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Effects of Diuron and Fluometuron Metabolites on the Growth and Fiber Quality of Cotton (*Gossypium hirsutum*)

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Concern continues to exist over the possible effects of long-term herbicide use on cotton yields. Herbicides were suggested as one potential cause of the long-term plateau in cotton yields (Meredith and Bridge, 1984). Soil-applied herbicides have been found to reduce yields of cotton in comparison to cotton kept weed-free by cultural methods (Corbin et al., 1988; Gaylor et al., 1983; Hayes et al., 1981; Rogers et al., 1983). Both the dinitroaniline and substituted-urea herbicides were identified as potential causes of these yield reductions. Several factors can affect the tolerance of cotton to herbicides and phytotoxic metabolites, including the concentration and soil availability, persistence of the compound, and environmental conditions. High application rates of diuron and fluometuron reduced the growth of cotton (Eshel, 1969). Reductions of field-grown cotton yields by fluometuron also were rate dependent (Hayes et al., 1981). Residues of fluometuron in three Mississippi River Delta soils (Rogers et al., 1985) corresponded to the documented reductions in cotton yield associated with herbicide use (Rogers et al. 1983).

An additional factor that has received relatively little attention is the possible effects of herbicide metabolites on cotton growth. The accumulation of metabolites in soil could be expected as a consequence of long-term herbicide use, but little information on the phytotoxicity of these compounds is available. Soil metabolites of trifluralin [2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine] did not reduce cotton growth, yield, and fiber quality (Koskinen et al. 1984, 1985). Comparable studies with the metabolites of diuron and fluometuron have not been reported. The present studies were conducted to examine the effects of relatively high soil concentrations of the principal metabolites of diuron and fluometuron on the growth, yield, and fiber quality of cotton.

MATERIALS AND METHODS

The effects of the herbicides diuron and fluometuron, and their respective metabolites, were examined in separate experiments. The principal soil metabolites and their parent compounds used in these experiments (Table 1) were obtained from E.I. DuPont De Nemours and Co. and Ciba Geigy Corp., respectively. Chemical purity exceeded 95% for these compounds, which were used without further purification. Each compound was

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dissolved in methanol, and treatment solutions were made by further dilution of these stocks in methanol.

Table 1. Rates of metabolites of diuron and fluometuron used in cotton growth and yield experiments and methods of application.

Compound	Rate[a]	Method[b]
Diuron,		
N'-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea	0.51 mg/kg	ppi
	0.40 kg/ha	pre
	1.34 kg/ha	pre
DCPMU, 1-(3,4-dichlorophenyl)-3-methylurea[c]	0.51 mg/kg	ppi
DCPU, 1-(3,4-dichlorophenyl)urea	0.45 mg/kg	ppi
DCA, 3,4-dichloroaniline	0.49 mg/kg	ppi
Fluometuron,		
N,*N*-dimethyl-*N'*-[3-(trifluoromethyl)phenyl]urea	1.0 mg/kg	ppi
	1.12 kg/ha	pre
TFMPU, 3-(trifluoromethyl)phenylurea	1.0 mg/kg	ppi
DMFM,		
N-methyl-*N'*-[3-(trifluoromethyl)phenyl]urea	1.0 mg/kg	ppi
TFMA, 3-(trifluoromethyl)aniline	1.0 mg/kg	ppi

[a]Concentrations in ppi treatments refer to the treated zone (5 kg soil) in the surface 10 cm of the bucket.
[b]Herbicides were sprayed in MeOH on the soil surface preemergence (pre) or applied in MeOH and incorporated before planting (ppi).
[c]Formerly called MDCPU (1-methyl-3-[3,4-dichlorophenyl]urea).

Dundee silt loam soil (Aeric Ochraqualf) with the following properties: pH 6.4, organic matter 0.7%, 17 mequiv./100 g soil CEC, 16% clay and 56% silt, was used in experiments with diuron or the metabolites of diuron. Experiments with fluometuron and metabolites of fluometuron were done with a Bosket silt loam (Mollic Hapludalf) soil having the following properties: pH 7.6, organic matter 0.3%, 9 mequiv./100 g soil CEC, 11% clay and 66% silt. In both experiments approximately 17 kg of soil was placed in 19 L plastic buckets. Quantities of diuron, fluometuron, or individual metabolites were applied in 10 ml of methanol to an additional 5 kg of soil, resulting in soil concentrations shown in Table 1. In addition to the treatments shown in Table 1, soils (5 kg) were treated with 10 ml of methanol only to serve as untreated controls in each experiment. The treated soils were mixed and placed on top of the 17 kg of untreated soil in the buckets. The following day the pots lightly watered and planted with 5 seeds of cotton cultivar 'Stoneville 213' per pot. Preemergence applications (pre) consisted of herbicides sprayed in 10 ml methanol onto 22 kg soil previously planted with cotton. An additional treatment was prepared, consisting of the commercial formulation of fluometuron applied preemergence using a greenhouse spray table to the surface of untreated soil (22 kg) already in pots at a rate of 2.22 kg/ha in water at 187 L/ha.

Plants were arranged in randomized complete block designs in both experiments. Plants treated with diuron or diuron metabolites were grown outside in the spring of 1986 with 10 replications of each treatment. Plants treated with fluometuron or fluometuron metabolites were grown in a single greenhouse in the spring of 1987 with 12 replications. The following procedures were used in both experiments: plants were thinned to one per pot at the 2-leaf stage; complete water-soluble fertilizer was applied weekly; monocrotophos (dimethyl 2-methylcarbamoyl-1-methylvinyl phosphate) and aldicarb (2-methyl-2-[methylthio]propionaldehyde O-[methylcarbamoyl]oxime) were applied at recommended rates during the course of the experiments to control insect infestations.

The dates of first flowering and boll opening were recorded and final plant height was measured. Cotton lint weight was determined as the difference between the total seed cotton weight and the weight of the acid-delinted seeds. Span length, strength, and micronaire of the cotton were determined by Starlab, Inc., Knoxville, TN. Each experiment was treated as a randomized complete block and subjected to one-way analysis of variance. Differences in means were determined using least-significant difference (LSD) procedures.

RESULTS AND DISCUSSION

Diuron and the metabolites of diuron had no significant (P=0.05) effect on the yield of cotton (Table 2), as determined by analysis of variance. This is in agreement with field studies in which diuron had no adverse effect on yield over three years of cotton production (Upchurch et al., 1969). Dates of initial flowering and boll opening were not recorded for this experiment, but major differences would not be expected on the basis of the yield data.

Table 2. Growth and yield of cotton grown on soil treated with diuron and soil metabolites of diuron.

Treatment[a]	Ht.[b]	Bolls	Seed Cotton	Lint
	(cm)	(no./plant)	—(g/plant)—	
Diuron ppi	79	16.0	70.4	26.1
Diuron pre (0.40)	87	18.1	75.6	27.4
Diuron pre (1.34)	83	17.8	70.8	27.2
DCPMU	78	18.8	76.9	27.9
DCPU	80	16.0	63.7	24.7
DCA	80	18.4	82.9	31.0
Control	76	18.8	75.1	27.7

[a]Values in parentheses indicate application rate (kg/ha). All other rates are as described in Table 1.
[b]Final plant height. All values shown are means of 10 replications. Treatment effects for all parameters were nonsignificant (P=0.05) as determined by analysis of variance.

Fluometuron incorporated (ppi) uniformly throughout the surface 7 to 10 cm at a concentration of 1.0 mg/kg of soil increased the yield of cotton (seed cotton or lint) over that of the untreated control plants by 10% (Table 3). The yield increase was due to an increase in the number of bolls (Table 3) and the percentage lint of the bolls. Plants treated with fluometuron-ppi had 52.2% lint compared to 50.9% in the nontreated controls. Similar stimulatory effects on cotton yield have been reported for diuron (van Rijn, 1972).

Table 3. Growth and yield of cotton grown on soil treated with fluometuron and soil metabolites of fluometuron.

Treatment[a]	Ht.[b]	Flowers Days[c]	Flowers No.[d]	Bolls Days[c]	Bolls No.[d]	Seed Cotton	Lint
	(cm)					—(g/plant)—	
Fluo. ppi	91	69.8	25.2	114.4	14.5	58.6	30.6
Fluo. pre	90	63.0	24.2	108.8	12.5	50.1	25.1
TFMPU	92	64.0	25.7	110.1	13.4	53.9	27.3
DMFM	91	63.7	22.5	108.8	13.3	52.8	26.7
TFMA	82	62.4	25.0	107.3	11.4	47.6	23.9
Control	94	64.8	26.3	110.7	13.3	53.4	27.2
LSD (5%)	NS	3.5	2.1	3.6	1.7	4.1	2.4

[a]Rates of application are described in Table 1.
[b]Final plant height. All values shown are means of 12 replications.
[c]Number of days from planting until first flower or boll opening.
[d]Total number of flowers or bolls produced.

Substantial leaf injury was noted 2 weeks after planting with the fluometuron-ppi treatment and flowering and boll opening were delayed in comparison to nontreated plants (Table 3), indicating that fluometuron delayed plant maturity. However, the total numbers of flowers was not adversely affected. Hiranpradit and Foy (11) reported that subtoxic levels of fluometuron delayed leaf senescence in maize, suggesting a mechanism to account for the delay in maturity caused by the fluometuron-ppi treatment in this experiment. The delay in maturity may have contributed to the increase in yield by allowing greater vegetative growth and reducing scenescence of older leaves. The preemergence spray application of fluometuron did not increase yield. These plants may not have been exposed to as much fluometuron as plants receiving the ppi treatment due to the initial placement of the herbicide at the soil surface.

Other studies indicate that cotton has only marginal tolerance to higher rates of these herbicides. Seedling growth was reduced 50% by 4 and 8 mg/kg of fluometuron incorporated into the soil (Eshel, 1969; Rubin and Eshel 1971). Eshel (1969) also demonstrated that injury could be substantially reduced by surface application of the herbicide instead of incorporation. Preemergence applications in the field of 3.36 kg/ha fluometuron or diuron reduced yields of cotton (Chandler and Savage, 1980; Hayes et al., 1981). Rates of fluometuron and diuron comparable to those used in these experiments had no effect on cotton yields.

The seed cotton yield of plants grown on soil treated with the metabolite TFMA was reduced by 11% compared to the untreated control (Table 3). Similar effects were measured in lint yield. Fewer bolls were produced by the TFMA-treated plants, but the timing of flowering and boll opening were not affected. These results are different from those of Rubin and Eshel (1971), who found that TFMA applied to a clay soil with 1.5% organic matter at rates up to 25 mg/kg soil did not affect the fresh weight of cotton grown for 30 days. None of the other metabolites affected the seed cotton or lint yields (Table 3).

Cotton fiber quality is an important determinant of a cotton crop's economic value. The cotton fiber properties span length (2.5% SL and 50% SL), micronaire, and strength (E1 and T1) were measured on samples from individual plants treated with these compounds. Micronaire is an index often associated with fiber maturity, with lower values suggesting less developed fibers. Fiber span length and strength are more important than micronaire in the determining fiber quality. Analysis of variance indicated that neither herbicide or any of the metabolites affected these fiber properties (Table 4).

Table 4. Fiber properties of cotton harvested from plants grown in soil treated with diuron, fluometuron, or their principal metabolites.

	Span Length		Strength		
Treatment[a]	2.5% SL	50% SL	E_1	T_1	Micronaire
			(%)	(cN/Tex)	
Diuron ppi	1.08	0.55	7.9	20.0	3.8
Diuron pre (0.40)	1.09	0.55	7.8	19.5	3.7
Diuron pre (1.34)	1.08	0.54	8.1	20.3	3.3
MDCPU	1.09	0.55	7.8	20.4	3.6
DCPU	1.09	0.55	8.2	20.1	3.6
DCA	1.09	0.54	7.9	20.4	3.5
Control	1.09	0.55	7.9	19.8	3.4
Fluo. ppi	1.11	0.54	8.2	18.8	4.1
Fluo. pre	1.11	0.55	8.0	19.5	4.4
TFMPU	1.10	0.54	8.1	19.2	4.4
DMFM	1.10	0.54	7.9	18.9	4.3
TFMA	1.10	0.54	8.2	19.4	4.3
Control	1.10	0.54	8.2	19.2	4.2

[a]Rates of application are described in Table 1. Results shown are for two separate growth experiments, which were analyzed separately. Values shown are treatment means. Analysis of variance showed treatment effects to be nonsignificant (P=0.05).

Metabolites concentrations used in these experiments were chosen to exceed the maximum levels that might be encountered in field situations. The principal metabolites of both diuron and fluometuron are produced both in the cotton plant and in soil during the metabolism of these herbicides (Geissbuhler et al., 1975). Recommended rates of fluometuron application range from 0.84 to 2.2 kg/ha. The pathway proposed for fluometuron degradation suggests sequential production of DMFM, TFMPU, and TFMA, respectively (Bozarth and Funderburk, 1971; Ross and Tweedy, 1973). Up to 66 and 14% of the applied fluometuron was converted to DMFM and TFMPU, respectively, during a 72 day period (Bozarth and Funderburk, 1971). However, less than 5% was converted to TFMA in the same study, suggesting that the concentration of TFMA used in these experiments is probably well above what would be expected following a single season application of fluometuron. Assuming that TFMA accumulates at the rate 0.1 mg/kg of soil (i.e. 5% of a 2.2 kg/ha application of fluometuron) per year, and that no further degradation occurs, the TFMA concentration (1.0 mg/kg) used in these experiments represents a 10 yr accumulation of TFMA. The fate of TFMA in soil has not been reported, but other substituted anilines are rapidly bound to soil organic matter where they have very limited bioavailability (Bollag and Loll, 1983).

Similar considerations are applicable to the diuron metabolites. Recommended rates (0.56 to 1.8 kg/ha) of diuron are slightly less than those for fluometuron. Dalton et al. (1966) determined the concentrations of DCPMU, DCPU, and DCA in soils that had 4 to 7 yr of consecutive diuron applications. Concentrations approximately 1 yr after the last diuron application were 0.4 mg/kg soil or less, except for one field which had 0.8 mg/kg of DCA. Concentrations of extractable DCPMU were below 1 mg/kg soil during an 84-day period after addition of 4 mg/kg soil of diuron in another study (Walker and Roberts, 1978). DCPMU was slowly degraded in the soil, but DCPU was degraded more rapidly. It was also suggested by Walker and Roberts (1978) that a substantial fraction of the DCPMU was converted to bound residue and that some DCPMU was converted directly to DCA.

These experiments provide the first account of the effects of these herbicide metabolites on cotton yields. When concentrations of metabolites in agricultural soils are considered against the rates used in these experiments the evidence strongly indicates that the metabolites of diuron and fluometuron do not adversely affect the yield of cotton. The possibility exists that these compounds may have effects at higher concentrations, but most research indicates that metabolite concentrations in soils are well below the concentrations used in these experiments. The only metabolite affecting cotton yield, TFMA, is probably present in soil only at very low concentrations. However, the concentrations of this compound have not been measured after long-term fluometuron use. While the possibility of interactions of these compounds with their parent herbicides or other pesticides cannot be completely discounted, these findings suggest that these compounds are not likely to be contributing factors in the yield of cotton on soils with long-term herbicide use.

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