Excluding Pests from Red Ginger Flowers with Insecticides and Pollinating, Polyester, or Polyethylene Bags

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ABSTRACT Exclusion bags and pollinating bags were evaluated for efficacy against pests of red ginger, *Alpinia purpurata* (Vieill.) K. Schum. Exclusion bags made from spunbonded polyester or polyethylene floating row covers, and nonwoven polyethylene pollinating bags were secured to flowers with masking tape alone and in combination with foliar sprays of chlorpyrifos. Bagging flowers significantly reduced the mean percentage of flowers infested with ants, *Pheidole megacephala* (F.) and *Technomyrmex albipes* (F. Smith), and banana aphids, *Pentalonia nigronervosa* Coquerel. A single foliar application of chlorpyrifos reduced only the mean percentage of flowers infested with banana aphids. One foliar spray of chlorpyrifos before bagging flowers significantly reduced the mean percentage of flowers infested with ants, banana aphids, cotton aphids, *Aphis gossypii* Glover, and cardamom thrips, *Sciothrips cardamomi* (Ramakr). Eight, 16, and 49% of flowers harvested from spunbonded polyethylene, pollination, and spunbonded polyester bags, respectively, were mechanically injured or sunburned.

KEY WORDS red ginger, floating row cover, pollination bags

A LIMITING FACTOR in marketing red ginger is insect infestations, resulting in flower injury, reduced vase life and quarantine rejection (Tsuda & Hara 1990, Hata & Hara 1992, Hata et al. 1992; V.L.T. & B.K.S.H., unpublished data). As many as 1,500 aphids, in addition to mealybugs, thrips, scales, ants, and earwigs, may be found in a single inflorescence (B.K.S.H., unpublished data).

Field applied insecticides alone cannot eliminate red ginger pests (Hata & Hara 1988, 1992; Hata et al. 1992). Treatments after harvest, such as vapor heat, hydrogen cyanide fumigation, insecticidal dips, and hot-water immersion, do not eradicate all pests or result in a significant reduction in vase life (Tenbrink et al. 1990, 1991a, b; Hansen et al. 1991a, b; 1992). A systems approach can eliminate pests of red ginger, such as aphids, mealybugs, thrips, earwigs, scales, and ants, by reducing these populations in the field using foliar applications of chlorpyrifos at 2-wk intervals, then treating after harvest with a combination of fluvalinate and insecticidal soap (potassium salts of fatty acids) (Hata et al. 1992). However, this approach is dependent on repeated chemical insecticide applications before harvest. Many commercial ginger plantings in Hawaii are located near residential areas or are solid plantings without walkways, resulting in complaints of pesticide odor or poor coverage with insecticides, respectively. In addition, insect pests on ginger live within flower bracts, which limit the effectiveness of contact pesticides. No systemic insecticides are registered for use on red ginger.

Lightweight floating row covers are used primarily for low growing, high yield truck crops. The use of these row covers results in accelerated crop maturity, extended growing seasons, reduction or exclusion of certain insect pests and diseases, and frost protection (Perring et al. 1989, Adams et al. 1990, Webb 1991, Webb & Linda 1992, Wells & Loy 1993). Use on perennial tropical crops such as red ginger is limited because row covers are not designed for long term use, plants are too tall, and cut-floral crops require multiple harvests. However, pollinating bags that are used to exclude pollen, or bags made from lightweight floating row covers designed to fit over red ginger flowers, may exclude all insect pests if flowers are bagged in the bud stage before pest establishment. We report here the use of exclusion bags against certain pests of red ginger.

Materials and Methods

Efficacy studies were conducted from October 1992 through May 1993. Experimental plots were established in an existing 4-yr-old ginger planting at the University of Hawaii at Manoa

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Waiakea Experiment Station in Hilo, HI (elevation 183 m). Treatment plots were arranged in a randomized complete block experimental design with four replicates. Each replicate contained ≈225 plant stalks. Plots (5.4 by 5.4 m) were separated by 2.4-m walkways.

Study 1. Nonwoven polyethylene pollinating bags (23 by 46 cm), (Delnet [31 g/m^2], Applied Extrusion Technologies, Middletown, DE) were placed over buds at first emergence (appearance of red at the terminal) and fastened at the base with 1.9-cm masking tape (Shurtape, Hickory, NC). The following six treatments were used: (1) pollinating bags only, (2) chlorpyrifos 50 DF (dry flowable) (Pageant; DowElanco, Indianapolis, IN) applied to the entire plant at 2-wk intervals throughout the trial, (3) chlorpyrifos 50 DF applied before bagging with pollinating bags and at 2-wk intervals thereafter to the stalk and over the bag, (4) one application of chlorpyrifos to the flower bud and stalk before applying pollinating bags, (5) one application of chlorpyrifos DF applied to the flower bud and stalk, and (6) an untreated control. Chlorpyrifos was applied as a foliar spray at 0.6 g (AI)/liter to treatments 2 and 3 at ≈702 liters/ha and to treatments 4 and 5 at ≈87.5 liters/ha using a backpack sprayer (Solo, Newport News, VA) equipped with an 8004 Teejet nozzle (Spraying systems, Wheaton, IL) at 276 KPa. A spreader-sticker (Ad-here; Occidental, Lanthrop, CA) was added at a rate of 0.39 ml/liter solution to all chlorpyrifos applications.

In accordance with commercial standards, flowers were harvested weekly at one-third to one-half maturity and stripped of all leaves except for the terminal leaf. Treatment efficacy was evaluated by dissecting the flower bracts and terminal leaf sheath and counting 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); green shield scale, *Pulvinaria psidii* Maskell; bigheaded ant, *Pheidole megacephala* (F.); and an ant, *Technomyrmex albipes* (F. Smith). Flowers were considered infested if a single live (moving) insect was found. Mealybugs and scales, which are sedentary, were turned over and their legs observed for movement.

Study 2. Exclusion bags (23 by 46 cm) were made from lightweight floating row covers, spunbonded polyester (Reemay 2006 UV [20 g/m^2], DuPont, Wilmington, DE) and spunbonded polyethylene (Agryl P10 [10 g/m^2], American Agrifabrics, Alpharetta, GA) by cutting them into 46^2 pieces, folding in half, and heat sealing (Clampco heat sealer, Clampco, Cleveland, OH) at 274 and 177°C, respectively. The following seven treatments were used: (1) spunbonded polyethylene (Agryl P10), (2) pollinating bags (Delnet), (3) spunbonded polyester (Reemay 2006), (4) chlorpyrifos at 2-wk intervals; one application of chlorpyrifos applied to the flower bud and stalk before bagging with one of the following: (5) spunbonded polyethylene (Agryl P10); (6) pollinating bags (Delnet); (7) spunbonded polyester (Reemay 2006). The control plot was sprayed with water. Bagging procedure, insecticide application, and evaluation of efficacy were conducted as described in study 1. The percentage of flowers mechanically injured by the bags and the percentage of bags with holes were also recorded.

Table 1. Treatments and probability of significance for mean percentages of flowers infested with various insect pests

Pest	df	*F*	*P*
	Study 1		
Ants	5, 15	25.71	0.0001
Banana aphid	5, 15	160.88	0.0001
Cotton aphid	5, 15	9.88	0.0002
Mealybugs	5, 15	13.36	0.0001
Green shield scale	5, 15	9.28	0.0003
Cardamom thrips	5, 15	4.20	0.0138
	Study 2		
Ants	7, 21	34.82	0.0001
Banana aphid	7, 21	25.59	0.0001
Cotton aphid	7, 21	11.00	0.0001
Mealybugs	7, 21	4.05	0.0059
Green shield scale	7, 21	4.59	0.0030
Cardamom thrips	7, 21	5.71	0.0008

Data Analyses. The three species of mealybugs were pooled for analysis because of the inability to distinguish between immature life stages. The two species of ants were also pooled for analysis. The percentages of infested flowers harvested throughout the trial were transformed to arcsine square-root and subjected to analysis of variance (SAS Institute 1987), means were separated by Waller–Duncan k ratio t-test, and the standard error of the mean calculated.

Results and Discussion

The mean percentages of flowers (studies 1 and 2) infested with various insect pests before treatment were ants, 88.4 ± 1.9; banana aphids, 52.1 ± 2.1; cotton aphids, 36.7 ± 2.5; scales, 2.0 ± 0.5; mealybugs, 70.2 ± 2.7; and thrips, 6.9 ± 1.0, and did not vary significantly among treatments.

Study 1. All treatments except for the one application of chlorpyrifos significantly reduced the mean percentage of flowers infested with ants (Tables 1 and 2). Multiple applications of chlorpyrifos alone, multiple applications of chlorpyrifos plus pollinating bags, and one application of chlorpyrifos before covering with pollinating bags reduced the mean percentage of ant infested flowers to <10%, whereas the pollinating bags alone reduced the mean percentage of ant

Table 2. Mean ± SEM percentage of flowers infested with various insect pests after treatment with insecticide and exclusion bags, study 1

Treatment	n^a	Ants	Banana aphids	Cotton aphids	Mealybugs	Green shield scale	Thrips
Bag[b]	350	30.7 ± 0.2b	27.2 ± 0.1c	50.2 ± 1.5a	35.0 ± 0.1a	11.8 ± 0.0a	1.0 ± 0.2bc
Chlorpyrifos (one) + bag[c]	332	9.5 ± 0.1c	10.7 ± 0.1d	14.8 ± 2.9b	21.5 ± 0.4b	4.1 ± 0.1b	0.7 ± 0.3bc
Chlorpyrifos (2-wk interval) + bag	255	5.4 ± 0.4c	2.5 ± 0.0e	3.6 ± 0.7b	4.9 ± 0.0c	0.1 ± 0.1c	0.2 ± 0.2c
Chlorpyrifos (one)[d]	311	55.7 ± 0.5a	54.8 ± 0.1b	61.2 ± 0.1a	20.2 ± 0.3b	2.5 ± 0.3b	4.9 ± 0.2ab
Chlorpyrifos (2-wk interval)	278	6.6 ± 0.1c	12.9 ± 0.0d	40.6 ± 0.0a	4.9 ± 0.2c	0.2 ± 0.2c	2.2 ± 0.0abc
Control	362	65.2 ± 0.9a	72.0 ± 0.2a	49.5 ± 1.2a	29.3 ± 0.6ab	4.1 ± 0.2b	7.3 ± 0.1a

Means followed by the same letter in a column are not significantly different (Waller–Duncan k ratio t-test, $k = 100$).
[a] Total flowers harvested.
[b] Pollinating bags (Delnet).
[c] One application of chlorpyrifos to flower buds before bagging.
[d] One application of chlorpyrifos to flower buds.

infested flowers to <31%. All treatments significantly reduced the mean percentage of flowers infested with banana aphids. Multiple applications of chlorpyrifos plus pollinating bags were most effective against banana aphids, followed by multiple applications of chlorpyrifos, one application of chlorpyrifos before covering flowers with pollinating bags, pollinating bags alone, and one application of chlorpyrifos alone, respectively. There was no significant difference in banana aphid infestations between multiple applications of chlorpyrifos only and one application of chlorpyrifos before covering with pollinating bags. Multiple applications of chlorpyrifos or one application of chlorpyrifos before covering with pollinating bags significantly reduced cotton aphids. Applications of chlorpyrifos at 2-wk interval with or without pollinating bags significantly reduced mealybugs and green shield scales. Pollinating bags with or without chlorpyrifos significantly reduced cardamom thrips.

Study 2. All treatments significantly reduced the mean percentage of flowers with ants and banana aphids (Tables 1 and 3). Applying chlorpyrifos at 2-wk intervals or one application before covering buds with bags (Agryl P10, Reemay 2006, and Delnet pollinating bags), reduced the number of flowers infested with ants and banana aphids compared with bags alone or the control. One application of chlorpyrifos in combination with bags significantly reduced the percentage of flowers infested with cotton aphids and green shield scales compared with the control. Spunbonded polyethylene (Agryl P10) bags only resulted in a significantly higher percentage of flowers infested with cotton aphids. Flowers treated with chlorpyrifos at 2-wk intervals and one application of chlorpyrifos before the pollinating bag treatment had significantly fewer flowers infested with mealybugs. All treatments except pollinating bags (Delnet) alone, and spunbonded polyester (Reemay 2006) bags alone had significantly fewer flowers infested with cardamom thrips.

Holes, caused by bigheaded ants, were present in 42, 7, and 43% of spunbonded polyethylene (Agryl P10), pollinating bags (Delnet), and spunbonded polyester (Reemay 2006), respectively.

Table 3. Mean ± SEM percentage of flowers infested with various insect pests after treatment with insecticides and exclusion bags, study 2

Treatment	n^a	Ants	Banana aphids	Cotton aphids	Mealybugs	Green shield scales	Thrips
Spunbonded polyethylene (Agryl P10)	95	39.1 ± 0.1b	32.3 ± 0.3b	52.0 ± 0.3a	18.7 ± 0.1abc	21.1 ± 0.8a	2.6 ± 0.3bcd
Pollinating bag (Delnet)	118	26.9 ± 0.1b	30.6 ± 0.3b	11.3 ± 1.7b	28.8 ± 3.9ab	11.3 ± 0.6abc	10.1 ± 0.4ab
Spunbonded polyester (Reemay 2006)	111	14.0 ± 0.1c	23.9 ± 0.8b	3.3 ± 0.4bc	33.2 ± 0.8a	4.4 ± 0.6bcde	7.1 ± 0.1abc
Chlorpyrifos (2-wk interval)	113	2.5 ± 0.9de	1.3 ± 0.4c	3.5 ± 0.5bc	1.8 ± 0.6d	5.0 ± 0.6bcd	1.0 ± 0.3cd
Chlorpyrifos (one)[b] spunbonded polyethylene	121	3.8 ± 0.5d	0.0 ± 0.0c	0.0 ± 0.0c	7.3 ± 0.9bcd	2.2 ± 0.3cde	0.0 ± 0.0d
Chlorpyrifos (one)[b] pollinating bag	74	0.3 ± 0.3e	0.9 ± 1.1c	1.1 ± 0.4c	2.4 ± 0.9cd	1.5 ± 0.5de	0.3 ± 0.3d
Chlorpyrifos (one)[b] spunbonded polyester	115	1.7 ± 0.6de	0.2 ± 0.2c	0.2 ± 0.2c	16.0 ± 1.1abcd	0.0 ± 0.0e	0.2 ± 0.2d
Control	132	64.7 ± 0.1a	67.5 ± 0.8a	14.3 ± 1.2b	28.4 ± 0.1ab	13.3 ± 1.1ab	15.2 ± 1.9a

Means followed by the same letter in a column are not significantly different (Waller–Duncan k ratio t-test, $k = 100$).
[a] Total flowers harvested.
[b] One application of chlorpyrifos to flower buds before bagging.

One application of chlorpyrifos before bagging reduced the percentage of bags with holes to 7, 4, and 8%, respectively. In addition, flowers harvested from spunbonded polyethylene (Agryl P10), pollinating bags (Delnet), and spunbonded polyester (Reemay 2006) treatments were 8, 16, and 49% mechanical or sunburn injured, respectively. Similarly, chlorpyrifos combined with spunbonded polyethylene (Agryl P10), pollinating bags (Delnet), and spunbonded polyester (Reemay 2006) had 3, 6, and 65% mechanical or sunburn injured flowers. Unbagged flowers were not injured.

One application of chlorpyrifos plus bagging with Delnet, Reemay 2006, or Agryl P10 bags was as effective as applications of chlorpyrifos at 2-wk intervals, significantly reducing the mean percentage of flowers infested with banana aphids, cotton aphids, ants, and cardamom thrips on red ginger. Our study also showed that bags with or without one application of chlorpyrifos DF before bagging can reduce banana aphids below the threshold level (<33% infestation) established by Hata et al. (1992) needed to produce aphid-free flowers in a quarantine system for red ginger. However, the use of bags alone without an insecticide application may create a microclimate that is conducive to the development of certain pests (Wells & Loy 1993) such as the cotton aphids in this study. Flowers bagged with spunbonded polyethylene (Agryl P10) had a significantly higher percentage of flowers infested with cotton aphids. Therefore, an insecticide should be applied before the exclusion bag is placed over young flower buds to ensure exclusion of all insect pests.

The effectiveness of pollinating bags in reduction of mealybugs, cardamom thrips, and scales was not consistent in both studies. In study 1, pollinating bags plus one application of chlorpyrifos did not significantly reduce the percentage of flowers with mealybugs and green scales as compared with the control; however, significant reduction occurred in study 2. In addition, cardamom thrips in study 1 were significantly reduced with pollinating bags alone; however, thrips were not significantly reduced in study 2. A possible explanation for the lack of significant reduction of scales in study 1 is only a low percentage (4.1%) of flowers were infested with scales as compared with study 2 (13.3%). Although not significant, the percentages of flowers with mealybugs in study 1 were lower with pollinating bags plus one application of chlorpyrifos than the control. Likewise the percentages of flowers with cardamom thrips in study 2 were also lower with pollinating bags alone as compared with the control.

Only three types of exclusion bags were evaluated in our study although several other floating row cover materials are available. Spunbonded polyester (Reemay 2006) bags were most effective in excluding insect pests, followed by pollinating bags (Delnet) and spunbonded polyethylene (Agryl P10), respectively.

In crops where the use of row covers is not practical, exclusion bags may reduce pest populations and the use of insecticides. However, because bagging is labor intensive, this treatment will likely be limited to commodities with a high commercial value or to areas where conventional field spraying is not possible. With the variety of cost-effective synthetic fabrics available, physical exclusion of insect pests from commodities is an effective management tool.

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