INFLUENCE OF CHEMIGATION PARAMETERS ON
FALL ARMYWORM CONTROL IN FIELD CORN

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ABSTRACT

The application of pesticides in irrigation water (chemigation) is developing into a
highly efficient and economical pest management strategy as the influence of application
parameters are understood. In the current study, the effects of main-line water velocity,
injection port direction, and sprinkler nozzle type were evaluated with two rates of
chlorpyrifos to control fall armyworm larvae, Spodoptera frugiperda (J. E. Smith), in
whorl-stage field corn grown under 0.6 ha center pivot irrigation systems. Chlorpyrifos
injected into a main-line water velocity of 2.7 m/s generally gave as good or better fall
armyworm control than when injected into a water velocity of 0.9 m/s regardless of
sprinkler type. Upstream injection of chlorpyrifos formulated in non-emulsifiable oil
resulted in better control of fall armyworm than did downstream injection. Chlorpyrifos
applied with a 360° spray sprinkler with coarse plates and nozzle orifice diam. between
3.6 and 9.5 mm at a main-line water velocity of 0.9 m/s gave the poorest fall armyworm
control while an impact sprinkler gave the best control. The formulation droplet breakup
in the main line and at the sprinkler were important factors in the distribution of
insecticides to the target.

RESUMEN

La aplicación de insecticidas en el agua de irrigación (quimigación) se está convir-
tiendo en una estrategia de manejo integrado de plagas bastante eficiente. En este es-
tudio, los efectos de la velocidad del agua a través de el tubo principal de irrigación, la
dirección de la inyección, y el tipo de boquilla de irrigación, fueron evaluadas con dos
dosis de chlorpyrifos, con el propósito de controlar las larvas del cogollero del maíz,
Spodoptera frugiperda (J. E. Smith), en un campo de maíz en estado de mazorca,
cultivado bajo un sistema de irrigación centro-pivote de 0.6 has. El chlorpyrifos fue
inyectado en el tubo principal con una velocidad del agua de 2.7 m/s el cual dio un control
mejor o igual que cuando el producto fue inyectado en el agua a una velocidad de 0.9
m/s, sin que importara el tipo de boquilla de aspersión. Chlorpyrifos formulado con
aceite no emulsionable e inyectado contra la corriente, resultó en un mejor control que
la inyección en el mismo sentido de la corriente. El chlorpyrifos aplicado con un equipo
de aspersión de 360° con platillos gruesos y con una boquilla de aspersión con un orificio
de diámetro entre 3.6 y 9.5 mm con una velocidad del agua de la tubería principal de
Advances in irrigation systems and insecticide injection equipment design have stimulated research to improve the efficiency and reliability of insecticides conveyed in irrigation water (chemigation) against economic pests of production agriculture. For foliar chemigation, oil-soluble insecticides formulated with non-emulsifiable oils have the best potential for consistent and effective control of insect pests on plant foliage. These formulations form discrete droplets of oil-carrying insecticides that are transported in the irrigation water and adhere to the plant foliage at application (Young 1984 and Chalfant & Young 1981). Three times as much chlorpyrifos insecticide was found on the foliage of corn plants when formulated in oil than when formulated as an emulsifiable concentrate and chemigated with 0.6 mm of water (Wauchope et al. 1990).

The droplet size distribution of pesticides applied with conventional equipment influences their effectiveness (Smith et al. 1973 and Gebhardt et al. 1985). Therefore, the efficiency of chemigated pesticides probably is influenced by droplet size distribution. Sumner and Cochran (1988) developed a system to measure oil droplet size distribution emanating from irrigation sprinklers during chemigation. However, studies to correlate droplet size of oil-formulated insecticide with insect control in chemigation field tests have not been performed, since the determination of droplet size distribution of oil-formulated insecticide from irrigation sprinklers requires the collection and disposal of large volumes of insecticide during testing. Laboratory studies on the effect of irrigation and injection parameters on oil droplet size distribution (Grosselle et al. 1986, Cochran et al. 1984, 1986, 1988, Sumner & Cochran 1988) indicated that main line water velocity, pesticide injection direction (with respect to main-line flow), sprinkler nozzle diameter, system pressure, and sprinkler type all influenced the size of generated droplets. Therefore, if oil droplet diam. does in fact influence insect control, then the selection of the appropriate irrigation and pesticide injection systems are critical for achieving the maximum performance from a pesticide.

The purpose of the current research was to evaluate the influence of main-line water velocity, injection direction, and sprinkler type on the control of fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith) in whorl-stage field corn.

**Materials and Methods**

Lorsban 6 technical insecticide (chlorpyrifos) was evaluated against larvae of the FAW in whorl-stage field corn grown under two single tower center-pivot irrigation systems (0.6 ha each) in 1988 and 1989. Two low insecticide dosages (70 and 140 g/ha active ingredient; 12 and 25% of rates recommended by the Georgia Cooperative Extension Service) were selected to better separate parameter effects. Chemigation parameters evaluated were sprinkler type (Impact, Wobbler, 360° Super Spray, and Rotator), main-line water velocity (2.7 and 0.9 m/s), and pesticide injection port orientation (upstream center and downstream center). Pivot “A” was equipped with two sprinkler types, 1) Nelson (Route 4, Box 169, Walla Walla, WA) 33AA impact sprinklers with nozzle orifice diam. between 3.57 and 9.55 mm, operating at 310 kPa, and 2) Sennunger (6416 Old Winter Garden Rd, Orlando FL) Wobbler sprinklers with nozzle orifice diam. between 3.57 and 9.53 mm, operating at 138 kPa. Pivot “B” was also equipped with two sprinkler types, 1) Sennunger 360° Super Spray sprinklers with course plates and nozzle orifice diam. between 3.57 and 9.53 mm for application at 138 kPa, and 2) a Nelson
8A impact sprinkler package. In 1986, the impact sprinklers were replaced with Nelson Rotator R30 sprinklers with U4 plates and nozzle orifice diam. between 6.75 and 8.73 mm operating at 172 kPa. Two different interchangeable main-line injection port regions were utilized to achieve the desired main-line velocities at the injection port. For high main-line velocity, insecticides were injected into the center of a 6.4 cm diam. pipe with a water velocity of 2.7 m/s. For low main-line velocity, insecticides were injected into the center of a 10.8 cm diam. pipe with a water velocity of 0.9 m/s. A diaphragm injection pump, operating at 72 pulses/min, metered the oil-insecticide formulation into the water at 120 ml/min through a 6.4-mm diam. stainless steel tube. The insecticides were formulated in soybean oil and were delivered at a total volume of 4.9 liters/ha.

The area under each pivot was divided into quadrants. Treatment parameters in each quadrant consisted of a combination of one nozzle type and one insecticide rate. This arrangement provided four randomized, nonreplicated main plot treatment combinations in a $2 \times 2$ factorial split plot design. In each quadrant there were 20 plots, [2 rowo (1.83 m) wide by 3.1 m long] with 1.5 m between plots. In these subplots there were 5 treatments with 4 replications in a randomized block design with a $2 \times 2$ factorial for main-line velocity and injection direction, plus an untreated check.

In the spring of 1988 and 1989, ‘Pioneer 3365’ dent field corn was planted four weeks apart on alternate row beds under each of the two center pivot systems to provide for two treatment dates (four tests were conducted during each year). Corn plants in each plot were infested with laboratory reared (Burton 1969) FAW neonate larvae at the rate of 12 to 17 per plant in 1988 and 5 to 12 per plant in 1989, which were allowed to reach 2nd-3rd instar before treatments were applied. Artificial infestation of the whorl was accomplished using a rotating larval dispenser mounted on a tractor in 1988 (Sumner and Gross 1990) and a modified manual unit (H.R.S., unpublished) in 1989.

Chemigation treatments were applied between 7:00 and 10:00 AM when the wind velocity was less than 8 km/h. To maintain treatment integrity, portable, metal-framed, fiberglass-covered crop shelters, 1.8 m wide $\times$ 3.6 m long, were used to cover 16 plots in each quadrant that were not to be treated during each application. Four passes of the pivot across each quadrant were required to produce all combinations of main-line velocity and injection port orientation. Since new plant growth originates in the whorl and the plant grows fast enough to provide new untreated whorls with 5 to 6 days, plots for the second treatment date (second planting) were not covered when treatments on the first date were applied. Insect control was evaluated 3-3 days after treatments were applied. Ten plants in 1988 and 15 in 1989 were randomly selected from each plot, excised, placed in plastic bags and taken to the laboratory for examination. The number of live and dead FAW larvae found on each plant was recorded. Artificial infestation, chemigation treatment, and treatment efficiency evaluation dates for the tests are given in Table 1.

Mean differences in the percentage of live FAW larvae found on the plants were analyzed by ANOVA and means and interactions separated by least significant differences (LSD) at $P = 0.05$ (SAS Institute, Inc., 1985). Arcsine transformations of the percentage of live larvae were used for statistical analysis.

**RESULTS**

Variations between and within seasons, the application of the treatments, and the number of larvae surviving in the untreated checks did not allow a comparison between years and application dates. Therefore, each application date and pivot evaluation test was analyzed separately. Arcsine transformations of percent live larvae were analyzed,
TABLE 1. Artificial infestation, insecticide treatment, and evaluation dates for each pivot test.

<table>
<thead>
<tr>
<th>Pivot</th>
<th>Test</th>
<th>Infested Date</th>
<th>Larvae/plant</th>
<th>Treated Date</th>
<th>Evaluated Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>5/5/88</td>
<td>17</td>
<td>5/16/88</td>
<td>5/18/88</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>5/3/89</td>
<td>6</td>
<td>5/9/89</td>
<td>5/10/89</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>5/12/89</td>
<td>7</td>
<td>5/18/89</td>
<td>5/19/89</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>5/22/89</td>
<td>5</td>
<td>5/30/89</td>
<td>5/31/89</td>
</tr>
</tbody>
</table>

and results were no different from percent live larvae. Data are presented as percent live FAW larvae in Table 2.

1988 test: Pivot A—There was a significant interaction between sprinkler type and main-line velocity for FAW larval control on May 4. The impact sprinkler provided significantly better FAW control than the Wobbler sprinkler (7.4 and 19.7% live larvae, respectively, LSD = 11.5) at the high main-line velocity but no significant differences in the effect of nozzles were observed at the low main-line velocity. On May 18, FAW control was influenced by a significant interaction among sprinkler type, main-line velocity, and insecticide injection port orientation. With downstream insecticide injection, there were no significant differences in percent live FAW larvae between sprinklers or main-line velocities. With upstream insecticide injection, the Wobbler sprinkler provided better control than the impact sprinkler (13.1 and 40.2% live larvae, respectively, LSD = 13.2) at high main-line water velocities, while there were no significant differences in percent live larvae at low main-line water velocities. Chlorpyrifos injected upstream and applied from the Wobbler sprinkler was significantly more effective in reducing the percent of live FAW larvae when introduced into the high main-line water velocity than at low main line water velocity (13.1 and 29.4% live larvae, respectively, LSD = 13.2).

Pivot B—On May 11 there was a significant interaction between chemical rate, sprinkler type, and main-line water velocity for FAW control. For the high chlorpyrifos rate (140 g/ha) there were no significant differences in percent live FAW larvae between main-line water velocity and sprinkler type. However, there was a significant difference in percent FAW survival between the untreated and the treated plots (58.8 and 7.6% live larvae, respectively, LSD = 14.0, data not shown in Table 2). At the low chlorpyrifos rate (70 g/ha) there was a significant interaction between sprinkler type and main-line water velocity for FAW control. Chlorpyrifos delivered from the impact sprinkler provided better FAW control than when applied from the Super Spray sprinkler (4.0 and 27.7% live larvae, respectively, LSD = 14.0) at the high main-line water velocity. The Super Spray sprinkler was numerically but not significantly superior to the impact sprinkler (11.3 and 21.1% live larvae, respectively, LSD = 14.0) at the low main-line water velocity. On May 25, chlorpyrifos injected upstream was significantly better than downstream injection (18.5% and 30.2% live larvae, respectively, LSD = 10.5, data not shown in Table 2). Additionally, there was a significant interaction for percent FAW larval survival between chemical rate and main-line water velocity. The high chlorpyrifos rate controlled FAW larvae better than the low rate (12.1 and 48.2% live larvae, respectively, LSD = 10.5) when applied at the low main-line water velocity, while there were no significant differences in larval survival at the high main-line water velocity. Chlorpyrifos applied at 70 g/ha in the high main-line water velocity provided better FAW
TABLE 2. EFFECTS OF CHEMIGATION PARAMETERS ON THE CONTROL OF THE FALL ARMYWORM WITH CHLORPYRIFOS APPLIED BY CHEMIGATION. PERCENT LIVE LARVAE FOUND AFTER TREATMENT IN EIGHT TESTS.

<table>
<thead>
<tr>
<th>Year, Pivot, Test Date</th>
<th>Parameter</th>
<th>Sprinkler</th>
<th>Other*</th>
<th>Water velocity</th>
<th>% Live larvae</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>Low</td>
<td>Check</td>
<td>LSD</td>
</tr>
<tr>
<td>1988, A</td>
<td>Impact</td>
<td>7.4a*</td>
<td>7.9a</td>
<td>58.0a</td>
<td>11.5</td>
</tr>
<tr>
<td>May 4</td>
<td>Wobbler</td>
<td>7.9b</td>
<td>12.2a</td>
<td>78.5b</td>
<td>11.5</td>
</tr>
<tr>
<td>1988, A</td>
<td>Impact</td>
<td>40.2b</td>
<td>31.7a</td>
<td>46.0a</td>
<td>13.2</td>
</tr>
<tr>
<td>May 18</td>
<td>Wobbler</td>
<td>13.1a</td>
<td>29.4a</td>
<td>28.4a</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>Impact</td>
<td>24.4a</td>
<td>30.0a</td>
<td>46.0a</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>Wobbler</td>
<td>17.1a</td>
<td>19.2a</td>
<td>28.4a</td>
<td>13.2</td>
</tr>
<tr>
<td>1988, B</td>
<td>Impact</td>
<td>70 g/ha</td>
<td>4.0a</td>
<td>21.1a</td>
<td>76.0b</td>
</tr>
<tr>
<td>May 11</td>
<td>Super Spray</td>
<td>70 g/ha</td>
<td>27.7b</td>
<td>11.3a</td>
<td>51.7a</td>
</tr>
<tr>
<td></td>
<td>Impact</td>
<td>140 g/ha</td>
<td>7.3a</td>
<td>4.8a</td>
<td>57.5a</td>
</tr>
<tr>
<td></td>
<td>Super Spray</td>
<td>140 g/ha</td>
<td>8.1a</td>
<td>10.4a</td>
<td>66.0a</td>
</tr>
<tr>
<td>1988, B</td>
<td>Both*</td>
<td>70 g/ha</td>
<td>21.1a</td>
<td>48.2b</td>
<td>85.7b</td>
</tr>
<tr>
<td>May 25</td>
<td>Both</td>
<td>16.0a</td>
<td>12.1a</td>
<td>55.6a</td>
<td>17.2</td>
</tr>
<tr>
<td>1989, A</td>
<td>Impact</td>
<td>70 g/ha</td>
<td>30.8a</td>
<td>55.2a</td>
<td>85.3a</td>
</tr>
<tr>
<td>May 5</td>
<td>Wobbler</td>
<td>70 g/ha</td>
<td>59.8b</td>
<td>69.7a</td>
<td>96.8a</td>
</tr>
<tr>
<td></td>
<td>Impact</td>
<td>140 g/ha</td>
<td>40.2a</td>
<td>37.5a</td>
<td>96.8a</td>
</tr>
<tr>
<td></td>
<td>Wobbler</td>
<td>140 g/ha</td>
<td>23.3a</td>
<td>52.8a</td>
<td>88.4a</td>
</tr>
<tr>
<td>1989, A</td>
<td>Both</td>
<td>20.7</td>
<td>35.7</td>
<td>88.6</td>
<td>8.8</td>
</tr>
<tr>
<td>May 19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989, B</td>
<td>Super Spray</td>
<td>70 g/ha</td>
<td>71.8b</td>
<td>61.5b</td>
<td>87.1a</td>
</tr>
<tr>
<td>May 10</td>
<td>Rotator</td>
<td>70 g/ha</td>
<td>10.4a</td>
<td>23.8a</td>
<td>69.7a</td>
</tr>
<tr>
<td>Super Spray</td>
<td>140 g/ha</td>
<td>56.3b</td>
<td>82.4b</td>
<td>88.7a</td>
<td>20.8</td>
</tr>
<tr>
<td>Rotator</td>
<td>140 g/ha</td>
<td>14.6a</td>
<td>21.1a</td>
<td>82.5a</td>
<td>20.8</td>
</tr>
<tr>
<td>1989, B</td>
<td>Super Spray</td>
<td>70 g/ha</td>
<td>23.1a</td>
<td>67.7a</td>
<td>58.2a</td>
</tr>
<tr>
<td>May 31</td>
<td>Rotator</td>
<td>58.0b</td>
<td>68.8a</td>
<td>88.0a</td>
<td>25.0</td>
</tr>
</tbody>
</table>

*Within any test, vertical means with letters in common are not significantly different (P = 0.05).
** = Significant difference between horizontal means; LSD test, P = 0.05.
*Pesticide injection port orientation - upstream or downstream - or rate of chlorpyrifos applied - 70 or 140 g/ha.
*Beta – Applies to the two sprinkler types used on the pivot.
control than when applied in the low main-line water velocity (21.1 and 48.2% live larvae, respectively, LSD = 10.5).

1989 tests: Pivot A—There was a significant interaction among sprinkler type, insecticide rate, and main-line water velocity for FAW control on May 5. Chlorpyrifos applied at 70 g/ha in a high main-line water velocity performed significantly better with the impact sprinkler than with the Wobbler sprinkler (30.8 and 69.8% live larvae, respectively, LSD = 21.4). At 70 g chlorpyrifos per ha and low main-line water velocity there was no significant difference in FAW control between the sprinklers. However, chlorpyrifos (70 g/ha) applied from the impact sprinkler gave significantly better FAW control when used with the high main-line water velocity. At 140 g chlorpyrifos per ha, FAW control was not influenced by sprinkler type at either main-line water velocity. However, chlorpyrifos (140 g/ha) applied from the Wobbler sprinkler provided significantly better FAW control when used with high main-line water velocity than with the low main-line water velocity (23.3 and 52.8% live larvae, respectively, LSD = 21.4). On May 9, chlorpyrifos applied in the high main-line water velocity significantly decreased FAW larval survival compared with the low main-line water velocity (20.7 and 35.7% live larvae, respectively, LSD = 8.8); otherwise there were no significant differences in FAW control among the chemigation parameters.

Pivot B—A significant interaction among sprinkler types, main-line water velocity, and insecticide rate influenced the levels of control of FAW larvae on May 10. Chlorpyrifos, when applied at 70 and 140 g/ha in both low and high main-line water velocities yielded significantly better control of FAW larvae when delivered from the rotator sprinkler than from the Super Spray sprinkler. Significantly better FAW control was achieved when chlorpyrifos (140 g/ha) was applied in a high main-line water velocity from the Super Spray sprinkler than from the Rotator sprinkler (66.3 and 82.4% live larvae, respectively, LSD = 14.7). On May 31, a significant interaction between sprinkler type and main-line water velocity influenced percent FAW larval control. Chlorpyrifos (140 g/ha) applied at the high main-line water velocity from the Super Spray sprinkler provided significantly better FAW control than when applied from the Rotator sprinkler (33.1 and 58.0% live larvae, respectively, LSD = 15.0). Chlorpyrifos control of FAW was not significantly influenced by sprinkler type when applied at the low main-line water velocity.

**Discussion and Conclusions**

Significant interactions among and between the chemigation parameters indicated that the effect of any particular parameter on insecticidal performance was conditioned by one or more of the other parameters. High main-line water velocity positively influenced sprinkler performance in most tests. FAW larval control with chlorpyrifos injected at high main-line water velocity was generally as good or better than when injected at low main-line water velocity, regardless of sprinkler type. This finding suggests that a main-line water velocity at or below 0.9 m/s probably does not generate oil-pesticide droplets small enough to obtain satisfactory, uniform distribution of the insecticide to sprinklers in some of the systems tested. At low main-line water velocities, larger droplets are generated by the lower shear between the flowing water and the injected oil-pesticide than at high main-line water velocities. Upstream injection of oil-pesticide into the main line resulted in better insect control than with downstream insecticide injection (15.5 and 30.2% live larvae, respectively, LSD = 10.5) in 1988. Pivot B, date 2. Here again, improved insect control was obtained because smaller formulation droplets were generated by upstream insecticide injection than by downstream insecticide injection. An increase in main-line water velocity could probably be used to overcome the difference in droplet size and the resulting poor insect control found in downstream compared to upstream insecticide injection.
The combination of application parameters in these tests represents a wide range of conditions; however, with the variable results observed between tests, clear-cut evidence was not found to indicate that specific equipment combinations should be avoided when chemigating. The Super Spray sprinkler at low main-line water velocity resulted in the poorest FAW larval control while the impact sprinkler gave the best control. Formulation droplet size should be smaller with the impact sprinkler since it operates at high pressure through a high-shear small nozzle diameter. The impact sprinkler generally provided as good or better FAW larval control than the Wobbler or Super Spray sprinkler in these tests. The Rotator sprinkler performed as well as or better than the Super Spray sprinkler. Consistent and effective application uniformity of chemigated insecticides is influenced by proper selection of sprinkler type and main-line water velocity.

Chemigation at recommended insecticide rates has been successful with a large range of insecticide injection parameters and sprinkler types (Young 1986). Research designed to better understand chemigation parameters will ultimately result in the development of application methods, devices, and systems that will provide efficient control of FAW larvae and other pests at safe and effective application rates of pesticide. Formulation droplet size distribution is probably the key to understanding the advantages of specific chemigation equipment combinations that optimize pest control.

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LANGOSTA: A LEPIDOPTEROUS PEST COMPLEX ON SORGHUM AND MAIZE IN HONDURAS

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ABSTRACT

A lepidopterous pest complex, collectively referred to as “langosta” by subsistence farmers, is an important constraint to sorghum and maize production in southern Honduras. The objectives of this study were to identify the insect species in the langosta complex, determine their population density and their relationships to crop and non-crop vegetation. Relative and destructive whole plant samples were taken on intercropped sorghum and maize from May to August in plots managed using farmer’s technology and farmer’s technology plus weed control in 1988 and 1989. Weed identity and density were recorded. Spodoptera frugiperda (J. E. Smith), S. latifascia (Walker), Metagon pneumata rogenhoferi (Moschler), and Mocis latipes (Guenee) larvae were identified as the principal insect species in the langosta complex.

The fall armyworm, S. frugiperda, was the predominant species collected throughout the study period. Spodoptera latifascia and M. rogenhoferi were present only early in the season. Populations of S. frugiperda on the crops were higher in plots without weeds; Spodoptera latifascia and M. rogenhoferi populations did not appear to be influenced by non-crop vegetation in the treatment plots, but were influenced by vegetation adjacent to plots where they fed prior to planting. The grass looper, M. latipes, was present in mid-season and populations on sorghum and maize were higher in plots without weed control.