Seasonal Development and Management Strategies for Comstock Mealybug (Homoptera: Pseudococcidae) in New York Pear Orchards

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ABSTRACT Laboratory and field studies were conducted during 1988–1990 to investigate Comstock mealybug, *Pseudococcus comstocki* (Kuwana), infestations in pears (*Pyrus cummunis* L.) grown for processing in New York. The incidence and size of external infestations were reduced on pears that were put through various baths and dry brushing treatments, but not sufficiently to alleviate the nuisance posed by the insects to food handlers. In pear purees, insect fragment contaminants were found at rates directly related to the proportion of infested fruits used in the process. Contact toxicity of selected insecticides was assayed in the laboratory for mealybugs infesting the calyx of mature fruits. Chlorpyrifos, methomyl, carbaryl, and microencapsulated methyl parathion caused the greatest mortality; azinphosmethyl, phosmet, esfenvalerate, and endosulfan were no more effective than distilled water. Two generations of mealybugs develop per year in New York pear orchards; peak crawler emergence occurred at the petal fall stage and again in mid-July to early August. Crawlers emerge from egg masses laid under bark scales in the trees and predominate on green tissue and in the calyx of fruits. Acceptable control can be attained with one or two sprays of methyl parathion, diazinon, or methomyl, timed to coincide with each generation of crawlers; double-sided tape traps on the scaffold branches are the recommended monitoring tactic for the timing of sprays. Heavily infested orchards with no history of mealybug control measures may initially require a total of three or four applications, but this number can be reduced in subsequent years.

KEY WORDS Insecta, *Pseudococcus comstocki*, trapping, contaminants

THE COMSTOCK MEALYBUG, *Pseudococcus comstocki* (Kuwana), is a recognized pest of tree fruits in eastern regions of the United States, including apples (*Malus domestica* Borkh.) in Virginia (Woodside 1936, Cox 1940, Schoene 1941), Ohio (Cutright 1951), and New York (Weires 1984), apples and peaches (*Prunus persicae* (L.)) in New Jersey (Driggers & Hansens 1943), and pears (*Pyrus cummunis* L.) in Connecticut (Haeussler & Clancy 1944). Since its first reported occurrence in New York on mulberry (*Morus* sp.) and maple (*Acer* sp.) in 1918 (Hough 1925), it has been documented on many important ornamental and horticultural host plants (Johnson & Lyon 1988), but until recently has not been known as a pest of pears in this region. Two related species, *P. maritimus* (Ehrohom) and *P. obscurus* Essig, are established pests of pears in California (Bethell & Barnett 1978).

During the 1987–1989 growing seasons, a substantial number of New York pear growers experienced severe losses in attempting to market 'Bartlett' pears to processors because of unacceptable infestations of Comstock mealybug in the calyx end of the fruits at harvest (Fig. 1). Virtually all of these pears are made into puree for baby food, and because fruits used in this process are not peeled or cored, mealybug infestations have generated two primary objections within the food-processing industry. First, in severely infested lots of pears, the crawlers emerge from the calyx during the ripening process and are considered a noxious presence by workers in the plant. Second, large numbers of insects in the raw product could result in unacceptable contamination of the finished product. Because of these problems, food processors have adopted arbitrary standards of acceptability based on either percentage of pears infested with one or more mealybugs, or the number of mealybugs present per fruit, as determined by inspection before processing. Although no formal studies have been done to validate these infestation thresholds, industry representatives have reported no problems with employee concerns or product quality in the recent past using pears meeting these threshold levels.

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Fig. 1. Calyx of 'Bartlett' pear showing Comstock mealybug infestation.

Little information is available on the reason for the recent outbreaks of this pest in certain pear orchards. A number of researchers (Haeussler & Clancy 1944, Cutright 1951, Bartlett & Clancy 1972, Meyerdirk & Newell 1979, Meyerdirk et al. 1981) have worked on the identification and establishment of wasp parasite species attacking Comstock mealybug in Virginia and California, including the platygasterids *Allotropa burrelli* Muesebeck and *A. convexifrons* Muesebeck and the encyrtids *Clausenia purpurea* Ishii, *Pseudaphycus malinus* Gahan, and *Zarhopalus corvinus* (Girault). However, it is not known to what extent these species may contribute to control of Comstock mealybug in New York. Weires (1984) suggested that natural enemies provide control of mealybug on apples in New York unless disrupted by the pyrethroid flucythrinate. Although this material is no longer in use, the related compounds esfenvalerate, fenvalerate, and permethrin have been used to control pear psylla, *Psylla pyricola* Foerster, in New York orchards since the 1970s, and no severe mealybug problems were observed in pear blocks treated with these materials before 1987. Unlike observations on New York apples, Comstock mealybug infestations of pears have not generally been characterized by the growth of sooty mold fungi on the exterior surface of the calyx.

In an attempt to prevent a recurrence of the problems observed in 1987 and 1988, the 1989 tree–fruit pesticide recommendations for New York (Agnello 1988) advised that calyx infestations of mealybugs could be prevented by the application of one or two sprays of an organophosphate insecticide such as azinphosmethyl or phosmet during late July. Although complete pesticide spray records from all blocks of pears rejected by processors were not available, a representative sample from these orchards indicated that these recommendations did not adequately control fruit infestations in some orchards. Because it may be very difficult to control this pest with currently registered materials, pears may need to be treated more extensively with insecticides to reduce mealybug fruit infestations to acceptable levels. However, more intensive chemical applications would not only reduce growers' profits but could also increase the potential hazard to farmers and farmworkers and cause problems with excessive chemical residues on the fruit at harvest. Another element of uncertainty in managing Comstock mealybug is the lack of information about its seasonal development in New York, which would be needed to schedule control measures accurately. Meyerdirk & Newell (1979) charted male occurrence over several generations in California using pheromone traps baited with laboratory-reared females; however, this method required extensive effort and posed a hazard of accidental release from the cages. Fortunately, the subsequent identification of the Comstock mealybug sex pheromone (Bierl-Leonhardt et al. 1980) and evaluation of a controlled release formulation (Leonhardt & Moreno 1982) provided an efficient means of monitoring population development in the field.

To address the concerns of those involved in either the production or the processing of pears in this state, our purpose in this work was to investigate the effects of mealybug infestations on the quality of the processed product, to evaluate treatment of infested fruits with various preprocessing washes, and to monitor the population in the orchard to improve the timing of applications of different insecticides, which were compared for their effectiveness against the mealybugs.

Materials & Methods

Laboratory Bioassays. Contact toxicity of different insecticides to mealybugs was tested in laboratory trials using 'Bartlett' pears grown in Wayne County, N.Y., that had been rejected by food processors during the 1988 harvest. Mealybugs in the calyx of infested pears were treated topically with insecticides to compare the relative effectiveness of most of the materials currently registered for control of pear insects. To ensure viability of the insects, all fruits were held in cold storage (2°C) until being tested, and all assays were completed within 2 wk of the harvest date. Because immersion of intact fruits failed to contact mealybugs deep inside the calyx, the extreme tip of each fruit was cut off to expose the test insects, and a second cut below the infestation produced a slice ≈2 cm thick, with the infested calyx in the center. The mealybugs were confined to the calyx region by a ring of Bird Tanglefoot (The Tanglefoot Company, Grand Rapids, Mich.) applied around its periphery. The following pesticides were tested at recommended field concentrations ([AI]/379 liters):

azinphosmethyl (Guthion 50% wettable powder [WP]; Mobay Chemical Corporation, Kansas City, Mo.) at 113 g; carbaryl (Sevin 50% WP; Rhône-Poulenc AG Company, Research Triangle Park, N.C.) at 454 g; chlorpyrifos (Lorsban 50% WP; Dow Chemical Company, Midland, Mich.) at 170 g; endosulfan (Thiodan 50% WP; FMC Corporation, Philadelphia, Pa.) at 227 g; esfenvalerate (Asana 0.66 emulsifiable concentrate [EC]; E. I. Du Pont de Nemours & Company, Wilmington, Del.) at 7 g; methomyl (Lannate 1.8 liquid [L]; E. I. Du Pont de Nemours & Company, Wilmington, Del.) at 102 g; methyl parathion (Penncap-M 2 flowable microencapsulated [FM]; Pennwalt Corporation, Philadelphia, Pa.) at 113 g; mevinphos (Phosdrin 4 EC; E. I. Du Pont de Nemours & Company, Wilmington, Del.) at 113 g; and phosmet (Imidan 50% WP; ICI Americas, Wilmington, Del.) at 340 g. All pesticides were mixed with Triton B-1956 spreader-sticker (Rohm and Haas Company, Philadelphia, Pa.) at 170 ml/379 liters to improve area coverage, and distilled water was used as a check. For each pesticide solution, 250 μl were applied by micropipette to each of 10 calyx slices, and poured out after 3 min. The test slices were placed on a moist paper towel in an uncovered plastic container (24 by 30 by 10 cm), and held for 3 d at 25°C, then examined under a dissecting microscope to assess mealybug mortality; crawlers were considered to have survived if they appeared to move normally when disturbed. Because of the sessile nature of the crawler stages infesting the calyx at the end of the growing season, two types of assessment were made regarding the effect of treatments on the insects: obviously dead, or else moribund (i.e., not quite dead, but capable of only limited movement of one or two legs). Insects caught in the Tanglefoot barrier were excluded from the mortality counts. Percentage mortality was assessed for the total number of mealybugs present on the 10 slices per chemical treatment. This procedure was replicated four times to obtain an adequate number of specimens (n = 32–75) for each treatment.

Preprocessing Treatments. Different bath + brushing treatments were evaluated for their ability to remove mealybugs infesting the surface of 'Bartlett' pears grown in Ontario County, N.Y., in 1988. All fruits were held in cold storage (2°C) until being tested, 10 wk after harvest, at the food processing pilot facility located in the Department of Food Science and Technology, New York State Agricultural Experiment Station, Geneva. Pears with surface infestations of mealybugs were selected, grouped in batches of 100, and the insects on each fruit counted. Each batch was subjected to a 3-min bath in one of four treatments: water, 82°C; 1% DuBois 317 Lye Peeling Additive (blend of nonphosphated wetting agents used in commercial fruit and vegetable washes; DuBois Chemicals, Cincinnati, Ohio) in water, 38°C; 2% Insecticidal Soap (51% potassium salts of fatty acids; Safer, Newton, Mass.) in water, 38°C; and 2% Insecticidal Soap + pyrethrum solution (20% potassium salts of fatty acids, 0.2% pyrethrum; Safer, Newton, Mass.) in water, 38°C. Each treatment was replicated using three separate batches of pears. After immersion in the bath, the pears were run through a dry brushing unit, then examined again to determine numbers of mealybugs remaining on the external surfaces. No assessments of survival were made because the mealybugs had been killed by the holding period in cold storage before the test.

Puree Treatments. Pears infested with Comstock mealybug were processed into puree, which was examined for the presence of insect parts, to evaluate the effect of different calyx infestation levels on processed pear quality. The fruits used in these trials were grown in Orleans County, N.Y., in 1988, and held in cold storage (2°C) until being processed on 21 December. Batches of 200 pears each were prepared by mixing appropriate numbers of clean and infested fruits to produce mixtures with 0, 8, 25, 50, 75, and 100% of fruits containing mealybugs. Infested fruits contained mealybug crawlers primarily in the calyx end, although some were found occasionally at the stem end or on the fruit surface. The calyx and stem regions of each pear were dissected to count the number of insects per fruit. There were no differences among mealybug density categories in the infestation statistics, which were pooled as follows: mean number per fruit, 2.6; SD, 1.4; range, 1–9. The total insects per 200 pears in each category were: 8%, 50; 25%, 123; 50%, 263; 75%, 366; and 100%, 476. The calyx and stem were removed from all noninfested pears used, to ensure the exclusion of any undetected mealybugs that might have been present in these sites. For processing, the pears were halved, blanched at 104°C for 30 min, strained, and placed in a vat mixer; each batch produced ≈50 133-ml jars. Samples of 20 jars from each infestation level were brought to the Beech-Nut Nutrition Corporation plant in Canajoharie, N.Y., where personnel in the quality control division used standard extraneous analysis techniques (Fields et al. 1955; Geisman & Gould 1957; Association of Official Agricultural Chemists 1965, 1975; Kramer & Twigg 1966) to determine the number of insect fragments per jar.

1989–1990 Field Development Studies. The seasonal development of Comstock mealybug was monitored in unsprayed trees of two commercial pear orchards (Sodus, N.Y., and Williamson, N.Y.) in Wayne County (1989–1990), and summer development only was followed in unsprayed trees of one commercial pear orchard (Marlboro, N.Y.) in Ulster County (1989). The

Sodus orchard was 40 yr old, with trees 5.2 m tall, 4.0 m wide, and spaced 6.4 by 6.4 m. The Williamson orchard was 26 yr old, with trees 5.2 m tall, 4.6 m wide, and spaced 5.5 by 6.7 m. The orchard in Marlboro was 25 yr old, with trees 4.9 m tall, 3.8 m wide, and spaced 5.2 by 6.1 m. All three orchards contained primarily 'Bartlett' with some 'Bosc' trees planted in random locations, but all data were collected from 'Bartlett' trees. To monitor egg hatch and crawler activity in the Sodus and Williamson orchards in 1989, masses of unhatched eggs were collected from beneath bark scales starting in mid-April, held at ambient temperature in an insectary at Geneva, and examined under a dissecting microscope every 2–3 d. Batches of 6–16 egg masses were collected on 14 and 20 April in the Sodus orchard and on 14 and 21 April and 4 May in the Williamson orchard. Foliage and flower buds in both orchards also were inspected for crawlers on each collection date. On 4 May, when the first crawlers were found in flower buds at the Williamson site, samples of 25 buds per tree were collected from throughout the canopies of four unsprayed trees in each of the Wayne County orchards and examined in the laboratory for crawler infestations. Samples were collected again on 9 and 15 May, and a final assessment of first-generation hatch was made by inspecting 20 egg masses from bark sites in the Williamson orchard on 18 May.

First-generation crawler development was also monitored in 1990 in the Wayne County orchards. On 3 May, which was shortly before the petal fall stage, 20 fruit buds were randomly selected from each of five trees in each orchard that had not been sprayed the previous year and examined in the laboratory to determine levels of infestation. In addition, 20 egg masses were collected from beneath bark scales in the Williamson orchard and examined in the laboratory to evaluate hatch progress.

To monitor the start of male flight activity, pheromone traps were set out in the Wayne County orchards on 5 July 1989 and 6 July 1990. Each trap consisted of a Pherocon Tent Trap (Zoecon Corporation, Palo Alto, Calif.) baited with a square (13 by 13 mm) of 16-mil polymeric vinyl impregnated with 2,6-dimethyl-1,5-heptadien-3-ol (Zoecon Corporation, Palo Alto, Calif.) at a concentration of 4 mg/6.5 cm^2. One trap was placed in each of six unsprayed trees in each orchard in both 1989 and 1990. The traps were hung ≈1.5 m above the ground near the center of the tree canopy and checked every 3–4 d until male capture declined to zero. Emergence of the second-generation crawlers was monitored in unsprayed trees of both orchards using traps consisting of double-sided sticky tape wrapped around lower scaffold branches near the trunk. Clear cellophane tape was used in 1989, but white carpet tape was used in 1990 because it made the counting process easier. Two traps per tree were placed in five trees in each of the Wayne County orchards on 24 July 1989 and 20 July 1990, which was approximately 1 wk after adult females were observed laying eggs in bark crevices. Tape traps were examined for crawlers under a dissecting microscope in the laboratory every 3–4 d and replaced with new traps on each reading date. In the Marlboro orchard in 1989, one or two traps per tree were placed in six trees on 9 July, and crawler emergence was observed 4 d later. An application of insecticides was made on 15 July, and two traps per tree were placed in 12 trees, both sprayed and unsprayed, on 17 July. Counts were recorded 4 d later, and the data were used to obtain information about the timing of crawler activity and the effect of insecticide treatments on this activity (refer to the following section for details of the treatments).

1989 Insecticide Spray Trials. Chemical sprays were tested in all three orchards in 1989 and in the Wayne County orchards in 1990 for the control of crawlers of the spring and summer generations. In the Wayne County orchards, different insecticides were tested with either one or two sprays applied to control either or both the first- and second-generation Comstock mealybug crawlers. Insecticides were applied to runoff to single-tree plots using a handgun sprayer at a pressure of 31.6 kg/cm^2. One application of the following insecticides was made against crawlers of the first, second, or both generations (rates specified as [AI]/379 liters): azinphosmethyl (Guthion 35% WP; Mobay Chemical Corporation, Kansas City, Mo.) at 113 g; carbaryl (Sevin 50% WP) at 454 g; methomyl (Lannate 1.8 L) at 102 g; methyl parathion (Penncap-M 2FM) at 113 g. Two applications of the following insecticides were made against crawlers of the first or second generation: diazinon (D.z.n. 50% WP; CIBA–GEIGY Corporation, Greensboro, N.C.) at 227 g; and methomyl (Lannate 1.8 L) at 102 g. Treatments were arranged in a randomized complete block design and replicated twice in each orchard; treated trees were separated by one or more untreated buffer trees. One border row was designated as an untreated check in the Williamson orchard, and a block of nine trees in one corner of the orchard served as an untreated check at Sodus.

The following additional materials (at rates [AI]/ha) were applied as concentrate sprays with an airblast sprayer at 934.9 liters/ha by the grower to control other pests in the entire Sodus orchard: amitraz (Mitac 1.5 EC; Nor-Am Chemical Company, Philadelphia, Pa.) at 1,050.4 g on 29 May, at 945.3 g on 29 June and 15 July, and at 1,259.7 g on 3 and 17 August; chlorpyrifos (Lorsban 4EC; Dow Chemical Company, Midland, Mich.) at 373.5 g on 26 April; copper oxychloride sulfate (COCS 50% WP; United Agri-Products, Inc., Greeley, Colo.) at 1,680.6 g on 26 April;

endosulfan (Thiodan 50% WP) at 1,120.4 g on 15 July; formetanate hydrochloride (Carzol 92% soluble powder [SP]; Nor-Am Chemical Company, Philadelphia, Pa.) at 966.3 g on 3 August; mancozeb (Manzate 75% dry flowable [DF]; E. I. Du Pont de Nemours & Company, Wilmington, Del.) at 3,361.2 g on 29 May; mancozeb + dinocap (Dikar 72% + 4.7% WP; Rohm and Haas Company, Philadelphia, Pa.) at 4033.4 + 263.3 g on 17 May; mevinphos (Phosdrin 4 EC) at 560.2 g on 3 August and. at 419.9 g on 17 August; and petroleum oil (SunSpray 6E; Sun Refining & Marketing Co., Philadelphia, Pa.) at 37.4 liters on 14 and 26 April.

In the Williamson orchard, the grower applied the following additional materials (at rates [AI]/ha) as concentrate sprays in complete orchard applications with an airblast sprayer at 1,285.5 liters/ha to control other pests: amitraz (Mitac 50% WP; Nor-Am Chemical Company, Philadelphia, Pa.) at 924.3 g on 25 July and (Mitac 1.5 EC) at 1,155.4 g on 30 June and 8 August; azinphosmethyl (Guthion 50% WP) at 1,078.4 g on 17 May; copper hydroxide (Kocide 50% WP; Griffin Ag Products Company, Inc., Valdosta, Ga.) at 3,081.1 g on 25 April; ferbam (Carbamate 76% WP; FMC Corporation, Philadelphia, Pa.) at 2,346.0 g on 30 June; hexakis (Vendex 4L; E. I. Du Pont de Nemours & Company, Wilmington, Del.) at 615.4 g on 30 June; mancozeb (Manzate 75% DF) at 2,312.0 g on 17 May; oxythioquinox (Morestan 25% WP; Mobay Chemical Corporation, Kansas City, Mo.) at 771.8 g on 17 May; and petroleum oil (SunSpray 6E) at 26.5 liters on 25 April. In addition, the following materials (at rates [AI]/ha) were applied as concentrate sprays in alternate row middle applications with an airblast sprayer at 1,285.5 liters/ha: endosulfan (Thiodan 50% WP) at 771.8 g on 21 and 29 July; ferbam (Carbamate 76% WP) at 2,346.0 g on 31 May; and formetanate hydrochloride (Carzol 92% SP) at 710.6 g on 31 May. Finally, the following materials (at rates [AI]/ha) were applied as concentrate sprays in alternate row middle applications with an airblast sprayer at 642.4 liters/ha: hexakis (Vendex 4L) at 309.2 g on 9 August and streptomycin (Agristrep 17% WP; Pennwalt Corporation, Philadelphia, Pa.) at 198.2 g on 19 and 23 May.

The first spray against first-generation mealybugs was applied on 25 May, immediately after petal fall. Continuous bark inspection to monitor egg hatch in the orchards indicated this to be the most appropriate date to contact the greatest number of emerging crawlers. On 5 June, the effectiveness of the single-spray treatments was evaluated by sampling 25 fruit and leaf clusters selected randomly from throughout the canopy of each treated tree and examining them in the laboratory for live crawlers. Samples also were collected from four unsprayed trees as a check. Also on 5 June, because it appeared that the majority of crawlers had emerged, the second application was made in the designated double-spray treatment plots after the samples had been collected. On 16 June, the sampling procedure was repeated to assess the effectiveness of all (single- versus double-spray) treatments. On 10–12 July, a final evaluation of the first-generation treatments was made by sampling 100 randomly selected fruits from each tree and dissecting the calyx of each fruit in the laboratory to check for any mealybugs that had survived the treatments. All of the first-generation treatment evaluations were made according to the actual number of sprays applied by the time of the respective sample dates; e.g., trees destined to be sprayed for the control of second-generation crawlers only were evaluated here as checks, etc. The first of the second-generation sprays in Wayne County was applied on 7 August, and a second spray followed on 14 August in the appropriate plots. All insecticides and application methods were the same as for the first-generation sprays. On 25–28 August, ≈1 wk before harvest, the effectiveness of all treatments was compared by sampling 100 randomly selected fruits from each tree and dissecting the calyx of each pear in the field to check for infestation by any motile stages that had survived the treatments.

The Marlboro orchard was divided into both single-tree plots for handgun spray tests and larger plots containing 9–12 trees in three rows for tests of insecticides applied with an airblast sprayer. Three replicates of single-tree plots were used to minimize the amount of fruit to be treated (and eventually destroyed) with one of the test insecticides not registered for use on pears, chlorpyrifos (Lorsban 50% WP). These trees received two applications at 227 g (AI)/379 liters, applied to runoff using a handgun sprayer, on 15 and 27 July. The other insecticides tested were applied in two applications using an airblast sprayer traveling at 4.0 km/h. Spray volume was 1,682.8 and 2,655.1 liters/ha on 15 and 27 July, respectively, and the rates (AI)/ha on these two dates were: carbaryl (Sevin 80% sprayable powder [SP]; Rhône-Poulenc AG Company, Research Triangle Park, N.C.) at 4,033.4 g and 6,554.3 g; and methyl parathion (Penncap-M 2FM) at 1,120.4 g and 1,593.1 g. The two airblast treatments and an untreated check were replicated three times in a randomized complete block design. On 17 July, the grower sprayed the remainder of the orchard with methyl parathion (Penncap-M 2FM) at 1,866.2 g (AI)/ha in a single application of 747.9 l/ha with an airblast sprayer traveling at 4.0 km/h. Other materials (at rates [AI]/ha) applied by the grower to the entire orchard using an airblast sprayer at 747.9 l/ha were: amitraz (Mitac 1.5 EC) at 945.3 g on 22 June, 8 July, and 16 August; azinphosmethyl (Guthion 50% WP) at 588.2 g on 26 April, 20 May, and 8

June; captan (Captan 50% WP; ICI Americas Inc., Wilmington, Del.) at 560.2 g on 17 July and 16 August; formetanate hydrochloride (Carzol 92% SP) at 1,030.7 g on 20 May; mancozeb (Manzate 200 dry flowable [DF]; E. I. Du Pont de Nemours & Company, Wilmington, Del.) at 3,782.0 g on 26 April, 8 June, and 8 July; oxythioquinox (Morestan 25% WP) at 1,260.5 g on 26 April; and phosmet (Imidan 50% WP) at 1,680.6 g on 16 August.

All the sprays in the Marlboro test plots were applied against the second-generation crawlers. The first of the double-spray applications was made on 15 July, 2 d after crawler activity was first observed in the tape traps. The second group of tape traps was set out in three trees per treatment for each insecticide tested: carbaryl, chlorpyrifos, and methyl parathion, plus the check. The grower made his single-spray application on 17 July. Crawler control was assessed on 26 July by randomly selecting 50 fruits per tree and dissecting the calyx of each fruit in the laboratory to check for any mealybugs that had survived the treatments. The second of the double-spray applications was made on 27 July, and a final fruit evaluation was made on 23 August, in the same manner as the first sample.

1990 Insecticide Spray Trials. In the Wayne County orchards, the respective growers made one or two applications of an insecticide against either the first or both generations of mealybug crawlers, using an airblast sprayer in large-plot sections of their orchard. The Williamson orchard, which was 3.0 ha in size, was divided approximately in half, and each half received either one or two sprays against each of the two generations of mealybug crawlers, except for a block of 12 trees (four in each of three rows) in one corner of each plot that did not receive the second-generation sprays, to evaluate the effects of treating only the first generation. One border row was designated as an untreated check. The Sodus orchard, which was 2.8 ha in size, was divided into a 2.0-ha plot which received one spray per generation and a 0.8-ha plot which received two sprays per generation, except for a single row of 27 trees on the dividing line of each plot which did not receive the second-generation sprays. A block of nine trees in one corner of the orchard served as an untreated check. Applications of methyl parathion (Penncap-M 2FM) were made in the Williamson orchard at 420.5 g (AI)/ha, applied at 702 liters/per ha; the Sodus orchard was sprayed with the same insecticide at 280.6 g (AI)/ha, applied at 937 liters/ha.

The following additional materials (at rates [AI]/ha) were applied as concentrate sprays with an airblast sprayer at 934.9 liters/ha by the grower to control other pests in the entire Sodus orchard: amitraz (Mitac 1.5 EC) at 630.2 g on 3 and 22 July and 7 and 20 August; copper oxychloride sulfate (COCS 50% WP) at 5,041.3 g on 19 April; endosulfan (Thiodan 50% WP) at 2,242.8 g on 22 July; esfenvalerate (Asana 0.66 EC) at 221.8 g on 8 and 11 June; oxythioquinox (Morestan 25% WP) at 980.6 g on 28 April; and petroleum oil (SunSpray 6E) at 37.4 liters on 19 April. In the Williamson orchard, the grower applied the following additional materials (at rates [AI]/ha) as concentrate sprays in complete orchard applications with an airblast sprayer at 1,285.5 liters/ha to control other pests: amitraz (Mitac 1.5 EC) at 1,156.0 g on 1 August; copper hydroxide (Kocide 50% WP) at 3,081.1 g on 19 April; permethrin (Ambush 2EC; ICI Americas, Wilmington, Del.) at 77.2 g on 1 August; and petroleum oil (SunSpray 6E) at 26.5 liters on 19 April. In addition, hexakis (Vendex 50% WP; E. I. Du Pont de Nemours & Company, Wilmington, Del.) at 615.4 g (AI)/ha was applied on 22 June as a concentrate spray in an alternate row middle application with an airblast sprayer at 1,285.5 liters/ha. The following materials (at rates AI/ha) were applied as concentrate sprays in complete orchard applications with an airblast sprayer at 642.4 liters/ha: azinphosmethyl (Guthion 50% WP) at 1,078.4 g on 27 April; endosulfan (Thiodan 50% WP) at 2,313.7 g on 24 July; ferbam (Carbamate 76% WP) at 2,346.0 g on 4 and 22 May and 1 June; and oxythioquinox (Morestan 25% WP) at 771.8 g on 27 April. Finally, hexakis (Vendex 4L) at 1,234.2 g (AI)/ha was applied on 15 June as a concentrate spray in an alternate row middle application with an airblast sprayer at 642.4 liters/ha.

The first spray against first-generation crawlers was applied as soon after the petal fall stage as the weather allowed, which was 9 May in Sodus and 22 May in Williamson. A second application in the designated plots, at the same respective rates as in the first application, followed on 1 June in Williamson (using alternate row middles, ARM) and 19 May in Sodus (as a complete orchard spray). The effectiveness of the first-generation treatments was evaluated on 4 June and 26 June by sampling 10 fruit clusters and 20 leaf terminals from throughout the canopy of each of five trees per plot on each date, and examining them in the laboratory for live crawlers. In the Williamson orchard, two additional ARM sprays of methyl parathion at 773.1 g (AI)/ha were applied using 642.4 liters/ha on 10 and 18 July for control of obliquebanded leafroller, *Choristoneura rosaceana* (Harris). The sprays against the second-generation crawlers were applied on 7 August in Sodus and 3 and 9 August in Williamson. On 20 August, approximately 1 wk before harvest, the effectiveness of all treatments was compared by sampling 100 randomly selected fruits from each of six trees per plot and dissecting the calyx of each pear in the field to check for infestation by any motile stages that had survived.

Table 1. Mean (SEM) mortality of Comstock mealybug crawlers in the calyx of infested pears after topical application of insecticides at recommended field rates

Insecticide	g (AI)/379 liters	n	% Dead[a,b]		% Dead or moribund[a,b]	
Chlorpyrifos 50WP	170	56	81.3a	(10.9)	100.0a	(0)
Methomyl 1.8L	102	32	72.0a	(7.9)	78.3b	(7.8)
Carbaryl 50WP	454	53	67.6a	(14.5)	77.6b	(10.0)
Methyl parathion 2FM	113	46	56.8ab	(8.8)	75.0bc	(2.9)
Mevinphos 4EC	113	60	36.0bc	(17.0)	48.0bcd	(18.6)
Azinphosmethyl 50WP	113	63	29.8bc	(11.6)	37.3cde	(11.7)
Phosmet 50WP	340	63	21.3bc	(4.0)	24.3def	(2.9)
Esfenvalerate 0.66EC	7	70	17.5cd	(6.5)	19.3def	(5.0)
Endosulfan 50WP	227	75	0.8d	(0.8)	3.5f	(2.1)
Check	—	65	12.3cd	(4.9)	15.0ef	(5.4)

[a] Means in the same column followed by the same letter are not significantly different (for both analyses: treatment df = 13, error df = 28. Percent dead: $F = 6.18$; % dead or moribund: $F = 7.13$, $P \leq 0.05$, least significant difference test [SAS Institute 1985]).
[b] Arcsine square-root transformation applied to percentages before analysis.

Statistical Analyses. All mortality, control, and infestation percentages were subjected to an arcsine square-root transformation before analysis. Infestation numbers from the preprocessing treatments were transformed by $\log_{10}(X + 1)$ before analysis. Mealybug numbers from the cluster and harvest evaluations, and from the Marlboro crawler catches, were transformed by square root $(X + 0.5)$ before analysis. Data from the preprocessing tests, cluster site infestations, and all harvest evaluations were compared with an analysis of variance (ANOVA) and mean separation using the least significant difference test (Proc ANOVA, SAS Institute 1985). Data from the laboratory bioassays and cluster evaluations were compared with an analysis of variance and least-squares means separation (Proc GLM, SAS Institute 1985), to compensate for the unbalanced nature of the data. All the above procedures used $P \leq 0.05$. The regression of insect fragments in puree was generated using SYSTAT (Wilkinson 1989).

Results

Laboratory Bioassays. The results of the contact toxicity evaluations are shown in Table 1. Despite virtual immersion in the pesticide solutions, the crawlers were difficult to kill, and the most commonly used organophosphate insecticides, azinphosmethyl and phosmet, as well as the pyrethroid esfenvalerate, were no more effective than the distilled water check. The most effective material in these tests was the organophosphate chlorpyrifos, which is not registered for postbloom use in pears, followed by the carbamates methomyl and carbaryl and the organophosphate methyl parathion.

Preprocessing Treatments. Results of the bath + brushing treatments of infested fruits are given in Table 2. All the procedures lowered the maximum number in the ranges of mealybug crawlers per fruit, but there were no statistical differences among the various treatments. However, the percentage reduction in number of crawlers per fruit was significantly higher in the insecticidal soap treatment than with the lye-peeling additive. A comparable reduction was not observed in the insecticidal soap + pyrethrum treatment, although the rate of soap used was the same in both. All the treatments reduced the percentage of pears infested with one or more crawlers from 100% to approximately half that

Table 2. Comstock mealybug crawlers infesting the surface of pears before and after bath + brushing preprocessing treatments

Treatment	Pretreatment[a,b] No. per fruit		Posttreatment No. per fruit[a]		Posttreatment % Reduction[b,c]		Posttreatment % Infested[c]	
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	SE	$\bar{x}$	SE
Insecticidal soap, 38°C	2.33a	1–13	0.87a	1–11	61.8a	2.9	47.7a	3.5
Lye peeling additive, 38°C	2.56a	1–19	1.40a	1–11	44.3b	6.6	58.7a	6.1
Insecticidal soap + pyrethrum, 38°C	2.60a	1–16	1.27a	1–11	52.2ab	5.0	53.0a	3.5
Water, 82°C	2.63a	1–19	1.27a	1–12	53.4ab	11.3	52.0a	6.6

Means in the same column followed by the same letter are not significantly different (For all analyses: treatment df = 5, error df = 6. Pretreatment: $F = 0.21$; posttreatment no. per fruit: $F = 1.25$; % reduction: $F = 2.27$; % infested: $F = 1.36$, $P \leq 0.05$, least significant difference test [SAS Institute 1985]).
[a] $\log_{10}(X + 1)$ transformation applied to numbers before analysis.
[b] Reduction in mean number per fruit.
[c] Arcsine square-root transformation applied to percentages before analysis.

Table 3. Results of extraneous analysis of processed pear purees made from batches with different proportions of clean and mealybug-infested fruits

% Infested pears	n[a]	Whole mealybugs			Insect fragments			Other contaminants
		No. infested[b]	$\bar{x}$	Range	No. infested[b]	$\bar{x}$	Range	
0	19	0	0	—	12	1.32	1– 7	1 hair, 1 moth scale, 1 feather barb, insect wing fragments
8	21	0	0	—	21	3.10	1– 8	None
25	20	5	1.40	1–2	20	9.10	2–20	2 hairs, 2 thrips, 1 mite, 1 psylla
50	20	3	1.33	1–2	20	17.95	1–35	None
75	20	7	1.29	1–2	20	27.15	17–47	5 thrips, 1 pomace fly
100	19	11	1.36	1–3	19	31.16	16–56	5 hairs, 1 thrips

[a] Numbers of 133-ml jars examined.
[b] Numbers of 133-ml jars infested.

amount, but none was significantly more effective than any other.

Some additional observations were made of the effect of these procedures on the fruits and insects. Pears subjected to the 82°C water bath had browned skins at the completion of the 3-min bath. During the brushing phase of the treatments, the pears tended to roll longitudinally so that the calyx end, where most of the crawlers were located, generally did not come into contact with the brushes. There was no discernible damage to the fruit surface after the pears were brushed. The crawlers remaining on pears subjected to the treatments containing soap appeared to have significantly less wax on their filaments than did those in the other treatments.

Puree Treatments. Results of the extraneous analysis procedure are given in Table 3 and Fig. 2. Whole mealybugs were present in the puree samples made from batches containing 25% or more infested fruits; however, in the two lowest infestation levels (0 and 8%), only insect fragments were found. In most cases, it was not possible to exclude mealybugs as a possible source of these fragments. Although the calyx and stem were removed from all the pears in the 0% infested batch, it is possible that some undetected mealybugs were present on the fruit surface and contributed to the mean value of 1.32 fragments per jar in this batch. However, at least some of the fragments could be identified with certainty as parts of other insects; e.g., pieces of neuropteran or thysanopteran wings. In the 0% infested batch, 12 of the 19 jars analyzed (63%) contained at least one insect fragment; in all the remaining batches, 100% of the jars were contaminated. The relationship between percentage fruits infested and insect fragments per jar is expressed in the regression line (Fig. 2). The r^2 indicates that percentage fruits infested with mealybug explains 75.3% of the total variation in the number of insect fragments per jar ($P \leq 0.0001$). Substitution into the regression equation of the 1988 industry-accepted standard of an 8% infestation rate (as determined by packinghouse inspection) results in a predicted value of 3.93 ± 1.94 ($\bar{x}$ ± SE) fragments per 133-ml jar.

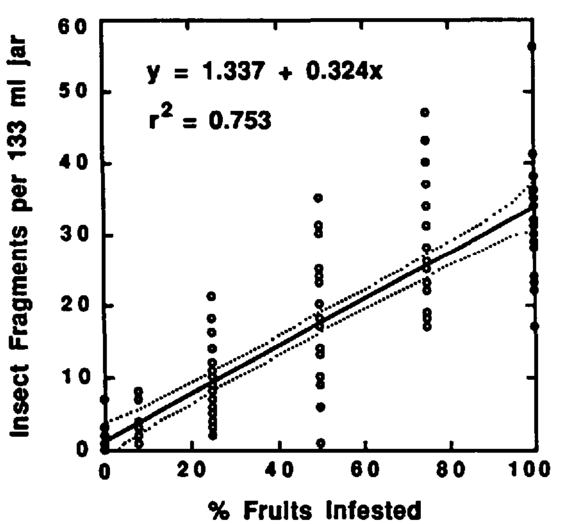

Fig. 2. Regression of number of insect fragments per jar as a function of percentage fruits infested based on extraneous analysis of pear purees conducted by commercial food processor quality control personnel. Dotted lines show the 95% CIs of the regression.

1989–1990 Field Development Studies. Initial inspection of the egg masses collected from beneath bark scales in early April during both years revealed, in some cases, one or two large, quiescent crawlers or adult females present with the eggs. These were assumed to have originated from the previous generation rather than from a very early hatch of the new generation. The progression of crawler emergence from the Wayne County egg mass samples in 1989 is shown in Fig. 3. Crawlers were first detected on 19 April in masses from the Sodus site and on 21 April from Williamson, although hatch continued throughout most of May. Of the 20 masses collected from the Williamson orchard on 18 May and examined in the laboratory, 11 contained unhatched eggs only, and the rest consisted of

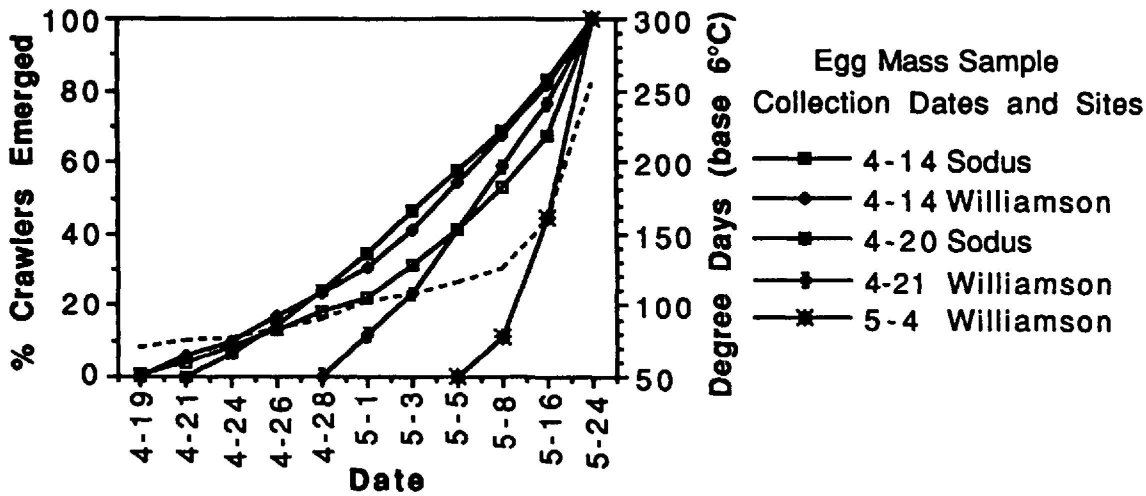

Fig. 3. Emergence of mealybug crawlers from eggs in five separate samples collected from beneath pear bark scales in Wayne County, N.Y., and held at ambient temperature at Geneva, N.Y., 1989. Dashed line indicates degree-days (base 6°C) accumulated from 1 January.

hatched eggs with few crawlers present. Most of the original egg masses collected had hatched by the time the trees reached the petal fall stage on 24 May, which corresponded with an accumulation of 250 degree-days (DD) (base 6°C) from 1 January. Of the flower bud samples examined for crawlers on three occasions after infestations were first observed in the orchard, the Williamson samples were 9, 4, and 1% infested on 4 (bud burst stage), 9 (early green cluster stage), and 15 May (late green cluster stage), respectively. None of the Sodus samples contained crawlers on any date. In the 1990 early-season inspections, crawlers were found in 24% of the flower buds collected on 3 May (petal fall stage) in each of the Wayne County orchards. Mean infestation rates were 1.94 crawlers per bud at Sodus and 0.52 per bud at Williamson. Of the mealybugs in the 20 egg masses collected on the same date, 97.5% were in the egg stage ($\bar{x}$, 25.3; SD, 15.6; range, 12–80; T, 506), and 2.5% were nymphs ($\bar{x}$, 0.7; SD, 1.2; range, 0–4; T, 13). Hatch seemed to be imminent because the red eyes of the nymphs were clearly visible inside the unhatched eggs. An unseasonably warm period during late April accounted for an accumulation of 176 DD (base 6°C) from 1 January by this phenological stage of development.

Field trapping results are given in Fig. 4. In 1989, the adult males first appeared in the Wayne County pheromone traps on 10 July, and peak catch was on 14 July at both sites. Adult females were observed laying second-brood eggs in bark crevices at Williamson on 18 July. Newly emerged crawlers were first captured on scaffold branches on double-sided tape traps on 31 July at Williamson, with peak emergence on 9 August. At the Sodus site, where the population was evidently much smaller, the first crawlers appeared on 11 August and continued to emerge at a low level until the end of August. In contrast to the Wayne County orchards, crawlers appeared much earlier at the Ulster County site, where the first catch occurred on 13 July. The Ulster County orchard is approximately 175 km farther south, so warmer temperatures could be expected to occur there earlier in the season, but a comparison of the heat unit accumulations at each site still reveals a difference in timing. At

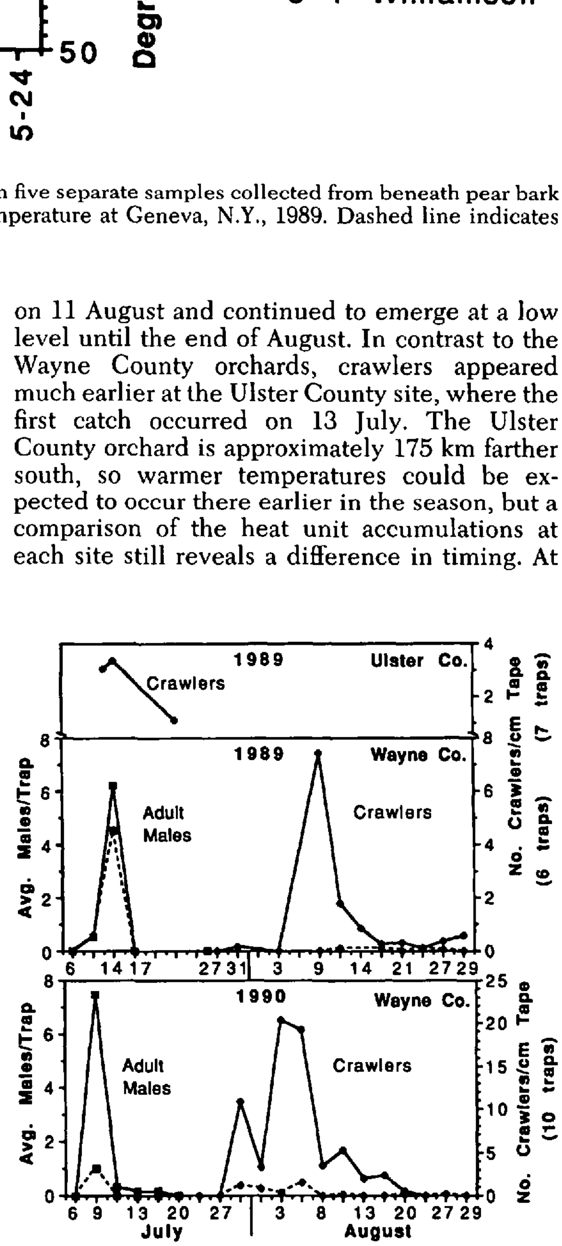

Fig. 4. Catches of adult males and crawlers in pheromone traps and tape traps, respectively, during two summer seasons in New York pear orchards. In the Wayne County graphs, solid lines represent the Williamson orchard, dotted lines the Sodus orchard.

Table 4. Effectiveness of various insecticide spray programs in controlling first-generation Comstock mealybug infestations in pears, Wayne County, 1989

Treatment	No. sprays	Cluster samples, 5 June: n	Cluster samples, 5 June: % Infested[a]	Cluster samples, 5 June: No./cluster[b]	Cluster samples, 16 June: % Infested[a]	Cluster samples, 16 June: No./cluster[b]	Fruit samples, 10 July: n	Fruit samples, 10 July: % Infested[a]	Fruit samples, 10 July: No./fruit[b]
Sodus									
Azinphosmethyl 35WP	1	100	6.0a	0.07a	2.0a	0.02a	400	0.75b	0.008a
Carbaryl 50WP	1	100	6.0a	0.06a	0a	0a	400	0.75b	0.005a
Diazinon 50WP	1	100	10.0a	0.10a	0a	0a	200	0a	0a
Diazinon 50WP	2	—	—	—	2.0a	0.02a	200	0a	0a
Methomyl 1.8L	1	150	7.3a	0.14a	2.0a	0.02a	400	1.00b	0.008a
Methomyl 1.8L	2	—	—	—	4.0a	0.04a	200	2.00b	0.010b
Methyl parathion 2FM	1	100	0a	0a	0a	0a	400	0a	0a
Check	0	350	6.6a	0.07a	4.3a	0.06a	1500	2.07b	0.010b
Williamson									
Azinphosmethyl 35WP	1	100	1.0a	0.01a	1.0bc	0.01ab	400	0.50ab	0.005ab
Carbaryl 50WP	1	100	1.0a	0.01a	0a	0a	400	0.25a	0.005ab
Diazinon 50WP	1	100	3.0a	0.03a	2.0bc	0.02abc	200	0a	0ab
Diazinon 50WP	2	—	—	—	0ab	0a	200	0.50ab	0.005abc
Methomyl 1.8L	1	150	10.7b	0.16b	5.0bc	0.06c	400	3.00c	0.020bc
Methomyl 1.8L	2	—	—	—	2.0bc	0.02abc	200	2.00bc	0.020abc
Methyl parathion 2FM	1	100	0a	0a	1.0bc	0.01ab	400	0a	0a
Check	0	350	3.7a	0.05a	4.6c	0.05c	1500	2.80c	0.030c

Means in the same column followed by the same letter are not significantly different (For 5 June: treatment df = 18, error df = 17. For Sodus, % infested: $F = 0.50$; no. per cluster: $F = 0.33$. For Williamson, % infested: $F = 2.22$; no. per cluster: $F = 1.59$. For 16 June: treatment df = 20, error df = 15. For Sodus, % infested: $F = 1.43$; no. per cluster: $F = 2.01$. For Williamson, % infested: $F = 1.28$; no. per cluster: $F = 1.94$. For 10 July: treatment df = 21, error df = 15. For Sodus, % infested: $F = 1.46$; no. per fruit: $F = 4.35$. For Williamson, $F = 4.05$; no. per fruit: $F = 3.61$, $P \leq 0.05$, least significant difference test [SAS Institute 1985]).

[a] Arcsine square-root transformation applied to infestation percentages before analysis.

[b] Square root ($X + 0.5$) transformation applied to infestation numbers before analysis.

Williamson, the first crawlers were caught at 1,196 DD (base 6°C) from 1 January; at the Ulster County site, the first catch was at 993 DD. Trap captures during the 1990 season in Wayne County were quite similar to those of the previous year. The adult male flight began and peaked on 9 July at both sites, then tapered off over the next 10 d. The first crawlers were caught in tape traps on 30 July, reaching a peak on 3 August and continuing at low levels for the remainder of the month.

1989 Insecticide Spray Trials. Tables 4 and 5 give the results of the summer inspections for first-generation crawlers infesting leaf and fruit clusters (June) and fruits (July) in the Wayne County orchards. Table 4 shows that the effects of the insecticide treatments varied somewhat among the different locations and sampling dates. Although there were few differences in infestation rates or numbers on 5 June, the single application of methomyl appeared to be distinctly less effective than other treatments in the Williamson orchard. Fruit inspections on 10 July indicate the best results against this generation of crawlers occurred with a single spray of methyl parathion or one or two sprays of diazinon, with single sprays of carbaryl and azinphosmethyl being comparable at Williamson only. When infested clusters across all treatments were classified according to the portion of each sample where the crawlers were found (Table 5), a significantly greater proportion of the infestations occurred on green tissue than on bark. In the fruit samples, the calyx was more frequently infested than the stem end at the Sodus site; this generalization would also apply at Williamson if the incidence of wax, produced by mealybugs in the calyx at some earlier time, were included as evidence of an infestation.

The effectiveness of treatments against the first, second, and both generations of crawlers, as determined by fruit infestation before harvest, is shown for all three orchards in Table 6. The population pressure was much greater in the Williamson orchard than it was at Sodus, which may have been responsible for some inconsistencies among treatments between the two locations. The only treatments that resulted in effective reductions of calyx infestation at both sites were two applications of diazinon or methomyl against the second generation of crawlers. Other treatments that were statistically just as effective, but at only one site, included one or two applications of methyl parathion, and single sprays (against either or both generations) of methomyl, carbaryl, and azinphosmethyl. Also, a number of anomalies were noted in the effectiveness of one versus two sprays of some materials; e.g., instances where carbaryl, methomyl, azinphosmethyl, or methyl parathion applied against both generations did not perform as well as respective sprays against the second generation alone. Even

Table 5. Sites and mean infestation rates of first-generation Comstock mealybug crawlers across all chemical control treatments in pear orchards, Wayne County, 1989

Sample type[a]	Sodus n	Sodus Site[b]	Sodus Infested[c]	Sodus No./site[d]	Williamson n	Williamson Site[b]	Williamson Infested[c]	Williamson No./site[d]
				5 June				
Leaf cluster	643	Green tissue	4.56a	0.56a	504	Green tissue	2.11a	0.37a
		Bark	0.44b	0.11b		Bark	0.89bc	0.13bc
Fruit cluster	257	Green tissue	1.00b	0.18b	396	Green tissue	0.89ab	0.22ab
		Bark	0.22b	0.11b		Bark	0c	0c
				16 June				
Leaf cluster	710	Green tissue	1.44a	0.31a	600	Green tissue	1.67a	0.38a
		Bark	0.44b	0.11b		Bark	0.22bc	0.03b
Fruit cluster	190	Green tissue	0.56b	0.09b	300	Green tissue	0.89ab	0.21a
		Bark	0b	0b		Bark	0c	0b
				10 July				
Fruit	3,700	Calyx	0.84a	0.43a	3,700	Calyx	0.84a	0.49a
		Stem end	0.19b	0.13b		Stem end	0.62a	0.41a
		Wax only (calyx)	0.19b	—		Wax only (calyx)	0.22a	—

Means in the same column followed by the same letter are not significantly different (For 5 June and 16 June: treatment df = 38, error df = 105; for Sodus, 5 June: % infested: $F = 2.54$; no. per site, $F = 2.90$; for Williamson, 5 June: % infested: $F = 2.37$; no. per site, $F = 2.56$; for Sodus, 16 June: % infested, $F = 2.22$; no. per site, $F = 2.32$; for Williamson, 16 June: % infested: $F = 1.36$; no. per site, $F = 1.38$. For 10 July: treatment df = 38, error df = 72; for Sodus, % infested: $F = 1.98$; no. per site, $F = 1.67$; for Williamson, % infested, $F = 2.23$; no. per site, $F = 2.01$; $P \leq 0.05$; least significant difference test [SAS Institute 1985]).

[a] Average number of fruit per fruit cluster, 1.0.

[b] Green tissue comprises leaves, leaf stems, and first-year shoot stems (without bark).

[c] Arcsine square-root transformation applied to infestation percentages before analysis.

[d] Square root (x + 0.5) transformation applied to infestation numbers before analysis.

the lowest infestations in the Williamson orchard were higher than commercially allowed tolerances for processing pears in 1988 and 1989, which ranged from 5 to 8%, depending upon the processor. Because at least one commercial food processor has used the proportion of fruit containing three or more crawlers as a criterion of acceptability, fruit from the Wayne County sites

Table 6. Preharvest calyx infestations of pears treated at various times with different insecticides to control Comstock mealybug, 1989

Treatment[a]	% Infested, Sodus, 28 August: Crawlers/fruit 1	2	3	4	5+	Total	% Infested, Williamson, 25 August: Crawlers/fruit 1	2	3	4	5+	Total	% Infested, Marlboro: 26 July	23 August
Azinphosmethyl 35WP (1,0)	9.5	3.0	2.5	0.0	1.0	16.0f	16.0	12.5	7.0	2.5	23.5	61.5fg	—	—
Azinphosmethyl 35WP (0,1)	7.0	2.0	0.5	0.0	0.5	10.0cdef	14.5	9.0	6.5	1.5	7.0	38.5cde	—	—
Azinphosmethyl 35WP (1,1)	3.0	0.5	0.0	0.0	0.5	4.0abcd	20.0	5.0	5.5	1.0	9.0	40.5cdef	—	—
Carbaryl 50WP (1,0)	6.0	3.0	1.0	0.5	1.0	11.5cdef	22.5	11.0	10.0	6.0	20.0	70.0g	—	—
Carbaryl 50WP (0,1)	2.0	0.5	0.0	0.0	0.5	3.0abc	12.5	6.0	4.5	1.5	1.5	26.0abc	—	—
Carbaryl 50WP (1,1)	6.0	1.5	0.5	0.0	1.0	9.0cdef	11.0	7.5	5.0	1.0	5.5	30.0bcd	—	—
Carbaryl 80SP (0,2)	—	—	—	—	—	—	—	—	—	—	—	—	50.7c	46.7cd
Chlorpyrifos 50WP (0,2)	—	—	—	—	—	—	—	—	—	—	—	—	0.7a	0.0a
Diazinon 50WP (2,0)	9.0	1.5	1.0	0.0	0.5	12.0def	16.5	12.0	7.0	6.0	15.5	57.0efg	—	—
Diazinon 50WP (0,2)	1.0	0.5	0.0	0.0	0.0	1.5ab	4.5	0.5	2.0	0.0	3.0	9.5a	—	—
Methomyl 1.8L (1,0)	6.0	1.0	0.5	0.0	1.5	9.0cdef	16.5	13.5	7.5	6.0	26.5	70.0g	—	—
Methomyl 1.8L (2,0)	7.0	0.5	0.0	0.0	1.5	9.0cdef	14.0	8.0	9.5	3.5	15.0	50.0defg		
Methomyl 1.8L (0,1)	4.5	0.5	0.0	0.0	1.5	6.5bcdef	8.0	3.5	3.5	1.5	4.0	20.5abc	—	—
Methomyl 1.8L (0,2)	1.0	0.0	0.0	0.0	1.0	2.0ab	7.5	2.0	2.5	0.0	4.0	16.0ab	—	—
Methomyl 1.8L (1,1)	3.5	3.5	1.5	1.0	1.0	10.5cdef	5.5	2.5	2.0	0.0	1.5	11.5ab	—	—
Methyl parathion 2FM (1,0)	2.5	1.0	0.5	0.0	0.5	4.5abcd	11.5	6.5	2.5	2.0	2.5	25.0abcd	—	—
Methyl parathion 2FM (0,1)	3.0	1.0	0.0	0.0	1.5	5.5bcde	17.5	6.5	6.5	1.0	7.0	38.5cde	—	26.0bc
Methyl parathion 2FM (1,1)	0.5	0.0	0.0	0.0	0.0	0.5a	13.0	8.0	5.5	4.5	2.0	33.0bcd	—	—
Methyl parathion 2FM (0,2)	—	—	—	—	—	—	—	—	—	—	—	—	11.3b	12.7b
Check (0,0)	8.3	1.8	0.8	1.0	2.3	13.7ef	17.8	14.8	10.0	7.0	25.5	76.7g	74.0c	66.0d

Means in the same column followed by the same letter are not significantly different (for Sodus and Williamson: treatment df = 17, error df = 16; for Sodus, $F = 3.18$; for Williamson, $F = 6.35$. For Marlboro: 26 July, treatment df = 3, error df = 8; $F = 28.18$; 23 August, treatment df = 4, error df = 10; $F = 17.83$; $P \leq 0.05$, least significant difference test [SAS Institute 1985]). Arcsine square-root transformation applied to infestation percentages before analysis.

[a] Sprays against first and second generations.

Table 7. Foliage and calyx infestations of pears treated with microencapsulated methyl parathion at various times to control Comstock mealybug, Wayne County, 1990

Generation treated (No. sprays)	Cluster samples[a]								Fruit samples, % Infested					
	4 June				26 June				20 August					
	Leaf		Fruit		Leaf		Fruit		Crawlers/fruit					Total[a]
	% Infested	No./cluster	% Infested	No./cluster	% Infested	No./cluster	% Infested	No./cluster	1	2	3	4	5+	
						Sodus								
1 (1)	0	0	0	0	0	0	0	0	1.7	0.5	0.2	0.0	0.0	2.3b
1 (2)	0	0	0	0	0	0	0	0	0.3	0.3	0.0	0.0	0.0	0.7ab
1 (1), 2 (1)	—	—	—	—	—	—	—	—	0.5	0.0	0.0	0.0	0.0	0.5a
1 (2), 2 (1)	—	—	—	—	—	—	—	—	0.2	0.0	0.0	0.0	0.0	0.2a
Check (0)	25.0	0.95	1.0	0.02	1.0	0.01	0	0	5.5	2.7	1.2	0.3	2.0	11.7c
						Williamson								
1 (1)	0	0	0	0	0	0	0	0	1.0	0.3	0.0	0.0	0.0	1.3a
1 (2)	0	0	0	0	0	0	0	0	0.7	0.5	0.0	0.0	0.0	1.2a
1 (1), 2 (1)	—	—	—	—	—	—	—	—	2.7	0.5	0.5	0.7	0.7	5.0b
1 (2), 2 (2)	—	—	—	—	—	—	—	—	1.8	0.7	0.0	0.0	0.0	2.5ab
Check (0)	8.0	0.41	0	0	5.0	0.05	1.0	0.01	8.0	7.2	5.2	4.5	60.2	85.5c

[a] Means followed by the same letter are not significantly different (treatment df = 4, error df = 25; $F = 18.24$, $P \leq 0.05$, least significant difference test [SAS Institute 1985]). Arcsine square-root transformation applied to infestation percentages before analysis.

were also classified according to number of crawlers per infested fruit (Table 6). Although higher infestation levels generally result in a greater incidence of multiple infestation, infested pears most often contain one or two crawlers, or else they contain five or more. Unlike the July samples, no fruits were seen at harvest with only the wax residue left from previous mealybug presence, although such cases are scored as "infested" by food processors.

Crawler catches in the Marlboro orchard were lowest ($\bar{x}$, 0.2/cm tape) in the chlorpyrifos plots and highest ($\bar{x}$, 4.2/cm tape) in the carbaryl plots. This was the only significant difference among the data ($F = 1.87$; treatment df = 3, error df = 20; $P \leq 0.05$, least significant difference test [SAS Institute 1985]). The catches in the methyl parathion and check plots averaged 2.9 and 1.1 crawlers/cm tape, respectively. The greatest reduction in fruit infestation in the Marlboro orchard resulted from two applications of chlorpyrifos against the second-generation crawlers. Although chlorpyrifos did exhibit considerable activity in the laboratory bioassays, at least some of this treatment's effectiveness in the field could be attributable to the fact that a handgun was used to apply this insecticide, a technique that would be expected to achieve much better spray coverage. The next best treatment, two applications of methyl parathion, was similar in effectiveness to the best of the commercially available products tested in the Williamson orchard, which had a comparable check population.

1990 Insecticide Spray Trials. Results of all the treatment evaluations are given in Table 7. Examination of leaf and fruit clusters on 4 and 26 June yielded similar trends on both occasions; no crawlers were found in any of the insecticide treatments at either site, and check populations were moderate. Fruit evaluation just before harvest indicated little difference in the treatments, all of which appeared to control effectively crawler infestations below currently accepted industry thresholds. At the Sodus site, infestation levels tended to decrease as the number of sprays increased. In the Williamson orchard, all the treatments reduced fruit infestation to low levels despite high population pressure, although the trees that received one spray per generation unaccountably had the highest level of crawlers. Although this orchard did receive the equivalent of three full spray applications, the extra one occurred immediately after the male flight peak. At this time, no immatures would have been present, and the adult females should have been relatively sheltered in bark crevices where oviposition occurs, so insecticidal mortality of the subsequent generation of crawlers should have been minimal. As in the previous year, the number of crawlers per fruit increased with infestation rate, so at the low numbers seen in these treatments, the majority of pears contained only one or two crawlers apiece.

Discussion

Although Comstock mealybug has been a recognized problem in New York pears only during the past few years, its documented occurrence years ago in other tree fruit crops of the region suggests that low populations have probably infested commercial orchards for a number of years but have escaped detection. Older recommendations for apple pest control in New York suggest that organophosphate insecticides, such as azinphosmethyl and phosmet, were once capable of controlling this insect, and their current inability to do so implies a tolerance or resistance to these materials in the populations now found in pear orchards. It is not clear whether mealybug populations have actually become more numerous in recent years, or if they have simply been noticed more frequently because of altered inspection and handling procedures used by commercial food processors.

Although each of the preprocessing bath + brushing treatments tested caused a considerable reduction in the number of fruits exhibiting surface crawler infestations as well as in the number of crawlers remaining on the skin of infested pears, it is doubtful whether removing roughly half of the insects would sufficiently remedy the nuisance they pose to fruit handlers. Furthermore, these procedures were not intended to address the problem of crawlers remaining inside the calyx, which could still contaminate the finished product, even if they had been killed by the baths. Results of the puree trials reveal the potential presence of insect fragments in pear puree made from even clean or marginally infested fruits. The low fragment numbers, and complete absence of whole mealybugs, in puree made from fruit conforming to industry infestation standards, would seem to argue for continued adherence to these thresholds (i.e., 8% infested, or 5% with three or more crawlers). However, in light of the potential economic and environmental costs of increased pesticide use in a crop that is only marginally profitable, a more detailed evaluation should be conducted to determine the fruit infestation rate at which a true defect action level for contaminants is reached in the finished product.

It is evident that the insecticides and spray schedules normally used by commercial pear growers are not adequate for preventing mealybug infestations that can cause a downgrading of their crops. The laboratory bioassays and field trials conducted here indicate considerable effectiveness against mealybugs of materials that are not used frequently in pears, particularly the carbamates such as methomyl, and nonconventional organophosphates such as chlorpyrifos and microencapsulated methyl parathion. However, the major constraint to effective control of the crawlers remains their inaccessibility to chemical sprays while in the calyx. Fortunately, the timing of control measures to coincide with crawler emergence, as monitored with tape traps, seems to be a workable strategy. The first-generation crawlers are present in low numbers before the bloom period, and hatch and emergence are apparently not complete until the petal fall stage, at which time most growers routinely apply a protective insecticide spray. The time of peak emergence for the second generation of crawlers appears to be a more variable event in New York, depending on orchard location; however, tape traps monitored regularly in a few trees can provide a reliable indication of crawler activity for a general region, and insecticide sprays based on these catches represent a suitable control strategy for the time being. In the future, it may be possible to establish a true treatment threshold by correlating trap catch numbers with fruit infestation levels, but no attempt has yet been made to gather this type of information.

According to the cluster evaluations made in June and July, crawlers are found infesting leaf clusters first, then gradually become more prevalent in fruit clusters. The higher frequency of occurrence on green tissue than on bark is consistent with their reported feeding preferences (Glass 1944, McKenzie 1967, Johnson & Lyon 1988). Once the insects actually reach the developing fruit, the protected calyx area is more likely to be infested, although some mealybugs can also be found around the stem axil when populations are high. This may be a consequence of less pesticide deposition in these sites, although adult females appear to seek the more protected areas for oviposition; however, we did not make life stage assessments of the mealybugs found in fruit at harvest.

The results of this study indicate that the effectiveness of control strategies is influenced by infestation levels of this pest, as well as by the history of control efforts in a given orchard. Although 1989 fruit infestation levels were within industry standards in a number of the Sodus plots, virtually none qualified at the Williamson location. In 1990, however, all treatment strategies produced acceptable fruit at both locations, despite check populations at least as large as those during the previous year. Some practical implications of these results may be that, in orchards that have never received directed control measures for Comstock mealybug, populations as high as those at Williamson will require more than two sprays to reduce infestations to commercially acceptable levels. However, once a seasonal program has been started, it may well be possible to cut back these measures to one well-timed application of a suitable insecticide against each generation of crawlers. Control of the second generation appears to be more crucial to fruit quality at harvest than are efforts directed against the first generation. Two sprays on a 7–10-d interval would be recommended to contact a majority of the emerging crawlers. These guidelines, which have been incorporated into the tree–fruit pest management recommendations for New York (Stiles et al. 1991), should be suitable at least as long as resistance to the identified products does not develop in local populations. However, for a long-term solution, the initial cause of this pest's outbreak after an apparent history as a noneconomic orchard resident may ultimately need to be investigated.

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