ganic materials. Indeed, the major portion of the diflubenzuron applied to soil in our study was associated with treated plant materials and this may have provided some protection from decomposition. However, our method of treating the soil is comparable to that which will occur when the chemical is used for insect control on cotton.

As would be expected, the residue pattern was more favorable for the plot that received the fewest applications. Therefore, if the levels of residues observed in this study should subsequently be judged undesirable, some limitation might be placed on the number of diflubenzuron applications to be used in commercial practice.

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Pesticide Interactions in Oats (*Avena sativa* L. 'Neal')

Dennis L. Bucholtz* and Terry L. Lavy[1]

According to greenhouse studies on oats (*Avena sativa* L. 'Neal'), interactions occur between both alachlor (2-chloro-2,6-diethyl-*N*-(methoxymethyl)acetanilide) and trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) and the photosynthesis inhibiting herbicides, atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine), cyanazine (2-[[4-chloro-6-(ethylamino)-*s*-triazine-2-yl]-amino]-2-methylpropionitrile), diuron (3-(3,4-dichlorophenyl-1,1-dimethylurea), and methazole (2-(3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione). The effect on oat dry weights of photosynthesis inhibiting herbicides applied to the soil was attenuated by the application of alachlor or trifluralin to the soil. Leaf necrosis, attributable to photosynthesis inhibiting herbicides, was decreased with the application of alachlor or trifluralin. However, the effect of a foliar application of atrazine on oat dry weights was not attenuated by the soil application of alachlor or trifluralin. Neither alachlor nor trifluralin reduced the effects of the photosynthesis inhibiting herbicides on CO_2 fixation or on respiration in excised leaves. Application of alachlor, phorate (*O*,*O*-diethyl *S*-(ethylthiomethyl)-phosphorodithiate), and trifluralin in combination with ^{14}C-labeled photosynthesis inhibiting herbicide decreased the root length and the amount of uptake of the ^{14}C-labeled photosynthesis inhibiting herbicides. A high correlation was observed between root length and the percentage of ^{14}C-labeled photosynthesis inhibiting herbicides taken up. These data show that alachlor and trifluralin inhibit root growth and thereby reduce absorption of the photosynthesis inhibiting herbicides.

The use of pesticides is common in today's agriculture. During the last decade, the use of combinations of two or more pesticides on the same crop has become prevalent in attempts to increase the number of pests controlled. When two pesticides are combined, three responses may occur: (1) they may act independently, (2) their combined effects may be greater than the sum of the responses given by the individual treatments, or (3) their combined effects may be less than the sum of the responses given by the individual treatments.

The objectives of this study were to determine whether interactions between commonly used pesticides alter plant responses and then to explain possible relationships among the pesticides and the responses they evoke.

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EXPERIMENTAL SECTION

A preliminary study was conducted to determine workable ranges of concentration for alachlor (2-chloro-2′,6′-diethyl-*N*-(methoxymethyl)acetanilide), atrazine

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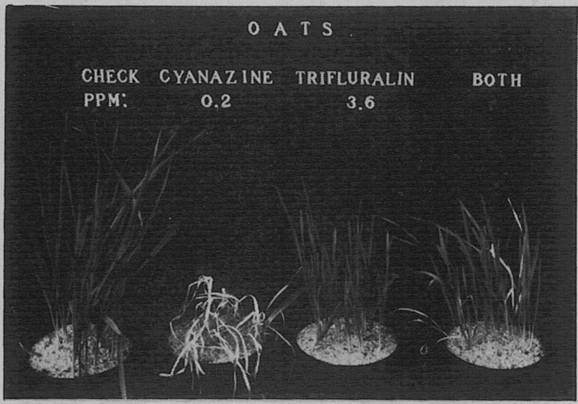

Figure 1. Oat plants showing an antagonistic interaction between cyanazine and trifluralin.

(2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine), cyanazine (2-[[4-chloro-6-(ethylamino)-*s*-triazine-2-yl]-amino]-2-methylpropionitrile), diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea), methazole (2-(3,4-dichlorophenyl-4-methyl-1,2,4-oxadiazolidine-3,5-dione), phorate (*O*,*O*-diethyl *S*-(ethylthiomethyl) phosphorodithiate), and trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) using oats (*Avena sativa* L. 'Neal') as a bioassay crop. After concentrations were established, methanol–water (1:3 v/v) solutions of technical grade pesticides were applied at four rates to 520-g samples of a Keith silt loam. This soil was found to contain 2.1% organic matter and 21.4% clay, and it had a pH of 6.5. The photosynthesis inhibitor (PSI) herbicides, atrazine, cyanazine, diuron, and methazole, were applied individually with alachlor, phorate, and trifluralin in 12 factorially arranged experiments. After application of the pesticides, sufficient time was allowed for the methanol to evaporate before the soil was mixed to distribute the chemicals evenly. The soil was then placed in 9-cm diameter plastic pots and seeded with approximately 50 oat seeds. Each treatment was replicated four times.

Visual symptoms of injury attributed to the PSI were first noticeable 10 days after planting. The severity of photosynthesis inhibition was measured by rating plants and assigning a value ranging from one to five. A value of one was given to a plant with no symptoms, two to a wilting plant (wilting even in moist soil), three to desiccated but still green leaf tissue, four to desiccated leaf tissue having both bleached and green tissue present, and five to completely bleached tissue. The plants were rated on alternate days for a total of five times. Regression analyses were performed on the mean of these five rating values. In addition, reduction in plant height was also rated as a measure of the bioactivity of alachlor, phorate, and trifluralin. However, height reduction resulting from alachlor, phorate, or trifluralin was unaffected by the PSI herbicides, and so these data are not presented.

Nineteen days after planting, the oats were harvested and dry weights measured. Regression analyses for both dry weights and ratings were performed for each of the 12 experiments. The regression model used to describe the response surface generated by the chemical combinations was the following:

$$Y = b_0 + b_1(\text{pesticide}) + b_2(\text{PSI}) + b_3(\text{pesticide})^2 + b_4(\text{PSI})^2 + b_5(\text{pesticide})(\text{PSI})$$

where Y = the dependent variable, either dry weight or rating; b_0, the intercept or the value for the untreated plants; b_1, b_2...b_5, the regression coefficients for the independent variables. Since the dry weight and rating values are inversely related, i.e., a smaller dry weight and a larger rating value both indicate a more severe effect of the pesticide or PSI, the *b*'s for the two variables should be of opposite sign. If b_5 is positive for dry weight or negative for rating, the response of the oats to the combination treatment is antagonistic. Conversely, if b_5 is negative for dry weight or positive for rating, the interaction was synergistic and indicates that a combination treatment results in more tissue damage or less growth than expected from the sum of the responses given by the treatments applied separately.

A study on pesticide uptake was conducted using six oat seedlings grown in washed sand contained in 250-mL Styrofoam cups. Treatments to the sand included the following: 0.5 μCi of ^{14}C-labeled atrazine, cyanazine, or diuron (sp act., 24.9, 5.6, and 4.1 μCi/mg, respectively), each in combination with nonradioactive alachlor, phorate, and trifluralin at 2, 6, 4 ppmw, respectively. Also applied was 0.5 μCi of ^{14}C-labeled phorate or trifluralin (sp act., 13.6 and 37.2 μCi/mg, respectively) in combination with nonradioactive atrazine, cyanazine, diuron, or methazole at 0.1, 0.2, 0.8, or 1.0 ppmw, respectively. ^{14}C-labeled pesticides with no additional treatments were also included. Nutrients were supplied to the sand culture by occasionally adding half-strength Hoagland solution (Hoagland and Arnon, 1950). Additional water was added by overhead sprinkling as needed. No water leakage from any of the pots was observed. Eighteen days after planting, the sand was washed from the oat roots, and the plants were dried in a forced-air oven at 70 °C for 2 days. The root lengths were then measured. Autoradiographs of the plants were made by exposing No-Screen x-ray film (Eastman Kodak Company) to the radioactive plants for 2 weeks. The entire plant was then oxidized in a Packard Tri-Carb Sample Oxidizer Model 306 and assayed for radioactivity in a Packard liquid scintillation counted Model 3320. The percentage of ^{14}C taken up was calculated by the amount of radioactivity found in the plants by the amount of radioactivity applied initially to the pots, times 100. A linear regression line was calculated expressing the relationship between ^{14}C-labeled PSI uptake and root length.

A study on photosynthesis and respiration was conducted with oat leaves. Leaf tips approximately 5 cm long were excised from 8-day-old oat plants and placed in 2-mL vials which contained 0.1 mL of 1% Tween 20 in water and 0 or 5 μmol of atrazine, cyanazine, diuron, or methazole in combination with 0 or 5 μmol of alachlor or trifluralin. The leaves were allowed to absorb these solutions in the greenhouse for 1 h and then were moved to a 0.4-L capacity chamber in which $^{14}CO_2$ was generated from 1 mg of $Ba^{14}CO_3$ (5 μCi/mg) with the addition of 2 mL of 6 N H_2SO_4. The chamber, vials, and leaves were then placed between two 300-W incandescent lamps and illuminated with 320 μeinstein m^{-2} s^{-1} for 2 h. The chamber temperature was maintained with water reservoirs at 26 ± 2 °C. Respiration of the leaves was measured by removing the leaves and vials from the illumination chamber and placing them in an upright position in 25-mL liquid scintillation vials containing 2 mL of 6 N NaOH. The scintillation vials were then capped and placed in a dark growth chamber at 28.5 ± 0.5 °C for 3.5 h. After this incubation period the NaOH was assayed for respired $^{14}CO_2$. The leaves were dried overnight in a 70 °C forced-air oven and then weighed and oxidized by the technique described above. The data on photosynthesis were expressed as leaf dpm/mg (dry weight basis). The value of the leaf dpm was the dpm in the leaf after the

Table I. Dry Weights of Oats Grown in Soil Treated with Two Pesticides[a]

		Photosynthetic inhibitors												
		Check	Atrazine, μg/g			Cyanazine, μg/g			Diuron, μg/g			Methazole, μg/g		
Pesticides		0	0.10	0.20	0.30	0.15	0.30	0.45	0.40	0.80	1.20	2.00	4.00	6.00
Alachlor, μg/g	0	1.44	0.61	0.28	0.33	0.96	0.40	0.32	1.15	0.92	0.44	0.36	0.36	0.26
	2	0.78	0.49	0.39	0.28	0.88	0.45	0.32	0.82	0.93	0.44	0.60	0.34	0.28
	4	0.60	0.48	0.29	0.22	0.55	0.32	0.33	0.63	0.63	0.39	0.38	0.33	0.24
	6	0.44	0.35	0.33	0.18	0.43	0.32	0.27	0.41	0.29	0.28	0.38	0.23	0.16
		LSD 0.05 = 0.20				LSD 0.05 = 0.18			LSD 0.05 = 0.23			LSD 0.05 = 0.18		
Phorate, μg/g	2	1.64	0.60	0.32	0.26	1.04	0.38	0.28	1.16	0.93	0.43	0.52	0.32	0.39
	4	1.50	0.87	0.36	0.30	0.86	0.41	0.34	1.25	0.85	0.41	0.50	0.34	0.37
	6	1.50	0.80	0.32	0.28	1.01	0.34	0.30	0.98	1.19	0.44	0.61	0.36	0.31
			LSD 0.05 = 0.27			LSD 0.05 = 0.30			LSD 0.05 = 0.30			LSD 0.05 = 0.25		
Trifluralin, μg/g	1.8	1.29	0.67	0.46	0.24	0.68	0.42	0.27	0.82	0.93	0.44	0.60	0.34	0.28
	3.6	1.08	0.55	0.40	0.28	0.68	0.34	0.25	0.63	0.63	0.39	0.38	0.33	0.24
	5.4	0.78	0.58	0.41	0.28	0.64	0.32	0.32	0.41	0.29	0.29	0.38	0.23	0.16
			LSD 0.05 = 0.24			LSD 0.05 = 0.18			LSD 0.05 = 0.21			LSD 0.05 = 0.16		

[a] Since all treatments were conducted simultaneously, those treatments receiving an application of only one pesticide were used for all 12 combinations. Data are expressed in grams and represent dry matter accumulations of oats during a 19-day period.

Table II. Rating Values of Photosynthesis Inhibitor Symptoms[a]

		Photosynthetic inhibitors												
		Check	Atrazine, μg/g			Cyanazine, μg/g			Diuron, μg/g			Methazole, μg/g		
		0	0.10	0.20	0.30	0.15	0.30	0.45	0.40	0.80	1.20	2.00	4.00	6.00
Alachlor, μg/g	0	1.0	2.3	3.3	3.4	2.0	3.8	4.2	1.0	1.0	3.0	3.0	3.0	4.1
	2	1.0	1.1	2.2	2.6	1.0	2.7	3.0	1.0	1.0	1.6	1.0	2.0	2.8
	4	1.0	1.0	1.8	2.5	1.0	2.1	2.6	1.0	1.0	1.1	1.0	1.5	2.1
	6	1.0	1.0	2.0	2.2	1.0	1.9	2.8	1.0	1.0	1.1	1.0	1.3	1.9
			LSD 0.05 = 0.4			LSD 0.05 = 0.4			LSD 0.05 = 0.2			LSD 0.05 = 0.4		
Phorate, μg/g	2	1.0	1.7	3.5	3.6	1.9	3.4	4.2	1.0	1.3	2.6	2.0	3.2	3.4
	4	1.0	1.5	3.3	3.3	2.0	3.3	3.6	1.0	1.5	2.4	2.0	3.0	3.5
	5	1.0	1.7	3.1	3.3	2.0	3.4	3.9	1.0	1.6	2.4	1.8	2.8	3.2
			LSD 0.05 = 0.4			LSD 0.05 = 0.4			LSD 0.05 = 0.4			LSD 0.05 = 0.7		
Trifluralin, μg/g	1.8	1.0	1.1	2.5	3.0	1.1	2.7	3.4	1.0	1.0	1.1	1.0	2.2	2.6
	3.6	1.0	1.2	2.1	2.6	1.0	2.5	3.0	1.0	1.0	1.0	1.0	1.4	2.3
	5.4	1.0	1.0	1.6	2.3	1.0	2.6	3.2	1.0	1.0	1.0	1.0	1.2	1.8
			LSD 0.05 = 0.4			LSD 0.05 = 0.03			LSD 0.05 = 0.1			LSD 0.05 = 0.7		

[a] Since all treatments were conducted simultaneously, those treatments receiving an application of only one pesticide were used for all twelve combinations. A value of one was given to a plant with no symptoms, two to a wilting plant, three to desiccated but still green leaf tissue, four to desiccated leaf tissue with both bleached and green tissue present, and five to completely bleached tissue. Each of the four replications were evaluated five times.

negligible loss due to respiration. The percentage respired was expressed as: [(dpm in the NaOH ÷ leaf dpm) ÷ 3.5 h] × 100. All the herbicide-treated and nontreated leaves were randomly placed in the $^{14}CO_2$ generation chamber simultaneously, and all treatments were replicated four times.

A study was conducted involving the foliar application of atrazine to oats growing in soil previously treated with alachlor or trifluralin. A sandy loam soil, amended with alachlor or trifluralin (each at 0, 3, or 6 μg/g), was potted and seeded as described above. Ten days after planting, the emerged oat plants received 0, 0.56, 1.12, or 1.68 kg/ha of formulated atrazine 80W delivered in 31 L/ha of 1% Tween 20 with a cabinet sprayer. The pots were laid on their sides so that contact of the spray droplets with the soil would be nominal. After being sprayed, the plants were watered by subsurface irrigation to avoid washing the atrazine from the leaves to the soil where it might be taken up by the roots.

RESULTS AND DISCUSSION

As indicated by the data on dry matter accumulation (Table I), the efficacy of the herbicides in the experiments involving the PSI herbicides, alachlor, and trifluralin was reduced when the herbicides were applied together. This reduced efficacy was restricted to the reduction of efficacy of the PSI herbicides as indicated by the data on visual symptoms (Table II). These data were attributed to the action of the PSI herbicides. The interactions of both dry matter accumulation and visual symptoms for these experiments are statistically validated by the regression equations presented in Table III. (See Experimental Section for interpretation of the regression equations). The bases for these interactions are only speculative. However, it would seem highly unlikely that both alachlor and trifluralin could cause the inactivation, i.e., the metabolism of PSI herbicides to nonphytotoxic products, especially since they are represented by the triazine, the substituted urea, and the oxadiazolidine chemical families. This reasoning concurs with the findings of Akobundu et al. (1975), who reported that alachlor did not affect atrazine metabolism in Japanese millet. In their in vitro study on protein synthesis in the chloroplasts, they indicated that a synergistic response occurred when alachlor and atrazine were applied together. This reaction is the reverse of the antagonistic response observed in the present in vivo study. The difference in response may be explained by the reported inhibition of root elongation by alachlor (Keeley et al., 1972). A less extensive root system would presumably reduce total absorption and would explain the observed decrease in injury by the PSI herbicide.

Trifluralin is not readily translocated from the roots (Ashton and Crafts, 1973; Strang and Rogers, 1971), and the main site of action of PSI herbicides is in the leaf.

Table III. Calculated b Values for the Polynomial Equation Expressing the Response of Oats to Pesticides and Photosynthetic Inhibitors

		Polynomial term[a]						
Pesticide	PSI[b]	Dependent variable, Y	Intercept, b_0	Pesticide, b_1	PSI, b_2	(Pesticide)^2, b_3	(PSI)^2, b_4	Pesticide × PSI, b_5
Alachlor	Atrazine	Dry weight	1.20	−0.16*[c]	−5.13*	0.00	6.56*	0.44*
		Rating	1.32	−0.33*	7.57*	0.04*	0.00	−0.54*
Alachlor	Cyanazine	Dry weight	1.30	−0.18*	−2.55*	0.00	0.61	0.35*
		Rating	1.26	−0.36*	5.55*	0.05*	2.92	−0.54*
Alachlor	Diuron	Dry weight	1.30	−0.18*	−0.19	0.00	−0.38*	0.10*
		Rating	0.94	−0.07	−0.04	0.02*	1.03*	−0.23*
Alachlor	Methazole	Dry weight	1.15	−0.12*	−0.27*	0.00	0.02*	0.02*
		Rating	1.47	−0.43*	0.32*	0.06*	0.02	−0.05*
Phorate	Atrazine	Dry weight	1.44	0.05	−9.65*	−0.00	19.2*	−0.06
		Rating	1.02	−0.05	14.0*	0.00	−17.5	−0.02
Phorate	Cyanazine	Dry weight	1.52	0.03	−5.19	−0.00	5.42*	−0.01
		Rating	0.95	−0.08	10.0*	0.01	−5.69*	−0.18
Phorate	Diuron	Dry weight	1.49	0.01	−0.60*	−0.00	−0.24	0.01
		Rating	0.96	−0.00	−0.85*	0.00	1.88*	−0.04
Phorate	Methazole	Dry weight	1.41	0.05	−0.56*	−0.00	0.06*	−0.00
		Rating	1.19	−0.12	0.69*	0.01	−0.04*	−0.01
Trifluralin	Atrazine	Dry weight	1.35	−0.05	−7.09*	−0.00	11.0*	0.33*
		Rating	1.23	−0.20*	8.11*	0.02	0.62	−0.62*
Trifluralin	Cyanazine	Dry weight	1.45	−0.10*	−4.34*	0.00	3.75*	0.23*
		Rating	1.20	−0.33*	5.86*	0.05*	2.64	−0.37*
Trifluralin	Diuron	Dry weight	1.39	−0.04	−0.20	−0.01	−0.49*	0.10*
		Rating	0.97	−0.12	0.12	0.03*	0.76*	−0.22*
Trifluralin	Methazole	Dry weight	1.28	0.02	−0.36*	−0.02*	0.03*	0.02*
		Rating	1.51	−0.49*	−0.43*	0.07*	0.01	−0.06*

[a] The equation fitted was as follows: $Y = b_0 + b_1(\text{pesticide}) + b_2(\text{PSI}) + b_3(\text{pesticide})^2 + b_4(\text{PSI})^2 + b_5(\text{pesticide})(\text{PSI})$. Alachlor, methazole, and phorate were applied at 0, 2, 4, 6 μg/g, atrazine at 0, 0.1, 0.2, 0.3 μg/g, cyanazine at 0, 0.15, 0.30, 0.45 μg/g, diuron at 0, 0.4, 0.8, 1.2 μg/g, and trifluralin at 0, 1.8, 3.6, and 5.4 μg/g of soil. [b] Photosynthetic inhibitor. [c] Regression coefficients followed by an asterisk indicate significance at the 5% level. The means of the data used to calculate the regression coefficients are presented in Tables I and II.

Table IV. Effect of Alachlor and Trifluralin on $^{14}CO_2$ Fixation of Oat Leaves Treated with Photosynthetic Inhibitor Herbicide

	$^{14}CO_2$ fixation, dpm × 10^{-3}/mg				
Herbicide	Check	Atrazine	Cyanazine	Diuron	Methazole
Check	51.5	12.4	1.6	19.6	38.9
Alachlor	49.1	10.6	3.0	21.1	49.0
Trifluralin	52.3	10.5	1.7	15.7	54.4
LSD 0.05	25.0	7.9	2.1	9.5	16.8

Table V. Effect of Alachlor and Trifluralin on Respiration Rate on Oat Leaves Treated with PSI Herbicide[a]

	PSI				
Herbicide	Check, %	Atrazine, %	Cyanazine, %	Diuron, %	Methazole, %
Check	0.021	0.021	0.068	0.247	0.017
Alachlor	0.039	0.034	0.068	0.185	0.015
Trifluralin	0.013	0.024	0.094	0.146	0.012
LSD 0.05	0.035	0.018	0.067	0.190	0.008

[a] Data are expressed as percentage of newly synthesized substrate respired, per hour.

Table VI. Effect of Foliarly Applied Atrazine on Oats Previously Treated with Soil-Applied Alachlor or Trifluralin[a]

Herbicide, μg/g		Atrazine, kg/ha 0	0.56	1.12	1.68
Alachlor	0	1.17	0.58	0.56	0.56
	2	0.88	0.41	0.36	0.37
	4	0.64	0.14	0.13	0.16
Trifluralin	2	1.04	0.44	0.36	0.41
	4	0.72	0.22	0.14	0.19

[a] Data are in grams of dry shoot weight. Data fitted to the polynomial equation are as follows: for alachlor, dry weight = 1.13 − 0.12(herbicide)* − 1.17(PSI)* −0.00(herbicide)^2 + 0.54(PSI)^2* + 0.02(herbicide)(PSI), for trifluralin, dry weight = 1.16 − 0.06(herbicide) − 1.30(PSI)* − 0.01(herbicide)^2 + 0.61(PSI)^2* + 0.01(herbicide)(PSI). An asterisk behind a term indicates significance at the 5% probability level.

Additionally, Anderson et al. (1967), Feeny (1966), and Oliver and Frans (1968) found that trifluralin inhibited root growth. The antagonistic responses shown in our studies between trifluralin and the PSI herbicides may be primarily due to decreased root absorption of the PSI herbicides (Tables I-III and Figure 1).

Alachlor and trifluralin themselves had no effect on photosynthesis (Table IV), nor did they have any influence on the inhibitory action of the PSI herbicides. Similarly, respiration rate of the newly synthesized substrate was unaffected by alachlor or trifluralin (Table V). These data support the hypothesis that the interaction observed in Tables I, II, and III are due to root inhibition and not due to effects on a specific site of inhibition. The lack of effect of alachlor on atrazine inhibition of photosynthesis concurs with the findings of Akobundu et al. (1975) in their study on isolated chloroplasts. As shown in Table IV, methazole did not inhibit CO_2 fixation. A metabolite of methazole, 1-(3,4-dichlorophenyl)-3-methylurea, is a potent inhibitor of photosynthesis, (Good, 1961; Jones and Foy, 1972), and Corbett (1974) postulates that methazole is herbicidal in that it acts as a precursor for this metabolite. If this is the case, then methazole in this short duration experiment would not be expected to be inhibitory to CO_2 fixation.

The percent of [^{14}C]PSI taken up by oats grown in sand ranged from less than 1% up to 26%, and root length ranged from 2 to 110 mm (Table VII). The high values for the correlation coefficients (r^2) (Table VII) indicated that there was a strong relationship between the amount of ^{14}C-labeled PSI herbicides taken up and the root length

Table VII. Effect of Pesticides on Root Length of Oats and on Absorption of Other Pesticides from Sand[a]

Nonradioactive treatment	Root length, mm	^{14}C uptake	Root length, mm	^{14}C uptake	Root length, mm	^{14}C uptake
	Atrazine		Cyanazine		Diuron	
Check	67	26.0	86	14.1	80	26.4
Alachlor	18	1.7	18	2.8	15	1.6
Phorate	78	11.3	76	7.9	60	16.5
Trifluralin	2	0.01	2	1.3	13	1.6
	Phorate		Trifluralin			
Check	110	7.2	3	0.44		
Atrazine	83	4.2	4	0.68		
Cyanazine	96	4.3	5	0.51		
Diuron	79	4.4	3	0.41		
Methazole	97	3.8	3	0.47		

[a] Data fitted to the regression equation are as follows: atrazine uptake = 1.06 + 0.22(root length)*, cyanazine uptake = 1.49 + 0.12(root length)*, diuron uptake = -0.054 + 0.31(root length)*, phorate uptake = 3.39 + 0.01(root length), and trifluralin uptake = 0.60 – 0.01(root length). Those terms followed by an asterisk were significant at the 1% probability level. The correlation coefficients (r^2) between root length and uptake were 0.58, 0.83, 0.84, 0.04, and 0.01 for atrazine, cyanazine, diuron, phorate, and trifluralin, respectively.

which was purposely varied by the application of the nonradioactive pesticides. This observation concurs with the results of the greenhouse study in which alachlor and trifluralin decreased the severity of symptoms produced by the PSI herbicides.

Comparison of the values of the three regression coefficients indicated that for at least the longer root systems (where the intercept contribution to total uptake is insignificant) atrazine was taken up two-thirds and cyanazine only one-third as readily as diuron (Table VII). The different regression coefficients for ^{14}C-labeled atrazine, cyanazine, and diuron perhaps suggest that each of the three has a distinct uptake site on the root.

If the observed dry weight and rating interactions were not due to root inhibition interactions, but to an interaction of a biochemical nature (and apparently not directly related to photosynthesis or respiration, based on the data in Tables IV and V), then any method of herbicide application should give the same results. Among the PSI herbicides used in these studies, atrazine is one which has bioactivity when applied foliarly. As shown in Table VI, when atrazine was applied foliarly to oat plants growing in soil treated with alachlor or trifluralin, no interaction occurred. This result is contrary to the findings in Tables I, II, and III, where an interaction did occur when atrazine was applied to the soil with alachlor and trifluralin.

In contrast to the synergism found in a similar study by Nash (1967), the phorate–PSI experiments showed no significant interaction in either dry weight or rating data (Tables I, II, and III). Although autoradiographs of plants treated with [^{14}C]phorate indicated that phorate translocation was unaffected by the application of the PSI herbicides, combustion analyses indicated that the uptake of phorate was decreased by the PSI herbicides (Table VII).

CONCLUSION

Greenhouse studies indicated that alachlor and trifluralin can attenuate the effectiveness of the photosynthetic inhibitors, atrazine, cyanazine, diuron, and methazole to injure oats. Further, regression analysis indicated that this attenuation could be attributed to decreased uptake of the photosynthetic inhibitors caused by the inhibition of root growth induced by alachlor and trifluralin. This proposal was further supported by the absence of an interaction on photosynthesis and respiration and on atrazine applied foliarly to plants growing in soil treated with alachlor and trifluralin.

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