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ALLELOPATHIC POTENTIAL OF *Ipomoea tricolor* (CONVOLVULACEAE) IN A GREENHOUSE EXPERIMENT

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Abstract—The allelopathic potential of *Ipomoea tricolor*, a plant used in Mexican agriculture to control weeds, and tricolorin A, the major phytogrowth inhibitor present in the so-called "resin glycosides" of this plant, have been evaluated by testing leachates of the plant and the compound on the germination and radicle growth of *Amaranthus hypochondriacus*, *Echinochloa crus-galli*, *Senna uniflora*, *I. tricolor*, and *I. purpurea*. The allelopathic potential of *I. tricolor* was evaluated in a greenhouse experiment with dry *I. tricolor* mixed with sterile and nonsterile soil in pots. *A. hypochondriacus* was sown in pots containing *I. tricolor*, 2-chloro-4-(ethylamino)-6-(isopropylamino)-1,3,5 triazine (Gesaprim) or 1-glyphosphate, and the glyphosphate salt of isopropylamine (Faena), two different commercial herbicides used as a comparison to *I. tricolor*. Number and dry weights of different monocotyledonous and dicotyledonous weeds and *A. hypochondriacus* growing in the different treatments were measured. *Ipomoea* and Faena herbicide had a similar inhibitory effect on monocots.

Key Words—Allelopathy, *Ipomoea tricolor*, Convolvulaceae, tricolorin A, resin glycosides, herbicides.

INTRODUCTION

The phytotoxic effect of plant residues on the growth of crops and weeds is an aspect that has been extensively studied in allelopathy. Extracts of decomposing

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field residues of barley, rye, broccoli, broadbean, wheat, rice, vetch, and sudangrass, among other crops and weeds, were found to be toxic to the growth of different test species. The challenge is to find plants and residues that are selectively phytotoxic to weeds and with an adequate safety margin on crops (Chou et al., 1977; Altieri and Doll, 1978; Anaya and del Amo, 1978; Ramos et al., 1983; Anaya et al., 1987, 1988; Einhellig and Leather, 1988).

Ipomoea tricolor Cav. (Convolvulaceae) is extensively used in Mexico in folk medicine and agriculture for many purposes. The seeds, with a high content of ergot-type alkaloids, have been used as a hallucinogenic agent in ritual ceremonies by members of the Zapotec and Chatin Indians in Mexico. Other species of the morning glory family are used traditionally all over the world as powerful cathartics. This purgative action is a consequence of the presence of glycosidic resins in foliar tissues, especially in roots and rhizomes of the species belonging to the Convolvulaceae family (Wagner, 1973). In the tropical zones of Mexico, farmers promote the growth of *I. tricolor*, other species of this genus, and some semidomesticated legumes, e.g., *Stizolobium* spp., to protect the soil and to control the growth of weeds. In the sugar cane fields of the state of Morelos, México, *I. tricolor* is grown extensively as a cover crop, especially from August to October. After this time, the whole plant is cut and incorporated into the soil as a green manure. Bioactivity-directed fractionation of organic extracts of the plant led to the isolation of a mixture of resin glycosides with high phytotoxic effects (Anaya et al., 1990). Tricolorin A, the major phytogrowth inhibitor present in the active fraction of the $CHCl_3$ extract (Figure 1) inhibited the radicle growth of *Amaranthus hypochondriacus* and *Echinochloa*

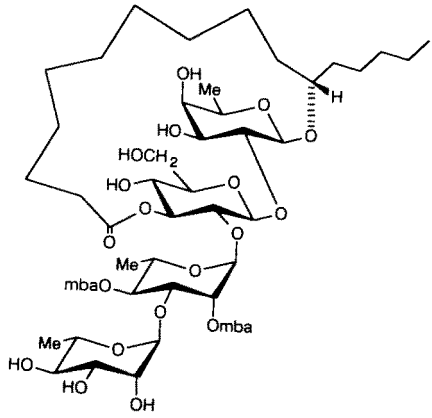

FIG. 1. Structure of tricolorin A (mba, 2-methylbutyroyl).

crusgalli with IC_{50} values ranging from 12 to 37 μM. This bioactive glycolipid displayed a broad range of activities, including antimicrobial and cytotoxic effects and inhibition of protein kinase C activity (Pereda-Miranda et al., 1993).

An objective of the present study was to compare the phytotoxicity of *I. tricolor* leachates and tricolorin A in vitro with that of two commercial herbicides on the germination and growth of *A. hypochondriacus* (Amaranthaceae) and *E. crusgalli* (Poaceae). A second objective was to compare the effect of dry *I. tricolor* incorporated into the soil (sterile and nonsterile) in pots with that of two commercial herbicides on the number and growth of weeds, and the growth of *A. hypochondriacus* (Amaranthaceae).

METHODS AND MATERIALS

Whole plants of *I. tricolor* were collected in Cañón de Lobos, Morelos, México, in March 1993. The plant material was air dried and crushed by hand.

Comparative Bioassays for Phytotoxicity. A bioassay was performed to determine the phytogrowth inhibitory effect of the leachate (2%) of *I. tricolor* mixed (50:50) with 1.5% pure agar. Osmotic pressure was checked to prevent the use of a highly concentrated leachate. Tricolorin A, and two commercial herbicides, 2-chloro-4-(ethylamino)-6-(isopropylamino)-1,3,5 triazine (Gesaprim, Ciba-Geigy), and 1-glyphosate and the glyphosate salt of isopropylamine (Faena, Monsanto) in concentrations of 10, 50, 100, 150, and 200 μg/ml were tested. Phytogrowth inhibitory activity was determined by seed germination and radicle growth tests on *A. hypochondriacus*, *E. crusgalli* (Poaceae), *Senna uniflora* (Fabaceae), *I. tricolor*, and *I. purpurea*. Distilled water plus methanol (9.9:0.1) mixed with 1.5% agar (50:50) was used as control.

The bioassay was performed in Petri dishes (10 seeds per dish for *A. hypochondriacus*, *E. crusgalli*, *I. tricolor*, and *I purpurea*, and eight seeds for *Senna uniflora*) with four repetitions per treatment in a complete block design. Petri dishes were incubated in darkness at 27°C. Percent germination and radicle growth were obtained after 24 hr for *A. hypochondriacus* and 48 hr for the rest of the test species. Data were analyzed by an ANOVA and Tukey's test.

Greenhouse Experiment. Soil for pots was collected in a crop field recently tilled from a farming community where *I. tricolor* is used as a cover crop for weed control, in the locality of Yautepec, near Cañón Lobos, Morelos, in July 1993. The soil was passed through a 2-mm sieve and divided in two parts. One part was sterilized before the addition of treatments. The experiment was performed in a complete random block design with four blocks. Each block contained 16 representative pots for a total of 64 pots. The pots contained 3 kg of soil and were rotated every three weeks to ensure uniform sunlight. The following treatments were used.

Abbreviations	Treatments
1VS	Sterile soil + 2.5% of vermiculite (control 1)
2VS	Sterile soil + 5% of vermiculite (control 2)
1VNS	Nonsterile soil + 2.5% of vermiculite (control 3)
2VNS	Nonsterile soil + 5% of vermiculite (control 4)
1IS	Sterile soil + 2.5% of *I. tricolor* (dried and milled)
2IS	Sterile soil + 5% of *I. tricolor* (dried and milled)
1INS	Nonsterile soil + 2.5% of *I. tricolor* (dried and milled)
2INS	Nonsterile soil + 5% of *I. tricolor* (dried and milled)
1GS	Sterile soil + 2.5% of vermiculite + 0.4% of Gesaprim
2GS	Sterile soil + 5% of vermiculite + 0.8% of Gesaprim
1GNS	Nonsterile soil + 2.5% of vermiculite + 0.4% of Gesaprim
2GNS	Nonsterile soil + 5% of vermiculite + 0.8% of Gesaprim
1FS	Sterile soil + 2.5% of vermiculite + 0.4% of Faena
2FS	Sterile soil + 5% of vermiculite + 0.8% of Faena
1FNS	Nonsterile soil + 2.5% vermiculite + 0.4% of Faena
2FNS	Nonsterile soil + 5% of vermiculite + 0.8% of Faena

Gesaprim is a 1,3,5-triazine herbicide with a selective pre- and postemergent action used to control annual weeds. Faena is a phosphonic acid product, a glyphosate that acts as a nonselective, nonresidual postemergent herbicide (Worthing, 1991; Draber and Fujita, 1992). The tested concentrations of herbicides were designed to be similar and higher than the mean content of Tricolorin A in *Ipomoea tricolor* (Pereda-Miranda et al., 1993).

Five seeds of *A. hypochondriacus* were sown in each pot. After two weeks, pots were thinned to one seedling of *A. hypochondriacus*. Five seeds of *E. crusgalli* and *S. uniflora* were sown in each pot that contained sterile soil. Number of monocotyledonous and dicotyledonous weeds in the nonsterile soil treatments was recorded five times during the experiment. Numbers of *E. crusgalli* and *S. uniflora* were recorded in the sterile soil treatments. The number of *I. tricolor* seedlings in the four treatments that contained this plant incorporated into the soil (sterile and nonsterile) was recorded four times during the experiment. Pots were watered when necessary. Basins were placed underneath each pot in order to collect drainage water, which was refrigerated for further bioassays and chromatographic analysis. After 45 days the experiment was completed. Plants were removed and separated into monocot and dicot weeds and *A. hypochondriacus*. Plants were dried and weighed. Data were analyzed by an ANOVA, contrasts, and Tukey studentized range tests (Méndez et al., 1992).

Bioassays with Drainage Water from Pots. A bioassay was performed to determine the effects of the drainage water from pots containing each of the treatments in the greenhouse experiment. In this bioassay, the drainage water

of the pot with the 2.5% proportion was mixed with that of the pot with 5% proportion of each treatment to make only eight treatments. These drainage waters were tested on germination and radicle growth of *A. hypochondriacus* and *E. crusgalli*. Bioassay was performed in a complete block design with four repetitions in Petri dishes with Whatman filter paper (No. 42), 10 seeds per treatment. Petri dishes were placed under the same conditions as the comparative phytotoxicity bioassay. Data were analyzed by ANOVA and Tukey's test.

Soil Analysis. Soil samples before and after the greenhouse experiment were analyzed at the Center of Ecology at UNAM in order to measure physical and chemical properties.

RESULTS AND DISCUSSION

Comparative Bioassays for Phytotoxicity

Results of the bioassays in Petri dishes testing aqueous leachates of *I. tricolor*, tricolorin A, and the two herbicides, Gesaprim and Faena, on the germination of *A. hypochondriacus*, *E. crusgalli*, *Senna uniflora*, *Ipomoea tricolor*, and *I. purpurea* are shown in Table 1. Aqueous leachates of the plant significantly inhibited germination of *E. crusgalli* and *I. tricolor*. Tricolorin A was the only treatment that strongly inhibited germination of *A. hypochondriacus*, and to a lesser extent, *E. crusgalli*. Tricolorin A slightly inhibited *I. tricolor* and *I. purpurea* germination, as all other treatments had no effect, on *S. uniflora*, a species that coexists with *I. tricolor* in the same habitat. Both herbicides slightly inhibited germination of *A. hypochondriacus* and *E. crusgalli*. Germination of *I. tricolor* was significantly inhibited by tricolorin A (100–200 μg/ml) and Faena herbicide. Germination of *I. purpurea* was slightly affected by tricolorin A and Faena.

Results of the bioassays in Petri dishes, which tested the same treatments on the radicle growth of test species, are shown in Table 2. Leachate of *I. tricolor* strongly inhibited the radicle growth of *A. hypochondriacus* and had a slight effect on *E. crusgalli* and *S. uniflora*, but it showed no effect on the radicle growth of the two *Ipomoea* species tested. Tricolorin A displayed a strong inhibitory effect on radicle growth of *A. hypochondriacus* and *E. crusgalli*. However, this bioactive compound had no effect on *S. uniflora*. Tricolorin A significantly inhibited radicle growth of *I. tricolor* at 150 and 200 μg/ml. This inhibitory effect was stronger on *I. purpurea*. The effect of the two herbicides tested in Petri dishes was different to that in the soil. Gesaprim significantly inhibited (34%) the radicle growth of *A. hypochondriacus* at 150 and 200 μg/ml. It stimulated *A. hypochondriacus* at 10 μg/ml, and had no effect on *E. crusgalli* and *S. uniflora*. Gesaprim caused a significant stimulation of radicle

TABLE 1. EFFECTS OF AQUEOUS LEACHATE AND TRICOLORIN A OF *Ipomoea tricolor* AND GESAPRIM AND FAENA HERBICIDES ON GERMINATION OF FIVE SPECIES

Treatments	Germination (%)				
	Amaranthus hypochondriacus	*Echinochloa crusgalli*	*Senna uniflora*	*Ipomoea tricolor*	*Ipomoea purpurea*
Control	95.0	90	80	65	60
Aqueous leachate (1%)	95.0	67.5[a]	100	55[a]	60
Tricolorin A (μg/ml)					
10	70.0[a]	92.5	80	65	45[a]
50	57.7[a]	70[a]	80	62.5	67.5
100	0	35[a]	80	62.5	50[a]
150	0	35[a]	80	55[a]	50[a]
200	0	27.5[a]	75	25[a]	57.5
Gesaprim (μg/ml)					
10	87.5	90	80	90	72[a]
50	92.5	90	80	70	52
100	97.5	90	72.5	76	56
150	85[a]	92.5	80	88	52
200	80[a]	82.5	80	76	52
Faena (μg/ml)					
10	100	77.5[a]	80	47.5[a]	57.5
50	92.5	75[a]	77.5	42.5[a]	55
100	85[a]	90	80	55[a]	50[a]
150	87.5	75.0[a]	80	42.5[a]	47.5[a]
200	85[a]	77.5[a]	80	30[a]	57.5

[a]Differences statistically significant ($P < 0.05$) with respect to control using a HSD Tukey's test.

growth of the two *Ipomoea* species tested. Faena had an inhibitory effect on radicle growth of *E. crusgalli*, *S. uniflora*, *I. tricolor*, and *I. purpurea* starting at 10–50 μg/ml. This herbicide did not affect the growth of *A. hypochondriacus*.

Greenhouse Experiment

Number of Seedlings of I. tricolor in Pots. The dry *I. tricolor* that was mixed with sterile and nonsterile soil (1IS, 2IS, 1INS, 2INS), contained some seeds of the species that went unnoticed until they germinated in the pots. The number of seedlings that emerged in these four treatments was recorded four times during the experiment and then was completely eliminated to avoid its competitive effect on the other plants. The split-plot ANOVA made with the logarithms of the number of these seedlings in the four dates recorded showed a significant effect for the interaction date–treatment.

TABLE 2. EFFECTS OF AQUEOUS LEACHATE AND TRICOLORIN A OF *Ipomoea tricolor* AND GESAPRIM AND FAENA HERBICIDES ON RADICLE GROWTH OF FIVE SPECIES

Treatments	Radicle growth inhibition (%)				
	Amaranthus hypochondriacus	*Echinochloa crusgalli*	*Senna uniflora*	*Ipomoea tricolor*	*Ipomoea purpurea*
Control	0.0	0.0	0.0	0.0	0.0
Aqueous leachate (1%)	60.0[a]	26.4[a]	20.8[a]	11.6	7.0
Tricolorin A (μg/ml)					
10	39.7[a]	52.2[a]	(13.1)[b]	(5.4)	7.2
50	55.0[a]	72.1[a]	9.3	17.3	36.7[a]
100	100[a]	78.2	7.7	17.1	32.6[a]
150	100[a]	78.0[a]	8.3	32.4[a]	23.0[a]
200	100[a]	77.5[a]	4.8	40.7[a]	43.0[a]
Gesaprim (μg/ml)					
10	(24.0)[a]	(14.6)	(13.1)	(7.2)	(55.0)[a]
50	(8.0)	(12.8)	5.1	(18.4)	(10.0)
100	19.6	3.7	10.0	(27.0)[a]	(55.8)[a]
150	20.0[a]	11.7	(6.2)	(31.0)[a]	(28.0)[a]
200	34.4[a]	(15.0)	8.2	(24.3)[a]	(70.5)[a]
Faena (μg/ml)					
10	(1.8)	25.0[a]	(15.9)	41.8[a]	46.0[a]
50	(6.0)	41.2[a]	40.9[a]	46.4[a]	55.4
100	(7.5)	55.5[a]	42.9[a]	53.4	59.7[a]
150	(1.8)	69.1[a]	52.3[a]	66.5[a]	58.5[a]
200	18.6	75.0[a]	52.3[a]	61.4[a]	66.0[a]

[a]Differences statistically significant ($P < 0.05$) with respect to control using a HSD Tukey's test.
[b]Number in parentheses indicates stimulation.

The analysis of interaction of treatments by dates on number of seedlings of *Ipomoea* is shown in Figure 2. There was a significant difference in the number of seedlings of *I. tricolor* in sterile (1IS and 2IS) and nonsterile (1INS and 2INS) treatments, particularly in the first date. There was a significant difference between 1INS treatment (prepared with the low proportion of *I. tricolor* added to soil) and the other three treatments in the second, third, and fourth measurements. Probably, in nonsterile soil, microorganisms quickly attack the seed population of *I. tricolor*, diminishing the possibility of germination and survival. Absence of microorganisms in sterile soil may have favored the integrity of *Ipomoea* seeds and their probability of survival and germination. With time, conditions of soil sterility were lost, and the number of germinated seeds came to be similar in all treatments, except in the 1INS. It is possible that in natural conditions, *I. tricolor* inhibits germination and growth of its own seeds.

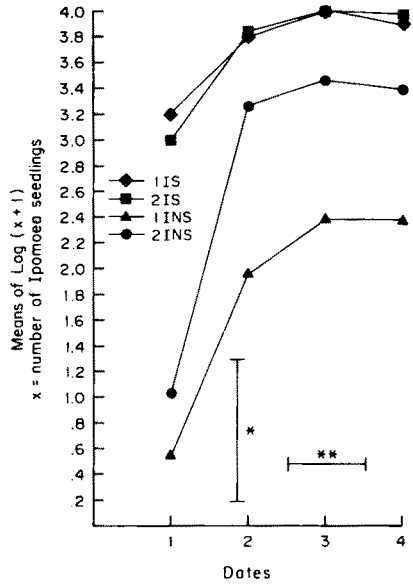

FIG. 2 Study of the interaction treatments by dates on number of seedlings of *Ipomoea* (all experimental data). *HSD for comparing treatments; **HSD for comparing dates.

The phytotoxic activity of the leachates and/or residues could be an autocontrol mechanism of the population. These seeds are rich in alkaloids and other important secondary metabolites, including resin glycosides, so it is also important to explore the ecological role that these compounds play in the establishment of biotic interactions, especially with predators and microorganisms.

Effects of Treatments on Number of Echinochloa *(Monocot) and* Senna *(Dicot) Plants in Sterile Soil.* The number of plants for each pot was recorded five times during the experiment. ANOVA showed that there was a significant difference among treatments. For both plant types, it is also possible to observe a significant effect for the interaction treatments–dates.

Tukey's studentized range test for the means of the logarithm of number of *Echinochloa* (monocot) plants in sterile soil (Table 3) shows that the number of plants is higher in control 2VS compared with the other treatments. There was no difference among IVS, 1IS, 2IS, and 2FS. These four treatments were different from 1FS, 1GS, and 2GS. These last two treatments were statistically different from each other and from 1IFS. The number of *Echinochloa* was significantly diminished by both Gesaprim treatments and treatment with Faena in low concentration (1FS).

TABLE 3. TUKEY'S STUDENTIZED RANGE TEST FOR LOGARITHM OF NUMBER OF *Echinochloa* (MONOCOT) AND *Senna* (DICOT) PLANTS IN STERILE SOIL[a]

Echinochloa (monocot)		*Senna* (dicot)	
Treatment	Mean	Treatment	Mean
2VS	1.40 ± 0.61 a	2VS	1.56 ± 0.38 A
2FS	1.30 ± 0.75 ab	2FS	1.40 ± 0.34 A
1VS	1.28 ± 0.73 ab	2IS	1.35 ± 0.48 AB
2IS	1.25 ± 0.72 ab	1VS	1.33 ± 0.75 AB
1IS	1.21 ± 0.71 ab	1IS	1.31 ± 0.19 AB
1FS	1.08 ± 0.73 bc	1FS	1.02 ± 0.32 BC
2GS	0.87 ± 0.74 cd	2GS	0.70 ± 0.78 DC
1GS	0.66 ± 0.64 d	1GS	0.35 ± 0.40 D

[a]Numbers with different letters are significantly different ($p < 0.05$).

The number of *Senna* (dicot) (Table 3) was the same in the control 2VS and Faena in high concentration (2FS). The control 1VS and the treatments 1IS and 2IS are not different from each other. The other treatments (1FS, 2GS, and 1GS) were significantly different. In fact, the number of *Senna* plants was significantly diminished by the two treatments with Gesaprim and Faena in low concentration. *Ipomoea* treatments affected the number of *Senna* only when compared with 2VS control and Faena in high concentration. The effect of Faena was unexpected when the results of the low and high concentrations were compared. The number of *Senna* and *Echinochloa* seedlings was affected only by the low concentration of Faena.

The analysis of interaction of treatments by dates on number of *Echinochloa* (monocot) plants in sterile soil is shown in Figure 3. Faena at low concentration (1FS) had the lowest number of seedlings at the second and third dates. There was a significant difference between both Gesaprim treatments and the other treatments at the fourth and fifth dates.

The analysis of interaction of treatments by dates on number of *Senna* (dicot) plants in sterile soil is shown in Figure 4. Regarding differences among treatments, Gesaprim and Faena at low concentration had low numbers of *Senna* plants at the third and fourth dates. At these same dates, control 2VS had the higher number of plants. Both concentrations of Gesaprim (1GS and 2GS) were significantly different from the other treatments in the fourth and fifth dates. Gesaprim and Faena at low concentration (1GS and 1FS) had a stronger effect on the number of *Echinochloa* and *Senna* plants compared with the high concentration (2GS and 2FS).

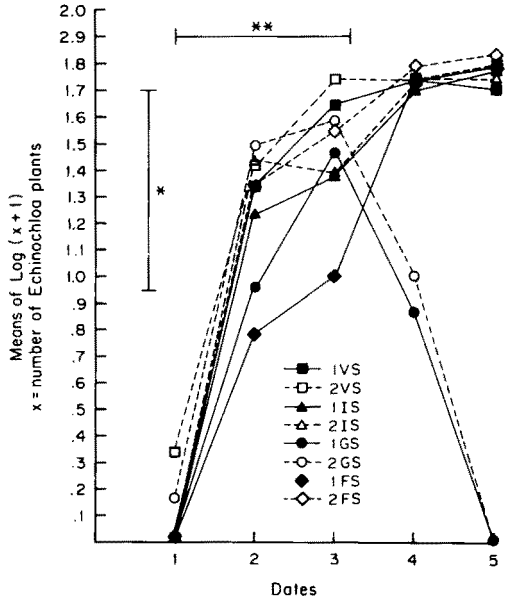

FIG. 3 Study of the interaction treatments by dates on number of *Echnochloa* plants (only data for sterile soil). *HSD for comparing treatments; **HSD for comparing dates.

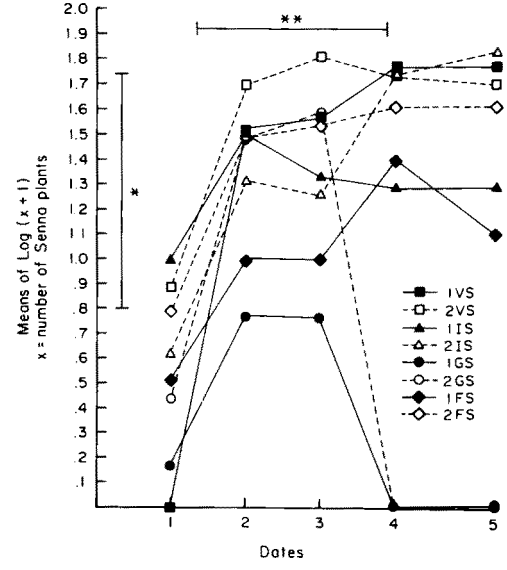

FIG. 4 Study of the interaction treatments by dates on number of *Senna* plants (only data for sterile soil). *HSD for comparing treatments; **HSD for comparing dates.

TABLE 4. TUKEY'S STUDENTIZED RANGE TEST FOR LOGARITHM OF NUMBER OF MONOCOTYLEDONOUS AND DICOTYLEDONOUS PLANTS IN NONSTERILE SOIL[a]

Monocotyledonous plants		Dicotyledonous plants	
Treatment	Mean	Treatment	Mean
2VNS	1.09 ± 0.42 a	1VNS	2.26 ± 0.23 A
1VNS	1.09 ± 0.40 a	2VNS	2.24 ± 0.12 A
1FNS	0.97 ± 0.64 a	1FNS	1.53 ± 0.33 B
1INS	0.73 ± 0.49 ab	1INS	1.41 ± 0.27 B
2INS	0.52 ± 0.41 bc	2INS	1.24 ± 0.34 B
2FNS	0.37 ± 0.23 bcd	2FNS	0.81 ± 0.26 C
2GNS	0.10 ± 0.23 cd	1GNS	0.55 ± 0.69 C
1GNS	0.07 ± 0.15 d	2GNS	0.54 ± 0.68 C

[a]Numbers with different letters are significantly different ($p < 0.05$).

Effects of Treatments on Number of Monocotyledonous and Dicotyledonous Plants in Nonsterile Soils. The split-plot ANOVA with the logarithms of the number of monocotyledonous and dicotyledonous plants in nonsterile soils showed that there was a significant difference between treatments. In the case of the number of dicotyledonous plants, there was a significant effect for the interaction treatments–dates. Tukey's studentized range test for the logarithm of the number of monocots in nonsterile soil (Table 4) showed that the two controls (1VNS, 2VNS) and 1FNS are not different. The rest of the treatments were different from each other. The number of monocots was significantly diminished by *Ipomoea* and Faena in high concentration; this effect was stronger with Gesaprim in both concentrations. In relation to the number of dicots, it was observed that treatments 1FNS, 1INS, and 2INS were significantly different from the controls. Treatments 2FNS, 1GNS, and 2GNS had a strong phytotoxicity on the number of dicots.

The analysis of interaction of treatments by dates on the number of monocotyledonous plants in nonsterile soil is shown in Figure 5. The two controls maintained the higher number of monocots from the beginning of the experiment. At the fourth and fifth dates, this is true also for Faena at low concentration. The two treatments with *Ipomoea* had a low number of monocots from the first to the fourth dates. Both treatments with Gesaprim differed from the other treatments from the third date to the final date. Faena at high concentration was significantly different from Faena at low concentration. It is possible to see that the effect of *Ipomoea* treatments is stronger compared with Faena at low concentration.

The analysis of interaction of treatments by dates on the number of dico-

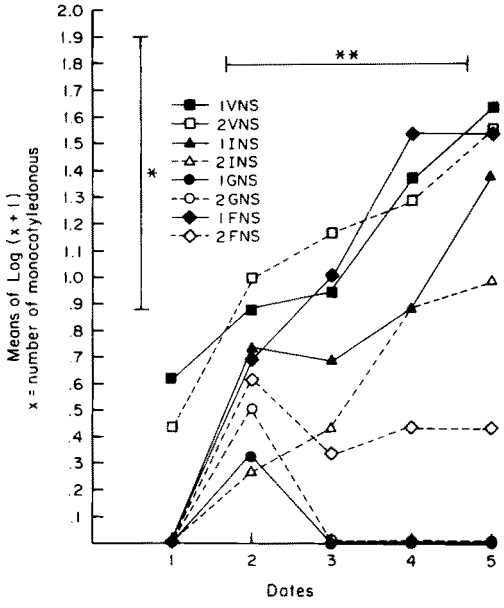

FIG. 5 Study of the interaction treatments by dates on number of monocotyledonous (only data for non-sterile soil). *HSD for comparing treatments; **HSD for comparing dates.

tyledonous plants in nonsterile soil is shown in Figure 6. Both controls had the higher number of dicots at the five dates recorded. At the first date both *Ipomoea* treatments and Gesaprim at the low concentration had the lower numbers of dicots. *Ipomoea* treatments and Faena at low concentration showed a similar effect on the number of dicots from the second date to the fifth date. From the third date to the end of the experiment, 2FNS and both Gesaprim concentrations had a strong phytotoxic effect on dicots.

Gesaprim herbicide eliminated all plants in the pots at the two concentrations used at the end of the experiment. The effect of Gesaprim on growth of plants in sterile and nonsterile soil was opposite to its effect in Petri dishes. In general, Gesaprim did not affect germination and growth of the test species in Petri dishes bioassays. Undoubtedly, the mediator role of the soil is a fundamental factor for the phytotoxic expression of this herbicide. On the other hand, Faena did not affect germination and growth of *Amaranthus* in vitro, nor the germination of *Senna*, but it inhibited significantly the radicle growth of *Echinochloa*, *Senna*, *Ipomoea tricolor*, and *I. purpurea* seedlings in these Petri dish bioassays.

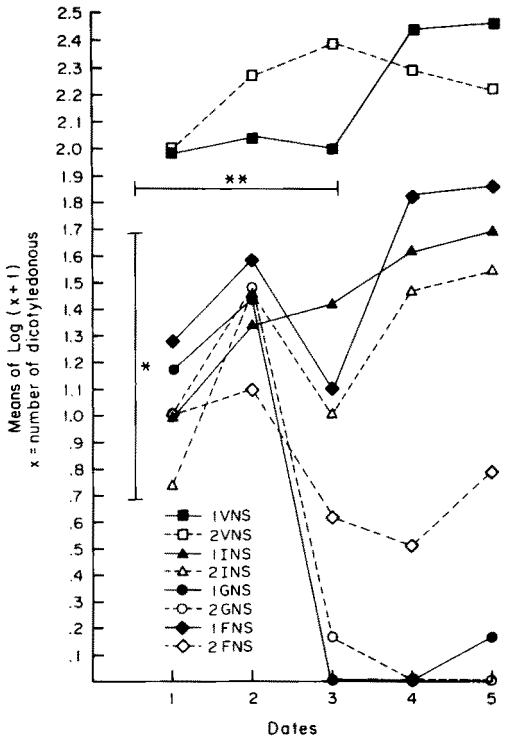

FIG. 6 Study of the interaction treatments by dates on number of dicotyledonous (only data for non-sterile soil). *HSD for comparing treatments; **HSD for comparing dates.

Effects on Echinochloa *and* Senna *Biomass in Sterile Soils and Monocot and Dicot in Nonsterile Soils.* Biomass, expressed as dry weight, was evaluated at the end of the experiment. Mean weights of *Echinochloa* (monocot) and *Senna* (dicot) in sterile soil, and monocots and dicots in nonsterile soil are shown in Table 5. Gesaprim eliminated all the plants at the two concentrations tested in sterile and nonsterile soils. In relation with sterile soil, the significant difference between treatments is focused on the effect of *Ipomoea* mixed in the soil and on biomass of *Echinochloa*. In relation with nonsterile soils, there was no significant difference in the biomass of monocots and dicots in the control, *Ipomoea*, and Faena treatments. On the other hand, there were no significant differences in the biomass of *Aviaranthus hypochondriacus* among all the treatments (data not shown).

TABLE 5. EFFECTS OF EIGHT TREATMENTS ON BIOMASS OF *Echinochloa* AND *Senna* PLANTS IN STERILE SOILS AND BIOMASS OF MONOCOTS AND DICOTS IN NONSTERILE SOILS

Treatment	Mean weight (g) *Echinochloa*	Mean weight (g) *Senna*	Total
Sterile soil			
1VS	2.2	0.15	2.35
2VS	2.78	0.15	2.93
1IS	1.6[a]	0.12	1.72
2IS	1.25[a]	0.11	1.36
1GS	0	0	0
2GS	0	0	0
1FS	2.02	0.11	2.13
2FS	2.12	0.10	2.22
Total	11.97	0.74	12.71
	Mean weight (g) of monocot	Mean weight (g) of dicot	
Nonsterile soil			
1VNS	0.03	0.08	0.11
2VNS	0.007	0.09	0.097
1INS	0.09	0.16	0.25
2INS	0.013	0.13	0.143
1GNS	0	0	0
2GNS	0	0	0
1FNS	0.003	0.04	0.043
2FNS	0.005	0.0017	0.0067
Total	0.148	0.50	0.6497

[a]Differences statistically significant ($p < 0.01$) with respect to control using a HSD Tukey's test.

Results of Bioassay with Drainage Water from Pots

The results from this bioassay are shown in Table 6. Effects of the drainage water from sterile and nonsterile soil treatments on radicle growth of *A. hypochondriacus* and *E. crusgalli* were different. It is possible to see that there was a specific response of each species to the treatments. ANOVA and Tukey's test showed that significant effects, particularly stimulations, were produced only by drainage water from nonsterile soils. The water from pots with *I. tricolor* produced a significant stimulation of radicle growth of *A. hypochondriacus*. Drainage water from Faena treatments significantly inhibited the growth of this species.

TABLE 6. EFFECTS OF THE LEACHATES FROM THE POTS ON THE RADICLE GROWTH OF *Amaranthus hypochondriacus* AND *Echinochloa crusgalli*.

Treatment	Inhibition (%)	
	Amaranthus hypochondriacus	*Echinochloa crusgalli*
Sterile soil		
VS	0	0
IS	(8)[a]	(2)
GS	1	(3)
FS	3	(4)
Nonsterile soil		
VNS	0	0
INS	(24)[a]	(54)[a]
GNS	9	(47)[a]
FNS	44[a]	(36)

[a]Differences statistically significant ($P < 0.05$) with respect to control using a HSD Tukey's test. Numbers in parentheses are stimulations.

On the other hand, *E. crusgalli* was significantly stimulated by water from pots with *I. tricolor*, Gesaprim, and Faena. Neither of the phytotoxic agents from the different treatments, except that from Faena, was leached out by the drainage waters. If we compare the results of the bioassays in Petri dishes (Table 2) with these of the drainage waters bioassays (Table 6), we can observe the essential effect of the soil on the expression of phytotoxicity and allelopathy. In relation to this, the effectiveness of a soil-applied herbicide depends on its adsorption in the soil. Organic matter is the predominant adsorbing component in it, so the amount of organic matter in the soil is a determining factor (Johnston, 1986; Rowell, 1994). The selectivity of triazines, for instance, results from their low solubility in water and their high colloidal absorption grade in the soil, so they have relatively long-term activity in the soil. This could explain the strong phytotoxicity of Gesaprim in the soil of the experiment that was rich in organic matter (Gerber et al., 1970; Addiscot and Wagenet, 1985).

Table 7 shows some physical and chemical properties of soil before and after the experiment. In general, conditions of the soil before and after the experiment change slightly. Before the experiment, sterilization of the soil increased total nitrogen and total phosphorus. After the experiment, the pH tended to be neutral. The soil was not saline, but *Ipomoea* and Gesaprim caused a small increase in the electrical conductivity of it. Organic matter is higher in sterile and nonsterile soil with *Ipomoea* and in soil of the nonsterile control and

TABLE 7. PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOIL BEFORE AND AFTER GREENHOUSE EXPERIMENT[a]

Soil	pH 1:2.5	EC (μohm)	MO (%)	K (meq/100 g)	Ca (meq/100 g)	Mg (meq/100 g)	CEC	TN (ppm)	TP (ppm)	Clay (%)	Silt (%)	Sand (%)	Texture
SSBE	6.7	112	3.45	4.15	8.63	5.9	30.46	1630	1100	20	30	50	Loam
NSSBE	6.2	143	3.90	4.42	7.95	8.85	31.62	1195	450	24	30	46	Loam
VS	7.0	113	3.68	4.37	8.40	9.31	31.40	1175	3250	26	30	44	Loam
VNS	7.0	95	4.21	3.84	7.72	8.85	23.32	1200	1350	26	28	46	Loam
IS	6.7	154	4.79	5.93	9.31	6.81	40.98	1605	1400	30	28	42	Clay loam
INS	7.4	209	4.23	6.11	8.17	6.58	27.93	1680	950	24	30	46	Loam
GS	6.7	239	3.81	4.43	9.08	7.26	32.64	1340	1250	26	28	46	Loam
GNS	7.0	154	3.49	7.74	9.31	6.58	27.91	1160	950	26	28	46	Loam
FS	7.3	125	3.64	4.20	9.53	8.63	32.90	1055	700	22	28	50	Loam
FNS	7.0	128	4.70	3.86	7.49	8.40	27.37	1145	1050	24	28	48	Loam

[a]Before the experiment: SSBE, sterile soil; NSSBE, nonsterile soil. After the experiment: VS, soil of the sterile control; VNS, soil of the nonsterile control; IS, sterile soil with *Ipomoea*; INS, nonsterile soil with *Ipomoea*; GS, sterile soil with Gesaprim; GNS, nonsterile soil with Gesaprim; FS, sterile soil with Faena; FNS, nonsterile soil with Faena.

nonsterile soil with Faena. Potassium was increased in *Ipomoea* treatments and in nonsterile soil with Gesaprim. Nitrogen was increased in sterile soil before the experiment and in both treatments with *Ipomoea*. Phosphorus is higher in almost all the sterile soils compared with the nonsterile ones.

In the greenhouse experiment, the biomass of *Echinochloa crusgalli* (sterile soil) was significantly diminished by the incorporation of *I. tricolor* into the soil, and also, the number of monocots and dicots in nonsterile soil. In fact, the number of monocots and dicots tended to diminish starting from the third date recorded in the greenhouse experiment in both *Ipomoea* treatments. It is possible to see that this tendency is stronger comparing these two treatments with Faena at low concentration. In the field, it is possible that the weed control effect of *Ipomoea tricolor* takes place in two stages, first, by the combination of the allelopathic potential of the living plant expressed through rain leachate and competition (interference); and second, when the plant is cut and incorporated into the soil. Decomposition of its residues acts as the second weed control factor before the sowing of sugar cane, corn, or other crops.

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