Project Title: Pest Management Grants Final Report

Contract # DPREG #98-0279

Contract Title: Development and Implementation of a Reduced-Risk Management Strategy in Fresh Cut Roses

Principal Investigator: Michael P. Parrella

Contractor Organization: University of California, Davis

Date: March 31, 2000

Prepared for California Department of Pesticide Regulation

Disclaimer

The statements and conclusions in this report are those of the contractor and not necessarily those of the California Department of Pesticide Regulation. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgements

We would like to acknowledge the funding from the California Department of Pesticide Regulation that made this work possible. We would like to thank the cooperating growers made this work possible: Aspen Nurseries, Kitayama Brothers, and Koch California.

This report was submitted in fulfillment of 98-0279, "Development and Implementation of a Reduced-Risk Management Strategy in Fresh Cut Roses" by the University of California, Davis under the sponsorship of the California Department of Pesticide Regulation. Work was completed as of March 30, 2000.

Table of Contents

List of Figures

List of Tables

Abstract

California growers produce 70% of all greenhouse fresh cut roses grown in the United States, which generated $64 million in revenue in 1998. The three key pests of roses are the twospotted spider mite, the western flower thrips, and powdery mildew. Frequent pesticide applications are directed against these pests because of the serious injury they cause; in many cases this has led to the development of resistance. There currently are no scouting guidelines or thresholds for the key pests of roses.

The goal of this study was to develop an integrated pest management program for fresh cut roses. Fixed precision sampling plans and thresholds have been developed for each key pest, and new reduced risk pesticides have been evaluated. The IPM program we have developed based on these studies is being implemented at nine greenhouses throughout the state.

Executive Summary

Production of ornamental crops in the greenhouse accounts for the most intensive use of conventional pesticides on a per acre basis in agriculture. Despite the fact that prophylactic sprays are expensive, threaten worker safety and can lead to pesticide resistance, greenhouse growers have been reluctant to adopt integrated pest management (IPM) practices that could potentially reduce pesticide use because of the perception that they would not achieve adequate control of pests.

Recent events have led many greenhouse growers to reconsider the use of IPM strategies. Pesticides have become more difficult to use because of re-entry intervals. The Food Quality Protection Act (FQPA) threatens the registration of older materials. Pesticides have also become more expensive, while recent studies have demonstrated that scouting can be cost effective.

In response to this demand for information on greenhouse IPM programs, UC Davis researchers have initiated an effort to develop methods that growers can use to minimize reliance on conventional pesticides. Using fresh cut roses as a model system, this work will lead to several advancements in greenhouse pest control. These include the development of fixed precision monitoring guidelines and action thresholds for key pests and the development of user guidelines for new reduced risk pesticides as substitutes for FQPA at risk materials.

Our specific objectives are:

Objective 1. Develop and implement monitoring procedures for the key pests of cut roses (first year).

Objective 2. Develop action thresholds for western flower thrips and twospotted spider mites (first year).

Objective 3. Evaluate the use of reduced-risk pesticides as substitutes for conventional pesticides in cut roses (first year).

Objective 4. Develop and implement a pest management program in cut roses that is based on the results of Objectives 1 to 3 (second year).

We were successful at completing all of our objectives. Fixed precision sampling plans for western flower thrips and twospotted spider mite, the two key arthropod pests of roses, have been developed. The thrips monitoring program is based on using yellow sticky cards and a threshold of 25 to 50 thrips per trap per week, with three traps placed in each rose variety. The mite monitoring program is based on a presence-absence sampling program with a tally threshold of 5 mites. The first leaf above the bend is sampled on 44 plants per 10, 000 square feet of greenhouse area. A monitoring program for powdery mildew that is based on environmental conditions has been developed. Temperature is recorded continuously in the greenhouse and when the average is between 65 and 80 degrees Fahrenheit for a critical period mildew control is implemented.

We have also evaluated new reduced risk products for mite management. Cinnamite, Floramite and Hexygon were shown to have good efficacy against immature and adult mites, while Conserve did not give adequate control for commercial production. Laboratory data gathered in a concurrent study indicated that Floramite is compatible with the mite predator, *Phytoseiulus persimilis*. Cinnamite and Conserve were not compatible under direct contact, but contact with dried residues may be acceptable.

Body of Report

Introduction

California growers produce 70% of all greenhouse cut roses grown in the United States, which had a wholesale value of $64 million in 1998. Cut roses have three key pests. These are the twospotted spider mite, *Tetranychus urticae*; the western flower thrips, *Frankliniella occidentalis*; and powdery mildew, *Sphaerotheca pannosa* var. *rosae*. Populations of all these pests can increase quickly in the greenhouse environment. This, along with the high quality standards for cut roses, has meant that they are subject to frequent pesticide applications. It is not uncommon for roses to receive 50-60 applications per year. There are no sampling methods or thresholds for rose pests, so there are no guidelines for timing sprays. Resistance against mites and thrips has become a serious problem in several greenhouses.

Powdery mildew is the most common disease affecting greenhouse cut roses. Mildew spores are airborne and are ubiquitous in the rose greenhouse. Outbreaks can occur rapidly when environmental conditions are appropriate. Because there is no system to predict when this will occur, growers typically use pesticides on a regular basis during the time of the year when environmental conditions favor mildew growth. The development of an environmental monitoring system for rose powdery mildew offers the possibility of a substantial reduction in fungicide use. Since mildew fungicides may also have a sublethal effect on mite predators, this system could benefit both mildew and mite control.

A new rose production system has come into use in the past few years that has important implications for pest management. In this system, called bent cane, most of the shoots are bent downward at the crown to intercept more light, leaving only a few stems to grow upward and produce flowers. This creates a perennial lower canopy and an annual upper canopy. The lower canopy becomes very dense, which prevents good pesticide coverage and thus interferes with spider mite control. At the same time, it creates a refuge for predatory mites. Western flower thrips, which are difficult to control biologically, are found only on the flowers and uppermost leaves. In the past, the need to control thrips chemically has often disrupted biological control of mites. In the bent cane system, pesticides can be directed to the annual portion of the crop with minimal interference to biological control in the perennial portion. The potential to combine biological and chemical control created by the bent cane system can only be effectively realized, however, if there are monitoring guidelines and thresholds for rose pests.

Materials and Methods

Objective 1. Develop and implement monitoring procedures for the key pests of cut roses.

A. Western flower thrips

The goal of this objective was to validate our sampling plan for western flower thrips in greenhouse roses. Previous work has indicated that sticky traps can be a cost effective, accurate tool for thrips monitoring in greenhouse roses. Current recommendations from that work suggest using 7 to 9 blue or yellow cards per pest management unit (the same or similar rose cultivar). It has been determined that 25 to 50 adult western flower thrips per card per week corresponds to 1 to 2 thrips per flower, which is the action threshold. Yellow sticky cards were placed in each pest management unit of the test greenhouses. Each week the number of western flower thrips on each card were counted and the card was replaced. Ten harvestable flowers were also collected weekly from four of the pest management units in each greenhouse. Thrips per flower were counted to confirm that trap count is a predictor of the number of thrips per flower. Validation took place for 7 weeks at the test greenhouse in Watsonville and for 20 weeks at the test greenhouse in Nipomo.

B. Twospotted spider mite

The goal of this objective was to develop a binomial (presence-absence) sampling plan for twospotted spider mites on bent cane roses. This study was conducted at two commercial rose greenhouses in Watsonville and one in Nipomo. Twenty randomly selected plants were sampled weekly at each operation. The first, third, fifth, seventh, and ninth leaves above and below the bend were removed and the underside sprayed with hairspray to trap mites on individual leaflets. These leaves were sent to the laboratory in Davis where the mites on each leaflet were counted as eggs, immatures, females, and males. We used this information to determine mite distribution within and between bent cane rose plants, from which a sampling plan was developed.

C. Powdery Mildew

The goal of this objective was to adapt a predictive model for grape powdery mildew for use by rose growers. An environmental monitor that measures temperature, relative humidity and leaf wetness was placed in the test greenhouse. Powdery mildew occurrence was monitored weekly so that mildew outbreaks could be correlated to environmental conditions.

Objective 2. Develop action thresholds for western flower thrips and twospotted spider mites.

A. Western flower thrips

Action thresholds of 1 to 2 thrips per flower were determined in previous studies.

B. Twospotted spider mite

The goal of this objective was to test the preliminary action threshold for mites. Economic injury levels and action thresholds have not been formally determined for this pest, although a preliminary action threshold of 5 mites per leaf (mobile stages) has been tested in field trials. We evaluated this threshold as we tested our binomial sampling plan. Only leaves with 5 or more mites will be considered to have mites present. In addition, experiments were conducted to test the relationship between twospotted spider mite density and rose plant photosynthesis. Bent cane roses, cultivar 'Kardinal', in an experimental greenhouse on the Davis campus were grouped into three mite densities as measured on the first leaf above the bend. These were low (less than or equal to 5 mobile mites); medium (more than 5 to 20 mobile mites); and high (greater than 20 mobile mites). Mites were hand removed from the tested leaf and photosynthesis and stomatal conductance were measured. The leaf nearest to each measured leaf that had no mites was used as a control.

Objective 3. Evaluate the use of reduced-risk pesticides as substitutes for conventional pesticides in cut roses.

A. Western flower thrips

No tests were done, as additional reduced risk materials have not become available. Laboratory trials with new products will continue as they become available.

B. Twospotted spider mite

The goal of this objective was to evaluate the efficacy of new reduced-risk pesticides for mite control. These trials included registered products as well as those for which registration is anticipated. Replicated trials were conducted in commercial rose greenhouses where the bent cane system is used. A precount and postcount of eggs and mobile stages was used to determine efficacy.

Objective 4. Develop and implement a pest management program in cut roses that is based on the results of Objectives 1 to 3.

The scouting methods used in the implementation of the IPM program were as follows.

A. Western flower thrips

Three yellow sticky traps were placed per 10, 000 ft. sq. greenhouse. Traps were examined weekly and all thrips counted.

B. Twospotted spider mite

We used a tally threshold of 5 mites per leaf on the first leaf above the bend and a sample size of 44 plants per 10, 000 square feet of greenhouse area.

C. Powdery mildew

We used weather stations to measure greenhouse temperature, leaf wetness, and relative humidity, which is used to calculate mildew pressure. Mildew incidence is also assessed during weekly scouting. Farm advisors and growers receive a weekly fax reporting current disease pressure and information on the presence of powdery mildew spores gathered by scouting. Evaluated together this information allows farm advisors and growers to make informed decisions about mildew control. For instance, if disease pressure is moderate but no mildew is seen (and thus no inoculum is present), there is no need for a control spray application. If there is only a small amount of mildew but pressure is high, then control sprays applied on a short interval are appropriate. The model gives growers a tool to better predict the need for mildew control, enabling them to move away from calendar sprays or routine sulfur volatilization.

C. Other pests

The presence of other pests such as whiteflies, aphids, mealybugs, botrytis, and downy mildew are detected during plant inspections for the key pests described above. Yellow sticky traps are also used to monitor for whiteflies and winged aphids.

Results

Objective 1. Develop and implement monitoring procedures for the key pests of cut roses.

A. Western flower thrips

Validation data has been collected from two greenhouses in Watsonville and one in Nipomo. Data was collected for 7 weeks in red, yellow, white, pink and orange flowers in Watsonville. Data was collected for 4 weeks (red flowers) and 20 weeks (pink flowers) in Nipomo. The data collected to date supports the sampling plan that we have developed. In Watsonville, we found that the regression equation generated from this data predicted that 25 to 50 thrips per yellow trap would correspond to 0.65 to 1.19 thrips per flower. This range varies with flower color, as summarized in **Table 1**. In Nipomo, we found that the regression equation generated from this data predicted that 25 to 50 thrips per yellow trap would correspond to 0.28 to 0.75 thrips per flower. This range varies with flower color, as summarized in **Table 2**. Both are acceptable ranges, as noticeable injury generally does not occur until there are 2 thrips per flower.

B. Twospotted spider mite

Work on this objective has been completed at the Watsonville and Nipomo sites. Only the Watsonville data is included in this discussion as sampling in Nipomo only terminated on March 30. We have determined that mites are aggregated within the plant, as most mites are located on the first to third leaves above and below the crown area of the plant (**Table 3**). Taylor's power law analysis (Taylor 1961) was used to describe mite distribution between plants. Again, mites were shown to have an aggregated distribution (**Figure 1**). The coefficients generated by the Taylor's analysis were used to calculate the sample size required to obtain a precision level of 0.25 according to the formula of Wilson and Room (1983).

C. Powdery mildew

Preliminary results suggested that the size of the difference between day and night temperatures as well as relative humidity were the most important environmental factors to consider in determining if a mildew outbreak would occur. Further analysis showed that the length of time for which the mean greenhouse temperature is between 65 and 80 degrees Fahrenheit was the most important factor in predicting mildew outbreaks. An example of the type of information on disease occurrence available to the grower is shown in **Figure 2**. In this example, an outbreak of powdery mildew does not occur until the mildew index remains at 100 for an extended period. Further refinements are needed to determine the role of relative humidity in disease outbreaks.

Objective 2. Develop action thresholds for western flower thrips and twospotted spider mites.

A. Western flower thrips

The validation of the sampling plan described under Objective 1A confirms that our action threshold is appropriate.

B. Twospotted spider mite

A preliminary analysis of the relationship between twospotted spider mite density and rose plant physiology suggests that our threshold of 5 mites per leaf is appropriate. Rose leaf photosynthesis and stomatal conductance were measured at three ranges of spider mite densities. Leaf photosynthesis was significantly reduced compared to the control when there were greater than 20 mobile mites per leaf **(Figure 3)**. Stomatal conductance was significantly reduced compared to the control when there were more than 5 mobile mites per leaf **(Figure 4)**.

Objective 3. Evaluate the use of reduced-risk pesticides as substitutes for conventional pesticides in cut roses.

A. Western flower thrips

No tests were done, as additional reduced risk materials have not become available. Laboratory trials with new products will continue as they become available.

B. Twospotted spider mite

We have completed a trial with five materials. They are Avid (which served as the control) Cinnamite, Conserve, Floramite and Hexygon. All are registered at the federal level; California registration of Floramite is expected within 6 months, while Hexygon will take longer. **Figure 5** shows the results when these materials were tested against immature spider mites. Treatments were evaluated 5 and 8 days after the first application; a second application of all materials except Hexygon was made 7 days after the first application. Avid, Cinnamite and Hexygon all gave excellent results, causing at least 80 % mortality by 5 days. Floramite gave about 70% control after 5 days. We tested the low rate of this material and will re-evaluate it at the higher rate. Conserve did not give adequate control of immature mites.

Figure 6 shows the results when these materials were tested against adult spider mites. Treatments were evaluated 5 and 8 days after the first application; a second application of all materials except Hexygon was made 7 days after the first application. None of the materials tested was as effective against adults as against immatures. Avid was somewhat effective against adults. The first Cinnamite application was not effective, while the second gave excellent control. This may be related to formulation problems that the manufacturer is now correcting, so we will re-test this material once it is available again. Conserve performed poorly against adult spider mites. Floramite also performed poorly, although control improved following a second application. We will re-test this material at a higher rate. Hexygon gave no control of adults after 5 days; this is not surprising as it is not labeled for adult control. Adult mortality improved substantially by 8 days, which is most likely an artifact of the small number of mites in the Hexygon samples.

Objective 4. Develop and implement a pest management program in cut roses that is based on the results of Objectives 1 to 3.

Implementation of an IPM program for fresh cut roses through the Pest Management Alliance Grants program began in March 2000. Nine cooperators in the Watsonville, Santa Barbara and San Diego areas were identified. The University of California Cooperative Extension farm advisor in each of these areas hired a scout and trained them in the scouting procedures that resulted from this study. The scouts collect data from an IPM house and a grower practice house weekly at each site. Pest management decisions in the IPM house are based on the thresholds established in this study, while the grower determines the pest management program to be used in the grower practice house. Pesticide use and crop economics will be compared under the two pest management regimes at the end of the study.

Discussion

We undertook these studies with the goal of generating the information needed to develop an integrated pest management program for greenhouse cut roses. The data we have gathered to date has moved us towards completion of that goal.

Western flower thrips.

Validation shows that our model can effectively predict the number of thrips per flower based on yellow sticky trap catch. The model explained more of the variation in the number of thrips per flower at low thrips levels than at high thrips levels. We will continue to work with a threshold of 25 to 50 thrips per trap per week.

Twospotted spider mites.

We have shown that mites have an aggregated distribution on rose plants, similar to the results of studies on numerous other crops. We have proposed a binomial sampling plan for this pest based on the data we have collected. This type of plan has been shown to be effective for mites in other crop systems. The sampling plan we propose is based on a tally threshold of 5 mites on the first leaf above the bend and a sample size of 44 plants per 10, 000 square feet of greenhouse area. This will give a precision of 25%, which is considered acceptable for pest management.

We have also shown that new reduced-risk pesticides for mite control can be efficacious, but that effectiveness varies with lifestage. All materials were more effective against immature than adult mites. This suggests that these products are best use as part of a scouting program that will provide information about mite lifestages. Based on the results of a concurrent project, we have determined that all of the products tested (except Avid, the control) can be used in conjunction with mite predators. The deleterious effect of Avid on the predator, *Phytoseiulus persimilis*, is shown in **Figure 7.**

Powdery mildew.

We have begun to determine the relative importance of different environmental factors in the development of rose powdery mildew in the greenhouse. Environmental monitoring is often used by greenhouse growers to predict crop growth, but its use for disease prediction in the greenhouse is a new concept. This type of information is commonly used to predict disease outbreaks in apples and grapes and we anticipate success in the rose system. The rose model is based only on temperature, and thus should be easy for growers to implement.

Summary and Conclusions

We have developed fixed precision monitoring programs and thresholds for the key pests of greenhouse grown cut roses -- western flower thrips, twospotted spider mite, and rose powdery mildew. This information will enable rose growers to more efficiently schedule and direct their pest control, as well as to more effectively combine chemical and non-chemical control methods. We have determined the location on the rose plant that is the most efficient sample unit for twospotted spider mites and we have confirmed that yellow sticky cards are an effective monitoring tool for western flower thrips. We have also developed a predictive model for rose powdery mildew. We will continue to refine our rose integrated pest management program as this work continues.

Beyond the immediate benefits to the rose industry, this project is important because it represents the first time that fixed precision monitoring guidelines have been developed for an ornamental crop. In addition, the use of environmental monitoring for disease prediction is a real innovation for ornamental crop IPM. While traps, plant inspections and phenological models are routinely used for insect scouting, this project represents the first use of an environmental model to predict disease outbreaks in an ornamental crop. We anticipate that this work will stimulate further development of IPM programs for ornamental crops.

References

Taylor, L. R. 1961. Aggregation, variance and the mean. Nature (London) 189: 732-735.

Wilson, L. T. and P. M. Room. 1983. Clumping patterns of fruit and arthropods in cotton, with implications for binomial sampling. Environmental Entomology. 12: 50-54.

Presentations Based on This Work

Casey, C. A. and M. P. Parrella. 1999. Development of a sampling plan and thresholds for twospotted spider mite on greenhouse roses. Presented at the annual meeting of the Entomological Society of America, Atlanta, GA December 12-16, 1999.

Appendix

Flower color	r^2	p	Equation of the regression line	Predicted thrips per flower at 25 thrips per card	Predicted thrips per flower at 50 thrips per card
All	0.36	<.0001	y = 0.06119 + 0.02265x	0.65	1.19
Yellow/orange	0.26	0.1053	y = 0.60131 + 0.01962x	1.09	1.58
White/pink	0.45	0.0002	y = -0.0754 + 0.01936x	0.41	0.89

Table 1. Predicted number of western flower thrips per flower at 25 and 50 thrips per yellow sticky trap (Watsonville).

Flower color	r^2	p	Equation of the regression line	Predicted thrips per flower at 25 thrips per card	Predicted thrips per flower at 50 thrips per card
Pink	0.53	0.005	y = 0.06042 + 0.00887x	0.28	0.50
Red	0.93	0.033	y = -0.0433 + 0.01582x	0.35	0.75

Table 2. Predicted number of western flower thrips per flower at 25 and 50 thrips per yellow sticky trap (Nipomo).

Vertical Position	**Mean no. of mites per leaf**
9U	0.61
7U	0.87
5U	0.84
3U	1.28*
1U	0.93*
1L	1.25*
3L	0.91*
5L	0.70
7L	0.53
9L	0.42
	p<0.001

Table 3. Mite distribution by vertical position within the bent cane rose plant. The number of mites on the 1st, 3rd, 5th, 7th, and 9th leaves above and below the bend was recorded weekly. Most mites were observed on the 1st and 3rd leaves in either direction from the bend (known as the crown area).

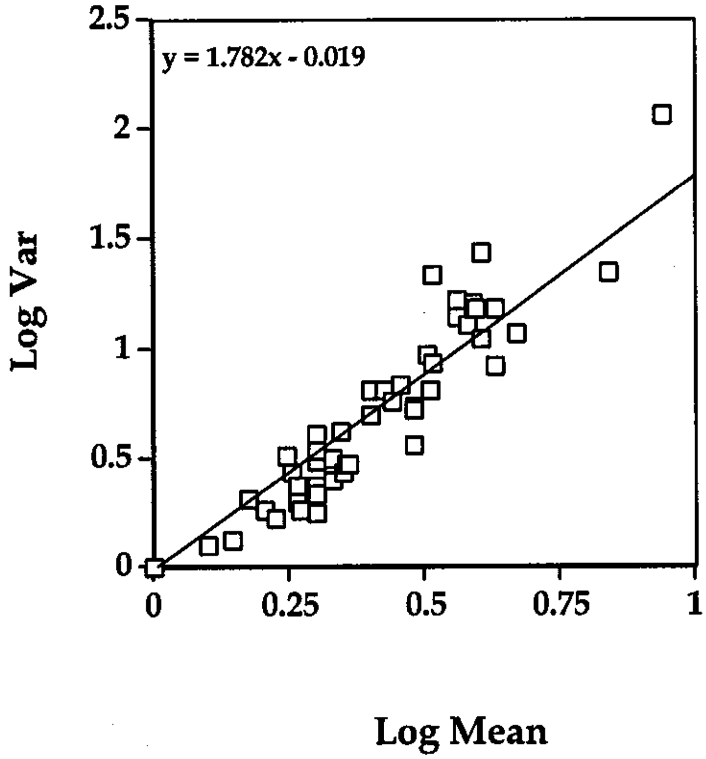

Figure 1a. Taylor's power law analysis of mite data from Watsonville. The equation of the regression line ($y = 1.782x-0.019$; $p<0.0001$; $r^2 = 0.94$) is used to calculate the Taylor's coefficients a and b, where a = intercept of the line = -0.0019 and b = slope of the line = 1.782. The variance is greater than the mean (slope>1), which indicates that mites have a clumped distribution in the greenhouse. Thus they are more difficult to locate than if they were uniformly distributed. We used this mathematical relationship to calculate the appropriate sample size for twospotted spider mites.

What is Taylor's Power Law? Insects and mites are typically distributed in a field or greenhouse in one of three patterns: clumped, random, or uniform. Clumped distributions are the most common. In order to determine how to most efficiently sample for an insect or mite, we need to understand how it is distributed. For example, more samples will be required to find a pest that is clumped compared to one that is uniformly distributed. If we describe the distribution in mathematical terms we can then calculate an approximate sample size. The most commonly used technique to do this is called Taylor's Power Law. It uses two parameters, the mean (or average) and the variance. The latter is a measure of how much variation there is in the samples. For example, if almost every plant sampled had 1 or 2 mites, there would be very little variation between plants and we could quickly make a decision about mite levels in the crop. In reality, some plants will have no mites, some will have a few, and some will have many mites. In this case the variance is high and more samples are needed to reach a decision about mite levels. The relationship between the distribution pattern and the mean and variance can be illustrated as follows.

Taylor's Power Law Analysis for clumped, random, and uniform patterns of insect or mite distribution:

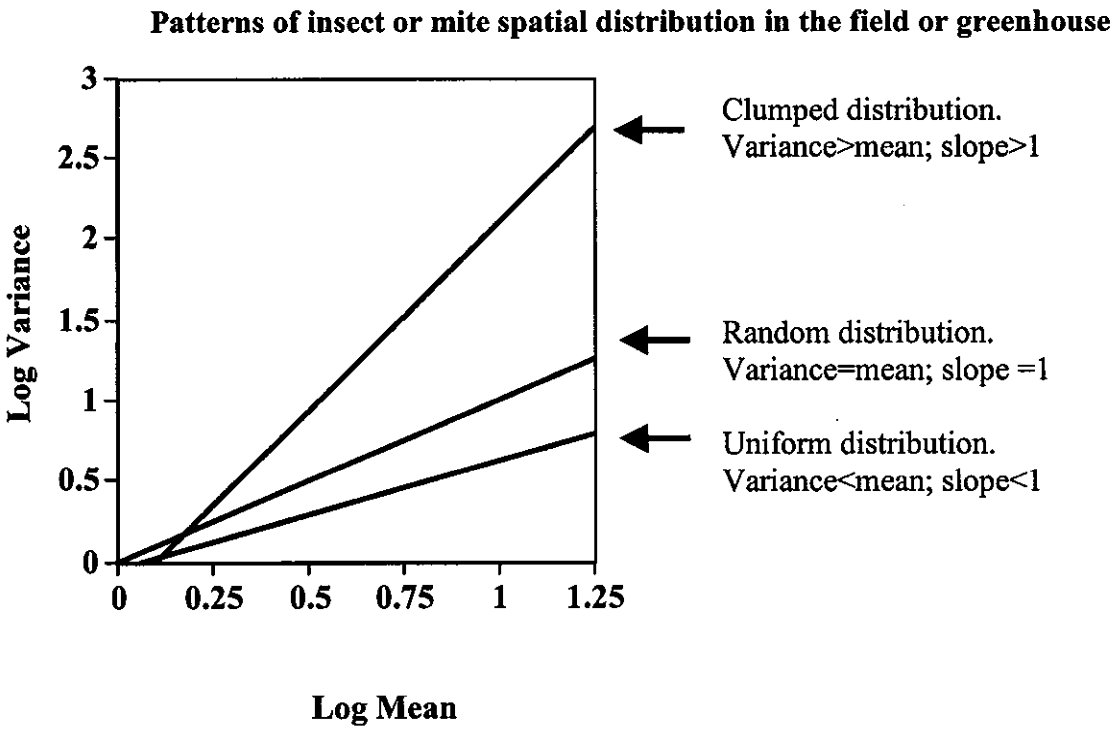

Figure 1b. Relationship between log variance, log mean, and spatial distribution.

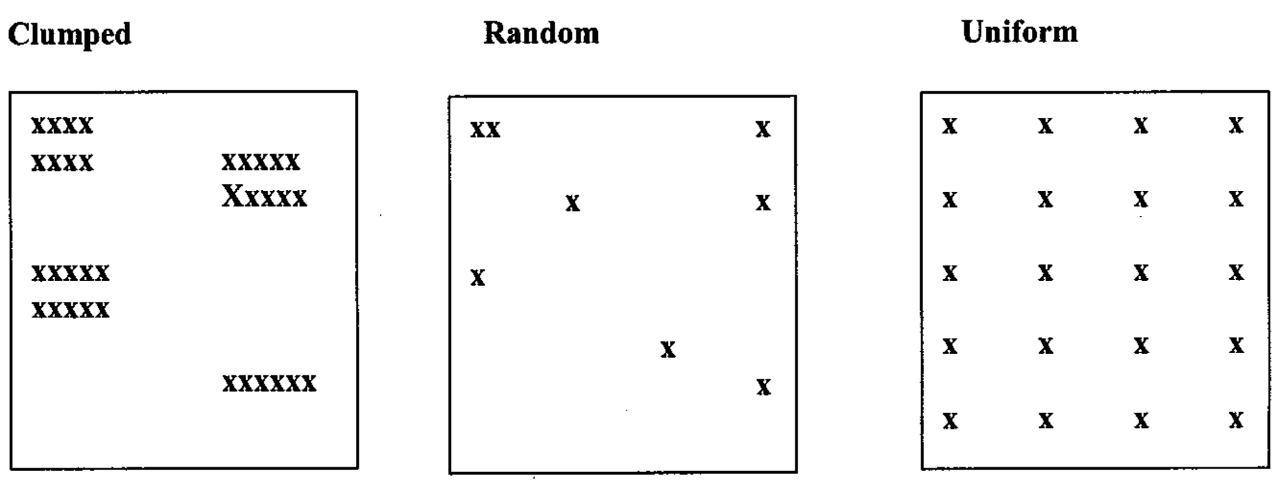

Figure 1c. Patterns of insect or mite distribution in the field or greenhouse.

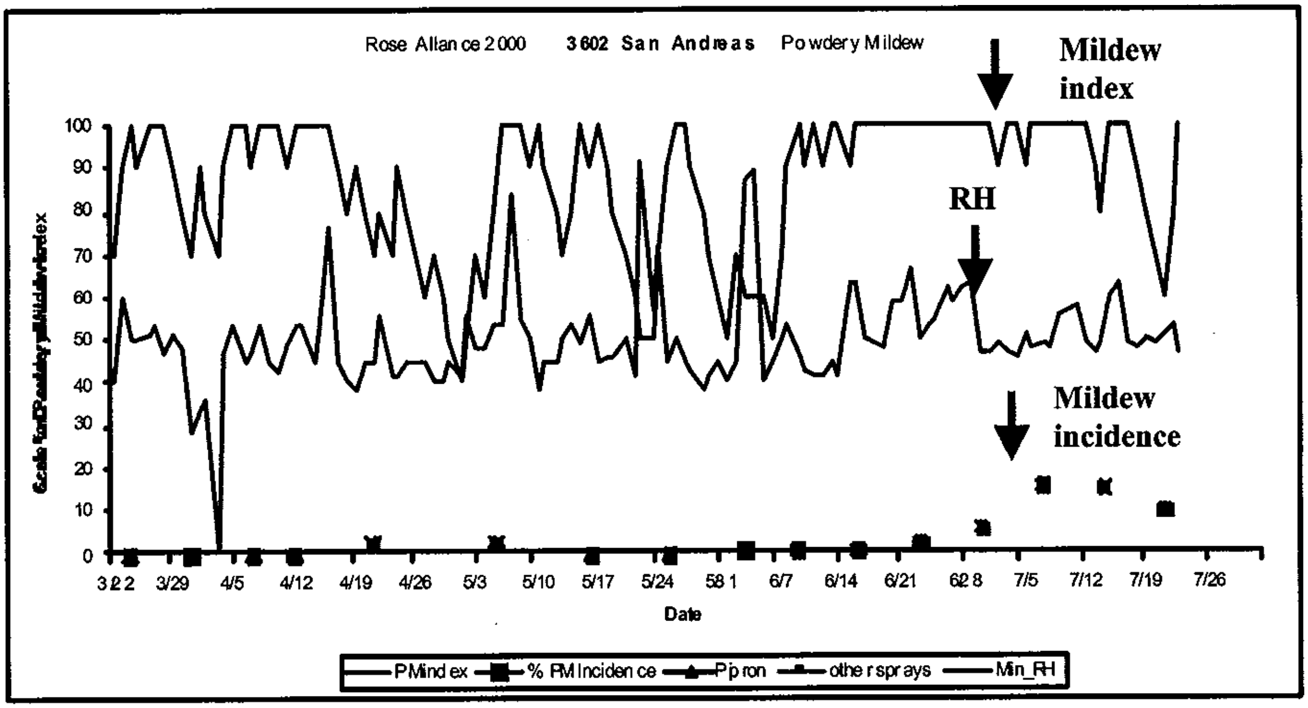

Figure 2. Relationship between mildew index, relative humidity, and incidence of powdery mildew. An outbreak of powdery mildew does not occur until mildew index remains at 100 for an extended period. Further refinements are needed to determine the role of relative humidity in disease outbreaks.

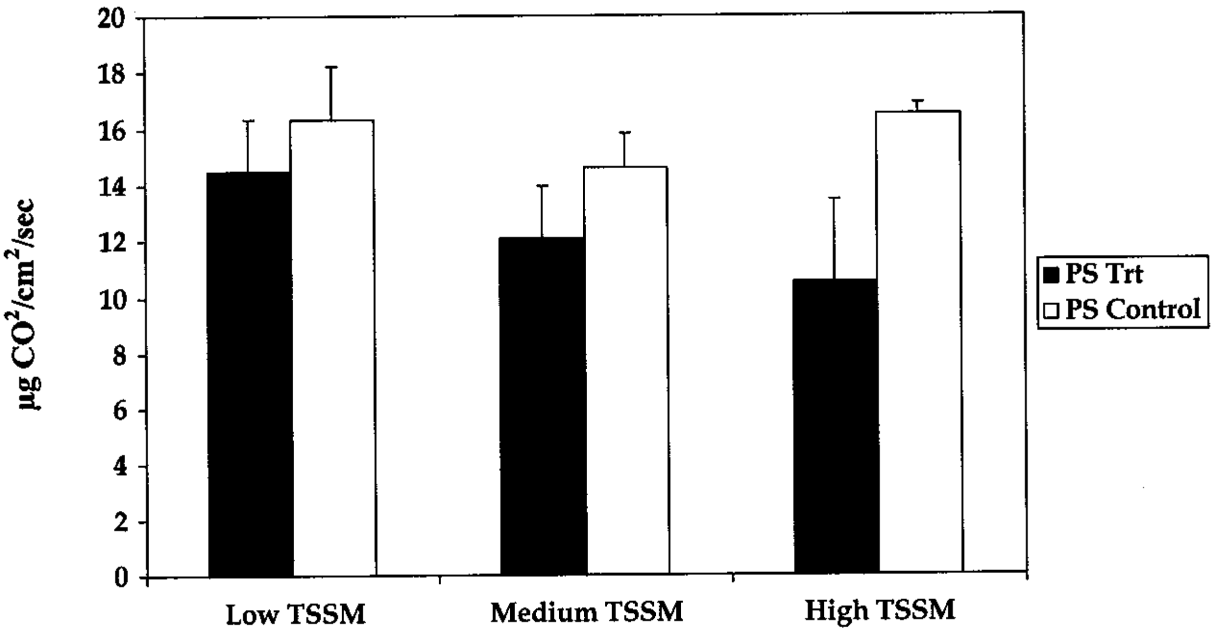

Figure 3. Effect of twospotted spider mite density on rose leaf photosynthesis. There was a significant reduction in photosynthesis only at the highest density.

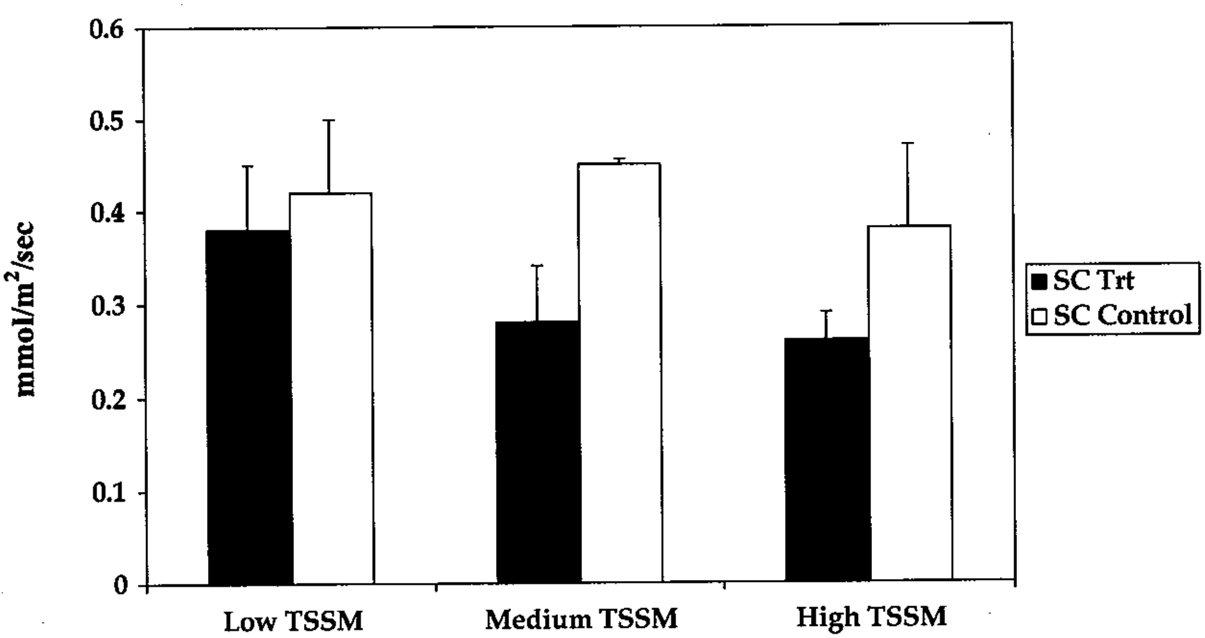

Figure 4. Effect of twospotted spider mite density on rose leaf stomatal conductance. These was a significant effect of density on conductance at medium mite densities.

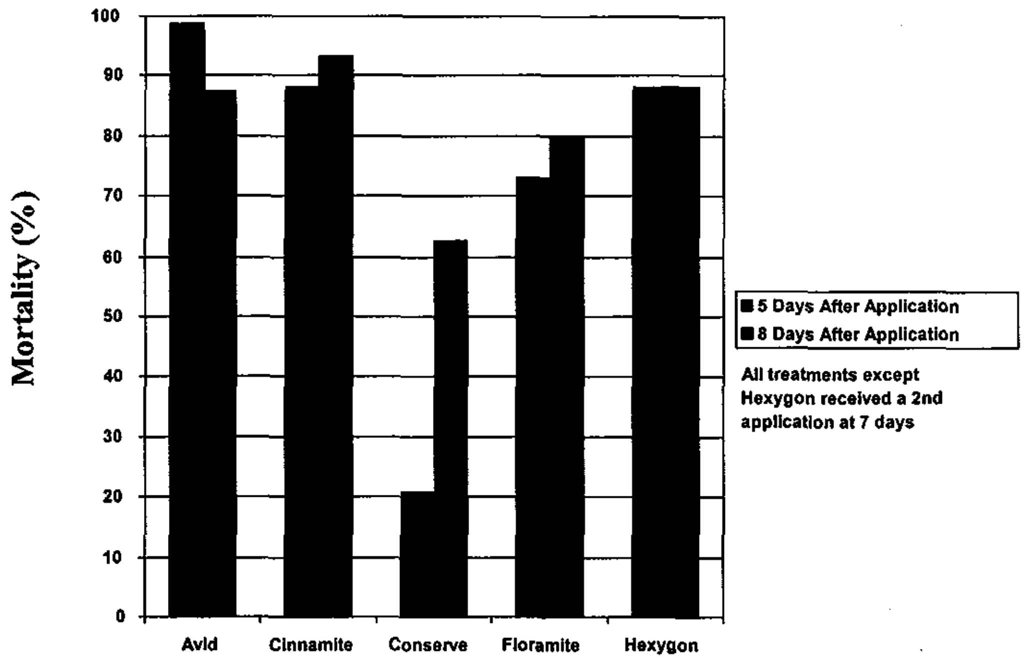

Figure 5. Mortality of immature twospotted spider mites 5 and 8 days after application.

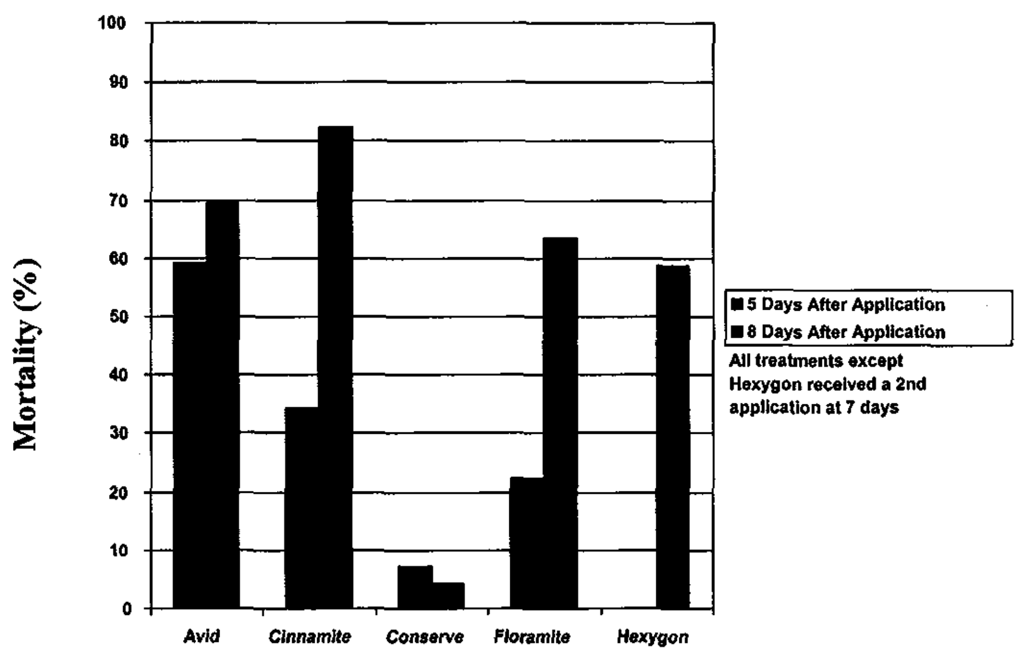

Figure 6. Mortality of adult twospotted spider mites 5 and 8 days after application.

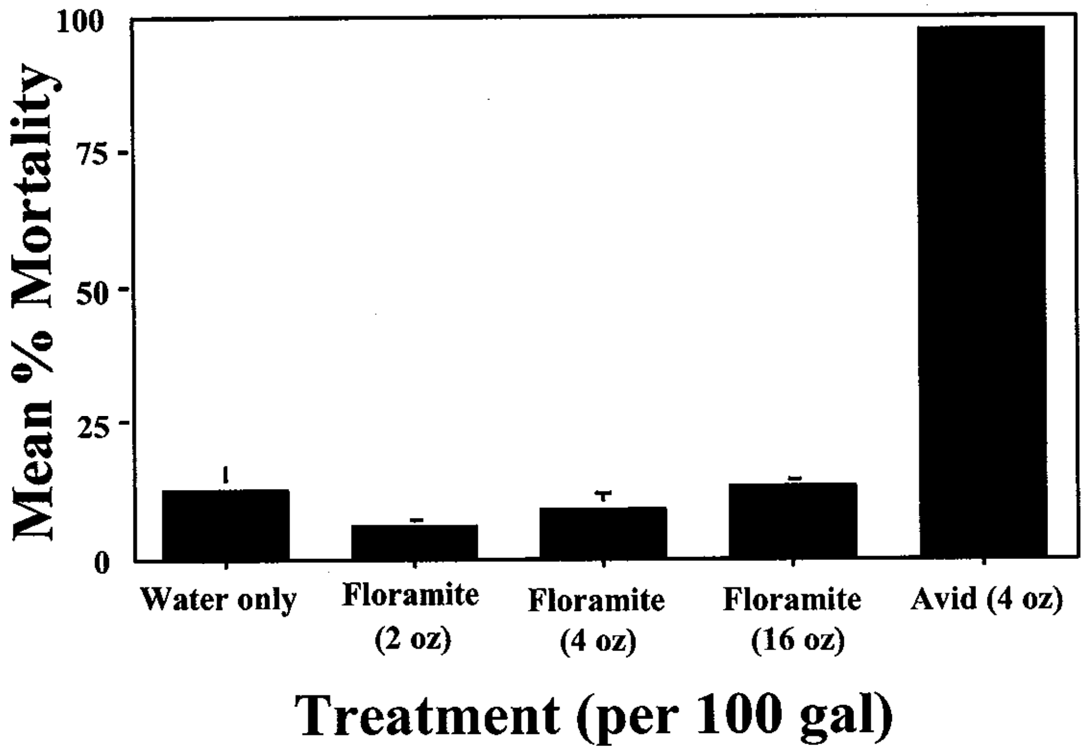

Figure 7. Compatibility of miticides with the twospotted spider mite predator, *Phytoseiulus persimilis*, after 24 hours.