Bull. Environ. Contam. Toxicol. (1993) 50:474–478

Environmental Contamination and Toxicology

Uptake of Pre-Emergent Herbicides by Corn: Distribution in Plants and Soil

Harry M. Pylypiw, Jr., Gregory J. Bugbee, and Charles R. Frink

The Connecticut Agricultural Experiment Station, 123 Huntington Street, New Haven, Connecticut 06504-1106, USA

Pre-emergent herbicides are routinely applied to corn fields to prevent weeds from reducing crop yields. If taken up by corn, these herbicides could enter people's diets either directly by the consumption of corn or indirectly by the consumption of meat and dairy products derived from livestock fed corn. Recently, a study found traces of the pre-emergent corn herbicides alachlor and atrazine in milk (Pylypiw and Hankin 1991). Although the source of the contamination remains undetermined, herbicide uptake by the corn used to feed dairy cows is a distinct possibility.

Much research has been done on the uptake of insecticides by corn, however, little exists on the uptake of pre-emergent herbicides. Harris and Sans (1969) examined the uptake of DDT, aldrin, dieldrin, and endrin by corn, oats, and alfalfa to determine if unacceptable residues occurred in crops used for animal feed. The concentration of dieldrin in the tissue varied from a trace to 0.02 ppm, depending in part on soil type. This was consistent with earlier work by Harris and Sans (1967) where uptake of dieldrin was less in muck soils than in mineral soils, despite the higher concentrations of residues found in the muck soil.

Bruce et al. (1966) pursued the relationship between concentrations of aldrin and heptachlor in soil and their uptake by oats, barley, corn, soybeans, and peanuts. These crops were chosen because the oil content of their seeds ranges from 2% to 45%. They found that uptake of aldrin/dieldrin and heptachlor/heptachlor epoxide increased linearly with percent fat in the seed as well as with concentration in the soil.

Send reprint requests to H. Pylypiw at the above address.

Weisgerber et al. (1974) used ^{14}C-labeled aldrin to follow its fate in maize, wheat, and soil. Most of the radioactivity recovered from maize and soil was due to conversion products such as dieldrin and a group of highly hydrophilic metabolites which could be more readily leached from the soil or taken up by plants. The amounts in the maize plants decreased by a factor of about 100 in the order roots, leaves, stems, and cobs. The total residue of radioactivity in the kernels was near the detection limit of 0.01 ppm expressed as aldrin.

The following study examines the uptake of the pre-emergent herbicides alachlor, atrazine, and metolachlor by sweet corn from planting until harvest and compares the concentrations in corn tissue with residues in the soil.

MATERIALS AND METHODS

Sweet corn (*Zea mays* var. Butter and Sugar) was seeded on 7 June 1990 in an area which had not been treated with any herbicides for several years. The soil was a sandy loam with a pH of 6.0 and an organic matter content of 3-5%. The site was nearly level, well drained, and typical of areas used to grow corn in many parts of the northeastern United States. One day after seeding the site was separated into 4 adjacent 10 x 10 meter plots. Each plot received one of the following herbicides according to label instructions: atrazine (AATREX 4L), 26 g AI/plot; alachlor (Lasso), 49 g AI/plot; metolachlor (Dual), 28 g AI/plot; and no herbicide (Control). Plant and soil samples were obtained at 2-week intervals starting on 21 June 1990 and continuing until harvest on 16 August 1990 when corn ears were also collected. Samples were obtained from 9 locations within a plot and then combined into 3 groups of 3 for testing. Only above-ground portions of the plants were gathered and soil samples were taken from a depth of 0-15 cm.

Corn plants and ears were tested using capillary gas chromatography with an electron capture detector for alachlor and metolachlor, and a nitrogen-phosphorus detector for atrazine. Specific conditions are given in Luke et al. (1981) and Okumura et al. (1991). Herbicide concentrations were determined by peak area external standard calculation. The limit of detection was 0.002 ppm. All samples were tested in duplicate. Confirmation of the herbicides was performed by mass spectrometry (Huang and Frink 1989). Soil samples were tested in triplicate using commercially available immunoassay kits (Millipore, Bedford, MA) with a limit of detection of 0.01 ppm (Goh et al. 1991).

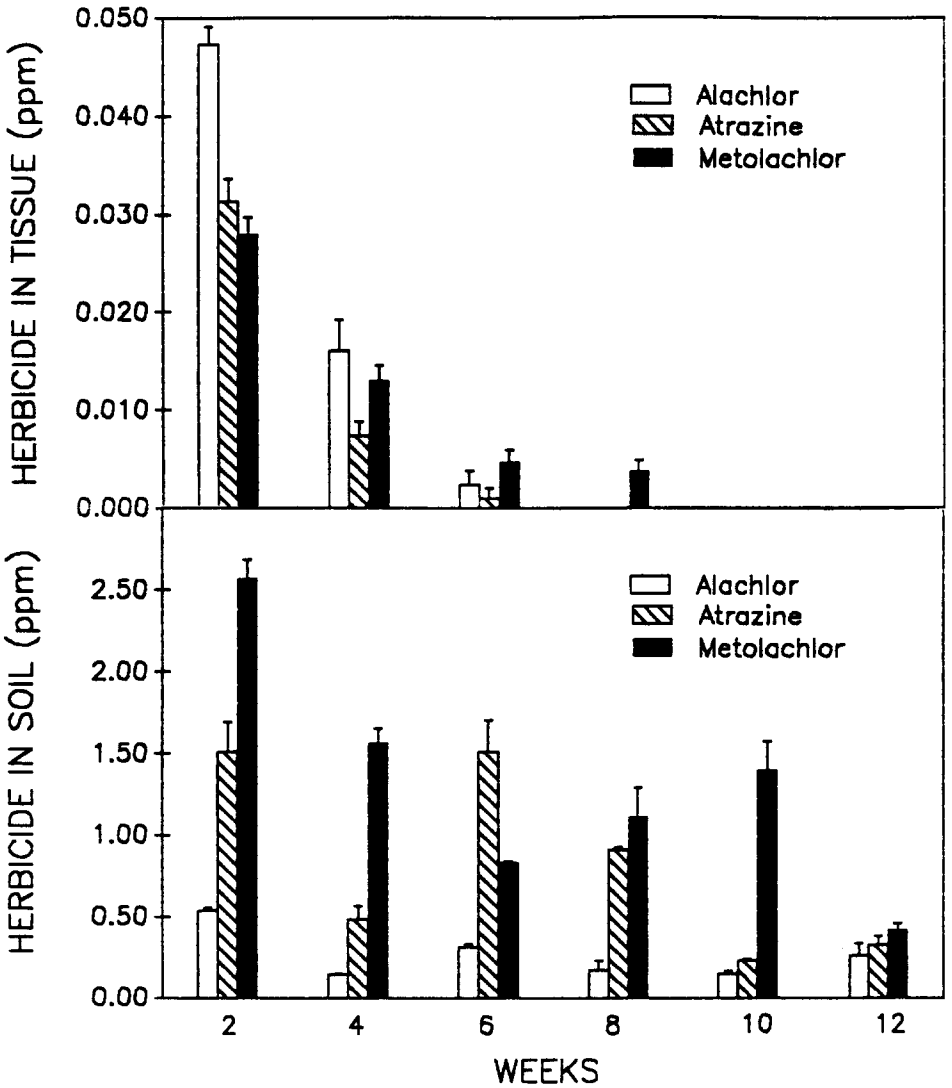

Figure 1. Concentrations of alachlor, metolachlor, and atrazine in corn plants and soil.

RESULTS AND DISCUSSION

The concentrations in ppm of the herbicides in corn plant tissue and soil are shown in Figure 1 along with the standard error of the mean of three determinations. Two weeks after the herbicides were applied the concentrations in plant tissue were somewhat inversely related to the concentrations in soil. This relationship disappeared with time and after 10 weeks the herbicides were below the detection limit of 0.002 ppm in plants and below 0.5 ppm in soil. Ears

collected after 12 weeks contained no detectable traces of herbicides. The slow decline of the pesticides in soil may be because of the formation of the persistent residues reported by Huang and Frink (1989) and Pignatello and Huang (1991). The relatively high levels of metolachlor in soil may be explained by the fact that it was applied at nearly twice the rate of the other herbicides. Curiously, this relationship was not duplicated in the corn tissue.

Herbicide uptake did not appear to be related to the water solubility or soil-water partition coefficient of the active ingredients. Atrazine, alachlor, and metolachlor have a water solubility of 33, 242, and 530 ppm, respectively (Farm Chemicals Handbook 1989). Atrazine has a soil-water partition coefficient of 98 and metolachlor is 121 (Pignatello and Huang 1991). No correlation between these numbers and the observed concentrations of herbicides in the tissue could be found. A possible explanation for these observations is that plant species which are resistant to herbicides likely have the ability to transform the active ingredient to a nonphytotoxic metabolite. For example, atrazine has been shown to be readily converted to hydroxyatrazine and amino acid conjugates (Weed Science Society of America 1989).

This study suggests that the use of alachlor, atrazine, and metolachlor in corn fields as a pre-emergent weed control will not likely cause the contamination of food or feed with the herbicides.

Acknowledgment. We thank Edward Naughton for planting the corn and care of the plots.

REFERENCES

Bruce WN, Decker GC, Wilson JG (1966) The relationship of the levels of insecticide contamination of crop seeds to their fat content and soil concentrations of aldrin, heptachlor and their epoxides. J Econ Entomol 59:179-181.

Farm Chemicals Handbook (1990) 76th Edition, Meister Publishing Co, Willoughby, OH.

Goh KS, Hernandez J, Powell SJ, Garretson C, Troiano J, Ray M, Greene CD (1991) Enzyme immunoassay for the determination of atrazine residues in soil. Bull Environ Contam Toxicol 46:30-36.

Harris CR, Sans WW (1967) Absorption of organochlorine insecticide residues from agricultural soils by root crops. J Agric Food Chem 15:861-863.

Harris CR, Sans WW (1969) Pesticides in soil. Absorption of organochlorine insecticide residues

from agricultural soils by crops used for animal feed. Pestic Monit J 3:182-185.
Huang LQ, Frink CR (1989) Distribution of atrazine, simazine, alachlor and metolachlor in soil profiles in Connecticut. Bull Environ Contam Toxicol 43:159-164.
Luke MA, Froberg JE, Doose GM, Masumoto HT (1981) Improved multiresidue gas chromatographic determination of organophosphorus, organonitrogen, and organohalogen pesticides in produce, using flame photometric and electrolytic conductivity detectors. J Assoc Off Anal Chem 64:1187-1195.
Okumura D, Melnicoe R, Jackson T, Drefs C, Maddy K, Wells J (1991) Pesticide residues in food crops analyzed by the California Department of Food and Agriculture. Rev Environ Contam Toxicol 118:87-151.
Pignatello JJ, Huang LQ (1991) Sorptive reversibility of atrazine and metolachlor residues in field soil samples. J Environ Qual 20:222-228.
Pylypiw HM, Jr, Hankin L (1991) Herbicides in pooled raw milk in Connecticut. J Food Prot 54:136-137.
Weed Science Society of America (1989) Herbicide Handbook, 6th edition. Weed Science Society of America, Champaign, IL.
Weisgerber I, Kohli J, Kaul R, Klein W, Korte F (1974) Fate of aldrin-^{14}C in maize, wheat and soils under outdoor conditions. J Agric Food Chem 22:609-612.

Received March 10, 1992; accepted September 11, 1992.