INSECTICIDE DISTRIBUTION THROUGH AN IRRIGATED CORN CANOPY

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Abstract. *Center pivot sprinkler systems can apply chemicals as well as water to crops. This study was conducted to determine the horizontal and vertical distribution of an insecticide applied with a center pivot irrigation system to a corn crop. The experiment was conducted at Tifton, Georgia, using a 140 m long, three-span center pivot system equipped with conventional impact sprinklers operating at 487-kPa pressure. An insecticide formulated with peanut oil was injected at a rate of 0.56 kg/ha with a calibrated metering pump into the irrigation mainline of the center pivot system with a gross irrigation application of 2.54 mm. Irrigation and chemical application uniformity were measured with glass collectors spaced 6.1 m apart along the lateral on bare soil. At three sites along the lateral at the midpoint of each span, the vertical chemical concentration was measured from above the canopy, at the third, sixth, and ninth leaf below the top of the corn plants. The mean irrigation application depth was 3.00 mm with a distribution uniformity of 93.5%. The mean chemical application amount was 0.79 kg/ha with a distribution uniformity of 83.9%. Chemical concentrations in relation to that in the water above the canopy declined 59, 49, and 39% at the third, sixth, and ninth leaf from the top of the plant with approximately 50% of the applied chemical retained on the corn foliage. The chemical distribution was less uniform than the water distribution and indicates the necessity of uniform irrigation applications to achieve high-chemical application uniformity.* ***Keywords.*** *Chemigation, Center pivot, Application uniformity.*

Since its introduction in the 1950s, the center pivot irrigation system has become an effective production tool for applying water for crop growth and development. With the improvements in sprinkler irrigation technology, many systems can apply chemicals through the irrigation water. This method of chemical application eliminates much of the labor and cost (Threadgill, 1981, 1985) associated with conventional application methods. This would result in energy savings, reductions in production cost, and reductions in compaction due to reduced traffic over the field.

Young (1980) reported that control of fall armyworms on corn was difficult with conventional spray application techniques. The maximum amount of water that could be applied economically with ground equipment resulted in poor penetration of the canopies of crops such as corn because of the low volume of water, and it did not provide adequate control of insects without multiple applications. He proposed to use irrigation water as a carrier for the insecticide to supply the volume of water needed to penetrate all plant recesses where fall armyworms feed, particularity in the whorl of developing leaves. He compared different formulations of chloropyrifos on corn for the control of fall armyworms and concluded that chloropyrifos tech + oil applied in the irrigation water effectively controlled fall armyworm larvae.

Young (1981) conducted tests under a center pivot irrigation system to determine the amount of insecticide residues in irrigation water and on treated corn plants. He also evaluated its effectiveness in controlling corn earworm and fall armyworm in sweet and field corn. Foliar residues on sweet corn contained 10 times more insecticide from oil formulations than from water soluble formulations. In field corn the oil formulation gave a fourfold higher foliar residue level than a water soluble formulation.

Young also determined from the above studies and previous experiments that insect control increased by adding oil to an emulsifiable concentrate formulation. This indicated preferential removal of insecticides formulated in oil from the water carrier by the foliage. He observed that insect control with oil suspended insecticides resulted in very low insect damage to the corn.

These oil formulations increased the affinity of the insecticide for the plant foliage and insects. Little is known about the actual quantity of oil formulated insecticide removed from irrigation water by plant foliage. Chemicals injected into irrigation water are assumed to have the same distribution uniformity as the irrigation water. This distribution has been observed with chemicals applied to the soil such as nutrients, herbicides, and nematicides. However, chemicals intended for foliar application must be

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distributed and retained throughout the plant canopy. Literature on rainfall penetration of corn plant canopies (Haynes, 1940) reports that a large quantity of water was intercepted by the foliage and carried to the ground by stemflow. Sampling this stemflow can provide an indication of the removal of the oil formulated insecticide by the plant foliage from the irrigation water. This study was undertaken to define the horizontal and vertical distribution in a corn canopy of irrigation water and an oil formulated insecticide when applied through a center pivot irrigation system.

Procedure

A center pivot irrigation system (16.5 cm id × 140 m) located at the irrigation research farm on the Coastal Plain Experiment Station applied an insecticide (chloropyrifos, technical grade) formulated with peanut oil at a rate of 0.56 kg/ha to field corn. A calibrated metering pump (Pulsafeeder Microflow) injected the formulation into the mainline of the center pivot irrigation system. Conventional impact sprinklers operating at a pressure of 487 kPa at the pivot point on the center pivot irrigation system were used in all tests. Total water flow into the system was 23 L/s.

Uniformity of Application

Glass collectors with 100-mm diameter surface openings were placed at ground level along the pivot lateral on bare soil at 6.1-m intervals beginning at 24.4 m from the pivot point and continuing to the end of the lateral. A known quantity of the insecticide-peanut oil formulation was injected into the irrigation water while the pivot passed over the line of collectors. The irrigation water volume in each collector was measured after each pass.

The evenness of water distribution during an irrigation is the water application uniformity, technically described as the coefficient of uniformity. The coefficient of uniformity can be calculated for each type of irrigation system: sprinkler, trickle, center pivot. For center pivots, a modified method is used because each collector represents a different size segment of a circular irrigated field. Using this method, the coefficient of uniformity is calculated using as equation developed by Heerman and Hein (1968):

$$C_u = 100\left[1 - \frac{\sum_{s=1}^{n} D_s S_s \left| D_s - \frac{\sum_{s=1}^{n} D_s S_s}{\sum_{s=1}^{n} S_s} \right|}{\sum_{s=1}^{n} D_s S_s}\right] \quad (1)$$

where

D_s = the depth of water applied at collector s

S_s = the distance from the pivot point to collector s

n = the number of collectors

The coefficient of uniformity for insecticide distribution was determined by substituting concentration (mg/L) or application amount (kg/ha) of insecticide in the collectors for D_s in equation 1.

Canopy Distribution Test

Tests to evaluate the removal of insecticide by foliage from irrigation water passing through the corn canopy were performed at sites, 49, 98, and 124 m from the pivot point (fig. 1). Two replications of the canopy distribution test were conducted. Each site represents the midpoint between each of the three towers on the center pivot system. At each site along the pivot, four levels in the corn canopy were sampled. Level one was above the canopy so that no foliage would interfere with the sample collection and was a reference for the insecticide concentration coming out of the irrigation system. Level one collectors consisted of five glass collectors with 100-mm diameter surface openings. Level two consisted of five 25-mm diameter, 60-mL test tube collectors attached at the leaf overlap on individual corn stalks at approximately the third leaf from the top of the corn plants, as shown in figure 2. These collectors intercepted irrigation water and insecticide as they flowed down the corn stalks. Level three consisted of five, 25-mm diameter, 60-mL test tube collectors attached to the corn stalk at the sixth leaf from the top of the corn plant. Level four collectors at the ninth leaf from the top of the corn plant consisted of five funnels attached to five stalks with tubing running to a 250-mL flask on the ground. The center pivot system then passed over the three collector locations while applying the insecticide-peanut oil formulation at the rate of 2.34 L/ha in 2.54 mm of irrigation water. For each replication, different corn stalks were used at each site along the center pivot irrigation system.

Chemical Analysis of Samples

As soon as the irrigation system had completely passed the collectors, a measured volume of hexane was added to each sample to extract the insecticide from the irrigation water. The samples were stored in the laboratory at –6° C until analyses could be performed. The hexane was then

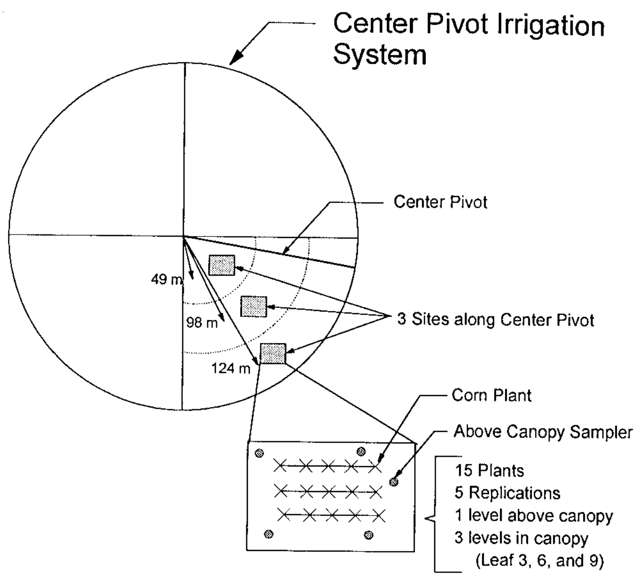

Figure 1–Location of sampling sites along the center pivot irrigation system used for the canopy distribution test.

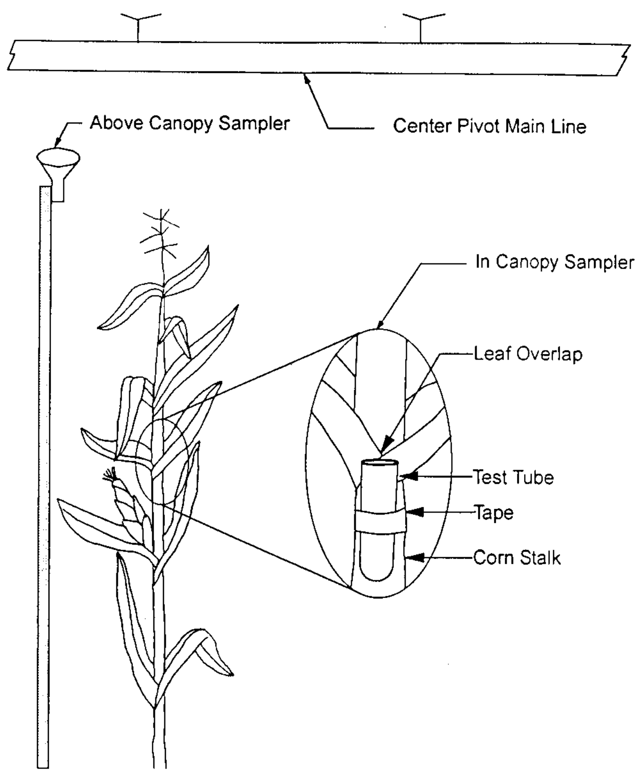

Figure 2–Schematic of above canopy sampler and individual corn plant with attached test tube collector used to collect stem flow.

removed from each sample with a pipette and analyzed for insecticide content. The volume of water collected was measured and recorded.

A spectrophotometer (Beckman DK-2A) was used to determine the amount of insecticide in the irrigation water samples. The analytical procedure for direct spectrophotometric analysis (absorbance at 289 nm) of chloropyrifos was modeled after a procedure developed by the manufacturer (Dow Chemical Company, personal contact with technical representative). The insecticide-

Table 1. Mean irrigation water depth (mm), insecticide concentration (mg/L), insecticide application rate (kg/ha), and uniformity (%) obtained during center pivot uniformity testing

Rep	Irrigation Water (Uniformity*)	Insecticide Concentration (Uniformity)	Insecticide Application Rate (Uniformity)
1	3.06a† (91.9%)	26.8ab (81.3%)	0.81a (82.9%)
2	3.06a (93.4%)	30.1a (85.2%)	0.92a (84.6%)
3	2.88a (95.1%)	22.1b (83.3%)	0.63b (83.9%)
Mean	3.00 (93.5%)	26.3 (83.3%)	0.79 (83.9%)

* Coefficients of uniformity calculated using the Heerman-Hein (1968) equation for center pivot uniformity.

† Column means followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

peanut oil formulation applied at the rate of 2.34 L/ha in 2.54 mm of irrigation water gave an insecticide concentration in the irrigation water of approximately 25 mg/L. This concentration was in the spectrophotometer's linear region at 289 nm. An absorbance curve was developed for the insecticide.

Analysis of Data

The design of the canopy distribution test was a split-plot design with subsampling. The main plot treatment was the site along the center pivot lateral at which the samples were taken. The subplot treatment was the level in the corn canopy at each site where the samples were taken. Least-squares analyses of variance were computed for the uniformity data.

Results

Uniformity of Application

Table 1 and figure 3 present results from three replications of the application uniformity test. The mean irrigation water depth applied was 3.0 mm with mean

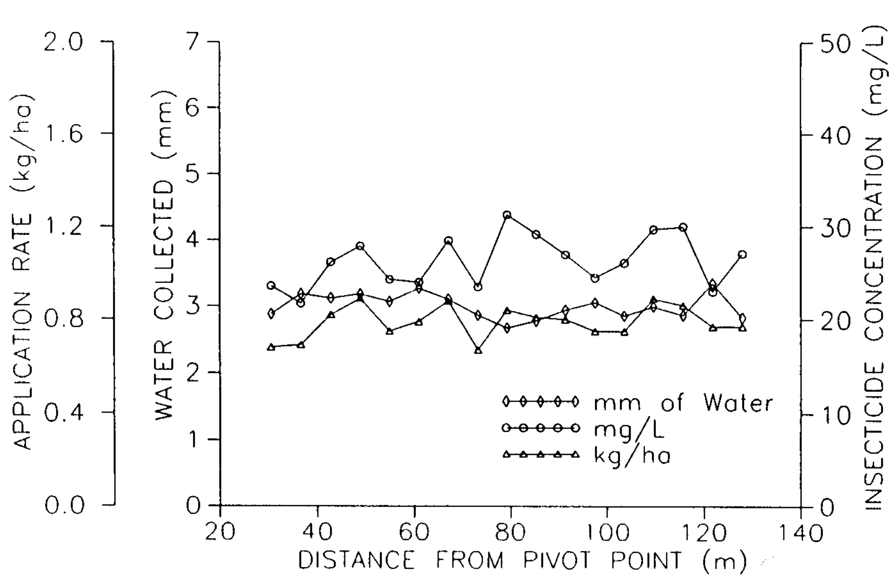

Figure 3–Distribution of water and insecticide along the center pivot irrigation system.

coefficient of uniformity, 93.5%. Analysis of variance for water volume indicated that significant differences were due to the distance from the pivot point. Replications were not significantly different.

The mean insecticide concentration determined for the three replications was 26.3 mg/L with mean coefficient of uniformity, 83.3%. Analysis of variance indicated that the distance from the pivot point did not have a significant effect on concentration. However, there were significant differences between replications.

The mean insecticide application rate coefficient of uniformity was 83.9%. Analysis of variance for the insecticide application rate indicated that insecticide application rates did not differ significantly with respect to distance from the pivot point. However, replications were significantly different.

These results show that the insecticide distribution was less uniform than the irrigation water. Therefore, a requirement for effective chemical application through an irrigation system should be that the system has a high coefficient of water distribution uniformity. Constant metering of the insecticide formulation with a high precision metering pump also should be required.

Canopy Distribution Test

Table 2 presents data from the collectors at four levels in the corn canopy. Differences between the top level (above canopy) and the other levels indicate that 57, 49, and 39% of the insecticide were retained by the corn foliage between the top of the corn canopy and the third, sixth, and ninth leaves, respectively. These results suggest that most of the insecticide-peanut oil formulation removed from the irrigation water was near the top of the canopy where the formulation first contacted the plant foliage. These results suggest that approximately 50% of the insecticide-peanut oil formulation was removed from the irrigation water by the top nine leaves.

Table 2 shows the mean water volumes collected. These results demonstrate the funneling effect of the corn foliage, but many collectors overflowed at levels three and four. Samples which overflowed were not included in the statistical analysis.

Table 2. Mean insecticide concentration (mg/L) and water volume (mL) for the four level canopy distribution test

Level	Insecticide Concentration (mg/L)	Water Volume (mL)
1 Above Canopy	20.2	22.7
2 Third Leaf	11.4	29.8
3 Sixth Leaf	9.9	46.6
4 Ninth Leaf	7.9	193.3

Summary and Conclusions

A uniformity distribution test of irrigation water and insecticide was conducted on a 140-m center pivot irrigation system. The mean coefficient of uniformity of irrigation water distribution was 93.5% for the irrigation system while the mean insecticide concentration and application rate coefficient of uniformities were 83.3 and 83.9%, respectively. These results support studies which show that chemical distribution can only be as uniform as the water uniformity (Fischbach, 1971; Bryan and Thomas, 1958). These results show that the insecticide distribution was less uniform than the water. Therefore, a first requirement of effective chemical application through an irrigation system should be that the system have a high coefficient of water distribution uniformity. Also, constant metering of the insecticide formulation with a high precision metering pump should be required.

A distribution test of the vertical distribution of irrigation water and insecticide in a corn canopy when applied through a center pivot irrigation system was conducted. The distribution of an oil formulated insecticide throughout a sprinkler irrigated corn canopy indicated that up to 50% of the insecticide-peanut oil formulation applied to the field corn by overhead sprinkler irrigation adhered to and was retained by the corn foliage between the top of the corn canopy and the ninth leaf.

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