posit was recovered from abaxial surfaces compared to adaxial surfaces except in the interior canopy at 14 kg·cm^{-2} (Table 4). Thus distribution of deposits was more uniform at high pressure in the interior canopy.

Test 4. Interactions between the two pressure/nozzle combinations and leaf surface were significant so analyses were conducted at each level. Again, interior and abaxial locations received less dye (Table 5). Distribution was more uniform over leaf surfaces in the interior canopy at high pressure.

Test 5. Delivery volume for this experiment varied between treatments according to nozzle size and pressure while delivery rate of active ingredient (dye) was maintained constant between treatments by adjusting concentration. Similar distribution of dye on lower (abaxial) leaf surfaces was obtained with the tractor-drawn and table chain-drawn boom sprayers (Figs. 1 & 2). Spray deposition on abaxial leaf surfaces tended to increase at all canopy positions as spray volume increased in response to larger nozzle orifice, higher pressure or both.

The simplest explanation increased deposition at high volume is that canopy penetration depends directly on momentum of the impacting droplet. Since momentum is the product of mass and velocity, momentum would increase with increases in one or both of these parameters. Velocity of the droplet at the nozzle orifice would vary directly with pressure, although air friction would tend to decelerate small droplets produced by high pressure more quickly than large droplets due to the increase in surface to volume ratio with decreased size. Droplet size is also a function of orifice size. Therefore, the combination of large orifice and high pressure, maximized penetration and deposition on interior, abaxial surfaces, by maximizing spray volume and droplet momentum.

Based on the results from this study, we may make the following conclusions: 1) coverage obtained using water sensitive cards estimated by visual and computer image analysis methods gave similar results; 2) the table chain-driven boom sprayer provided a good model of a tractor-drawn boom sprayer, both in terms of coverage and spray deposit, 3) High-volume sprays obtained by increasing either pump pressure or nozzle orifice tended to improve canopy penetration and deposition of spray material on abaxial leaf surfaces. Therefore, delivery volume of hydraulic sprayers should be increased to increase spray contact with hard to reach pests, such as the silverleaf whitefly, that reside on abaxial surfaces and may escape control, especially in the interior canopy.

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THE USE OF MATING DISRUPTION TO CONTROL TOMATO PINWORM, *KEIFERIA LYCOPERSICELLA* (WALSINGHAM)

wherein male TPW are inhibited from locating and mating with females following mass application of synthetic female sex attractant. When successful, mating disruption eliminates oviposition of viable eggs and consequently larval feeding on leaves and fruit.

Several commercial formulations and application methods are now available. We report results of field trials with three of these formulations carried out over four growing seasons. All trials were carried out during the spring in tomato fields in the Immokalee area.

Materials and Methods

1992

NoMate TPW Fiber (Formally Scentry Inc. 610 Billings MA, now Ecogen Corp., Langhorn PA.) containing 0.3% (Z)-4-tridecen-1-yl acetate and 7.1% (E)-4-tridecene-1-yl acetate in inert ingredients including hexane was applied at a rate of 1.74 oz (0.13 oz ai)/ac to 40 acres of staked tomato on 3 March to 6 March. The hollow plastic pheromone-containing fibers were mixed with Bio-Tac adhesive at a rate of 25.7 oz/ 1 gal and applied directly to the polyethylene-mulched bed surface at 625 locations per acre. Each application site contained approximately 40 fibers. Treated fields consisted of four 10-acre blocks. Flight activity was monitored using wing traps each baited with a single TPW pheromone lure. One trap was placed approximately 75 ft into each block of tomato at canopy height. Two additional traps were placed in an adjacent watermelon field to the east, which had previously been planted to tomato and contained numerous tomato volunteers (near check), and three traps were placed in an untreated control block of tomato approximately one mile to the south (far check). Traps were monitored twice a week for TPW adults. On 6 May, TPW eggs and mines were sampled in four quadrants of the treated and far check fields. At each sample site, a leaf was taken between the seventh to ninth node from the top of 20 randomly selected plants.

1993

CheckMate TPW, (Concep, Inc. Bend, Oregon) was evaluated for the control of TPW. Treatments consisted of a 10-acre plot treated with the mating disruptant, and an untreated control plot in the adjoining 60-acre field. The treated plot was bordered on three and one-half sides by woods and, on part of the fourth side, by the control plot separated by about 200 ft. Six pheromone baited wing traps were placed on a transect through each plot. The transect through the untreated control plot began 200 ft. away from the treated area, and extended for approx. 0.5 miles. Mating disruptant tags were stapled to 3.5-inch surveyors flags and applied to the center row of the three-row blocks of tomatoes at the rate of 200 tags per acre(0.31 oz a.i.). The tomatoes were planted on 28-30 Dec. 1992 (control plot), and 3 Jan. 1993 (treated plot). Tags and traps were set out on 5 Feb. 1993. Treatments were scouted every three to four weeks for the presence of TPW leaf mines. Wing traps were monitored for adult pinworm moths twice per week.

1994

CheckMate TPW was again evaluated in a 13.3-acre treated plot. Pheromone tags were placed as high up as possible on the limbs of the plants at the rate of 200 tags per acre(0.31 oz a.i.). Six pheromone baited wing traps were placed on a transect through the treated field, an adjacent (transition area) tomato field (19.5 acres), and an untreated control field (22 acres), located two miles south of the treated plots. The tomatoes were planted on 13 Dec. (control plot), 20 Dec. (treated plot), and 25 Dec. 1993 (transition plot). Tags were set out on 27 Jan. 1994 and pheromone traps were set out on 3 Feb. 1994. Treatments were scouted every three to four weeks for the presence of TPW leaf mines. Wing traps were monitored for adult TPW moths twice per week.

1995, Trial 1.

Decoy TPW (AgriSence, A Division of Biosys, Palo Alto, CA.) mating disruptant was evaluated at two different rates: 300 clips per acre (0.84 oz a.i.) on 27.4 acres, and 400 clips per acre (1.13 oz a.i.) on 24.6 acres plus an untreated check (25.5 acres). The test plots comprised 77.5 acres of the youngest tomatoes in a 245-acre tomato production field, and were separated by approximately 500 ft of non-crop land. Tomatoes were planted between 17 Jan. and 20 Jan. 1995. Pheromone clips were applied to the string of every other tomato row following first tie on 16 Mar. Six pheromone baited wing traps were set out in a transect across each of the plots on 16 Mar. Lures and trap bottoms were replaced on 19 Apr. Treatments were monitored on 17 Apr., 9 May, and 22 May for the presence of TPW leaf mines by examining 33 feet of row in six random locations in each plot. Wing traps were monitored for adult TPW moths twice per week.

1995, Trial 2.

The untreated plot was planted 27 Feb. 1995 with greenhouse raised tomato seedlings at 18-inch spacing on six fumigated beds 32 inches wide and 240 ft long covered with black polyethylene mulch. Four blocks of three beds each were divided into nine plots 40 feet long and one row wide of which one was not treated with insecticide to control TPW. Pheromone wing traps and baits were used to monitor TPW populations. Decoy TPW mating disruption clips were applied at the rate of 300/acre (0.84 oz a.i.) on 25 Jan. Moths were monitored by two wing traps baited with TPW pheromone placed 75 ft into the north and south sides of the field.

All treatments in 1992, 1993 and 1994 received biweekly applications of insecticides including members of the organophosphate, organochlorine, carbamate, and pyrethroid families. In 1995 (Trial 1), all plots were treated with imidacloprid, which allowed a 70% reduction in the use of pyrethroids, a 66% reduction of organochlorines (endosulfan), and the elimination of organphosphates from the spray program.

Results

Initial trap counts on all treatments in each of the four years were less than one adult per trap per day.

1992. Trap counts remained at or below one adult per day in treated blocks except for the last week when three adults per trap were registered (Fig. 1). In contrast, an average of 32 adults per trap per day were counted from the far check and 13 adults per trap per day from the near check. Pinworm mines at harvest in the far check averaged 61.5 mines per 20 leaves over four sampling sites, while the mean in the treated plot was 16 mines (Fig. 2).

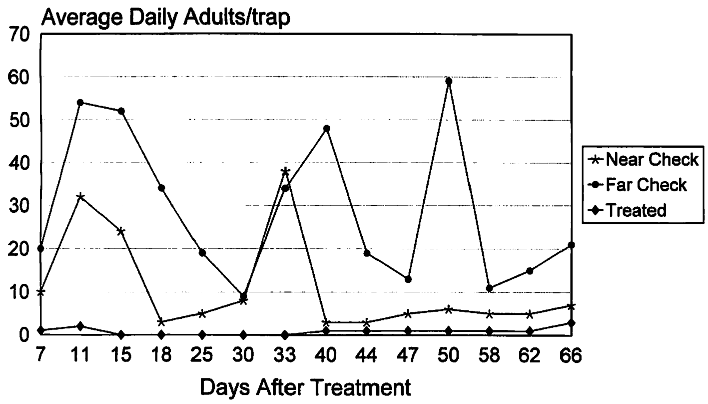


Figure 1. Number of tomato pinworm adults captured in wing traps, Spring 1992.

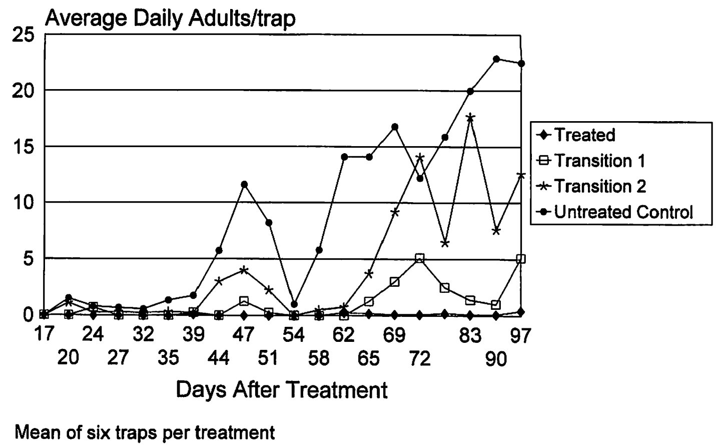


Figure 3. Number of tomato pinworm adults captured in wing traps, Spring 1993.

1993. Counts in the two traps nearest the treated area (transition 1 = 200 ft. away, and transition 2 = 260 ft. away: See Fig. 3) mirrored the untreated control plot but were lower in a direct relationship to the distance from the treated area. Trap counts in the treated plot never exceeded one adult/trap/day. No pinworm mines were found in leaves of plants from either treatment during the spring of 1993.

1994. Trap counts in the field adjacent to the treated area showed a similar tendency to the untreated control two miles away, but at a much reduced level (Fig. 4). Trap counts in the treated plot never exceeded one adult/trap/day. No pinworm mines were found in plants from any treatment during 1994.

1995, Trial 1. Trap counts in both of the treated areas remained around two adults/trap/day, until 56 days after the treatments began, when counts in the 300 clips/acre treatment began to increase (Fig. 5). At the end of the trial, 64 days after treatment, trap counts in the untreated control were running around 35 adults/day, the 300 clips/acre treatment were averaging around 15 adults/day, and the high rate of 400 clips/acre had not exceeded five adults/day.

No pinworm mines were found in any treatments 54 days after treatment began. At 67 days after treatment, the average number of pinworm mines observed on 33 feet of row were 50 in the untreated control, 49 in the 300 clips/acre treatment, and 35 in the 400 clips/acre treatment (Fig. 6).

1995, Trial 2. Counts remained below three per trap per day following treatment for all but three sample dates (7, 31 and 40 days after treatment), until 65 days after treatment when counts increased to 10 to 15 per day. In comparison, counts in untreated plots averaged 60 adults per trap per day over the same period (Fig. 7).

Pinworm damaged fruit was estimated at 16.6% and 17.4% for number and weight respectively in treated plots compared to 21.1% and 21.3% in untreated plots.

Discussion

The number of adults captured in wing traps in the treated areas in 1992 (Fig. 1), 1993 (Fig. 3) and in 1994 (Fig. 4) remained very low when compared to the untreated controls. This would suggest that the disruptant was affecting the males ability to locate and mate with the female moths. Trap counts in transition areas (adjacent fields) demonstrated pheromone activity surrounding treated areas. The decreased number of mines in 1992 in the treated plot as compared to the far check demonstrates the disruptant's efficacy (Fig. 2). The lack of pinworm mines in all of the treatments in 1993 and

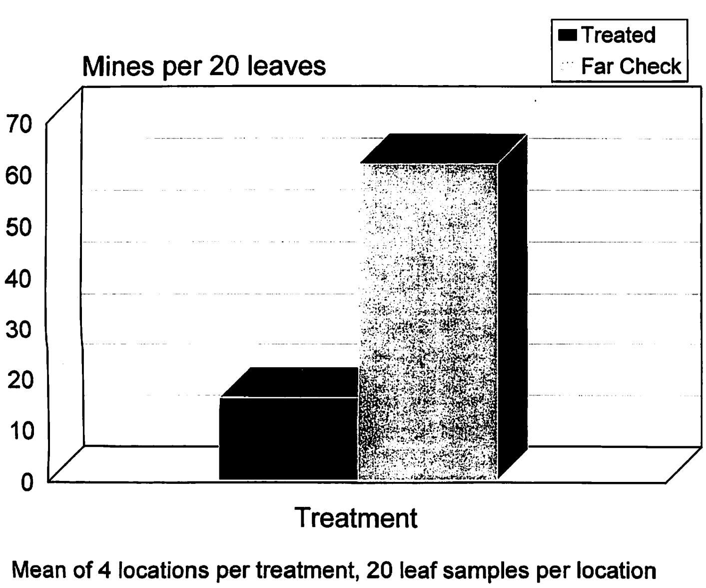


Figure 2. Tomato pinworm mines at harvest, Spring 1992.

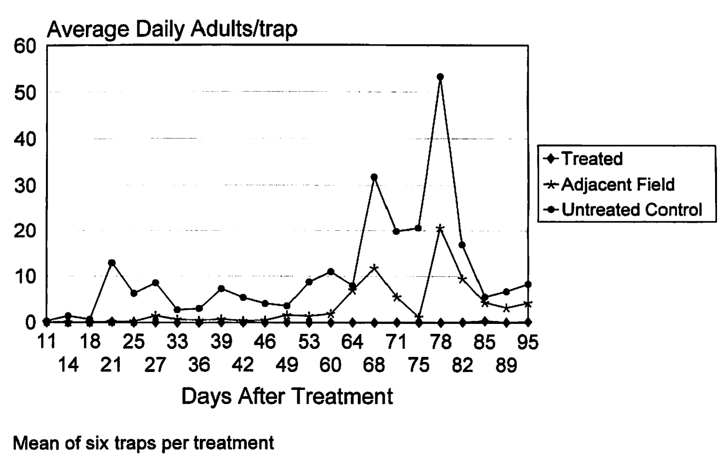
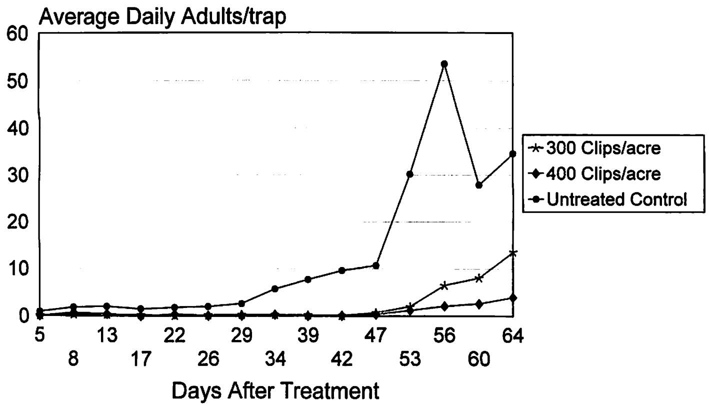


Figure 4. Number of tomato pinworm adults captured in wing traps, Spring 1994.



Mean of six traps per treatment

Figure 5. Number of tomato pinworm adults captured in wing traps, Spring 1995, commercial production field.

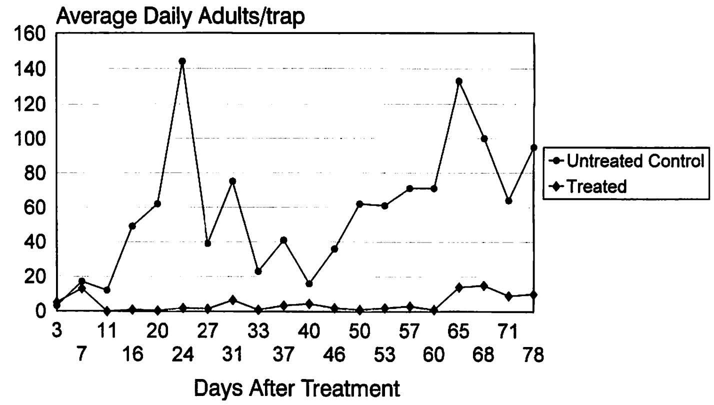
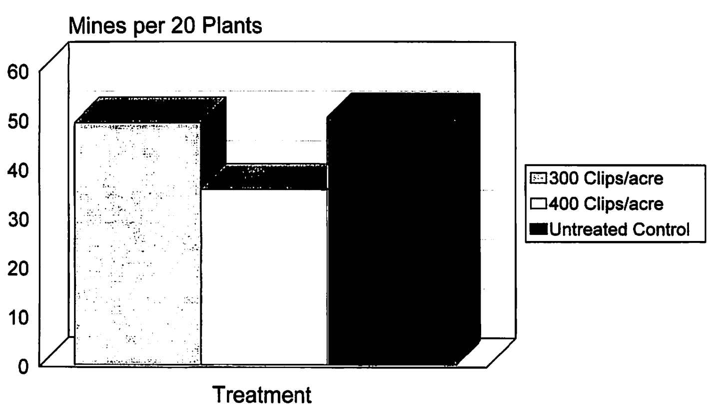


Figure 7. Number of tomato pinworm adults captured in wing traps, Spring 1995, Southwest Florida Research and Education Center.

1994 is probably a function of high pinworm mortality due to the intense spray program that was being used in an effort to control the silverleaf whitefly.

The use of imidacloprid for the control of the whitefly in spring 1995 provided an opportunity to test mating disruption on a large scale in an environment with reduced insecticide usage. During 1995 in trial 1, adult trap counts in the treated areas remained very low throughout the trial. The lower rate of Decoy TPW began to lose effectiveness after 56 days, but the high rate maintained low trap captures through the end of the trial (Fig. 5).

In trial 1 during 1995, pinworm mines rose dramatically in only 13 days from none being found on 9 May 1995 to a large number in every plot by 22 May 1995. There were no significant differences between the treatments for number of pinworm mines. The rapid increase in mines may be a function of mated females moving into the treated areas from the surrounding production fields. Harvest started on the surrounding production fields seven to eight weeks before the last leaf mine samples were taken. Once harvesting began, applications of insecticides were discontinued.



Mean of 20 plants with 6 sampling locations per treatment

Figure 6. Tomato pinworm mines at harvest, Spring 1995, commercial production field.

In trial 2 during 1995, adults captured in wing traps in the treated plot remained very low until 65 days after treatment, while counts in the untreated control field reached over 140 adults per trap per day (Fig. 7). At harvest there was a reduced level of damage in the treated plots when compared to the untreated controls.

Several formulations of pheromone emitters exist that are efficacious against the TPW. Close attention should be paid to the proper distribution and recommended rates of pheromone emitters. Fields should be treated prior to the build up of large pinworm populations, and efficacy might be affected by insect pressure from nearby tomato plantings. Mating disruption with pheromone emitters appears to be an effective strategy for the control of the TPW.

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