# Pest Management Before Harvest and Insecticidal Dip After Harvest as a Systems Approach to Quarantine Security for Red Ginger

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**ABSTRACT** A systems approach consisting of insecticide application before harvest and use of an insecticidal dip after harvest provided quarantine security that eliminated all insect pests of red ginger, *Alpinia purpurata* (Vieill.) K. Schum., including the banana aphid, *Pentalonia nigronervosa* Coquerel; cotton aphid, *Aphis gossypii* Glover; citrus mealybug, *Planococcus citri* (Risso); obscure mealybug, *Pseudococcus affinis* (Maskell); longtailed mealybug, *Pseudococcus longispinus* (Targioni-Tozzetti); cardamom thrips, *Sciothrips cardamomi* (Ramakr); black earwig, *Chelisoches morio* (F.); and an ant, *Technomyrmex albipes* (F. Smith). Insecticide application consisted of chlorpyrifos 50 dry flowable (DF) applied to the foliage at 2-wk intervals, or chlorpyrifos 20 microencapsulated (MEC) applied as an insecticide barrier treatment. A 5-min dip with a combination of fluvalinate 2.0 flowable (F) and insecticidal soap (potassium salts of fatty acids) with agitation after harvest killed any remaining survivors as long as field populations had <6% mealybug infestation, <33% banana aphid infestation, and <70% cotton aphid infestation. These procedures plus a final inspection of flowers for live insects ensured pest-free ginger flowers that met quarantine security requirements.

**KEY WORDS** red ginger pests, systems approach, quarantine security

RED GINGER, *Alpinia purpurata* (Vieill.) K. Schum., is known for its long shelf life and exotic appearance in floral arrangements. The demand for red ginger in the world market has steadily increased Hawaiian export sales by an average of 28.7% annually since 1985 (Hawaii Agricultural Statistics Service 1990). Unfortunately, red ginger is a host for various quarantine pests (Hansen et al. 1991a, in press). Because of quarantines established by various states, the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), and foreign countries, Hawaiian red ginger shipments are commonly rejected because of insect infestations. Several pests identified in our study are not quarantine pests; however, because of the difficulty in identifying morphologically similar species, shipments are sometimes rejected.

Flower shippers currently disinfest flowers by opening each flower bract while the flower is submerged in a chemical insecticide or soap solution (Hata & Hara in press). This method is expensive and results in constant exposure of packers to insecticides and mechanical injury to flowers (Hata & Hara in press). Treatments after harvest such as vapor heat, hydrogen cyanide fumigation, methyl bromide fumigation, and irradiation are not acceptable for various reasons including inability of the treatment to control mixed insect infestations, phytotoxicity, lack of treatment facilities, and lack of U.S. Environmental Protection Agency registration (Hansen et al. 1991a, b, in press). In addition, treatments after harvest cannot reduce insect feeding or oviposition before harvest; therefore, field pest management is essential for management of quarantine pests of red ginger such as mealybugs and cardamom thrips (Tsuda & Hara 1990).

A systems approach of crop pest management before harvest, culling after harvest, and final product inspection has been successful against several quarantine pests on various fruit crops (Moffitt 1989, Jang & Moffitt in press). This approach to quarantine security unifies pest management practices and treatments both before and after treatment into a unified system. Treatments or management procedures that are not

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effective alone can therefore meet quarantine security.

Insecticides and insecticidal dips have been successful in reducing pests on red ginger, but unsuccessful in total eradication of pests (Hata & Hara 1988b; Tenbrink et al. 1990, 1991a; Hansen et al. 1992). Hata & Hara (1988b, in press) showed that several insecticides significantly reduced the green scale, *Coccus viridis* (Green), and the banana aphid, *Pentalonia nigronervosa* Coquerel, in the field when insecticide was applied at 2-wk intervals. Tenbrink et al. (1990, 1991b) demonstrated that fluvalinate or insecticidal soap (potassium salts of fatty acids) was not phytotoxic and was effective against banana aphids as a dip after harvest. Tenbrink et al. (1991a) also demonstrated that a combination of fluvalinate and insecticidal soap applied as a dip after harvest was more effective against mealybugs than either alone. However, Tenbrink et al. (1991a) could not achieve total mortality of mealybugs with the combination dip; this level of effectiveness is desired for quarantine security.

The objective of our study was to evaluate a systems approach to quarantine security including (1) a program of insecticide application before harvest, (2) a dip with fluvalinate and insecticidal soap after harvest, and (3) a final inspection of flowers.

## Materials and Methods

Experimental plots were established at the University of Hawaii, Waiakea Agricultural Experiment Station in Hilo, HI (elevation 183 m), on 1 May 1991. Treatment plots were arranged in a complete randomized experimental design with four replicates. Each replicate contained 10 plots with ≈75 plant stalks per plot. Plots (1.8 by 1.8 m) were separated by a 2.4-m walkway. Selected insecticides were applied at the following rates: chlorpyrifos 50 dry flowable (DF) (Pageant, DowElanco, Indianapolis, IN) at 0.6 g (AI)/liter, and chlorpyrifos 20 microencapsulated (MEC) (Empire, DowElanco) at 0.6 g (AI)/liter. The insecticidal dip after harvest consisted of fluvalinate 2.0 flowable (F) (Mavrik Aquaflow, Sandoz Crop Protection, Des Plaines, IL) at 0.1 g (AI)/liter, combined with insecticidal soap (Safer Insecticidal Soap Concentrate, Safer, Newton, MA) at 9.6 ml (AI)/liter by volume.

Evaluation 1 was taken before insecticide application. Evaluations 2–4 were insecticide applications before harvest. Evaluations 5–7 were insecticide application before harvest, insecticide application after harvest and a combination of insecticide treatment before and after harvest.

**Treatment Before Harvest.** Insecticide sprays were applied to runoff with a compressed air sprayer with a 8004 Teejet nozzle (Spraying systems, Wheaton, IL) at 276 KPa. Chlorpyrifos 50 DF was applied as a foliar spray at ≈347 liters/ha to the entire plant, especially the flowers. Chlorpyrifos 20 MEC was applied as an insecticide barrier treatment at a rate of ≈628 liters/ha between the ginger stalks and within a 0.6-m radius around the plant with the same equipment as foliar applications. A spreader-sticker, Triton B-1956 (Rohm and Haas, Philadelphia, PA), was added at a rate of 0.23 ml/liter solution to all treatments, including the control plots. Insecticides were applied on 15 May 1991 and continued at 2-wk intervals for a total of six applications.

In accordance with commercial standards, flowers were harvested weekly at ⅓ to ½ maturity and stripped of all leaves except the terminal leaf. Treatment efficacy was evaluated by dissecting the flower bracts and terminal leaf sheath and observing for the banana aphid, *P. nigronervosa*; cotton aphid, *Aphis gossypii* Glover; citrus mealybug, *Planococcus citri* (Risso); obscure mealybug, *Pseudococcus affinis* (Maskell); long-tailed mealybug, *Pseudococcus longispinus* (Targioni-Tozzetti); cardamom thrips, *Sciothrips cardamomi* (Ramakr); black earwig, *Chelisoches morio* (F.); and an ant, *Technomyrmex albipes* (F. Smith), with the aid of a binocular dissecting microscope. The criterion for insect mortality for all insects was no movement. Mealybugs, which are sedentary, were turned over and their legs observed for movement.

Data before treatment (evaluation 1) were taken on 6 May 1991. Data were taken every 2 wk thereafter alternating with insecticide applications. Flowers harvested during the weeks of insecticide applications were removed from the field and were not included in the evaluation.

**Insecticidal Dip Only.** The dip-only treatment was tested with control flowers from the last three insecticide applications. Control flowers harvested from the field were divided into two groups. Half the flowers were dipped in water (control) and the other half were dipped in the insecticidal dip. Flowers were dipped floral end first into a 20-liter bucket. Flowers in evaluations 5 and 6 were gently agitated 10 times in an up-and-down motion, then left undisturbed in the solution for 5 min. Flowers treated in evaluation 7 were agitated 10 times, left undisturbed for 5 min, then agitated an additional 10 times before removal (total of 20 strokes). Twenty-four to 48 h after dipping, efficacy was evaluated by the same criteria as for treatments before harvest.

**Insecticides Before Harvest and Insecticidal Dip After Harvest.** Flowers harvested from plots treated with chlorpyrifos 50 DF or chlorpyrifos 20 MEC were divided into two groups. Half the flowers were dipped in water (control for treatment after harvest); the other half was dipped in the insecticide combination after harvest. Dipping procedures and evaluation methods were identical to those for the insecticidal dip procedure done after harvest.

Table 1. Mean percentage of flowers infested with various insect pests after pest management with insecticides before harvest

| Treatment[a] | n[b] | (AI) g/l | Banana aphids | Cotton aphids | Ants | Mealybugs | Thrips adults | Thrips nymphs | Earwigs |
|---|---|---|---|---|---|---|---|---|---|
| Evaluation 1[c] (pretreatment) | | | | | | | | | |
| Chlorpyrifos foliar[d] | 60 | 0.6 | 39.3a ± 8.0[g] | 38.8a ± 9.8 | 52.5a ± 6.8 | 41.0a ± 17.0 | 44.0a ± 11.4 | 26.8a ± 11.1 | 25.0a ± 3.1 |
| Chlorpyrifos barrier[e] | 58 | 0.6 | 38.0a ± 5.5 | 41.3a ± 12.7 | 38.0a ± 10.3 | 59.0a ± 9.4 | 50.8a ± 4.6 | 32.3a ± 8.8 | 22.0a ± 9.6 |
| Control[f] | 62 | — | 52.8a ± 10.4 | 47.5a ± 10.4 | 59.8a ± 11.0 | 55.0a ± 7.2 | 35.3a ± 4.8 | 30.0a ± 5.7 | 28.5a ± 7.8 |
| Evaluation 2 | | | | | | | | | |
| Chlorpyrifos foliar | 68 | 0.6 | 11.8b** ± 5.6 | 21.0b** ± 5.0 | 2.8c** ± 1.6 | 18.3b* ± 6.2 | 5.3b** ± 3.1 | 2.8b** ± 1.6 | 1.3a ± 1.3 |
| Chlorpyrifos barrier | 81 | 0.6 | 60.8a ± 3.1 | 69.0a ± 3.7 | 17.8b ± 4.8 | 58.5a ± 5.7 | 51.5a ± 5.6 | 37.0a ± 7.2 | 4.8a ± 1.8 |
| Control | 84 | — | 72.3a ± 5.1 | 48.3a ± 7.0 | 65.8a ± 1.8 | 53.5a ± 7.6 | 38.8a ± 9.2 | 45.3a ± 8.6 | 10.3a ± 5.9 |
| Evaluation 3 | | | | | | | | | |
| Chlorpyrifos foliar | 62 | 0.6 | 13.8c** ± 6.1 | 34.8a ± 14.1 | 4.7b** ± 2.9 | 7.5b** ± 4.5 | 6.0b** ± 4.2 | 1.5b** ± 1.5 | 0.0b* ± 0.0 |
| Chlorpyrifos barrier | 72 | 0.6 | 45.6b ± 3.4 | 72.9a ± 12.1 | 2.8b ± 1.6 | 35.3a ± 8.0 | 58.2a ± 5.3 | 30.7a ± 0.7 | 2.8ab ± 1.6 |
| Control | 74 | — | 71.8a ± 5.2 | 83.8a ± 6.6 | 68.8a ± 6.2 | 41.6a ± 3.0 | 41.8a ± 4.0 | 21.8a ± 7.7 | 6.8a ± 1.4 |
| Evaluation 4 | | | | | | | | | |
| Chlorpyrifos foliar | 54 | 0.6 | 4.3b* ± 2.8 | 36.5a ± 6.5 | 4.3b** ± 2.7 | 6.3b** ± 4.5 | 10.5b** ± 4.8 | 6.3a ± 2.9 | 5.0a ± 3.3 |
| Chlorpyrifos barrier | 68 | 0.6 | 20.0ab ± 5.2 | 53.3a ± 7.0 | 0.0b ± 0.0 | 4.3b ± 2.7 | 15.8b ± 3.5 | 6.3a ± 2.3 | 0.0a ± 0.0 |
| Control | 54 | — | 50.3a ± 13.0 | 60.3a ± 4.7 | 52.3a ± 3.3 | 24.0a ± 2.1 | 44.3a ± 4.6 | 11.2a ± 2.7 | 8.0a ± 3.1 |
| Evaluation 5 | | | | | | | | | |
| Chlorpyrifos foliar | 33 | 0.6 | 10.8b* ± 6.4 | 54.0a ± 19.2 | 0.0b* ± 0.0 | 3.3a ± 3.3 | 0.0b** ± 0.0 | 3.3a ± 3.3 | 0.0a ± 0.0 |
| Chlorpyrifos barrier | 34 | 0.6 | 8.8b ± 5.9 | 84.6a ± 3.6 | 3.3ab ± 3.3 | 2.5a ± 2.5 | 7.5b ± 4.4 | 2.5a ± 2.5 | 0.0a ± 0.0 |
| Control | 27 | — | 60.6a ± 20.5 | 83.3a ± 11.8 | 19.3a ± 4.8 | 12.1a ± 4.1 | 58.9a ± 8.9 | 8.5a ± 4.9 | 3.3a ± 3.3 |
| Evaluation 6 | | | | | | | | | |
| Chlorpyrifos foliar | 25 | 0.6 | 16.1a ± 10.5 | 69.6ab* ± 11.3 | 2.8a ± 2.8 | 6.3a ± 6.3 | 8.6b* ± 5.1 | 0.0a ± 0.0 | 0.0a ± 0.0 |
| Chlorpyrifos barrier | 30 | 0.6 | 33.2a ± 6.2 | 93.9a ± 3.6 | 0.0a ± 0.0 | 0.0a ± 0.0 | 22.5ab ± 4.0 | 9.7a ± 3.4 | 0.0a ± 0.0 |
| Control | 25 | — | 57.0a ± 17.1 | 45.5b ± 8.8 | 24.1a ± 14.7 | 19.9a ± 10.7 | 47.6a ± 13.8 | 16.8a ± 11.8 | 4.3a ± 4.3 |
| Evaluation 7 | | | | | | | | | |
| Chlorpyrifos foliar | 38 | 0.6 | 12.9b** ± 7.6 | 79.9ab* ± 3.8 | 18.6a ± 7.6 | 1.8b* ± 1.8 | 41.5ab** ± 5.2 | 0.0b** ± 0.0 | 3.1a ± 3.1 |
| Chlorpyrifos barrier | 37 | 0.6 | 27.2b ± 3.2 | 95.7a ± 2.5 | 16.4a ± 7.3 | 3.6b ± 3.6 | 10.7b ± 10.7 | 5.9b ± 3.5 | 0.0a ± 0.0 |
| Control | 40 | — | 62.6a ± 10.1 | 73.1b ± 9.2 | 7.1a ± 2.5 | 29.9a ± 8.0 | 77.3a ± 6.1 | 44.3a ± 5.8 | 4.3a ± 2.5 |

Percentages subject to ANOVA (*, **, $P < 0.05$, $P < 0.01$, respectively). Means followed by the same letter in a column are not significantly different by Scheffe's multiple-comparison procedure (SAS Institute 1987).

[a] Spreader-sticker (Triton B-1956) added to treatments before harvest at 0.23 ml/liter. Flowers in evaluations 5, 6, and 7 were dipped in water.

[b] Total flowers harvested.

[c] Evaluations at 2-wk intervals alternating with insecticide applications.

[d] Chlorpyrifos 50 DF at 0.6 g (AI)/liter at 2-wk intervals as a foliar treatment.

[e] Chlorpyrifos 20 MEC at 0.6 g (AI)/liter at 2-wk intervals as a barrier treatment.

[f] Control plots sprayed with water.

[g] SEM for means of percentages.

Table 2. Treatments and probability of significance for mean percentage of flowers infested with insect pests after insecticide applications before harvest for evaluations 2–7

| Pest | Treatment | df | $F$ | $P$ |
|---|---|---|---|---|
| Evaluation 2 | | | | |
| Banana aphid | Chlorpyrifos DF (foliar) | 2 | 50.63 | 0.0002 |
| Cotton aphid | Chlorpyrifos DF (foliar) | 2 | 16.20 | 0.0038 |
| Ant | Chlorpyrifos DF (foliar) | 2 | 217.81 | 0.0001 |
| Ant | Chlorpyrifos 20 MEC (barrier) | 2 | 217.81 | 0.0001 |
| Mealybug | Chlorpyrifos DF (foliar) | 2 | 8.99 | 0.0157 |
| Thrips (adult) | Chlorpyrifos DF (foliar) | 2 | 30.47 | 0.0007 |
| Thrips (nymph) | Chlorpyrifos DF (foliar) | 2 | 11.58 | 0.0087 |
| Evaluation 3 | | | | |
| Banana aphid | Chlorpyrifos DF (foliar) | 2 | 30.58 | 0.0007 |
| Banana aphid | Chlorpyrifos 20 MEC (barrier) | 2 | 30.58 | 0.0007 |
| Ant | Chlorpyrifos DF (foliar) | 2 | 160.62 | 0.0001 |
| Ant | Chlorpyrifos 20 MEC (barrier) | 2 | 160.62 | 0.0001 |
| Mealybug | Chlorpyrifos DF (foliar) | 2 | 13.08 | 0.0065 |
| Thrips (adult) | Chlorpyrifos DF (foliar) | 2 | 27.13 | 0.0010 |
| Thrips (nymph) | Chlorpyrifos DF (foliar) | 2 | 12.10 | 0.0078 |
| Earwig | Chlorpyrifos DF (foliar) | 2 | 5.95 | 0.0377 |
| Evaluation 4 | | | | |
| Banana aphid | Chlorpyrifos DF (foliar) | 2 | 6.51 | 0.0314 |
| Ant | Chlorpyrifos DF (foliar) | 2 | 110.73 | 0.0001 |
| Ant | Chlorpyrifos 20 MEC (barrier) | 2 | 110.73 | 0.0001 |
| Mealybug | Chlorpyrifos DF (foliar) | 2 | 13.06 | 0.0065 |
| Mealybug | Chlorpyrifos 20 MEC (barrier) | 2 | 13.06 | 0.0065 |
| Thrips (adult) | Chlorpyrifos DF (foliar) | 2 | 15.20 | 0.0045 |
| Thrips (nymph) | Chlorpyrifos 20 MEC (barrier) | 2 | 15.20 | 0.0045 |
| Evaluation 5 | | | | |
| Banana aphid | Chlorpyrifos DF (foliar) | 2 | 8.48 | 0.0178 |
| Banana aphid | Chlorpyrifos 20 MEC (barrier) | 2 | 8.48 | 0.0178 |
| Ant | Chlorpyrifos DF (foliar) | 2 | 7.87 | 0.0210 |
| Thrips (adult) | Chlorpyrifos DF (foliar) | 2 | 25.43 | 0.0012 |
| Thrips (adult) | Chlorpyrifos 20 MEC (barrier) | 2 | 25.43 | 0.0012 |
| Evaluation 6 | | | | |
| Thrips (adult) | Chlorpyrifos DF (foliar) | 2 | 5.44 | 0.0448 |
| Evaluation 7 | | | | |
| Banana aphid | Chlorpyrifos DF (foliar) | 2 | 13.76 | 0.0057 |
| Banana aphid | Chlorpyrifos 20 MEC (barrier) | 2 | 13.76 | 0.0057 |
| Mealybug | Chlorpyrifos DF (foliar) | 2 | 8.07 | 0.0199 |
| Mealybug | Chlorpyrifos 20 MEC (barrier) | 2 | 8.07 | 0.0199 |
| Thrips (adult) | Chlorpyrifos 20 MEC (barrier) | 2 | 13.99 | 0.0055 |
| Thrips (nymph) | Chlorpyrifos DF (foliar) | 2 | 55.67 | 0.0001 |
| Thrips (nymph) | Chlorpyrifos 20 MEC (barrier) | 2 | 55.67 | 0.0001 |

**Data Analysis.** Because of low populations, the three species of mealybugs were pooled for analysis. The percentage of infested flowers and means for the number of insects per flower were subjected to analysis of variance (ANOVA). Means were separated by Scheffe's multiple-comparison procedure. Percentages were analyzed because the number of flowers harvested varied among plots and to evaluate our ability to meet quarantine security. A flower was considered infested if a single live insect was found. The means and standard deviations for the mean number of insects per flower and the standard error for the mean percentage of flowers infested were also calculated. All analyses were done with software for personal computers (SAS Institute 1987).

## Results and Discussion

The mean percentage of flowers infested with various insect pests among treatments before insecticide applications did not vary significantly (Table 1).

**Insecticides Only Applied Before Harvest.** Foliar or barrier treatments of chlorpyrifos significantly reduced the mean percentage of flowers infested with banana aphids, cotton aphids, ants, mealybugs, thrips, and earwigs compared with the control in one or more evaluations, but never eradicated (Tables 1 and 2). Foliar treatment with chlorpyrifos 50 DF reduced the mean percentage of flowers infested with adult or nymphal stages of thrips in evaluations 2 through 7, and was more effective than the barrier treatment of chlorpyrifos 20 MEC (Tables 1 and 2). Similarly, the mean percentage of flowers with banana aphids was significantly reduced in evaluations 2–7 with foliar treatment except in evaluation 6. This treatment provided more reduction than the barrier treatment (Tables 1 and 2). Numbers of flowers infested with ants were similarly reduced in foliar and barrier treatments in all evaluations except in evaluation 2, where the

**Table 3. Mean percentage of flowers infested with various insect pests after pest management with insecticides before harvest and a dip after harvest with fluvalinate and insecticidal soap**

| Treatment[a] | n[b] | Banana aphids | Cotton aphids | Ants | Mealybugs | Thrips adults | Thrips nymphs | Earwigs |
|---|---|---|---|---|---|---|---|---|
| Evaluation 5 | | | | | | | | |
| Chlorpyrifos foliar and dip[c] | 33 | 0.0 ± 0.0[f] | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Chlorpyrifos barrier and dip[d] | 32 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Dip after harvest only[e] | 27 | 6.3 ± 3.6 | 3.1 ± 3.1 | 0.0 ± 0.0 | 16.8 ± 11.8 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Evaluation 6 | | | | | | | | |
| Chlorpyrifos foliar and dip | 26 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Chlorpyrifos barrier and dip | 30 | 0.0 ± 0.0 | 7.2 ± 7.2 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Dip after harvest only | 24 | 3.1 ± 3.1 | 0.0 ± 0.0 | 0.0 ± 0.0 | 3.1 ± 3.1 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Evaluation 7 | | | | | | | | |
| Chlorpyrifos foliar and dip | 40 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Chlorpyrifos barrier and dip | 38 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Dip after harvest only | 39 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 3.9 ± 3.9 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |

[a] Spreader-sticker (Triton B-1956) added to treatments before harvest at 0.23 ml/liter.
[b] Total flowers harvested.
[c] Chlorpyrifos 50 DF at 0.6 g (AI)/liter at 2-wk intervals as a foliar treatment and insecticidal dip consisting of fluvalinate 2.0 F at 0.1 g (AI)/liter in combination with insecticidal soap at 9.6 ml (AI)/liter by volume.
[d] Chlorpyrifos 20 MEC at 0.6 g (AI)/liter at 2-wk intervals as a barrier treatment and insecticidal dip consisting of fluvalinate in combination with insecticidal soap at above rates.
[e] Control plots sprayed with water and insecticidal dip consisting of fluvalinate in combination with insecticidal soap at above rates.
[f] SEM for means of percentages.

foliar treatment was significantly more effective than the barrier treatment. The mean percentage of flowers with mealybugs was significantly reduced after one foliar application (evaluation 2), and the barrier treatment reduced the mean percentage of flowers infested with mealybugs after three applications at 2-wk intervals (Tables 1 and 2). Mean percentages of flowers infested with cotton aphids in evaluation 2 and earwigs in evaluation 3 were significantly reduced only in the foliar treatment only (Tables 1 and 2). However, foliar and barrier treatments significantly reduced ($F = 14.41$; df = 2; $P = 0.0051$) the mean number of cotton aphids per flower in evaluation 3; we observed 80, 17, and 3 aphids per flower in control, barrier, and foliar treatments, respectively (data not shown). This corresponded with no significant difference in the mean percentage of flowers infested, which averaged 84, 73, and 35% in control, barrier, and foliar treatments, respectively (Table 1). Thus, the numbers of aphids per flower must be significantly reduced before there is a similar lowering in the percentage of flowers infested with not a single live aphid. Phytotoxicity was not observed with any of the treatments; however, Hata & Hara (1988a) observed phytotoxicity with chlorpyrifos 50 wettable powder on red ginger after five weekly applications at 2.4 g (AI)/liter.

**Insecticidal Dip After Harvest.** The insecticidal dip alone did not provide complete quarantine security. Although earwigs, cardamom thrips, and ants were completely eliminated, mealybugs, banana aphids, and cotton aphids were present in flowers treated with the dip alone in one or more evaluations (Table 3). Mealybugs were present in 3 to 17% of flowers dipped in fluvalinate and insecticidal soap in three evaluations, in agreement with the results of Tenbrink et al. (1991a), who demonstrated that mealybugs could not be eliminated with the insecticidal dip combination alone. Agitation of flowers in the insecticidal solution is an important factor in the success of use of insecticidal dips after harvest. The control plots in evaluation 7 had a higher mean percentage of flowers infested with banana aphids and cotton aphids than evaluation 6 (Table 1); however, with the increased agitation, aphids were eliminated (Table 3). Similarly, Tenbrink et al. (1990, 1991a) did not agitate the flowers; as a consequence, insecticide solution penetrated poorly and caused lower mortality.

**Insecticide Treatment Before Harvest and Insecticidal Dip After Harvest.** Foliar applications of chlorpyrifos 50 DF combined with the insecticidal dip after harvest eliminated 100% of all insect pests on red ginger including banana aphids, cotton aphids, ants, mealybugs, thrips, and earwigs (Table 3). Green scale, *C. viridis*, and longlegged ant, *Anoplolepis longipes* (Jerdon), were also eliminated by the foliar applications of chlorpyrifos 50 DF before harvest and dip after harvest, but numbers were too low for statistical analysis. Chlorpyrifos 20 MEC applied as a barrier treatment with the insecticidal dip

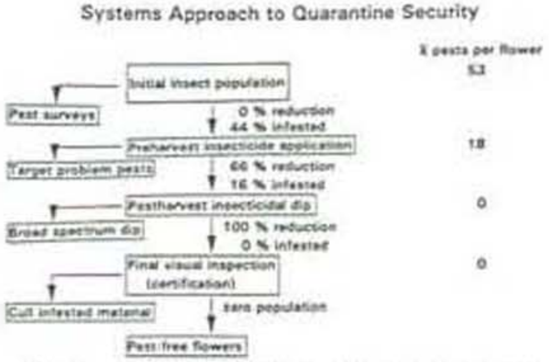


Fig. 1. Sequence of before- and after-harvest procedures used in a systems approach to quarantine security on red ginger. Mean number of all pests of red ginger per flower includes aphids, ants, mealybugs, thrips, and earwigs.

eliminated all insect pests in evaluations 5 and 7, but did not eliminate cotton aphids in evaluation 6 (Table 3). Therefore, to ensure pest-free red ginger, foliar applications of an effective insecticide such as chlorpyrifos in combination with a 5-min + 20-stroke insecticide dip of fluvalinate and insecticidal soap after harvest should be used as a quarantine security for red ginger.

Flowers with no insecticidal applications before harvest and with only an insecticidal dip combination after harvest were not totally pest-free, indicating that reduction of pest populations before harvest is essential. Jang & Moffitt (in press) stated that knowing the level of the field infestation is a key component in a systems approach to quarantine security. Therefore, because aphids are present in large numbers per flower in the field and mealybugs are difficult to eliminate from flowers with the insecticidal dip, management of aphids and mealybugs before harvest is very important. Pest monitoring, development of quarantine thresholds, and applications of effective insecticides are essential components of aphid and mealybug management before harvest. In addition, our system's approach requires flowers to be inspected, especially for aphids and mealybugs, to ensure quarantine security.

Although this approach to quarantine security is used successfully on several fruit crops, ours is the first known study to demonstrate the systems approach application to floricultural crops. Our approach to quarantine security is based on the fact that control measures such as chemical insecticides before harvest can reduce pests to a level at which a dip after harvest (e.g., combination of fluvalinate and insecticidal soap) is 100% effective (Fig. 1). To use this pest management strategy, pests should be identified, population levels assessed, and the determination made if the levels are above quarantine thresholds. If a pest population is at or above quarantine threshold, the pest population should be made the target of a specific effective control measure such as an effective chemical insecticide. For example, a federal quarantine pest in many ginger fields in Hawaii is the green scale, *C. viridis* (Animal and Plant Health Inspection Service 1989). Therefore, fluvalinate, an insecticide identified as effective against the green scale, should be used until the pest is brought under quarantine threshold (Hata & Hara 1988b, in press). Thereafter, the harvested flowers should be treated with an effective treatment after harvest such as the fluvalinate/insecticidal soap dip and inspected to ensure quarantine security.

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