranth and spotted spurge (*Euphorbia maculata*) did not differ among treatments, however treatment effects were masked due to application of post-directed herbicides.

In general weed control was lower in NT treatments than in CT treatments. Tillage seemed to have more effect on weed control than did the presence of a vetch cover crop in this study. These effects could be due to several factors. These plots have been maintained continuously since 1981 and the seed bank could have increased, especially in the no-till plots where reduced levels of weed control have been observed. This effect would be compounded in no-till plots where mechanical cultivation is not a control option. Reduced weed control could also be a result of an altered micro-climate under no-tillage conditions. No-tillage may enhance the germination of weeds under dry soil moisture conditions due to the presence of a moisture-conserving mulch. Soil pH also tended to decrease in the no-till plots. This decrease in pH may affect plant uptake of fluometuron thereby affecting weed control. Based on these data, fluometuron can provide less complete weed control under a no-tillage system.

Chemical analysis. Residual fluometuron concentrations were determined from soil samples taken approximately 1 wk prior to fluometuron application each year. Fluometuron

Table 8. Effect of tillage and cover on Palmer amaranth and spotted spurge control from preemergence and post-directed herbicides used in 1992.

Regime ^a	Weed Control		
	AMAPA ^b	AMAPA	EPHMA
	-----67 DAT-----	-----99 DAT-----	
	-----%-----		
NT NC	81	90	80
CT NC	95	84	73
NT VE	76	79	81
CT VE	94	76	85
LSD (0.05)	11	NS	NS

^aCT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

^bAMAPA, Palmer amaranth; EPHMA, spotted spurge.

concentrations detected prior to application are shown in Table 9. Residual fluometuron concentrations were not affected by tillage or cover crop.

In 1991 fluometuron degradation in the 0 to 8 and 8 to 15 cm soil depths was examined. First-order degradation of fluometuron in the 0 to 8 cm zone was observed ($r^2=0.98$); however, no differences in fluometuron degradation rate were observed among treatments (Table 10). Therefore, the four treatments were combined for subsequent regression analyses (Figure 1). The composite first-order degradation rate constant (K) for the 1991 data was 0.023 d^{-1} and the corresponding half-life for fluometuron degradation was 30 d. Fluometuron concentrations in the 8 to 15 cm depth were $<200\text{ ng g}^{-1}$ soil throughout the sampling period (Figure 1). The fluometuron concentrations detected indicated that some fluometuron may have leached through this zone into subsurface soil, however the majority of fluometuron was degraded while still at or near the surface.

In 1992 fluometuron degradation was examined in the 0 to 4, 4 to 8, and 8 to 15 cm soil depths. This modification was made because the long-term effects of the various treatments on the soil properties were most prominent at the soil surface. It was hypothesized that by decreasing the depth of the surface soil zone, these effects could be examined with greater sensitivity and differences among treatments might be observed. As in 1991, no differences in

Table 9. Residual fluometuron concentrations prior to treatment in 1991 and 1992.

Year	Regime ^a	Soil Depth	Fluometuron Concentration
		-----cm-----	-----ppb-----
1991	NT NC	0-8	88
	CT NC	0-8	69
	NT VE	0-8	76
	CT VE	0-8	80
1992	NT NC	0-4	212
	CT NC	0-4	209
	NT VE	0-4	238
	CT VE	0-4	222
1992	NT NC	4-8	95
	CT NC	4-8	138
	NT VE	4-8	105
	CT VE	4-8	173
1992	NT NC	8-15	48
	CT NC	8-15	58
	NT VE	8-15	115
	CT VE	8-15	111

^aCT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

Table 10. Herbicide degradation rate constants (K) and calculated initial half-lives ($t_{1/2}$) for fluometuron in surface soil.

Year	Regime ^a	Depth	K	C.I. ^b	r ²	t _{1/2}
		cm	day ⁻¹			d
1991	NT, NC	0-8	0.023	(0.0099, 0.0364)	0.97	30
1991	CT, NC	0-8	0.029	(0.0208, 0.0362)	0.99	24
1991	NT, VE	0-8	0.018	(0.0089, 0.0273)	0.98	38
1991	CT, VE	0-8	0.023	(0.0106, 0.0346)	0.97	30
1992	NT, NC	0-4	0.036	(0.0173, 0.0542)	0.97	19
1992	CT, NC	0-4	0.037	(0.0220, 0.0514)	0.98	19
1992	NT, VE	0-4	0.056	(0.0076, 0.1035)	0.92	12
1992	CT, VE	0-4	0.039	(0.0190, 0.0592)	0.97	18

^aCT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

^bConfidence interval.

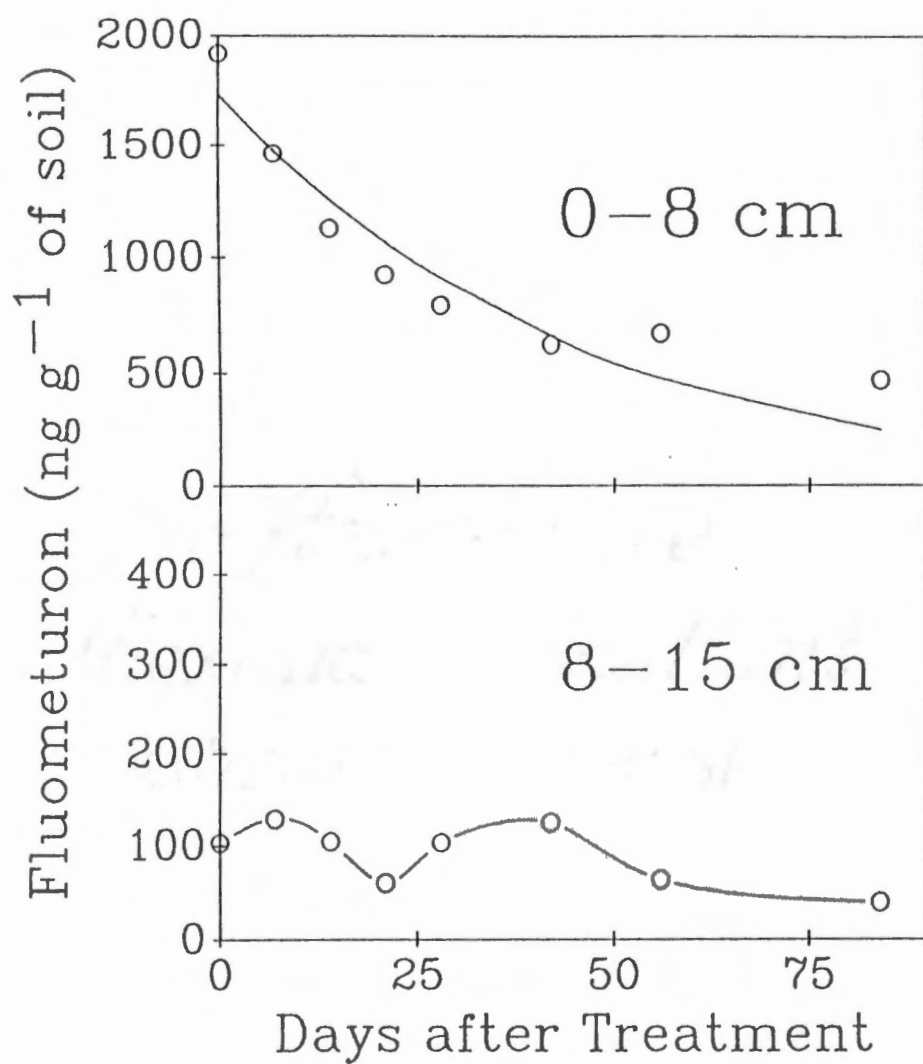


Figure 1. Change in fluometuron concentration over time at 0 to 8 and 8 to 15 cm in 1991.

degradation rates among treatments were observed in 1992 at any of the soil depths (Table 10). The treatment means were regressed as in 1991 (Figure 2). The composite value for K in the 0 to 4 cm depth was 0.0399 d^{-1} . The corresponding half-life for this K value was 17 d (Figure 2). Fluometuron concentrations in subsurface depths were $<500 \text{ ng g}^{-1}$ in the 4 to 8 cm zone and $<200 \text{ ng g}^{-1}$ in the 8 to 15 cm zone (Figure 2). These results are similar to those reported for 1991.

It appears that fluometuron degradation is occurring most rapidly in the 0 to 4 cm depth and that most of it is degraded before it can leach to the subsurface depths. These data indicate a greater degradative potential of soil from the 0 to 4 cm depth than from soil from the 0 to 8 cm depth. This would be expected due to higher organic matter content near the surface which supports a greater population of soil microorganisms. Fluometuron degradation is due primarily to microbial degradation, therefore this would explain the shorter half-life of fluometuron in soil from the 0 to 4 cm depth than in soil from 0 to 8 cm depth. Fluometuron leaching into the 4 to 8 cm zone would also account for the more rapid fluometuron disappearance in the 0 to 4 cm zone in 1992 compared to 1991.

The fluometuron concentration on vetch was determined at each sampling date (Table 11). Fluometuron concentrations are presented as μg of fluometuron per g of vetch. Initial fluometuron concentrations on vetch were $>600 \mu\text{g g}^{-1}$ in 1991

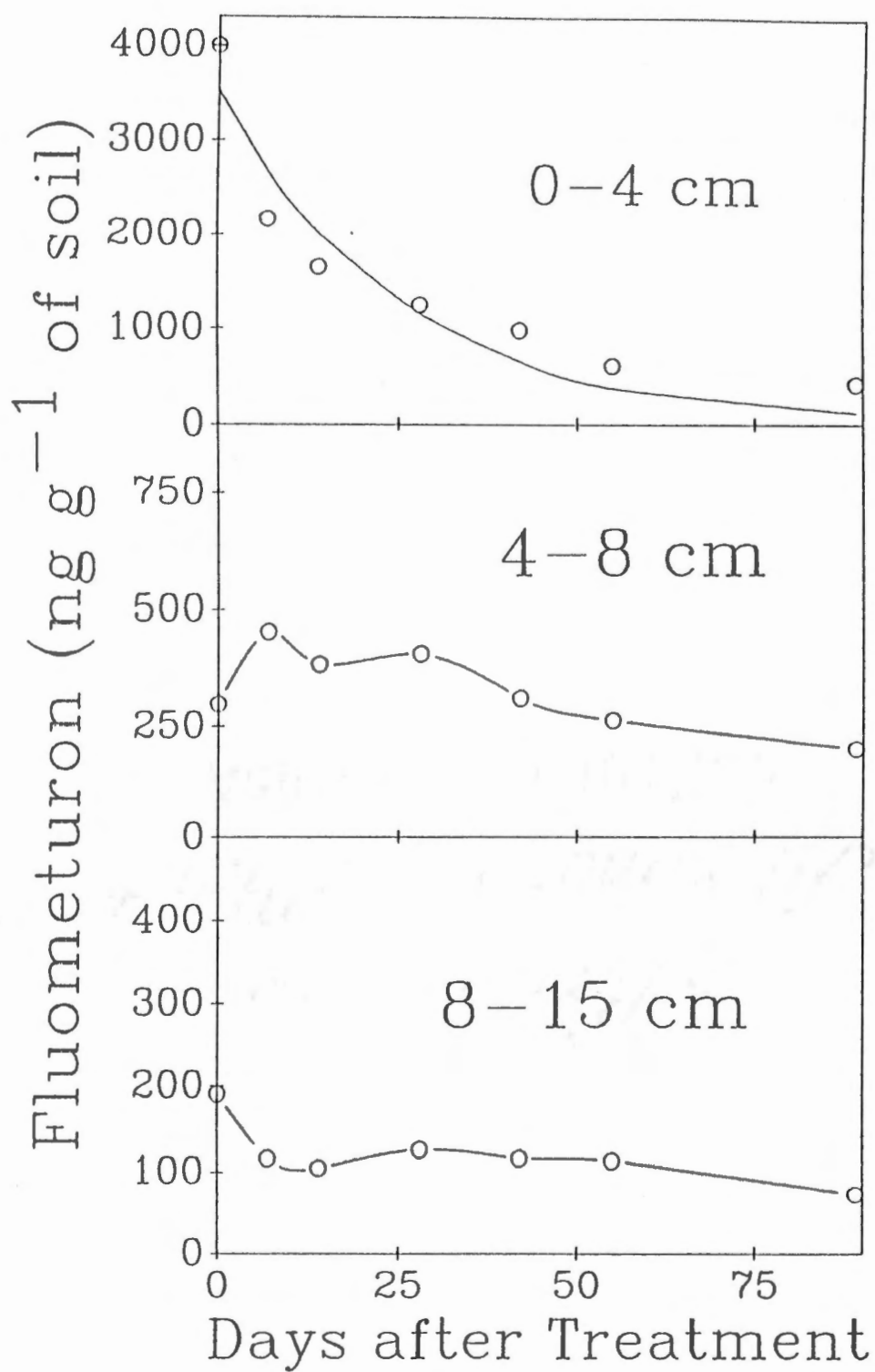


Figure 2. Change in fluometuron concentration over time at 0 to 4, 4 to 8, and 8 to 15 cm in 1992.

Table 11. Fluometuron concentrations recovered from vetch.

WAT	Fluometuron Concentration	
	1991	1992 ^a
	----ug g ⁻¹ vetch ^b -----	
0	632	529
1	27	20
2	26	9
3	13	--
4	12	2
6	8	--
LSD (0.05)	288	270

^aDashes indicate dates where no vetch samples were collected.

^bdry weight basis

and $>500 \mu\text{g g}^{-1}$ in 1992. Variations in initial fluometuron concentrations are likely due to variations in the amount of vetch residue remaining at the time of fluometuron application. Fluometuron concentrations decreased to $<30 \mu\text{g g}^{-1}$ by 1 WAT in both years. This indicates that fluometuron may be initially intercepted by vetch residues, however it does not remain on the vetch for extended time periods. Fluometuron could be degrading while on the vetch, but no differences in fluometuron concentrations were observed in the soil dissipation experiment. This indicates that fluometuron moves from vetch to soil rapidly and that vetch does not interfere significantly with fluometuron reaching the soil surface.

The dissipation data do not explain the differences in weed control observed among the various no-till and conventional-till treatments. No differences in degradation rate were observed among treatments in either year; therefore, the fluometuron concentration in soil is not affected by tillage or cover crop. This indicates that fluometuron bioavailability may be affected, rather than total concentration remaining in the soil. Long-term no-tillage, using cover crops plus cotton plant residues to reduce soil erosion, can affect soil properties near the soil surface such as organic matter content and pH. These conditions could affect bioavailability of fluometuron without affecting degradation patterns. Further research

will investigate these possibilities.

Weed control is one of the major problems encountered in no-till crop production. In no-tillage cotton production mechanical cultivation is normally not a management option. Chemical weed control must be adequate to maintain crop yields and quality. These data indicate that fluometuron may be less effective when applied to soils planted to no-till cotton, especially under continuous no-till culture. Increased fluometuron rates may be needed to maintain sufficient levels of weed control. Tank-mixtures of fluometuron with other herbicides can have a synergistic effect and may provide greater control than either herbicide alone. Crop and herbicide rotations are other options for difficult weed problems. Additional research should focus on these areas in order to determine how best to manage weeds while maintaining soil resources.

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PART IV

EFFECT OF COVER CROP AND TILLAGE ON FLUOMETURON
BIOAVAILABILITY. 2. ADSORPTION TO SOIL COLLOIDS AND
DEGRADATION UNDER CONTROLLED CONDITIONS.

ABSTRACT⁵

The effects of tillage and vetch cover crop on fluometuron degradation and adsorption to soil colloids under controlled conditions were determined. Fluometuron degradation over time was determined for four tillage treatment by cover crop regimes: no-till no cover (NT NC), conventional-till no cover (CT NC), no-till vetch cover (NT VE), and conventional-till vetch cover (CT VE). At the 0 to 4 cm soil depth, fluometuron degradation rate was slower in NT VE compared to CT NC; however, CT NC did not differ from NT NC or CT VE. No differences in fluometuron degradation rate were observed among treatments in soil from the 4 to 8 or 8 to 15 cm depths. Calculated initial half-lives of fluometuron ranged from 49 to 90 d. Soil adsorption of fluometuron was affected by tillage and cover crop. In surface soils (0 to 4 cm), fluometuron adsorption was greater in no-tilled plots than in conventional-tilled plots. Soil adsorption of fluometuron was also greater on

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soils with a vetch cover crop. Soil adsorption of fluometuron was positively correlated with organic matter content and cation exchange capacity. These data indicate that tillage and cover crop may affect soil dissipation of fluometuron, however soil physical and chemical properties which affect fluometuron bioavailability may be altered.

Nomenclature: Fluometuron, (N, N-dimethyl-N'-[3-(trifluoromethyl)phenyl]-urea).

Additional index words. Dissipation, no-till, adsorption, bioavailability.

INTRODUCTION

Fluometuron degradation under field conditions was reported on in a previous paper (2). The study reported here was conducted to evaluate the effects of tillage and cover crop on fluometuron degradation and adsorption under controlled conditions. Previous studies have shown the effects of various environmental conditions on fluometuron degradation. Rogers et al. (10) reported that fluometuron degradation was greater at 30 C than at 10 C for three different soil series. Fluometuron degradation also tended to increase at higher moisture levels. Bouchard et al. (1) reported that fluometuron degradation increased as temperature increased from 15 C to 37 C. However no fluometuron degradation occurred at 7 C. The effects of

tillage and cover crop on fluometuron degradation have not been documented.

The objectives of the following studies were to evaluate the effects of tillage and cover crop on fluometuron degradation under controlled conditions, and to determine the degree to which these management practices affect soil adsorption of fluometuron.

MATERIALS AND METHODS

Adsorption Study. The adsorption of fluometuron onto a Lexington silt loam (Fine-silty, mixed thermic Typic Paleudalf) was determined using a slurry technique similar to that of Talbert and Fletchall (11). Soil was collected from a study established at Jackson, Tennessee on which cotton had been continuously planted conventional till or no-till into either vetch or no cover since 1981. Soil chemical and physical properties are in Table 1. Soil was screened through a 2 mm sieve and 10 g soil was added to 50 ml plastic screw top centrifuge tubes. Twenty ml of 0.01 M CaCl_2 solution containing either 0 or 1 μg of analytical fluometuron was added to each tube. Tubes were capped and placed on a reciprocating shaker which was operated at 200 cycles per minute (cpm) for 12 h. After 12 h equilibration, samples were centrifuged at 8000 rpm for 10 min. The samples were filtered through two Whatman No. 1 filter

Table 1. Physical and chemical characteristics of soils from the various tillage and cover crop regimes.

Trmt ^a	Depth	pH ^b	Organic Matter ^c	CEC ^d	Sand ^e	Silt ^e	Clay ^e
	cm		%	cmol kg ⁻¹	----	--%--	----
NT NC	0-4	5.1	2.0	8.8	6	79	15
NT NC	4-8	5.5	1.0	7.3	6	79	15
NT NC	8-15	6.5	0.9	7.3	6	78	16
CT NC	0-4	5.5	1.3	7.7	7	80	13
CT NC	4-8	5.7	1.3	7.5	6	80	14
CT NC	8-15	6.3	1.1	7.5	7	78	15
NT VE	0-4	4.7	2.5	9.6	7	78	15
NT VE	4-8	4.9	1.1	7.2	7	78	15
NT VE	8-15	5.7	0.9	7.2	7	78	15
CT VE	0-4	5.0	1.5	7.7	6	80	14
CT VE	4-8	5.0	1.5	7.5	6	79	15
CT VE	8-15	5.6	1.1	7.7	5	80	15

^a CT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

^bSoil pH was determined using a 1:1 soil to water suspension (7).

^cSoil organic matter content was determined by wet oxidation with potassium dichromate and sulfuric acid (9).

^dCEC, Cation exchange capacity was determined by extraction and subsequent calculation of exchangeable bases and acids (3).

^eParticle size analyses were performed using the hydrometer method (4).

papers (Whatman, Clinton, NJ) to remove particulates. These samples were quantified by HPLC as described by Mueller and Moorman (10). Centrifuge tubes containing no soil were included to account for any fluometuron adsorbed by the tube. Any reduction in fluometuron concentration was assumed to be from adsorption by the soil. A distribution coefficient (K_d), which is the ratio of the amount of herbicide adsorbed to the amount remaining in solution, was calculated for each treatment by depth combination.

Degradation Study. Studies were conducted in 1992 to quantify fluometuron degradation in soils which had been continuously tilled or no-tilled into either vetch or no cover since 1981. The study was established at Jackson, Tennessee on a Lexington silt loam (2). Soil chemical and physical properties are shown in Table 1. To evaluate fluometuron degradation under controlled conditions, soil was collected from the field study on May 4, 1992, prior to planting of the field study and prior to fluometuron application. Soil was collected with an 8 cm diameter plugger-type sampler. Soil samples were collected from each plot and samples were collected from three soil depths; 0 to 4, 4 to 8, and 8 to 15 cm. Approximately 1.5 kg of soil was collected for each treatment by depth combination. Moist soils were placed in plastic bags and stored at 4 C for 1 wk. All soil samples were screened to pass a 2 mm sieve. Soil moisture content was determined to be approximately

field capacity (25%) for all treatment by depth combinations and moisture contents were not adjusted.

The study was established as a randomized complete block with a two-by-two factorial arrangement of treatments. The factors consisted of tillage systems (conventional or no-till) and cover crop (vetch or no cover). The study was designed to continue for 12 wk with three replicates of each treatment by depth combination being removed from the incubator at 0, 1, 2, 3, 4, 6, 8, and 12 wk after treatment (WAT).

A sample of moist soil (40 g dry weight equivalent) was added to 250 ml polyethylene bottles with screw-top cap. A 40 $\mu\text{g ml}^{-1}$ stock solution of fluometuron in water was prepared. Each bottle was fortified with 1.0 ml of stock solution to give a fluometuron concentration of 1 part per million (ppm) in soil. Bottles were capped and soils contents were thoroughly mixed to incorporate fluometuron throughout the soil. Soils were incubated at 30 C for the respective number of weeks at which time they were removed from the incubator and frozen until HPLC analysis. At 4 WAT all bottles remaining in the incubator were removed and vented for 30 min to prevent the development of anaerobic conditions inside the bottles.

Sample extraction. Soil extractions and HPLC analyses were conducted as described previously. Samples were allowed to thaw at room temperature. Extractions were accomplished by

adding 80 ml of methanol to each bottle and shaking 16 h on a reciprocating shaker at 200 cpm. Soil extracts were filtered through two Whatman No. 1 filter papers (Whatman, Clinton, NJ) to remove particulates, and analyzed by HPLC as previously described (10).

RESULTS AND DISCUSSION

Adsorption Study. Fluometuron adsorption was affected by tillage and cover crop. At a soil depth of 0 to 4 cm, fluometuron adsorption was greater in the NT VE treatment when compared to the CT NC treatment (Table 2). At the 4 to 8 cm depth fluometuron adsorption was greater in CT treatments than in NT VE treatment. Fluometuron adsorption was not effected by tillage or cover crop in the 8 to 15 cm soil depth.

The trends in fluometuron adsorption can be explained by noting the distribution of organic matter throughout the soil profile. In no-tillage organic matter is left on the soil surface while in conventional-tillage organic matter is distributed throughout the plow layer. Trends for fluometuron adsorption at the 4 to 8 cm depth were similar to organic matter contents among treatments.

Fluometuron adsorption to soil was correlated with various soil characteristics (Table 3). Soil organic matter content was the soil characteristic most highly correlated

Table 2. Distribution coefficients of fluometuron adsorption onto soils from various tillage and cover crop regimes.

Depth	NT NC ^a	CT NC	NT VE	CT VE	LSD ^b
cm	-----Kd-----				
0-4	2.23	1.70	2.96	2.14	0.99
4-8	1.66	2.15	1.05	2.17	0.97
8-15	1.37	1.38	1.28	1.63	0.33
overall LSD = 0.94					

^a NT NC, no-till, no cover; CT NC, conventional-till, no cover crop; NT VE, no-till, vetch cover crop; CT VE, conventional till, vetch cover crop.

^bLeast significant difference at the 0.05 probability level for means within a soil depth and overall treatments.

Table 3. Correlation of distribution coefficients of fluometuron adsorption on soils with soil characteristics.

Factors		Organic		%	%	%
Correlated	pH	Matter	CEC	Sand	Silt	Clay
Kd	-0.55	0.89**	0.81**	0.07	0.12	-0.20

** Significant at 1 % level; all other correlations not significant

with K_d . Cation exchange capacity (CEC) was also highly correlated with K_d . Correlations between K_d and other soil characteristics were not significant. These data agree with the findings of Liu and Cibes-Viade (8) where they reported that fluometuron adsorption was highly correlated with percent organic matter and CEC in 48 soils found throughout Puerto Rico. They also reported a significant correlation between adsorption and clay percentage, however in our study the percentage in the clay fraction was uniform across treatments.

Degradation Study. First-order kinetics explained fluometuron degradation at each soil depth under controlled conditions ($r^2=0.99$). Degradation rate at 0 to 4 cm was more rapid in CT NC than in NT VE, although all regimes had a half-life of >49 d. For ease of presentation the data were pooled and the means are presented in Figure 1. Individual treatment means are listed in Table 4. Soil in the 0 to 4 cm zone had a first-order rate constant (K) of 0.0112 and the corresponding fluometuron half-life of 62 d. At 4 to 8 cm the K was 0.0097 and the half-life of fluometuron was 71 d. Soil from the 8 to 15 cm zone had a K of 0.012 and a fluometuron half-life of 58 d.

Fluometuron tended to dissipate most slowly under NT VE at all soil depths. Fluometuron dissipation also tended to be slower under no-tillage than conventional tillage at 0 to 4 and 4 to 8 cm regardless of the cover crop effect. Slow

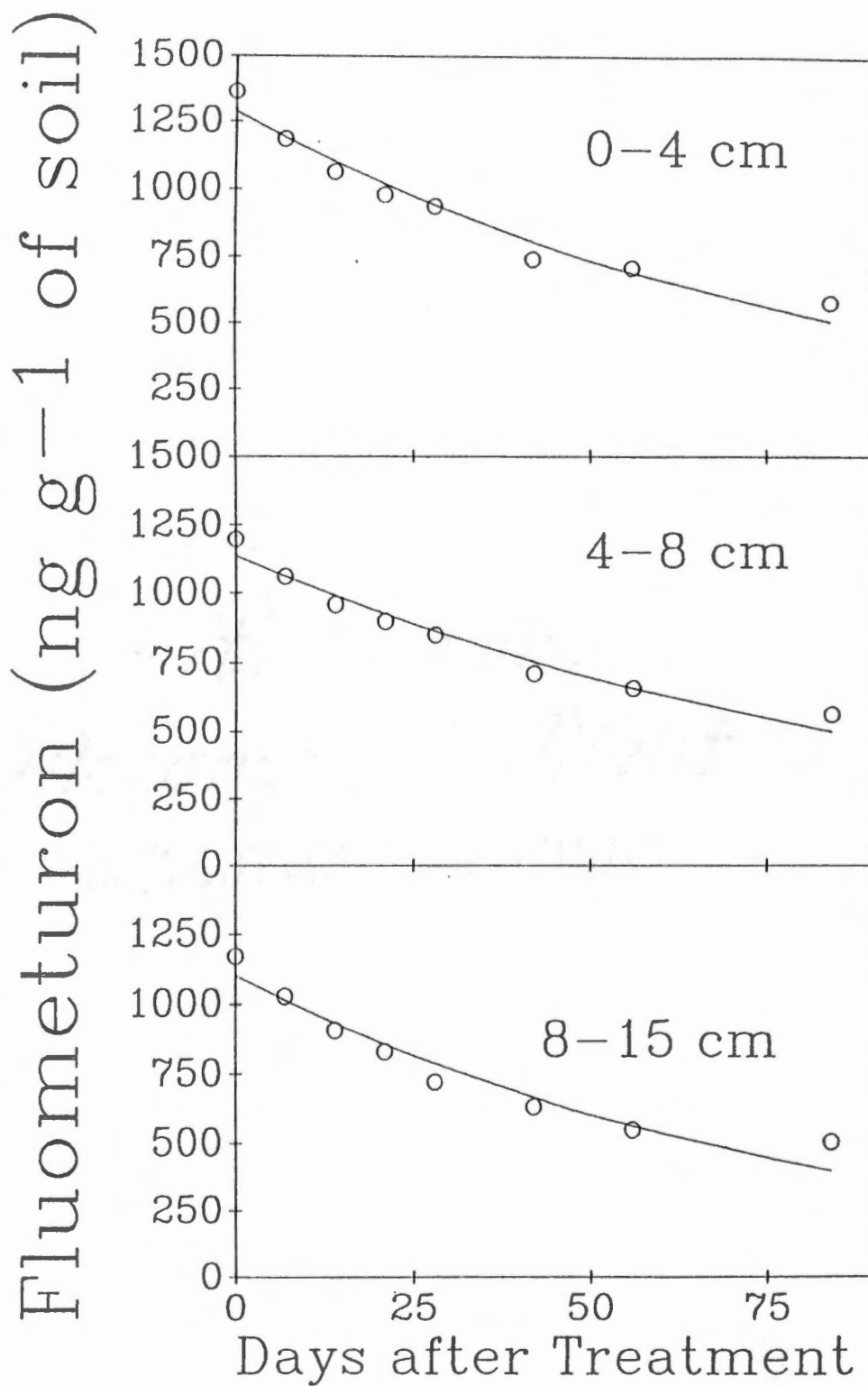


Figure 1. Change in fluometuron concentration over time in soil from 0 to 4, 4 to 8, 8 to 15 cm at 30 C.

Table 4. Herbicide degradation rate constants (K) and calculated initial half-lives ($t_{1/2}$) for fluometuron at each soil depth.

Regime ^a	Depth	K ^b	C.I. ^c	r ²	$t_{1/2}$
	cm	day ⁻¹			d
NT, NC	0-4	0.012	(0.0088, 0.0154)	0.99	57
CT, NC	0-4	0.014	(0.0118, 0.0168)	0.99	49
NT, VE	0-4	0.009	(0.0064, 0.0114)	0.99	78
CT, VE	0-4	0.010	(0.0068, 0.0127)	0.99	71
NT, NC	4-8	0.009	(0.0073, 0.0104)	0.99	79
CT, NC	4-8	0.013	(0.0104, 0.0149)	0.99	55
NT, VE	4-8	0.008	(0.0047, 0.0107)	0.99	90
CT, VE	4-8	0.010	(0.0082, 0.0121)	0.99	68
NT, NC	8-15	0.014	(0.0082, 0.0201)	0.99	49
CT, NC	8-15	0.013	(0.0095, 0.0172)	0.99	52
NT, VE	8-15	0.008	(0.0063, 0.0104)	0.99	83
CT, VE	8-15	0.013	(0.0090, 0.0176)	0.99	52

^aNT NC, no-till, no cover; CT NC, conventional till, no cover; NT VE, no-till, vetch cover; CT VE, conventional till, vetch cover.

^bFirst-order rate constant.

^cLower and upper limits of 95% confidence interval.

dissipation of fluometuron under NT VE could be related to fluometuron adsorption. The NT VE regime had the highest amount of fluometuron adsorption in the 0 to 4 cm depth (Table 2). This adsorption could slow dissipation by removing fluometuron from the soil solution, thus making it unavailable for degradation. The same process could explain the slower dissipation of fluometuron under no-tillage than conventional tillage at 0 to 4 cm.

Initial fluometuron degradation rate was determined by calculating fluometuron degradation rate constants for 0 to 4 WAT samples only (Table 5). No differences in degradation rate were observed among regimes at 0 to 4 or 4 to 8 cm depths. At 8 to 15 cm fluometuron dissipation was slower in NT VE than in either of the regimes with no cover crop. However fluometuron dissipation did not differ between NT VE and CT VE.

An important difference to note between this study and a field study reported by Brown et al (2) is that in the field study, fluometuron reached the 4 to 8, and 8 to 15 cm zones by leaching through the 0 to 4 cm zone. In this study soils from all of the depths were fortified with the same concentrations of fluometuron. Residual fluometuron concentrations were determined prior to the study and are shown in Table 6. Results from this study permit the comparison of the degradative potential of soil from the three depths. Fluometuron was degraded most rapidly by soil

Table 5. Initial (0 to 4 WAT) herbicide degradation rate constants (K) and calculated initial half-lives ($t_{1/2}$) for fluometuron at various soil depths.

Regime ^a	Depth	K ^b	C.I. ^c	r ²	$t_{1/2}$
	cm	d ⁻¹			d
NT, NC	0-4	0.0158	(0.0077, 0.0239)	0.99	44
CT, NC	0-4	0.0142	(0.0123, 0.0160)	0.99	49
NT, VE	0-4	0.0122	(0.0060, 0.0184)	0.99	57
CT, VE	0-4	0.0140	(0.0105, 0.0176)	0.99	49
NT, NC	4-8	0.0104	(0.0062, 0.0146)	0.99	67
CT, NC	4-8	0.0147	(0.0088, 0.0207)	0.99	47
NT, VE	4-8	0.0124	(0.0066, 0.0183)	0.99	56
CT, VE	4-8	0.0125	(0.0110, 0.0140)	0.99	55
NT, NC	8-15	0.0194	(0.0170, 0.0217)	0.99	36
CT, NC	8-15	0.0201	(0.0186, 0.0216)	0.99	34
NT, VE	8-15	0.0108	(0.0068, 0.0148)	0.99	64
CT, VE	8-15	0.0180	(0.0147, 0.0213)	0.99	38

^aNT NC, no-till, no cover; CT NC, conventional till, no cover; NT VE, no-till, vetch cover; CT VE, conventional till, vetch cover.

^bFirst-order rate constant.

^cLower and upper limits of 95% confidence interval.

Table 6. Residual fluometuron concentrations in experimental soils prior to treatment in 1992.

Regime ^a	Depth	Fluometuron
		Concentration
	-----cm-----	-----ppb-----
NT NC	0-4	212
CT NC	0-4	209
NT VE	0-4	238
CT VE	0-4	222
NT NC	4-8	95
CT NC	4-8	138
NT VE	4-8	105
CT VE	4-8	173
NT NC	8-15	48
CT NC	8-15	58
NT VE	8-15	115
CT VE	8-15	111

^aCT, conventional tillage; NT, no-tillage; NC, no cover crop; VE, vetch cover crop.

from the 8 to 15 cm zone, while fluometuron half-life values were greatest in soil from the 4 to 8 cm depth. Although these differences were small, it would be expected that the greatest degradative potential would be in soil near the surface since fluometuron degradation occurs primarily by microbial degradation. Microbial activity should be greater at the soil surface in no-till due to the higher organic matter content. Microorganisms typically decrease with depth in the soil profile as does organic matter (8). In contrast, conventional tillage tends to stimulate microbial activity at plow-sole depth due to the inversion and fragmentation of surface residues (8). However due to a lack of differences among treatments they were combined and this could explain the inconsistencies in fluometuron degradation by soil from different depths.

These data indicate that tillage and cover crop do not greatly affect fluometuron degradation rate. However long-term use of these practices changes soil physical properties which affect bioavailability of fluometuron. The major change in soil properties with continued use of no-till is an increase in organic matter content in the surface 4 cm of soil. This leads to a corresponding increase in CEC in that depth. No-till also tended to decrease soil pH slightly. The vetch cover crop tended to increase organic matter content and CEC but to a lesser extent than tillage. Vetch also decreased pH slightly as compared to the no cover

treatment. This could be due to the additional nitrogen added to the soil by vetch.

Although treatment differences in fluometuron degradation were minimal, there were treatment differences in fluometuron adsorption. The changes in soil physical properties among treatments presumably had a significant effect on adsorption. Treatments which resulted in increased organic matter content and increased CEC tended to have higher levels of adsorption. Although the actual concentration of fluometuron in soil did not differ due to treatment, the differences in amount of fluometuron adsorbed could explain the reduced weed control observed in no-till treatments in the field. The reduced bioavailability of fluometuron under long-term no-tillage culture may require an increase in fluometuron application rates to maintain weed control at levels comparable to that of conventional-tillage.

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PART V

GENERAL SUMMARY

The objectives of this research were to determine: (1) the effects of long-term no-tillage and cover crops on efficacy and degradation of fluometuron in the field, (2) the effect of no-tillage and cover crops on soil adsorption of fluometuron in the field, and (3) the effects of no-tillage and cover crops on fluometuron degradation under controlled conditions.

Long-term use of no-tillage can reduce weed control provided by fluometuron. Weed control differences were not observed at 22 d after treatment (DAT) in 1991, but by 45 DAT control of Palmer amaranth was lower in no-tillage (NT) than in conventional-tillage (CT) treatments. In 1992 Palmer amaranth control was lower in NT than in CT treatments at 22 and 67 DAT. Tillage appeared to have more effect on weed control than did the presence of a vetch (VE) cover crop.

Degradation of fluometuron in the field was determined for each tillage and cover crop regime. Degradation of fluometuron did not differ among treatments in surface soils (0 to 8 cm). Dissipation of fluometuron in subsurface soils (8 to 15 cm) did not differ among treatments.

Fluometuron on vetch residue was quantified in 1991 and 1992 to determine if fluometuron was being intercepted by the vetch residue. Fluometuron concentrations decreased greatly by 1 wk after treatment (WAT). Although fluometuron may be initially intercepted by vetch residue, it is rapidly

moved to the soil. Fluometuron in soil did not differ among treatments. This indicates that degradation of fluometuron does not occur on vetch but rather that fluometuron is released to the soil.

Adsorption of fluometuron on soil colloids was determined for each tillage and cover crop regime. Adsorption of fluometuron was affected by tillage and cover crop. Adsorption of fluometuron was highest in NT VE at the 0 to 4 cm soil depth. At the 4 to 8 cm depth adsorption of fluometuron was greater in CT VE than in NT VE. This follows the same pattern as the distribution of organic matter within the soil profile. In NT organic matter remains near the soil surface, while in CT organic matter is distributed throughout the plow layer.

Adsorption of fluometuron on soil was correlated with various soil characteristics. Soil organic matter was the soil characteristic most highly correlated with fluometuron adsorption. Cation exchange capacity (CEC) was also highly correlated with adsorption. Adsorption was not correlated with pH or particle size.

Degradation of fluometuron in each tillage and cover crop regime was determined under controlled conditions. Degradation of fluometuron at each soil depth was described by first-order kinetics. At 0 to 4 cm fluometuron degraded faster under CT NC than under NT VE, although half-life of fluometuron was >49 d in all residues. At 4 to 8 and 8 to

15 cm depths, no differences in degradation of fluometuron were observed among treatments. However, fluometuron tended to degrade slower under NT VE at all soil depths. Dissipation of fluometuron also tended to be slower under NT than under CT at 0 to 4 and 4 to 8 cm regardless of the cover crop. Slow dissipation of fluometuron under NT VE could be related to soil adsorption of fluometuron. With greater adsorbed fluometuron, less would be available for degradation.

These data indicate that tillage and cover crop do not greatly affect degradation of fluometuron. However, long-term use of these practices alters soil chemical and physical properties, which can affect bioavailability of fluometuron. The major change in soil properties with continued use of no-till is an increase in organic matter content in the surface 4 cm of soil. A corresponding increase in CEC was observed at that depth. These two factors were highly correlated with adsorption of fluometuron. Adsorption of fluometuron might explain differences in weed control among treatments since degradation did not appear to be affected by treatment. Increased adsorption of fluometuron would remove fluometuron from soil solution thereby making it unavailable for degradation, as well as reducing the concentration available for weed control. The reduced bioavailability of fluometuron under long-term no-tillage may require increased

fluometuron application rates to maintain weed control at levels comparable to that of conventional-tillage.

*Conventional
tillage
weed control
rates*

St. John's
APPENDIX
Alexander's Brilliant
1810-1811

Table A-1. Environmental conditions at Jackson from April-June, 1991.

Day	April			May			June		
	Temp.		Rain	Temp.		Rain	Temp.		Rain
	Max	Min		Max	Min		Max	Min	
	(C)		(cm)	(C)		(cm)	(C)		(cm)
1	62	35		79	58		88	71	
2	73	43		73	49		90	68	0.66
3	76	53		78	54		91	73	
4	76	53	0.76	72	59	0.56	94	70	
5	64	52	0.48	76	64	4.24	93	68	0.41
6	78	54		77	51	0.05	82	62	
7	83	61		76	47		82	62	
8	84	63	1.04	72	48		83	62	
9	77	66	0.05	69	57	1.40	83	61	
10	75	45	1.19	77	65	0.18	86	67	
11	67	47		74	66	2.62	86	68	0.58
12	74	47	1.27	82	67	2.24	79	69	1.73
13	69	56	1.27	72	64	2.54	86	71	0.28
14	74	61	3.89	71	63	0.64	86	71	
15	68	59	2.06	86	67		89	74	
16	71	48		87	66	1.93	90	70	0.23
17	81	53		82	69		85	70	
18	82	59		90	65	4.37	87	64	
19	68	59	3.81	82	69	0.03	86	68	
20	72	55	0.03	85	69	0.25	88	70	
21	62	48		77	66		91	70	1.04
22	60	47	0.05	82	68		87	67	4.06
23	63	50		79	71		84	69	0.13
24	69	51		86	72	0.18	85	72	
25	70	53		85	71	0.25	85	69	6.55
26	81	57		79	68	2.26	80	67	
27	74	62	0.46	72	64	2.51	82	65	
28	72	59	4.19	83	67		82	68	
29	74	54	2.44	83	72		86	69	
30	67	55		89	73		91	73	
31				89	73				
Total			19.6			26.2			15.7

Table A-2. Environmental conditions at Jackson from July-Sept., 1991.

Day	July			August			September		
	Temp.		Rain	Temp.		Rain	Temp.		Rain
	Max	Min		Max	Min		Max	Min	
	(C)		(cm)	(C)		(cm)	(C)		(cm)
1	93	74		88	60		87	70	
2	95	75		91	65		93	72	0.97
3	93	70	0.51	94	71		93	71	0.03
4	92	70	0.76	94	72		86	72	
5	87	70		95	69	0.15	87	72	0.10
6	91	70		96	72		76	68	2.34
7	92	73		97	72		87	67	
8	88	72		98	74		90	69	
9	92	68	0.20	94	70	1.45	92	71	3.15
10	93	75		90	72	0.46	88	71	0.08
11	93	74		81	67		90	73	
12	94	77		87	63		91	72	
13	95	71		87	62		92	74	
14	92	69	0.13	84	62		91	69	
15	87	69		86	63		92	70	
16	87	69		89	63		92	71	
17	90	70		90	68		92	70	
18	91	70		86	68		87	68	
19	90	67		88	64		88	52	0.36
20	90	69		86	56		66	40	
21	91	72		82	58		65	42	
22	95	72		81	56		75	48	
23	96	74		88	61		82	58	0.08
24	97	73	0.18	92	64		68	58	1.73
25	93	70	4.57	92	66		72	49	0.15
26	84	71		82	72	0.15	70	49	
27	84	67		88	73		68	38	
28	88	67		91	73	0.08	72	43	
29	87	68		86	73	0.05	81	49	
30	88	68		84	70	1.07	86	53	
31	85	62		89	70				
Total			6.4			3.4			9.0

Table A-3. Environmental conditions at Jackson from April-June, 1992.

Day	April			May			June		
	Temp.		Rain	Temp.		Rain	Temp.		Rain
	Max	Min		Max	Min		Max	Min	
	(C)		(cm)	(C)		(cm)	(C)		(cm)
1	58	38		82	56		78	56	
2	50	28		83	62		78	60	
3	47	27		83	62		78	63	3.99
4	58	37		80	41		71	54	2.84
5	65	34		83	44		77	59	1.47
6	65	42		67	42		82	63	
7	65	50	0.38	63	44		84	67	4.19
8	71	47		69	42		77	67	0.08
9	81	53		74	44		80	69	0.79
10	79	56	1.12	82	51		82	66	0.33
11	83	55		83	56		84	66	1.65
12	83	58		83	63		83	65	2.18
13	69	48		82	58	0.23	80	65	3.45
14	79	52		81	52		72	65	
15	86	58		81	59		84	69	
16	86	61	0.30	86	64		89	70	
17	78	61	0.05	86	67		91	75	
18	81	63	0.03	85	66	0.23	91	75	0.10
19	81	63	0.18	84	66	1.83	91	65	
20	73	61	2.72	81	61		89	65	
21	69	53	1.14	87	63	0.30	88	59	0.71
22	66	49		82	64		73	47	
23	78	54		84	65		78	56	
24	86	60		83	65	0.03	82	63	
25	83	45		68	54		88	72	
26	63	40		73	56	0.05	91	60	
27	55	41	0.05	71	55	0.15	79	62	0.38
28	56	34		67	54	0.03	81	56	0.25
29	63	39		57	54	1.85	81	60	
30	73	43		63	55	1.55	84	68	0.69
31				72	49				0.36
Total			6.0			6.3			28.3

Table A-4. Environmental conditions at Jackson from July-Sept., 1992.

Day	July			August			September		
	Temp.		Rain	Temp.		Rain	Temp.		Rain
	Max	Min		Max	Min		Max	Min	
	(C)		(cm)	(C)		(cm)	(C)		(cm)
1	77	69	0.46	85	61		87	63	
2	88	69	0.08	80	59		85	67	0.03
3	91	69	0.81	84	65	1.55	85	66	0.25
4	86	66	0.03	85	67		76	64	
5	89	69	0.91	81	69		83	65	
6	83	70	1.63	82	67	0.15	87	66	
7	88	73		86	67		88	70	
8	92	74		87	68		90	68	
9	91	72		92	74		91	70	
10	97	72		92	75		90	68	
11	91	73	0.03	88	68	0.38	83	51	
12	92	72		88	68		77	49	
13	92	71		85	67		80	52	
14	93	73		84	64		84	57	
15	89	72	0.81	76	56	0.89	88	63	
16	87	72	0.10	76	53		85	59	
17	83	68	4.32	78	57		85	62	
18	83	73		82	57		79	68	3.76
19	84	67		84	63		84	64	0.23
20	89	64		84	63	0.03	77	64	
21	90	70		83	64	0.05	84	68	
22	88	72	0.03	85	66	0.03	85	69	4.45
23	86	72	1.12	85	68		75	50	0.15
24	89	72		82	69	2.29	69	51	
25	92	73	0.08	88	70		69	55	
26	87	73	0.25	90	72		69	61	1.40
27	90	71	0.81	90	74	0.08	69	56	0.20
28	85	66		74	58	2.18	74	50	
29	85	64		74	52		76	48	
30	84	71		80	56		69	43	
31	89	69	1.91	84	61				
Total			13.4			7.6			10.5

VITA

Blake Alan Brown was born in Knoxville, Tennessee on December 29, 1963. He graduated from North Side High School in Jackson, Tennessee in May 1982. He entered the University of Tennessee at Knoxville in September 1982 and completed a Bachelor of Science degree in Plant and Soil Science in June 1987. In June 1987, he entered the University of Tennessee, Knoxville, as a Graduate Research Assistant in the Department of Plant and Soil Science. He received his Master of Science degree with a major in Weed Science in December 1989. In January 1990 he began work toward the Doctor of Philosophy at the University of Tennessee in the Department of Plant and Soil Science. He received his Ph.D. in May 1993 with an emphasis in Weed Science.

The author is a member of the Weed Science Society of America, the Southern Weed Science Society, and the Tennessee Agricultural Chemicals Association. Following graduation he accepted a position with E. I. DuPont de Nemours, Inc. in Lincoln, Nebraska.