

# Protective and Yield Enhancement Qualities of Kaolin on Lemons<sup>1</sup>

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## Abstract

*Kaolin (Surround) was highly effective at preventing citrus thrips populations from reaching damaging levels in Arizona lemons. Applications should be initiated before thrips become numerous. Applying the material before petal fall may offer protection of early set fruit, but may not be necessary if thrips densities are low. However, since kaolin should be applied in advance of thrips populations increase, determining the benefits of pre-petal fall applications of kaolin is difficult. Kaolin applied on a maintenance schedule offers continual suppression of thrips populations, whereas traditional standard insecticides offer temporary population knockdown. Kaolin did not interfere with photosynthesis or stomatal conductance, and may possess yield enhancement qualities.*

## Introduction

Citrus thrips, *Scirtothrips citri* (Moulton) is currently the most economically damaging insect pest affecting Arizona citrus. Although the feeding action of citrus thrips can leave citrus leaves highly distorted, it is the scarring of the fruit rind during petal fall, which is of the most economic concern. Petal fall is defined as the period of time when about 80% of the flower petals have dropped from the developing fruit. In Arizona, three weeks may pass from the time the when large numbers of petals begin to shed until 80% of petal fall is completed. During this period the fruit is susceptible to scarring by thrips, and because honeybees are usually present, applications of broad-spectrum insecticides are risky. Alternative biorational insecticides are needed to fill the niche between the onset and end of petal fall.

Following petal fall, lemons are susceptible to scarring by thrips until the fruit reaches approximately 1 inch in diameter (Kerns et al. 1997, Kerns and Tellez 1998). During this period, which typically occurs from late March to early June, citrus thrips can be extremely numerous and difficult to control. Since citrus thrips populations can increase rapidly, and individual thrips can scar the fruit in a short period of time, insecticides have been the only practical means of control. Unfortunately the number of economical and efficacious insecticides available for thrips control is extremely limited in citrus. Label restriction and revocation actions currently being taken by the EPA through the implementation of FQPA threaten to further limit our ability to effectively manage thrips. Carzol (formetamate HCL) is currently under review by the EPA, and dimethoate is scheduled for review within 1-2 years. Under the current situation, without access to these materials, thrips management would become much more costly and less effective. Therefore, it is imperative that alternative insecticides be identified.

A number of insecticide alternatives have been investigated for managing citrus thrips over the past five years. The most promising of these is Kaolin (Surround). Kaolin is non-insecticidal hydrophobic mineral particle film that acts as a physical barrier protecting plants against certain insects and diseases. Surround was developed by Engelhard Corporation of Iselin, NJ, in cooperation with Drs. Michael Glenn and Gary Puterka of the USDA/ARS at Kearneysville, WV. Kaolin is sprayed

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on as a liquid, which evaporates, leaving a film on the plant or crop surface. Kaolin's primary mode of action appears to be repellency, so it is imperative that the material be applied before thrips are numerous. In addition to its action against insect, in other tree fruits, Kaolin has been shown to protect against sunburn, and decreases heat stress leading to better fruit retention, size, and yield (Glenn *et al.* 1999).

In this study we compare the effects of conventional insecticides versus Kaolin on the development of thrips populations on lemons when applied pre-petal fall and post petal fall. We also report information concerning the effects of Kaolin on photosynthesis and yield enhancement in lemons.

## Materials and Methods

Eleven-year old 'Limoneira 8A Lisbon' lemon trees grown on the Yuma Mesa were used in these studies. All small plot tests were randomized complete block designs consisting of four replicates. Each plot consisted of four trees in a square spaced 28 ft apart.

Treatments included a commercial standard of formetamate (Carzol) or spinosad (Success) applied post petal fall when thrips reached or exceeded a threshold of 10% infested fruit (Table 1). These treatments contained a non-ionic surfactant, Kinetic at 0.1% v/v. Other treatments included kaolin applied beginning at pre-petal fall and post petal fall, and continued as needed to maintain coverage of new flush and expanding fruit (Table 1). Kaolin was applied with a surfactant designated MO-3 at 1pt/ 50lbs of kaolin. All applications were applied with a Bean handgun sprayer calibrated to deliver 300 gal/ac.

The protocol for this trial originally also included applications of kaolin applied pre- and post petal fall tank mixed with formetamate or dimethoate for thrips knockdown. However, the addition of insecticide was never required. For thrips control analysis, data from these plots were pooled by replicate with the corresponding kaolin alone treatments.

Percent-infested fruit were estimated by sampling ten fruit per tree for the presence or absence of immature citrus thrips. Applications and evaluation continued until approximately 80% of the fruit on the tree were 1.0 inch or greater in diameter. Fruit damage was estimated on Aug 19, by rating the degree of scarring to the rind. Scarring was rated as 1=no scarring, 2=slight scarring partially around the stem, 3= scarring encircling the stem, 4=slight scarring on the side of the fruit and 5=major scarring on the side of the fruit. Fruit with a damage rating of 1 or 2, are not considered to be scarred heavy enough to cause a downgrade in quality. Fruit with a rating of 3 are considered sufficiently scarred to be downgraded to choice and fruit with a rating of 4 or 5 are considered suitable for juice. Differences among insecticide treatments for thrips infestation and fruit damage were separated using ANOVA and an F protected LSD,  $P < 0.05$ .

The same treatments evaluated for thrips control were also evaluated for their impact on leaf gas exchange and yield. However, for these evaluations, the data from the kaolin / insecticide tank mixes were not pooled with data from the kaolin alone treatments. Instead, once the fruit had exceed 1 inch in diameter and were no longer susceptible to scarring by thrips, the treatments originally scheduled to receive insecticides in addition to kaolin received an additional late season (mid July) application of kaolin (designated kaolin pre-pf+ and kaolin post pf+) (Table 1). This was done to determine if late season applications of kaolin for heat protection enhance yield beyond those applied only during the thrips susceptibility period.

Leaf gas exchange was measured on July 15, 1999. Six standard control trees and six trees treated with Kaolin post pf were selected. There were still significant amounts of Kaolin on the treated leaves. Gas exchange measurements were collected on four leaves per tree, including photosynthesis (A), transpiration (E), and stomatal conductance ( $g_s$ ). Photosynthetically active radiation (PAR) data was also collected. All measurements were collected when photosynthetically active radiation (PAR) was above the light saturation point, and at least  $800 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$  (Table 2). Gas exchange data were collected using an ADC-4 infrared gas analyzer (ADC Bioscientific Ltd., Hoddeston, Herts., England). Differences among insecticide treatments for gas exchange measurements were separated using an independent samples t-test for equality of means assuming equality of variance (SPSS Inc., Chicago, IL).

Yield data was collected on October 4, 1999. Fruit was harvested from individual trees, then automatically weighed and optically sized by an automatic fruit sorter/grader (Autoline Inc., Reedley, CA). We attempted to grade the fruit in the field using the sorter/grader, but found that without first washing the fruit, it was difficult for the sorter to distinguish between the

silvery-white Kaolin residue and the silvery-gray thrips scarring. We hope to refine our optical grading in the future to allow us to grade in the field.

## Results and Discussion

Kaolin pre-pf applications were initiated during bloom prior to full petal fall, and were applied on 3 occasions (Table 1). Based on visual perception, it appeared that a single 50-lbs/ac application was insufficient to provide adequate coverage. Thus a second application was applied 7 days later on Apr 1. On Apr 2 the test received approximately 1 inch of precipitation that washed off much of the kaolin. Thus on Apr 9, a third application was needed. Based on our experiences, it appears that 75-100 lbs/ac of kaolin should be used for the initial application followed by applications of 50 lbs/ac for maintenance. Kaolin post pf applications were initiated on Apr 20 following petal fall, and commercial standard insecticide applications began on May 10, triggered by a 10% infestation threshold (Table 1).

Before petal fall, thrips populations were moderate in all but the plots that received kaolin pre-pf, which were very low (Fig. 1). Populations in all the plots declined in late April and did not reach the action threshold until May 6, which triggered an application of formetamate in the commercial standard. During this period, thrips populations in all plots treated with kaolin remained low. Formetamate was effective in lowering the thrips populations to an acceptable level, but required re-treatment with spinosad on May 28.

On August 19, fruit were visually graded for thrips damage (Fig. 2). Thrips population densities were moderate throughout the trial (Fig. 1), and 50% of the fruit in the untreated plots was graded as fancy, and there were no significant differences among treatments in the percentage of juice fruit produced (Fig. 2). Plots receiving kaolin pre-pf produced the highest percentage of fancy fruit (95%), significantly more than in the commercial standard (83.33%), but not different from the kaolin post pf plots (91%). Although there were some susceptible fruit present in the kaolin post pf treatments prior to the initiation of post pf treatments, there were no obvious benefits from applying the kaolin pre-pf. However, thrips densities were not high throughout the pre-pf period, otherwise the kaolin pre-pf applications may have been justifiable.

Photosynthesis, transpiration and stomatal conductance of leaves treated with Kaolin were not significantly different than that of leaves of the trees treated with standard post pf insecticides (Table 2). It appears that application of the clay does not interfere with normal leaf function, either by blocking the incidence of light on the leaf surface, or by congesting the stomata on the underside of the leaves. Additionally, there were no obvious phytotoxicity problems associated with Kaolin on citrus.

Yield of lemons treated with Kaolin was greater than that of lemons treated with either the standard pf treatment, or the untreated control. Unfortunately, high variability among the treatments and a small number of replications led to no significant differences (Table 3). There were no discernable effects of insecticide on fruit size. It is possible, if variability was reduced, that yield of Kaolin trees might outstrip that of the untreated controls and that of conventionally treated trees. Such an occurrence might be due to the Kaolin treated fruit being cooled by the applications, leading to reduced water loss and resultant drop.

Kaolin appears to be an excellent insecticide alternative for citrus thrips management in lemons. Based on these data and previous experiments, Kaolin should be applied preventable before citrus thrips become numerous, and maintenance applications must be continued to cover new growth until the fruit reaches 1 inch in diameter. Whether or not kaolin applications should be initiated during bloom or after petal fall is not certain, but obviously depends on the thrips populations during this period. Pre-petal fall applications would offer protection of susceptible fruit at a time when insecticides are avoided because of the inevitable presence of honeybees. But these applications may not be necessary due to the unpredictable possibility of low thrips populations.

## Literature Cited

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Table 1. Treatments, application timing, and rates.

Treatments <sup>1</sup>	Date of application						
	Mar 25	Apr 1	Apr 9 <sup>2</sup>	Apr 20	May 10	May 28	July 15 <sup>3</sup>
Kaolin pre-pf	50 lbs/ac	50 lbs/ac	75 lbs/ac	50 lbs/ac	50 lbs/ac	50 lbs/ac	
Kaolin post pf				75 lbs/ac	50 lbs/ac	50 lbs/ac	
Kaolin pre-pf+	50 lbs/ac	50 lbs/ac	75 lbs/ac	50 lbs/ac	50 lbs/ac	50 lbs/ac	50 lbs/ac
Kaolin post pf+				75 lbs/ac	50 lbs/ac	50 lbs/ac	50 lbs/ac
Standard post pf					formetamate 1.5 lbs/ac	spinosad 6 oz/ac	

<sup>1</sup>All applications were applied at 300 gal/ac. All kaolin applications included the surfactant MO-3 at 1 pt/ 50 lbs of kaolin. All standard treatments included Kinetic at 0.1% v/v. Thrips data from the Kaolin pre-pf and Kaolin pre-pf+ treatments and the Kaolin post pf and Kaolin post pf treatments respectively were pooled for analysis.

<sup>2</sup>Rain on Apr 2 removed much of the previously applied kaolin making this application necessary.

<sup>3</sup>These applications did not target thrips, but were applied as further protection against heat stress.

Table 2. Leaf gas exchange measurements of trees treated with standard post petal fall insecticides and Kaolin post petal fall.

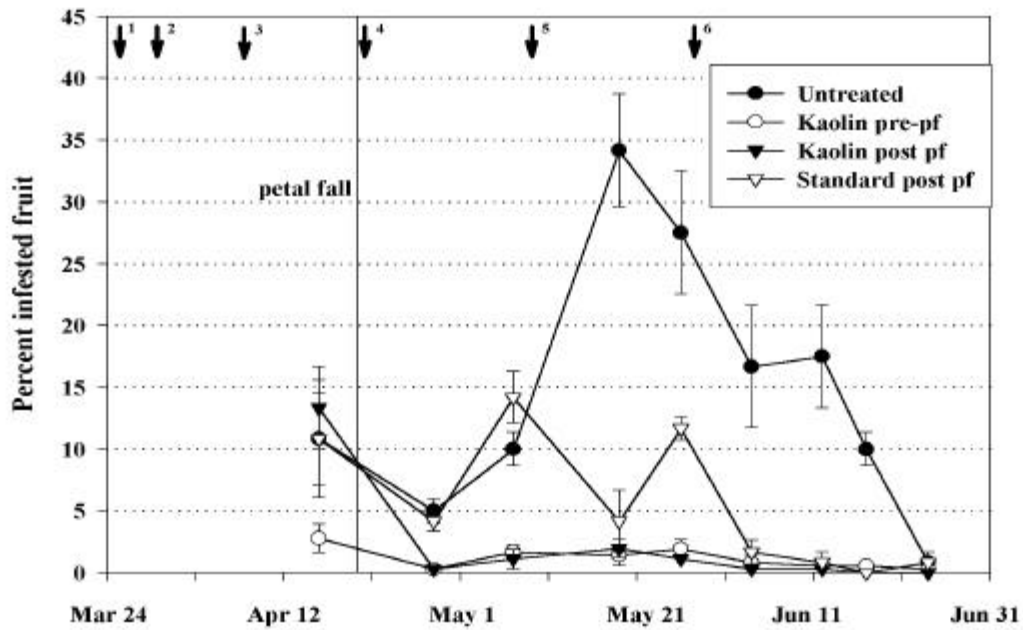
Treatments	Date of application			
	PAR ( $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ )	Photosynthesis ( $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ )	Transpiration ( $\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ )	Stomatal Conductance ( $\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ )
Standard post pf	1652	10.07	1.96	0.0372
Kaolin post pf	1896	9.39	1.94	0.0329
Significance <sup>1</sup>		0.238	0.816	0.135

<sup>1</sup> Values greater than 0.05 are considered to be non-significant.

Table 3. Effect of kaolin treatments on yield and size of 'Limoneira 8A Lisbon' lemons harvested on Oct 4.<sup>1</sup>

Treatments	Yield (Lbs/tree)	Fruit size (%)							
		63	75	95	115	140	165	200	235
Untreated	64.16 a	0.1 a	0.3 a	4.0 a	29.9 a	32.8 a	13.0 a	18.6 a	1.2 b
Kaolin pre-pf	90.07 a	0.0 a	0.1 a	2.4 b	25.2 a	33.8 a	12.7 a	22.4 a	3.2 a
Kaolin post pf	90.64 a	0.0 a	0.0 a	3.2 ab	27.0 a	33.5 a	13.0 a	20.9 a	2.2 ab
Kaolin pre-pf+	89.92 a	0.0 a	0.1 a	3.0 ab	27.3 a	34.4 a	12.4 a	20.2 a	2.5 ab
Kaolin post pf+	94.83 a	0.0 a	0.1 a	3.3 ab	29.0 a	34.5 a	11.4 a	18.7 a	2.9 ab
Standard post pf	79.44 a	0.0 a	0.2 a	2.9 ab	26.2 a	34.4 a	13.2 a	20.6 a	2.5 ab

<sup>1</sup>Means separation by Duncan's Multiple Range Test, p=0.05. Values within a column that are followed by the same letter are not significantly different.



**Figure 1** Efficacy of pre and post petal fall applications of kaolin to citrus thrips on lemons.

<sup>1</sup>Kaolin pre-pf, 50 lbs/ac (Mar. 25).

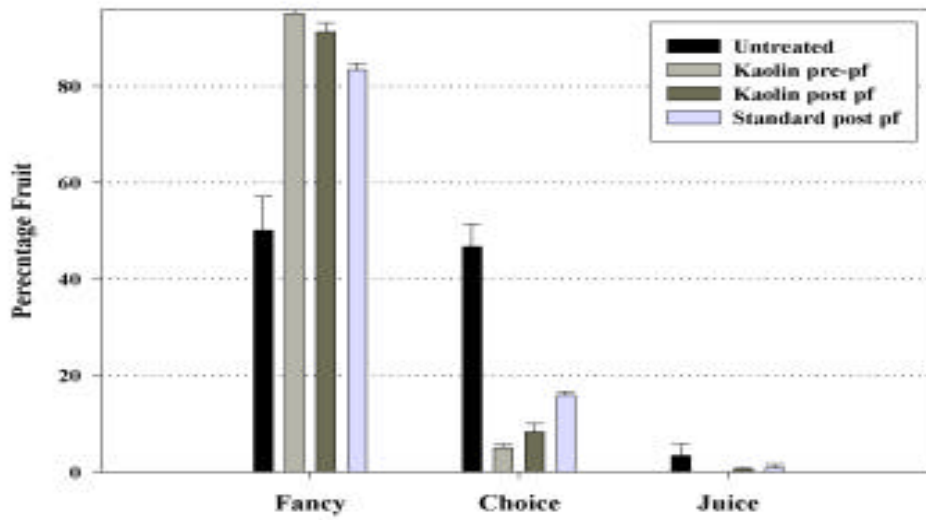
<sup>2</sup>Kaolin pre-pf, 50 lbs/ac (Apr. 1), washed off by rain on Apr. 2.

<sup>3</sup>Kaolin pre-pf, 75 lbs/ac (Apr. 9).

<sup>4</sup>Kaolin pre-pf, 50 lbs/ac; Kaolin post pf, 75 lbs/ac (Apr. 20).

<sup>5</sup>Kaolin pre-pf and Kaolin post pf, 50 lbs/ac; Standard post pf – formetamate, 1.5 lbs/ac (May 10).

<sup>6</sup>Kaolin pre-pf and Kaolin post pf, 50 lbs/ac; Standard post pf – Spinosad, 6oz/ac (May 28).



**Figure 2** Percentage of fruit graded as fancy, choice, or juice due to citrus thrips scarring following applications of kaolin beginning pre-petal fall, or kaolin or a commercial standard post petal fall.