Physiological Aspects of Fluometuron in Cotton and Cucumber

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Warburg experiments indicated that fluometuron-[3-(*m*-trifluoromethylphenyl)-1,1-dimethylurea], at rates up to 10 p.p.m., did not affect respiration of cotton or cucumber. Both Warburg and $^{14}CO_2$ fixation studies indicated that fluometuron inhibited photosynthesis by these species. A subsequent investigation of the differential susceptibility of cotton (resistant) and cucumber (susceptible) to fluometuron revealed that differences in absorption and translocation did not adequately account for their differential response. Metabolic studies indicated that cucumber degraded fluometuron to the monomethylated and demethylated derivatives. These derivatives plus the aniline derivative and an unidentified compound were constituents of cotton extracts. Phytotoxicity experiments indicated that the differential susceptibility of these species was primarily attributable to a differential ability to degrade fluometuron to less or nonphytotoxic compounds.

Fluometuron [3-(*m*-trifluoromethylphenyl)-1,1-dimethylurea] is one of the more recently introduced substituted urea herbicides, and it is used widely as a pre-emergence herbicide for cotton. Fluometuron differs from other common substituted ureas in that the halogen member of the molecule is fluorine and in that the fluorine is attached to a methyl group rather than directly to the phenyl ring. Some plants treated pre-emergence with this herbicide emerge apparently devoid of chlorophyll. Thus, because of differences in structure and symptomatology, it seemed desirable to see if the effects of fluometuron on several physiological processes were typical of those associated with this group of herbicides.

Soon after the introduction of the substituted ureas, Cooke (1955) observed that the sugar content of plants treated with monuron decreased sharply. Wessels and van der Veen (1956) and Cooke (1956) reported almost simultaneously that several substituted ureas were very efficient inhibitors of the Hill reaction of isolated chloroplasts. The site of action of the substituted ureas was also localized by Bishop's (1958) observation that diuron did not affect photosynthesis of *Scendesmus* adapted to do photoreduction using hydrogen instead of water.

Substituted ureas can be absorbed by either roots or shoots. Translocation occurs in the xylem and is restricted to an acropetal direction (Audus, 1964). Attempts to correlate differences in absorption with differential susceptibility have been only partially successful. Differences in the distribution of absorbed radioactivity appear to be involved in the differential responses of plants (Geissbuhler *et al.*, 1963a; Smith and Sheets, 1967).

The ability of biological systems to degrade substituted urea herbicides was initially established in studies concerned with their dissipation from soils (Sheets, 1964). Apparently, recent interest in their metabolism in higher plants was stimulated by Welker's (1961) report that two unidentified ^{14}C-metabolites were formed from ^{14}C-monuron by *Abutilon theophrasti*. Geissbuhler *et al.* (1963b) reported that *Polygonum* and *Galinsoga* degraded ^{14}C-chloroxuron to the monomethylated, demethylated, and aniline derivatives. They suggested that differences in the rate of degradation by the two species might be involved in their differential susceptibility. Smith and Sheets (1967) have recently reported similar schemes of degradation for monuron and diuron in cotton and soybean. The major constituents of leaf extracts of cotton (resistant) were nonphytotoxic, whereas the major constituents of soybean (susceptible) were phytotoxic. Geissbuhler (1964) has reported that excised roots of *Vicia* were more efficient than shoots in degrading ^{14}C-chloroxuron. The mechanism of these degradations is not known.

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MATERIALS AND METHODS

Cotton (*Gossypium hirsutum* L. var. DPL Smoothleaf) and cucumber (*Cucumis sativus* L. var. Long Green) were used as test species. They are resistant and susceptible, respectively, when grown in nutrient solution containing 1 to 10 p.p.m. of fluometuron. Experiments were conducted in a growth chamber with plants approximately 14 days old. The ^{14}C-fluometuron used had a specific activity of 10.28 μc. per mg. and was labeled at the trifluoromethyl group. Radioassays in the metabolic studies were conducted using a Beckman liquid scintillation counter (Model 1650), and radioassays in the $^{14}CO_2$ fixation study were conducted with a Mylar end window Geiger-Müller tube counter.

Respiration Study. The effect of 0, 1, 5, and 10 p.p.m. of fluometuron on respiration of cotton and cucumber was measured using standard manometric techniques (Umbreit *et al.*, 1957). The first true leaves were excised and promptly sectioned into 25-sq. mm. pieces. Duplicate flasks containing 300 mg. of tissue were employed, and the experiment was conducted three times. Temperature was maintained at 25° C., and a 20-minute equilibration period was allowed after immersion of flasks in the water bath. After equilibration manometers were closed, treatments were applied, and readings were taken at 30-minute intervals for 120 minutes.

Photosynthesis Study. Initial photosynthesis experiments were also conducted using established manometric techniques (Umbreit *et al.*, 1957). These experiments were similar to the respiration experiments, except that 100 mg. of leaf tissue were used, treatments were applied 30 minutes

after closing the manometers, and readings were taken at 15-minute intervals for 90 minutes.

The effect of fluometuron on $^{14}CO_2$ fixation and distribution of ^{14}C-compounds was determined using the procedures of Couch and Davis (1966). Duplicate treatments of 0, 1, and 10 p.p.m. of fluometuron were applied via the nutrient solutions to intact plants. After 12 hours in the light, one leaf from each treatment was tagged, outlined on paper, excised under water, and secured in 25-ml. beakers of demineralized water for transfer to the photosynthetic chamber.

Absorption and Translocation Study. Root-treated plants were grown in an aerated 1 p.p.m. ^{14}C-fluometuron solution for 0, 12, 24, and 48 hours. Foliar treatments were applied by spotting three 0.1-ml. aliquots of a 1 mg. per ml. 95% aqueous ethanol solution inside 0.5-cm. diameter lanolin rings, and treatment time was 48 hours. Root and foliar treatments were duplicated. Treated plants were processed according to the procedure of Yamaguchi and Crafts (1958) and were exposed to Kodak No-Screen x-ray film for 5 days.

In the second experiment, plants were grown in 250 ml. of a 1 p.p.m. ^{14}C-fluometuron nutrient solution for 0, 12, 24, 48, and 72 hours, and solutions were replenished daily. There were four replicates per treatment. The quantity and radioactivity of the solutions were determined upon termination of treatments. Containers with no plants were included to correct for loss by evaporation and/or volatilization. When treatments were terminated the roots were rinsed, and the rinse water was radioassayed. Plants were immediately dissected into roots and shoots, and the fresh weight of the segments was measured. Segments were homogenized in 100 ml. of acetone for 5 minutes, and the homogenates were Soxhlet-extracted with acetone for 24 hours. Data were corrected for quenching and expressed as micrograms of ^{14}C-fluometuron per gram of plant material.

Qualitative Metabolic Study. In the initial experiment, plants were grown in a 2 p.p.m. ^{14}C-fluometuron solution for 0, 12, 24, and 48 hours, and plants were extracted as described. The extraction procedure removed 40 to 60% of the absorbed radioactivity from the plant material. Extracts were evaporated to near dryness in a Virtis freeze dryer (Model 10-145mRBA) and were resuspended in 1.0 ml. of acetone. Aliquots sufficient to give 5000 d.p.m. were spotted on Eastman silica gel G thin-layer plates (Type K301R), which were developed in a chloroform-ethanol (95 to 5, v./v.) solvent system. Developed chromatograms were exposed to Kodak No-Screen x-ray film for 10 days, and densities of the images cast on the autoradiographs by the fractions were used as indices of their relative concentrations.

Metabolite Identification Study. The ^{14}C-compounds present in extracts of the plants were tentatively identified by cochromatography. The known probable metabolites were not radiolabeled, but their location was determined by observing thin-layer plates impregnated with a fluorescent indicator under an ultraviolet lamp.

Metabolite Phytotoxicity Study. Relative phytotoxicities of fluometuron, DMFM, TFMPU, and TFMA (Table IV) to cotton and cucumber were measured by determining the concentrations required to reduce gain in fresh weight by 50% after 4 days. Weighed plants were placed in 250 ml. of various concentrations of the compounds. Solutions were replenished daily with nutrient solution, and the plants were weighed again upon termination of the experiment. Gain in fresh weight was determined, and data were expressed as per cent of check. Treatments were duplicated, and the experiment was conducted three times.

Quantitative Metabolic Study. In the second metabolic study, treatment rate was reduced to 1 p.p.m., and treatment time was extended to 96 hours. Plants were dissected into roots and shoots, the segments were weighed and extracted, chromatograms were prepared, and autoradiographs were developed to locate the ^{14}C-compounds on the chromatograms. The ^{14}C-compounds were removed from the thin-layer plates and radioassayed. Data were expressed as per cent of total radioactivity.

Plant Segment Metabolic Study. A final experiment was conducted using excised cotton roots and shoots. The segments were placed in 250 ml. of 1 p.p.m. ^{14}C-fluometuron for 24 hours. Streptomycin was added at 30 μg. per ml. to retard possible microbial growth. The segments were extracted, and the extracts chromatographed as previously described.

RESULTS AND DISCUSSION

Respiration Study. Since no effects were observed on respiration of cucumber or cotton at the rates tested, the data are not presented.

This observation is consistent with reports by other investigators that several substituted ureas did not affect respiration of leaf tissue or algae at rates which inhibited photosynthesis (Geoghegan, 1957; Sikka and Pramer, 1967; Wessels and van der Veen, 1956).

Photosynthesis Study. The effects of fluometuron on apparent photosynthesis and $^{14}CO_2$ fixation are shown in Tables I and II, respectively. Photosynthesis was shown to be inhibited by both methods. Differences in the susceptibility of the two species were not as obvious in the oxygen evolution experiments as in the $^{14}CO_2$ fixation. This is explainable on the basis of differences in the methods of chemical application. Moreland and Hill (1962) reported that chloroplasts from plants differing in susceptibility are equally susceptible to Hill reaction inhibition by the substituted ureas. On the basis of this observation, one would expect photosynthesis of diced leaf tissue floating in a fluometuron solution to be inhibited more effectively than leaves of root-treated plants. Whether photosynthetic inhibition resulted from interference with the Hill reaction or the reduction of CO_2 is not obvious from these experiments. However, a consideration of the literature for other substituted ureas indicates the former reaction.

Data concerning the effect of fluometuron on distribution of ^{14}C-compounds revealed no appreciable effect on cotton by either 1 or 10 p.p.m. of fluometuron. With cucumber, both rates caused decreases in the relative concentrations of sucrose, glyceric acid, and hexose phosphates and increases in the relative concentrations of aspartic acid, glutamic acid, and alanine (Table III). Similar observations have been reported by Ashton *et al.* (1961) and Couch and Davis (1966) for monuron and atrazine.

These data are explainable on the basis of the existence of two CO_2 fixation pathways. Typical products associated with the two processes are shown with the checks and the 10 p.p.m. cucumber treatment, respectively. Light fixation under favorable conditions is so much more efficient than dark fixation that the products associated with dark fixation are completely masked. Thus, light fixation in treated cucumber was so effectively inhibited that the products formed by the dark fixation pathway accumulated most of the $^{14}CO_2$ fixed—i.e., fluometuron modified distribution of ^{14}C-compounds to resemble that associated with dark fixation studies. Since there was no effect on the relative concentrations of the various ^{14}C-compounds formed until light fixation had been almost completely blocked, it would appear that fluometuron acted on the energy supplying photolytic process rather than the CO_2 reducing process.

Since the effects of fluometuron on these physiological processes were typical of those reported for other substituted ureas, the primary mode of action appeared to be inhibition of the Hill reaction. Consequently, the atypical toxicity symptoms are apparently secondary in nature, and subsequent studies were directed toward determining the basis of the difference in the susceptibility of cotton and cucumber to fluometuron.

Absorption and Translocation Study. Autoradiographs of treated plants indicated that roots and leaves of cotton and cucumber absorbed ^{14}C-fluometuron, but that translocation was limited to an acropetal direction. The quantity of radioactivity absorbed appeared to increase with time. This was confirmed by the results of the second experiment (Figures 1 and 2). Although cucumber absorbed significantly more radioactivity than cotton during the first 48 hours, there was no significant difference in the amounts absorbed after 72 hours. The reduced rate of absorption by cucumber after 48 hours coincided with decreases in growth and transpiration. No toxicity symptoms were observed on cotton, and growth and transpiration were apparently not affected.

Thus, differential absorption does not appear to be an important factor in the differential susceptibility of cucumber and cotton. This is in agreement with the conclusion of Smith and Sheets (1967) that differences in absorption were not involved in the differential response of cotton and soybean to monuron and diuron. However, they felt that differential absorption was responsible for differences in the susceptibility of oats, corn, and soybean.

Autoradiographs indicated radiolabeled compound(s)

Table I. Effect of Fluometuron on Apparent Photosynthesis of Cucumber and Cotton

Time,[a] Min.	Accumulated μl. O_2 Evolved			
	Check[b]	1 p.p.m.[b]	5 p.p.m.[b]	10 p.p.m.[b]
	Cucumber			
15	25.0 a,1	22.7 a,1	19.2 a,1	21.9 a,1
30	64.5 b,1	60.1 b,1	60.2 b,1	62.5 b,1
45	84.0 c,1	72.4 c,2	75.2 c,2	64.8 b,3
60	103.7 d,1	88.9 d,2	87.6 d,2	68.8 b,3
75	125.7 e,1	110.9 e,2	100.8 e,3	68.8 b,4
90	148.5 f,1	139.6 f,2	121.3 f,3	68.8 b,4
	Cotton			
15	12.0 a,1	10.7 a,1	12.0 a,1	10.7 a,1
30	21.7 b,1	19.5 b,1	20.6 b,1	20.6 b,1
45	33.0 c,1	31.6 c,1	31.3 c,1	30.1 c,1
60	43.8 d,1	39.8 d,2	37.8 d,2	30.9 c,3
75	49.5 e,1	46.7 e,2	42.9 e,3	31.4 c,4
90	54.9 f,1	52.6 f,2	47.8 f,3	32.0 c,4

[a] Means for any time with a given crop and treatment that are followed by the same letter are not significantly different at the 5% level according to Duncan's new multiple range test. [b] Means for any treatment with a given crop and time that are followed by the same number are not significantly different at the 5% level according to Duncan's new multiple range test.

Table II. Effect of Fluometuron on Light Fixation of $^{14}CO_2$ by Cotton and Cucumber Expressed as Per Cent of Check

Treatment	Cucumber		Cotton	
	C.p.m. × 10^{3}[a]	% check[b]	C.p.m. × 10^{3}[a]	% check[b]
Check	769	100.0	363	100.0
1 p.p.m.	34	4.5	278	76.9
10 p.p.m.	24	3.1	61	16.6

[a] Counts per minute per square centimeter of leaf surface; average of duplicates. [b] Differences betweeen crops and treatments were significant at the 1% level according to Duncan's new multiple range test (except cucumber 1 and 10 p.p.m.).

Table III. Effect of Fluometuron on the Relative Amounts of ^{14}C-Compounds Following Light Fixation of $^{14}CO_2$ Expressed as Per Cent of Total Fixed

Compound	Cucumber[a]			Cotton[a]		
	Check	1 p.p.m.	10 p.p.m.	Check	1 p.p.m.	10 p.p.m.
Sucrose	24.9 a	14.1 b	4.0 c	57.2 a	56.9 a	55.1 a
Glyceric acid	4.1 a	0.6 b	0.0 b	3.0 a	6.8 a	0.0 a
Malic acid	12.9 a	11.0 a	6.6 a	9.3 a	6.4 a	9.5 a
Glycine-serine[b]	2.1 a	7.2 b	4.0 a	6.9 a	10.8 b	12.8 b
Aspartic acid	8.4 a	16.8 b	54.9 c	5.6 a	4.9 a	6.6 a
Alanine	2.5 a	2.6 a	7.9 b	10.0 a	7.1 a	6.4 a
Hexose phosphates	22.8 a	19.0 b	0.0 c	1.1 a	1.0 a	1.0 a
Glutamic acid	2.6 a	1.9 a	14.7 b	3.5 a	2.5 b	2.4 b
Cystine	2.1 a	1.9 a	0.0 b	...	...	...
Citric acid	9.3 a	14.2 b	6.4 a	1.5 a	0.8 a	2.9 a
Unidentified	11.7 a	11.0 a	2.1 b	2.0 a	2.6 a	3.5 a

[a] Means for any treatments with a given compound and crop followed by the same letter are not significantly different at the 5% level according to Duncan's new multiple range test. [b] Spots unresolved.

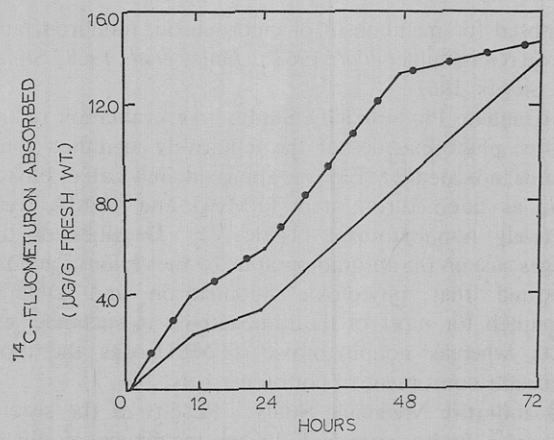

Figure 1. Absorption of radioactivity from a ^{14}C-fluometuron solution by cotton and cucumber

● Cucumber
— Cotton

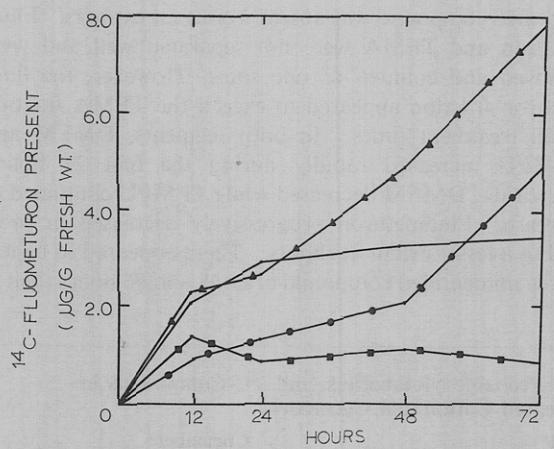

Figure 2. Localization of radioactivity absorbed by cotton and cucumber from a ^{14}C-fluometuron solution

● Cotton shoot
■ Cucumber root
▲ Cucumber shoot
— Cotton root

absorbed by cotton was uniformly distributed throughout cotton plants with the exception of some accumulation in the lysigenous glands. Radiolabeled compound(s) absorbed by cucumber appeared to be rapidly moved to the shoots and showed a striking tendency to accumulate along leaf margins. The phytotoxicity of this radiolabeled compound(s) was confirmed by the initial appearance of chlorosis and necrosis in this area. Results of the second experiment were complementary to those of the first. There was significantly more radioactivity in cotton roots than shoots during the first 48 hours. However, there was always more radioactivity in cucumber shoots than roots. The quantity of radioactivity in cucumber roots did not increase significantly after 12 hours, and there was a sixfold difference in the quantity appearing in the roots and shoots after 72 hours.

Since the primary mode of action of the substituted ureas is inhibition of the Hill reaction, and since they are relatively nonphytoxic to nonphotosynthetic plant parts, the retention of fluometuron in roots and lysigenous glands of cotton is of obvious value as a protective mechanism. Differential distribution of absorbed herbicide also appeared to be involved in the differential susceptibility of *Galinsoga* and *Polygonum* to chloroxuron and cotton and soybean to monuron and diuron (Geissbuhler *et al.*, 1963a; Smith and Sheets, 1967). That herbicide accumulation in lysigenous glands can serve as a protective mechanism was demonstrated by Davis *et al.* (1959) with simazine. The nature of the forces involved is unresolved, but it is interesting that chloroxuron, which tends to be strongly adsorbed on organic materials, seems to be retained in plant roots to a greater extent than do monuron, diuron, metobromuron, and fluometuron (Geissbuhler *et al.*, 1963a; Smith and Sheets, 1967; Voss and Geissbuhler, 1966).

Qualitative Metabolic Study. Autoradiographs of chromatograms of ^{14}C-fluometuron root-treated cotton and cucumber extracts are shown in Figure 3. Cucumber was apparently able to degrade fluometuron to two ^{14}C-metabolites, whereas cotton degraded fluometuron to four ^{14}C-metabolites. Also the quantity of radioactivity in the ^{14}C-metabolite fractions increased with time in both species. However, most of the radioactivity in cucumber extracts

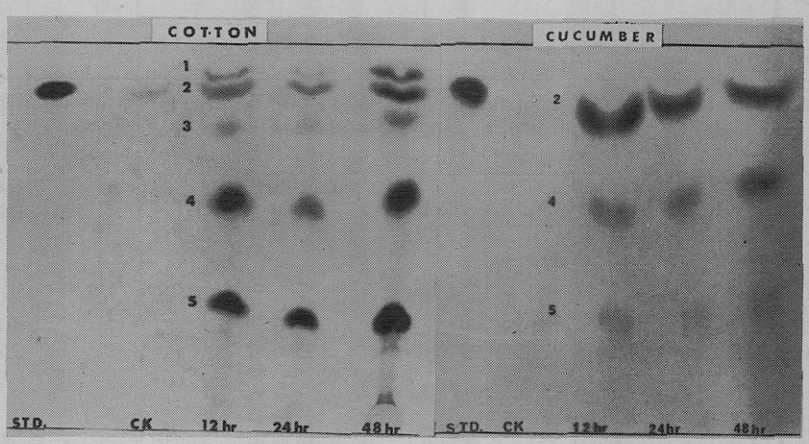

Figure 3. Autoradiographs of chromatograms of extracts of ^{14}C-fluometuron–treated cotton and cucumber

1 = TFMA, 2 = fluometuron, 3 = UK, 4 = DMFM, 5 = TFMPU

persisted in the intact herbicide fraction at the longest treatment time, while in cotton extracts most appeared in the metabolite fractions at the earliest treatment time.

Metabolite Identification Study. Results of the experiments directed toward identifying the ^{14}C-metabolites are shown in Table IV. These data indicate the ^{14}C-metabolites in cucumber were DMFM and TFMPU (Table IV). These derivatives plus TFMA and an unidentified compound were present in cotton extracts. Thus, degradation apparently proceeds according to the scheme shown in Figure 4. Similar schemes of degradation have been proposed for metabolism of chloroxuron, monuron, and diuron (Geissbuhler *et al.*, 1963b; Onley *et al.*, 1968; Smith and Sheets, 1967).

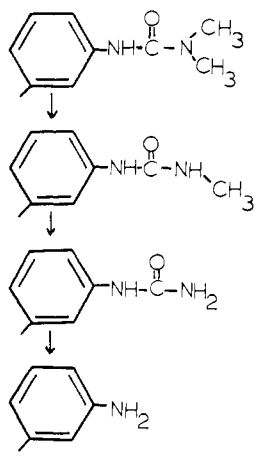

Figure 4. Proposed pathway of fluometuron metabolism in cotton

Metabolite Phytotoxicity Study. An evaluation of the relative phytotoxicities of the tentatively identified compounds indicated DMFM was approximately half as phytotoxic as fluometuron, and TFMPU and TFMA were relatively nonphytotoxic (Table V). Densities of the images cast on the autoradiographs by the various fractions indicated that phytotoxic fluometuron and DMFM accounted for most of the radioactivity in cucumber extracts, whereas nonphytotoxic TFMPU was the most important constituent of cotton extracts.

Quantitative Metabolic Study. Results of the second metabolic study confirmed the predominance of phytotoxic fluometuron and DMFM in both roots and shoots of cucumber (Figures 5 and 6). Also distribution of radioactivity in the segments did not differ appreciably. Distribution of radioactivity in cotton roots and shoots varied qualitatively and quantitatively (Figures 7 and 8). TFMA did not appear to be present in shoot extracts, and the unidentified compound was absent from root extracts. Fluometuron and TFMA were not separated well and were removed and counted as one spot. However, the fluometuron fraction appeared to exceed the TFMA fraction at all treatment times. In both segments, DMFM and TFMPU increased rapidly during the first 24 hours. Thereafter, DMFM decreased while TFMPU continued to increase. Fluometuron progressively decreased in roots and to a lesser extent in shoots. There appeared to be less of the unidentified compound after 48 and 96 hours than at

Table IV. R_f Values of Fluometuron, Several Synthesized Probable Metabolites, and ^{14}C-Compounds in Acetone Extracts of ^{14}C-Fluometuron-Treated Cotton and Cucumber

Knowns[a]		Cotton[a]		Cucumber[a]	
Compound	R_f value	Compound	R_f value	Compound	R_f value
TFMA[b]	0.90 a	1	0.90 a		
Fluometuron[c]	0.85 b	2	0.86 b	2	0.86 a
DMFM[d]	0.54 c	3	0.74 c		
TFMPU[e]	0.32 d	4	0.56 d	4	0.59 b
		5	0.29 e	5	0.31 c

[a] R_f values for any two compounds in a given group followed by the same letter are not significantly different at the 1.0% level according to Duncan's new multiple range test.
[b] 3-Trifluoromethylaniline.
[c] Fluometuron.
[d] Desmethyl-fluometuron.
[e] *N,m*-Trifluoromethylphenylurea.

Table V. Relative Phytotoxicity of Fluometuron,[a] DMFM, TFMPU, and TFMA to Cotton and Cucumber as Evidenced by Reduction in Fresh Weight

Fluometuron[a]		DMFM[a]		TFMPU[a]		TFMA[a]	
Treatment, p.p.m.	% check[a]	Treatment, p.p.m.	% check[a]	Treatment, p.p.m.	% check[a]	Treatment, p.p.m.	% check[a]
			Cotton				
1.0	114.86 a	1.0	122.9 a	1.0	83.3 a	1.0	102.5 a
5.0	57.3 b	5.0	105.4 b	5.0	79.3 a	5.0	72.9 b
10.0	17.4 c	10.0	49.2 c	10.0	87.2 a	10.0	76.0 b
25.0	0.0 c	25.0	22.0 d	25.0	46.5 b	25.0	82.2 b
			Cucumber				
0.05	83.0 a	0.05	66.8 a	5.0	63.8 a		
0.10	46.9 b	0.10	65.9 a	10.0	55.1 a		
0.20	23.9 c	0.20	49.5 b	25.0	23.9 b		

[a] Any two means followed by the same letter are not significantly different at the 5.0% level according to Duncan's new multiple range test.

12 and 24 hours. It is significant that nonphytotoxic TFMPU was the major ^{14}C-compound in cotton shoot extracts at all times. This distribution of radioactivity in extracts of ^{14}C-fluometuron treated cotton is in excellent agreement with data reported by Smith and Sheets (1967) for ^{14}C-diuron- and ^{14}C-monuron-treated cotton.

The final metabolic experiment was conducted to evaluate further apparent differences in fluometuron degradation by cotton roots and shoots. Autoradiographs of extracts of ^{14}C-fluometuron-treated cotton roots and shoots indicated that the same ^{14}C-compounds previously observed were present. Both segments were efficient in degrading fluometuron, but the major ^{14}C-metabolite in roots was phytotoxic DMFM, while nonphytotoxic TFMPU was the major ^{14}C-metabolite in shoots. This is consistent with Geissbuhler's (1964) report that roots and shoots of *Vicia* could degrade ^{14}C-chloroxuron. Although there were differences in degradation by cotton and cucumber and by cotton roots and shoots, *N*-demethylation was the primary reaction involved in each case.

Thus, after 96 hours approximately 90% of the radioactivity in cucumber root and shoot extracts appeared in phytotoxic fractions, while only approximately 50% in cotton roots and approximately 30% in cotton shoots persisted in these fractions. Consequently, it appears that the major factor involved in the differential susceptibility of cotton and cucumber is the ability of the former to degrade fluometuron rapidly to less or nonphytotoxic derivatives. One might question this proposal, since the efficiency of the extraction procedure was approximately 50%, and since the form of the radioactivity in the residue was unresolved. However, the availability of any phytotoxic compounds in the residue to exert a toxic effect on the plants is also questionable, and the extraction efficiency for both species was approximately the same. It also seems likely that at least part of the radioactivity in the residue is in the form of various metabolites, since several of these can apparently readily form conjugates (Williams, 1959). Also, under field conditions where the amount of herbicide available for absorption might be more limited, possibly the quantity of phytotoxic compounds reaching photosynthetic parts of cotton plants might be even smaller.

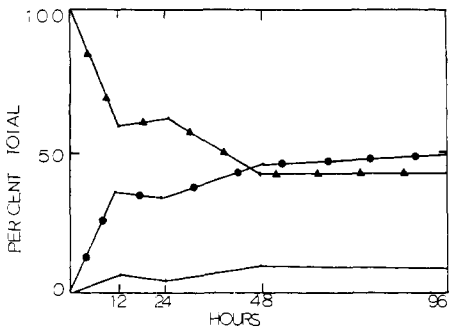

Figure 5. Distribution of radioactivity in root extracts of ^{14}C-fluometuron-treated cucumber

● DMFM
▲ Fluometuron
— TFMPU

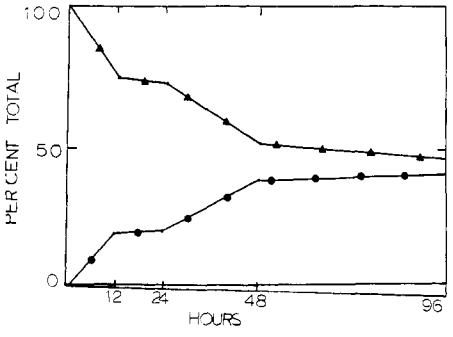

Figure 6. Distribution of radioactivity in shoot extracts of ^{14}C-fluometuron-treated cucumber

● DMFM
▲ Fluometuron
— TFMPU

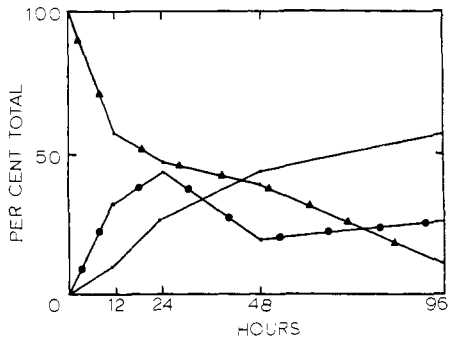

Figure 7. Distribution of radioactivity in root extracts of ^{14}C-fluometuron-treated cotton

● DMFM
▲ TFMA and fluometuron
— TFMPU

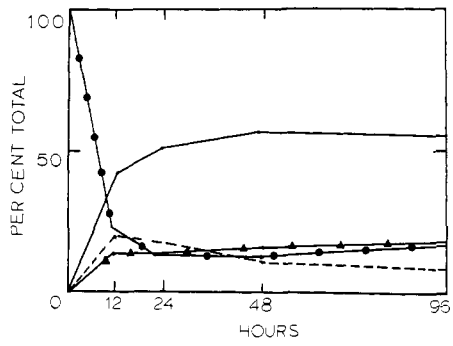

Figure 8. Distribution of radioactivity in shoot extracts of ^{14}C-fluometuron-treated cotton

● Fluometuron
▲ DMFM
- - - Unknown
— TFMPU

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