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Impact of Corn Canopy on Foliar Distribution of Chlorpyrifos (Lorsban®) When Applied via a Center Pivot Irrigation System

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There are exposure risks when workers enter corn fields following insecticide applications. Coutts (1980) reported that worker risk is a function of contact between worker and the insecticide. According to Matsumura and Madhukar (1980), the probability of risk increases as the frequency of contact between workers and insecticides increases. When workers contact treated foliage, the insecticide may dislodge onto clothing or bare skin and be absorbed into the body (Gunther et al. 1977). The severity of the risk through exposure to the insecticide depends on many factors, including how plant height and leaf area match worker body height, and the distribution of the insecticide on the leaves at different plant heights.

Data documenting the foliar distribution of insecticides applied to corn through a center-pivot irrigation system at different plant heights are lacking. Young (1982) stated that chemigation is likely to provide good insecticide distribution to all plant parts because the insecticide is normally applied in a large volume of water. Therefore, an insecticide applied through a center-pivot may increase workers' chances for exposure due to its thorough distribution over the foliage. A resulting hypothesis may be that workers will encounter greater exposure if in contact with R3 stage corn (milk stage and maximum foliage, approximately 2.1 to 2.4 m height) than if in conatct with V9 stage corn (mid-vegetative growth, approximately 1.3 to 1.55 m height, Ritchie et al. 1986). The R3 corn would likely to have more leaf area present to contact and hold insecticide residue and also would have an increased the probability of leaf contact with the unprotected areas of the body such as the head and neck. Workers may also expose their forearms and hands to a greater extent when walking through R3 corn by shielding their face from the abrasive effects of the leaves.

This research was undertaken to test the above mentioned hypothesis under field conditions at V9 and R3 stages of corn. The objectives were to determine the distribution of a chemigated insecticide within the plant canopy at V9 and R3 corn, and to compare the insecticide residues found at different plant heights during each growth stage.

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MATERIALS AND METHODS

The study was conducted in a center-pivot irrigated corn-field in 1988 near Concord (Dixon County), Nebraska. The insecticide was chlorpyrifos (Lorsban® 4E) applied at 1.12 kg of active ingredient (AI)/ha to corn at V9 and R3 stages. The experimental design was randomized complete block with each treatment replicated three times. The chlorpyrifos was applied in 0.64 cm water with a high angle, high pressure (4.23 kg/cm, 414 Kpa), 384.3 m center pivot irrigation system (Lindsey® Model 1234, Lindsey, NE). The insecticide was injected midstream into the irrigation line through a one-way check valve by a positive displacement diaphragm pump (PULSA-feeder Microflo 680, Interpace Corp., Rochester, NY). Weather data during first (July 1, 1988; V9 stage) and second applications (August 20, 1988; R3 stage) were: mean temperatures, 16.67^0 and 18.89^0C; mean humidities, 74% and 90% RH; and mean wind speed, 10 km and 15 km/hr, respectively.

The vertical distribution of chlorpyrifos (Lorsban® 4E) through a corn canopy was measured using gauze pads attached to a specially constructed pole (apparatus). The gauze pads (Durham and Wolfe 1962) included three layers: bottom layer of glassine paper (10.2 x 10.2 cm), middle layer of tagboard (10.2 x 10.2 cm) and top layer of 12-ply surgical gauze (10.2 x 10.2 cm) (Johnson and Johnson Co., New Brunswick, NJ). The three layers were bound with adhesive masking tape, leaving an exposed surface of 6.4 x 6.4 cm. Preliminary analysis indicated that the exposure pads contained no materials that would interfere with chlorpyrifos detection. Poles (Fig. 1) were 1.3 cm id (inside diameter) conduit 2.44 m in length. Six heavy duty aluminum rods (6.34 mm d) were welded to each pole at a 90^0 angle at 30.5 cm increments. The lowest (first) arm (66.0 cm long) was welded to the pole about 61 cm from the end to allow the pole to be inserted into the ground approximately 30.5 cm, positioning the first arm 30.5 cm above the ground. The remaining 2nd, 3rd, 4th, 5th and 6th arms were 55.9, 45.7, 35.6, 25.4 and 15.2 cm in length, respectively, and they were installed on the same pole at vertical intervals of 30.5 cm in ascending order from the first arm. Prior to insecticide application, a gauze pad was fastened onto the end of each arm with a stainless steel clip. The pads were oriented in such a way that they did not overlap one another. Fifteen (15) poles (apparati) with gauze pads were used for each treatment replication and they were arranged in three sets each including five poles. The poles were inserted into the soil parallel to corn rows so that the corn leaf architecture was not disturbed. The poles in each set were placed 0.3 m perpendicular to the plants towards the middle of the row and spaced 0.91 m apart from each other.

Immediately after each insecticide application, the gauze pads were removed from each pole and placed in individual ziploc bags (Dow Consumer, Products Inc, Indianapolis, IN), stored on ice in coolers, transported to the laboratory and stored at -20^0C until extraction. Field fortified samples were prepared and later analyzed to determine insecticide stability during handling and storage of samples.

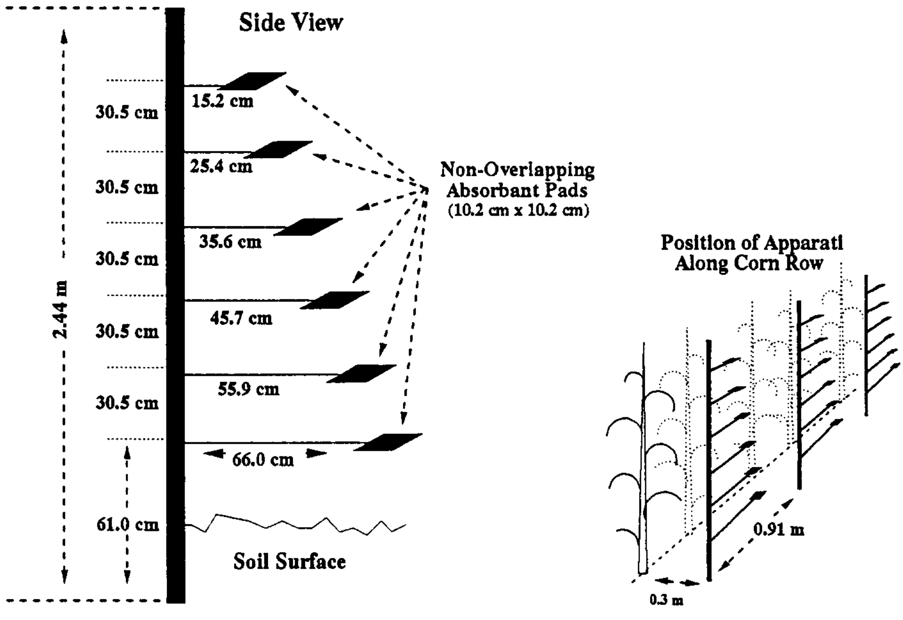

Figure 1. Apparatus used to capture chlorpyrifos (Lorsban®4E) applied to corn at V9 and R3 stages of development, Dixon County, Nebraska, 1988.

This procedure consisted of spiking gauze pads (n=3) with 10 μg (AI) of technical grade chlorpyrifos (99.8% purity) in 1 mL of hexane applied with a pipetman (Reinen Instrument Co., Waburn, MA) each day of operation. Fortified samples were stored, extracted and analyzed in the same manner as other pads. Recovery rate of fortified samples for chlorpyrifos was 94%.

Extraction of chlorpyrifos from gauze pads included removing tape borders and using only the 6.4 x 6.4 cm exposed surface of the gauze pad. Each gauze pad was placed in a 250 mL erlenmeyer flask containing 35 mL chromatography grade n-hexane. Flasks containing samples were capped with neoprene stoppers that were wrapped with plastic cling sheets. These flasks were mechanically agitated for 30 minutes on a wrist action shaker (Burrell® Model 75, Pittsburgh, PA). All extracts were stored at -20°C until chemical analysis was performed.

Chlorpyrifos was analyzed using a gas-liquid chromatograph (Varian® 6000 Vista series gas chromatograph, Sunnyvale, CA) equipped with a Ni^{63} Electron Capture Detector (ECD) operated at 350°C. The column used was a 2 m x 2 mm (id) glass column packed with 3% OV-101 on gas chrom Q, 80/100 mesh. Injector and column temperatures were set at 250 and 220°C, respectively. The flow rate of carrier gas (nitrogen) was set at 60 mL/min. The minimal detection level for chlorpyrifos was 0.005 ng/μL.

Chlorpyrifos amounts were converted from ng/μL in each analyzed sample to $\mu g/cm^2$ of pad surface area. Data on insecticide amounts at various heights were subject to an analysis of variance to establish significant differences (SAS Institute 1985) and the mean separations were determined by Duncan's Multiple Range Test (DMRT) ($P > 0.05$).

RESULTS AND DISCUSSION

The mean plant heights for V9 and R3 stages of corn were 1.31 and 2.26 m, respectively. The chlorpyrifos (Lorsban®) was found at all heights at both corn stages. More chlorpyrifos residues on gauze pads were found at all heights in V9 corn compared to all heights in R3 corn (Table 1). The relatively small amounts of chlorpyrifos measured in R3 corn, especially at low heights indicated that the canopy may have had shielding effect and reduced the chlorpyrifos deposition onto gauze pads placed at lower levels.

In V9 corn, mean chlorpyrifos residues detected at heights of 0.3, 0.6, 0.9, 1.2, 1.5 and 1.8 m were not significantly different from each other ($P > 0.05$, DMRT) (Table 1). The chlorpyrifos residue amounts ranged from 0.19-0.23 $\mu g/cm^2$. The canopy in V9 growth stage did not alter the distribution of insecticides throughout the plant system. The insecticide amounts measured at heights above the corn plants (1.5 m and more) also did not significantly differ from amounts at various heights within the canopy.

In R3 stage corn, mean quantities of chlorpyrifos measured at heights of 0.3 and 0.9 m were significantly different from chlorpyrifos at 1.2, 1.5 and 1.8 m ($P > 0.05$, DMRT) (Table 1). These data indicated that as the depth in canopy increased, the level of foliar shielding of gauze pads increased. Thus, it is evident that the R3 corn canopy altered chlorpyrifos distribution within the corn canopy.

If the distribution patterns for other chemigated insecticides are similar to this study, then the insecticide residues present at various heights may affect the exposure of field workers to insecticides. In V9 stage corn, the insecticide may be found in high quantity because of saturated leaf canopy and workers may experience increased chances of exposure to lower legs and hands. Further, the uniform distribution of insecticides throughout the plants may provide more chemical per cm^2 to control corn insect pests. This suggests the following hypothesis for further study that insecticides may be applied at reduced rates to maintain some foliar feeding insect populations below the economic threshold level on V9 stage compared to R3 stage corn. In R3 stage corn, high insecticide quantities may be found in the upper canopy and workers could encounter increased chances of exposure to head, face, hands, shoulders, and upper body regions. The maximum canopy in R3 stage corn offers more insecticide retentive surface area. Although the actual amount of insecticide in R3 corn based on per cm^2 may be less than on V9 corn, R3 corn has the potential of providing high

Table 1. Mean chlorpyrifos (Lorsban® 4E)[a] found on gauze pads at various heights within a V9 and R3 stage corn canopy, Concord, Nebraska 1988

Height[b]	Stages of corn development	
	V9	R3
m	mean $\mu g/cm^2$	
0.31	0.19a[c]	0.027c
0.61	0.21a	0.036bc
0.91	0.21a	0.030c
1.22	0.23a	0.043ab
1.52	0.21a	0.043ab
1.83	0.21a	0.049a

[a] = Lorsban 4E applied at 1.12 kg (AI)/ha via a center pivot irrigation system
[b] = Pads placed on apparatus at each height above ground to measure distribution of chlorpyrifos within corn canopy
[c] = Means within column followed by the same letter do not differ significantly ($P > 0.05$), Duncan's Multiple Range Test, SAS Institute, 1985

exposure due to an increase in retentive surface area for the insecticide.

Based on results of this study, the canopy at various stages of corn growth may affect distribution of insecticides. Corn with a full canopy also provides an increased opportunity for exposure of field workers to insecticides.

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