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ABSORPTION AND TRANSLOCATION OF POLYCHLORINATED BIPHENYLS (PCBs) BY WEEDS

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ABSTRACT

Soybean, beet, fescue, corn, and sorghum were grown in soil treated with 1000 ppm PCB (Aroclor 1254). Inhibition of height, foliage fresh weight, and cumulative water use was found to be significantly reduced by PCB for soybean, beet, and fescue, but not for corn and sorghum. Uptake by these crop plants of ^{14}C-PCB applied to soil at 20 ppm (corn was grown in soil treated with 25 ppm ^{14}C-PCB) varied from 1.0 to 0.08 ppm (wet weight basis). Panicum bisulcatum Thunb., a C_3 plant, and Panicum virgatum L., a C_4 plant were grown in soil treated with 0, 1, 10, 20, 40, and 100 ppm ^{14}C-PCB. Absorption and translocation of ^{14}C-PCB to foliage did increase significantly with rate, but no difference between species was noted. Atrazine resistant and susceptible biotypes of Amaranthus retroflexus L. were grown on soil treated at the same rates as in the Panicum study. Absorption and translocation of ^{14}C-PCB in plant foliage increased significantly with rate of PCB applied. Height and foliage fresh weight were significantly lower for the susceptible biotype at the 40 and 100 ppm rates, but were significantly lower at the 100 ppm rate only for the resistant biotype. Almost four times as much ^{14}C-PCB was found in the foliage of the resistant biotype as was found in the foliage of the susceptible biotype.

INTRODUCTION

Polychlorinated biphenyls (PCBs) have been shown to be a ubiquitous pollutant, occurring in wildlife, waterways, and municipal sludges (2,3). With the increasing use of sludges as a source of fertilizer, the effect of PCBs upon crop plants and weeds needs to be studied. PCB bioaccumulates very rapidly in animals (2), yet not much is known about its accumulation in plants. It has been reported that PCBs accumulate in crop plants, but only in small amounts when high amounts of chemical were applied to the soil (6,11). The studies reported herein indicate that PCBs (specifically Aroclor 1254) do accumulate in both crop and weed species.

MATERIALS AND METHODS

Unlabelled PCB Studies

Analytical grade PCB (Aroclor 1254, obtained from the Monsanto Company), in ethanol, was thoroughly mixed with 300 g of Lakeland sand (Typic quartzipsamment siliceous, thermic, coated, 1% O.M., 5% clay, 6% silt, pH 4.7, C.E.C. = 1.5 me/100 g) in styrofoam pots at a rate of 1000 ppm. Three replications were used. Three individual crops of soybean (Glycine max (L.) Merr. "Ransom") and one crop

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each of beet (Beta vulgaris L. "Detroit Dark Red"), fescue (Festuca arundinacea Schrib. "Kentucky 31"), sorghum (Sorghum bicolor (L.) Moench "Savanna 4"), and corn (Zea mays L. "Pioneer 3369A") were grown. The crops were grown in growth chambers (200 hlx, 16 hr day, 30 C day, 18 night), kept at approximately 80% field capacity, and fertilized with a modified Hoagland's nutrient solution (12) every week. Water uptake was recorded periodically and heights and foliage fresh weights were taken at harvest.

Labelled PCB Studies

^{14}C-Aroclor 1254 (specific activity = 31.3 mCi/mmole, obtained from New England Nuclear (Lot no. 872-193), average molecular weight = 326.25) was mixed with Aroclor 1254 in ethanol (with 5 drops hexane added to aid solvation). Different amounts of radioactive PCB were mixed with unlabeled PCB for individual experiments. The ratios of ^{14}C-PCB activity to total PCB concentration used in the experiments were as follows: Crop studies at 20 ppm--183 dpm/ μg; Corn studies at 25 ppm--32.4 dpm/ μg; and Panicum and pigweed studies--47.8 dpm/ μg. The pots containing 20 ppm PCB were seeded with beet, fescue, soybean, and sorghum. Corn was grown in soil containing 25 ppm PCB. Two replications were used in each study. Pots containing 0, 1, 10, 20, 40, and 100 ppm PCB were seeded with Panicum bisulcatum Thunb. (obtained from the USDA Regional Plant Introduction Station, Experiment, Ga., Lot no. 225995), Panicum virgatum L. (Valley Seed Service, Fresno, Ca., collected in Texas, 1977), and two biotypes of Amaranthus retroflexus L. (redroot pigweed), designated R and S (courtesy of Dr. T. M. Monaco, Horticulture Dept., N.C. State Univ.). Biotype R has been found to be atrazine resistant while biotype S has been found to be susceptible to atrazine (4). Three replications were used. The plants were grown in growth chambers under conditions previously described.

At harvest, the plant tops were measured for height and foliage fresh weight; consequently, all PCB contents are reported on a wet weight basis. ^{14}C-PCB was extracted from the plant tops by homogenizing in 25-35 ml of a 1:1 hexane-acetone mixture (redistilled n-hexane for crop studies, Fisher pesticide grade hexane for Panicum and pigweed studies, and Fisher ACS certified acetone) for 1 minute in Virtis homogenizer. The extract was separated from the solid material by suction filtration and washed with an additional 10-15 ml of extractant. The filtrate was evaporated to near dryness under a hood and then redissolved in 5 ml hexane by sonication for 1 minute. A one ml aliquot was drawn and put into a scintillation vial containing 20 ml of cocktail (5.0 g of 2,4-diphenyloxazole, 0.1 g of 1,4-bis [2-(4-methyl-5-phenyloxazoyl)] benzene, 1000 ml of Triton X-100, and 1000 ml of toluene). ^{14}C activity was counted in a liquid scintillation spectrophotometer for 20 minutes, with the counting efficiency ranging from 73 to 89%.

RESULTS AND DISCUSSION

During the course of several experiments, it was observed that for crops grown on 1000 ppm PCB, responses could be categorized into two groups. Table 1. shows the percent inhibition of PCB-treated plants compared to controls for height, top fresh weight, and cumulative water use for each plant species. Soybean, fescue, and beet were significantly inhibited by the PCB (Table 1.). However, corn and sorghum crops were not significantly affected by the PCB. The different responses of corn and sorghum compared to soybean, beet, and fescue could not be explained by the fact that the two tolerant crops were grasses, since fescue, a grass, did exhibit some growth inhibition as a result of the PCB treatment. An attempt at correlating PCB toxicity to the amount of PCB absorbed and translocated to plant tops was also tried for various species (Figure 1.). A rate of 20 ppm soil-applied PCB was used to compare relative uptake of PCB. Much less PCB was absorbed and translocated to the foliage of the corn and sorghum crops than to beet and fescue foliage, but the amount extracted from corn and sorghum was only slightly greater than the amount in soybean foliage. Soybean was grown for only 16 days (the shortest relative growth period of any crop) which may have influenced the amount of PCB translocated; however, fresh weight production was adequate relative to other crops (7.3 g for soybean versus an average of 7.6 g for all other crops).

PCB has been shown to inhibit photosynthesis (1), possibly at photo-system II (with Aroclor 1221) (9) in a manner similar to that attributed to the s-chlorotriazine, substituted uracil, and urea-carbamate herbicides (5). Corn and sorghum both possess the C_4 metabolic pathway (7). Plants with C_4 metabolic pathways generally photosynthesize at much greater rates and efficiencies (in warm temperatures and at high light intensities) when compared to plants possessing C_3 metabolic pathways (7). It was theorized that perhaps the lack of PCB toxicity to C_4 plants (corn and sorghum) resulted from little or no disturbance of PCB on the photosynthetic pathways of these crops. PCBs are extremely lipophilic and would be expected to cause disturbance to membranes; however, no evidence for this has been found.

To test the C_4 versus C_3 hypothesis, two species of the genus Panicum, P. bisulcatum, a C_3 plant, and P. virgatum, a C_4 plant, were grown in PCB-treated soil to judge relative growth responses and amount of ^{14}C-PCB uptake into above-ground parts. PCB treatments of up to 100 ppm resulted in no significant weight or height reduction in either species. The amount of ^{14}C-PCB translocated to plant foliage did increase significantly with the amount of PCB present in the soil, yet no significant difference between the two species was detected (Figure 2.). At the 100 ppm rate of PCB, the average total PCB content (both ^{14}C-labeled and unlabeled) for P. bisulcatum and P. virgatum corresponded to 0.86 and 0.63 ppm, respectively. The interaction between species and PCB rate also proved not to be significant. It appeared that for rates of PCB up to 100 ppm, little or no damage was incurred by P. bisulcatum and P. virgatum, low levels of PCB were taken up, and little difference existed in the response of the plants to soil-applied PCB.

Corn and sorghum can be segregated from other crops used in this experiment by their tolerance to atrazine. Some researchers feel that the basis for this tolerance in biotypes of the same species is due to a structural change in a protein at the site of inhibition, which decreases the binding ability of the atrazine molecule to the inhibitory site (10). Corn and sorghum have the ability to dechlorinate atrazine (8). Two biotypes of Amaranthus retroflexus were grown in the same concentrations of PCB used in the Panicum Study. Table 2. shows the effect of PCB rate on the inhibition of pigweed heights and weights compared to controls. For biotype R (which has been found to be atrazine resistant) inhibition of height and weight occurred at the 100 ppm rate only. Plant height was inhibited by 58% and foliage fresh weight was inhibited by 69%. Biotype S (which has been shown to be atrazine susceptible) exhibited significant inhibition at the 40 and 100 ppm rates. However, at 100 ppm the height and foliage fresh weight were inhibited by 47 and 48%, respectively. These values were significantly less than for biotype R. The amount of ^{14}C-PCB translocated to pigweed tops also increased with increasing rate of PCB in the soil (Figure 3.).

No significant differences in amount of translocated activity was apparent at rates below 40 ppm. At 100 ppm, biotype R translocated nearly four times as much ^{14}C-activity as biotype S (113.0 vs. 30.0 dpm/ μg or 2.36 vs. 0.63 ppm, respectively). Statistical analysis (analysis of variance) confirmed the difference in uptake of ^{14}C-PCB to be significant. The biotype-PCB interaction also proved to be significant.

CONCLUSIONS

1. Crop and weed species absorb PCB from soil and translocate it into their foliage.
2. Corn and sorghum do not appear to be affected by PCB at rates up to 1000 ppm in the soil.
3. Panicum bisculcatum and Panicum virgatum are adversely affected by rates of 100 ppm PCB in the soil and do not appear to differ in the amount of ^{14}C-PCB taken up.
4. Biotypes of Amaranthus retroflexus are adversely affected by 100 ppm PCB in the soil and in these studies differed in the amount of ^{14}C-PCB absorbed and translocated into the foliage.

LITERATURE CITED

1. Cole, D. R. and F. W. Plapp, Jr. 1974. Inhibition of growth and photosynthesis in Chlorella pyrenoidsa by a polychlorinated biphenyl and several insecticides. Environ, Entomol. 3(2):217-220.

2. Gustafson, C. G. 1970. PCBs--prevalent and persistent. Environ. Sci. Tech. 4(10):814-819.

3. Lawrence, J. and H. M. Tosine. 1977. Polychlorinated biphenyl concentrations in sewage and sludges of some waste treatment plants in southern Ontario. Bull. Environ. Contam. Tox. 17(1):49-55.

4. Monaco, T. J. 1979. Personal communications. North Carolina State University, Raleigh, NC.

5. Moreland, D. E. 1977. Mode of action of herbicides, Chap. 4, In ACS Symposium Series, No. 37, Pesticide Chemistry in the 20th Century (J. R. Plimmer, ed.). American Chemical Society, Washington, D.C.

6. Pahren, H. R., J. B. Lucas, J. A. Ryan, and G. K. Dotson. 1979. Health risks associated with land application of municipal sludge. J. Water Poll. Control Fed. 51(11):2588-2601.

7. Salisbury, F. B. and C. W. Ross. 1978. Plant Physiology. Wadsworth Pub. Co., Inc. Belmont, Ca. pp. 123-126.

8. Shimabukuru, R. H. 1967. Atrazine metabolism and herbicidal selectivity Plant Physiol. 42:1269-1276.

9. Sinclair, J., S. Garland, T. Arnason, P. Hope and M. Granville. 1977 Polychlorinated biphenyls and their effects on photosynthesis and respiration. Can. J. Bot. 55:2679-2684.

10. Souza Machado, V., C. J. Arntzen, J. D. Bandeen, G. R. Stephenson. 1978. Comparative triazine effects upon system II photochemistry in chloroplasts of two common lambsquarters (Chenopodium album) biotypes. Weed Sci. 26(4):318-322.

11. Suzuki, M., N. Aizawa, G. Okano, and T. Takahashi. 1977. Translocation of polychlorobiphenyls in soil into plants: a study by a method of culture of soybean sprouts. Arch. Environ. Contam. Tox. 5:343-352.

12. Weber, J. B. Soil properties, herbicide sorption, and model soil systems, Chap. 6, In Research Methods in Weed Science (B. Truelove, ed.), Auburn, Alabama, Southern Weed Science Society (1977).

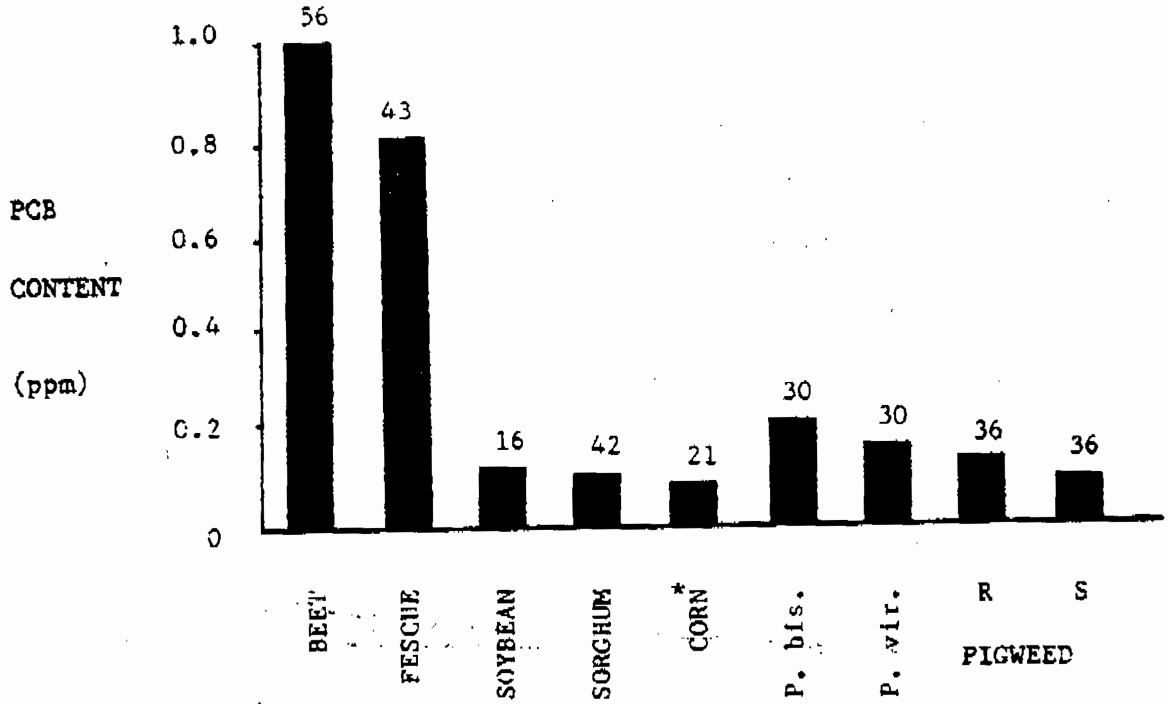
Table 1. The effect of 1000 ppm soil-applied PCB on height, fresh top weight, and water use by crop plants as expressed in percent inhibitions of untreated (control) plants.

	% Inhibition		
Crop	Height	Top Fresh Weight	Water Use
Soybean	15*	22*	52*
Soybean	28*	24*	46*
Soybean	17*	37*	32*
Fescue	--	16*	18
Beet	100*	100*	94*
Sorghum	1	3	6
Corn	1	12	11

*Significantly different from control at 5% level.

Table 2. The effect of PCB on the growth of Amaranthus retroflexus biotypes.

	% Inhibition			
	Variety R		Variety S	
PCB Rate	Height	Foliage Fresh Weight	Height	Foliage Fresh Weight
(ppm)				
0	0	0	0	0
1	-8	-16	27	-17
10	-8	-6	13	9
20	8	7	13	4
40	8	9	33	22
100	58	69	47	48
LSD .05	31	21	31	21



*Experiment carried out in soil containing 25 ppm PCB.

Figure 1. PCB content of various crop and weed species grown in soil containing 20 ppm PCB. (Numbers above bars refer to days of growth).

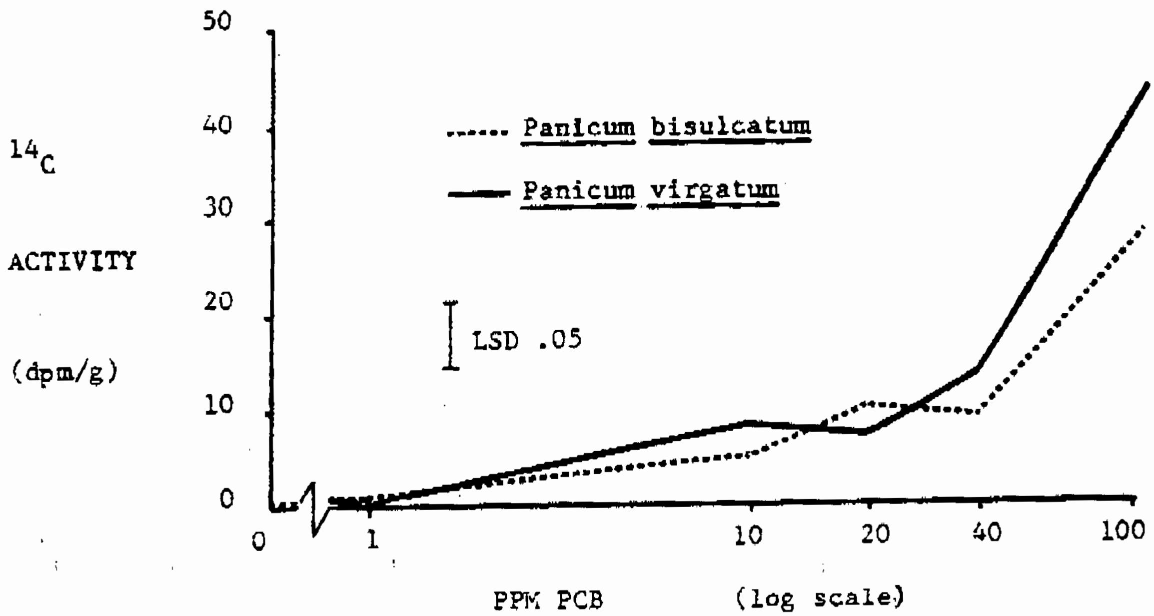


Figure 2. ^{14}C-PCB activity extracted from Panicum species grown in PCB treated soil.

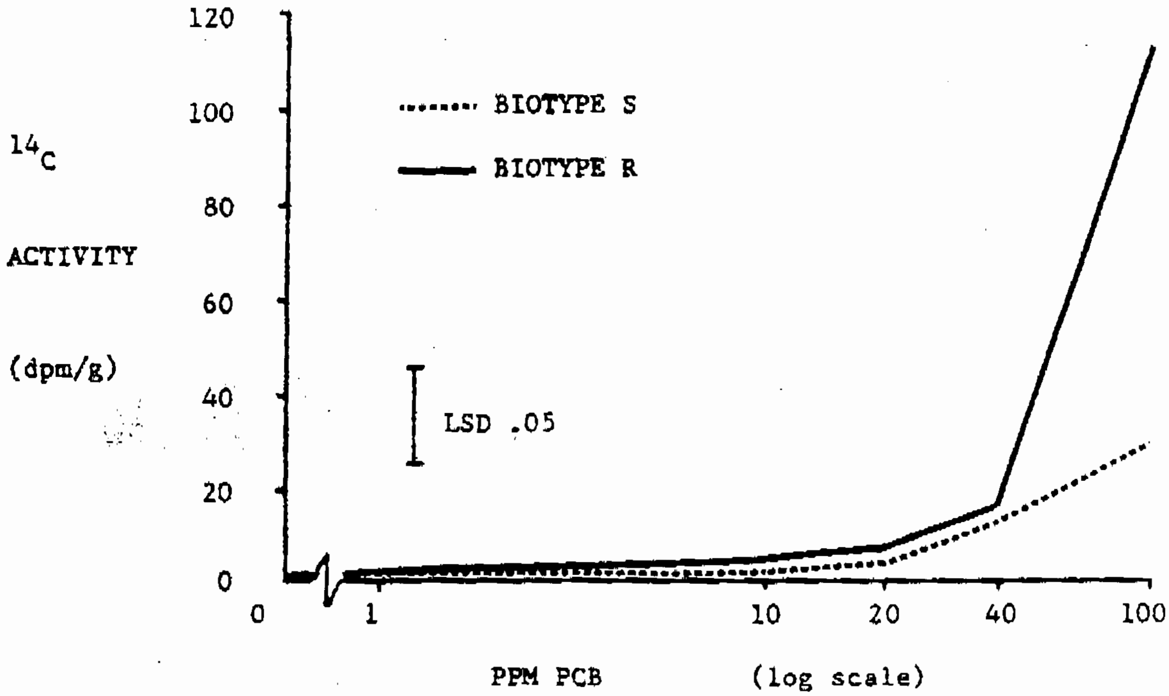


Figure 3. ^{14}C PCB activity extracted from <u>Amaranthus retroflexus</u> biotypes gr
in PCB treated soil.