Pest Management and Yield Enhancement Qualities of Particle Film Technologies in Citrus[1]

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Abstract

Surround WP and Snow were evaluated for their ability to manage citrus thrips populations in lemons on the Yuma Mesa, and their impact on lemon yield, fruit quality, and packout. Both Surround and Snow effectively controlled citrus thrips and prevented fruit scarring, but their ability to manage Yuma spider mite was inconclusive. Preference tests indicated that both Surround and Snow act primarily by repelling the thrips, but also induce some mortality. Surround produced higher yields than Snow at the first harvest (#8 ring), but did not differ from the commercial standard. There were no differences in yield among treatments for the strip harvest, nor were their any differences in total yield. These data suggest that Surround may have some yield or increased fruit earliness enhancement qualities and that Snow may be slightly detrimental. There were no statistical differences among any of the treatments in fruit size frequency or quality for any of the harvests, and there was no apparent benefit from applying an additional application of Surround or Snow post thrips season solely for quality, fruit size, or yield enhancement.

Introduction

Surround WP represents a new and unique approach to managing thrips, *Scirtothrips citri* (Moulton) in citrus. Unlike conventional insecticides that control citrus thrips through rapid curative action, Surround appears to act primarily as a repellent. However more research in citrus is need to confirm this assumption. Surround is a hydrophobic mineral particle film applied in water that forms a bright white physical barrier protecting plants against certain insects and diseases. Although the leaves are covered in a white film, there is no evidence that Surround interferes with photosynthesis or stomatal conductance.

In addition to its action against insects, in other tree fruits, Surround has been shown to protect against sunburn, and decrease heat stress which may lead to better fruit retention, size, and yield. Our preliminary data suggests that Surround may enhance yield in citrus, however, more data is needed to confirm this finding.

Snow is another kaolin-based product that is similar to Surround. Snow is commonly used in citrus sunburn protection and has demonstrated activity towards citrus thrips. Currently Snow is a more cost effective alternative than Surround, but because Snow contains a greater percentage of inert materials such as silica, it is not known whether it is as effective as Surround in controlling insects, or whether it will enhance citrus yield.

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In this study we compared the effects of conventional insecticides versus Surround and Snow on the development of thrips and mite populations and subsequent scarring on lemons. Additionally, we investigated the mechanism of action of Surround and Snow on citrus thrips in terms of repellency and mortality induction. We also report information concerning the effects of Surround on yield, fruit size, and quality in lemons.

Materials and Methods

Thirteen-year old 'Limoneira 8A Lisbon' lemon trees grown on the Yuma Mesa were used for these studies. The test was a strip-plot design consisting of four replicates and three main plots: a commercial standard insecticide regime, Surround, and Snow. There were two sub-plots: an early-season regime where Surround and Snow were applied for citrus thrips control (as needed to maintain coverage until 85% of the fruit equaled or exceeded 1.0 inch in diameter), and a full-season regime where an additional application of Surround and Snow were applied post thrips season in attempt to enhance fruit size and retention. The early-season applications consisted of Surround at 50 lbs/ac and Snow at 80 lbs/ac applied on 9 and 12 April; 1, 11, and 21 May; and 8 June. The commercial standard was applied as needed to maintain the thrips population at or below a 10% fruit infestation level, and as needed for spider mite control. The commercial standard consisted of Dimethoate 4E at 2qt/ac applied on 9 April, Danitol at 21 oz/ac applied on 11 and 21 May, and Success at 4 oz/ac applied on 8 June. The Surround and Snow treatments in the full-season treatment regimes received an additional application of 50 and 80 lbs/ac respectively, on 12 July. The commercial standard did not receive additional applications in the full-season regime sub-plots. All treatment applications included Kinetic non-ionic surfactant applied at 0.1% v/v. All treatments were applied using a PTO-driven orchard sprayer, calibrated to deliver 100 gal of spray solution per acre. The size of each sub-plot was 5 x 7 trees (0.5 ac), with trees being spaced 28 ft apart.

Pest infestation severity was estimated by sampling 50 fruit per plot for the presence or absence of immature citrus thrips and spider mites. Fruit damage was estimated on 9 October, by visually 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 enough to cause a downgrade from fancy to choice grade. Fruit with a rating of 3 are considered sufficiently scarred to be downgraded to choice grade and fruit with a rating of 4 or 5 are only considered suitable as juice grade fruit. Differences among insecticide treatments for thrips and mite infestation, and fruit damage were separated using ANOVA and an F protected LSD, $P<0.05$.

Fruit from each tree was harvested by hand using professional pickers from a local packinghouse. The experimental block was harvested three times, on 9 October 2001, 29 November 2001, and 4 February 2002. For the first harvest, the pickers sized the fruit on the tree, using a #8 metal ring with a diameter of the minimum marketable size for that date, as determined by the packinghouse. For the second harvest, a portion of the plots were ring picked, while the remaining plots were stripped. All the fruit was stripped on the third harvest. Since a portion of the plots were stripped during the second harvest, the data for this harvest was pooled with the third harvest to constitute a total strip harvest of the trees. Fruit from each subplot was harvested into plastic bins, each holding 1200 lbs. of fruit. Yields for each sub-plot were estimated as whole and fractional bins of harvested fruit. Yield data, are expressed in lbs. of fruit per acre.

For each of the three harvests, from 15 to 45 kg. of fruit was sampled from the fruit in each bin, and size (packout) data were collected from this sample. All fruits were sized using a portable optical fruit grader (Autoline, Inc., Reedley, CA). Each fruit that passed through the sorter was photographed and weighed. Weight, color, and fruit diameter data was collected for each fruit. Fruit was not physically sorted, but the data collected was stored in a laptop computer that is an integral part of the sorter. All fruit size results are reported on a percentage basis. Data for the second and third harvests were pooled. Differences among treatments for yield, packout, and quality were separated using ANOVA and an F protected LSD, $P<0.05$.

To determine the mechanisms of activity for Surround and Snow on citrus thrips, a series of preferential choice tests were conducted. For the first series of experiments we selected new fully expanded lemon leaves and treated half (choice test) or all (no choice test) of the ventral leaf surface with Surround or Snow, or left the leaves untreated. For the choice test, the apical 50% of the leaf surface area was treated. Leaves were placed in Munger cells where they could be infested with citrus thrips. The Munger cells were positioned over the center of the leaf and sealed with a Plexiglas sheet secured with 2 inch binder clips. Ten immature of adult citrus thrips were aspirated into each cell and left undisturbed at 82ºF for 24 hours, after which the number of dead thrips were recorded, and the number on either the treated portion, untreated portion, or on the top or sides of the cells were recorded. Each treatment was replicated four times.

For another preferential choice test we selected flush lemon growth to be used as the bioassay substrate instead of individual leaves. In this test, fresh lemon terminals 12 to 15 inches in length were cut in the field and placed in buckets of water for transport to the laboratory. In the laboratory, the terminals were rinsed in tap water to remove any insects, mites, or dust, and the stems were placed in 125 ml flasks filled with distilled water. The flask mouth was sealed around the stem with paraffin wax. Once the rinsed terminals were dry, they were treated with Surround or Snow, or left untreated. The terminals were then placed in sealed insectary cages constructed from polyvinyl plastic storage bins. Each cage consists of two 12 x 12 x 24 inch storage bins glued together top to top, with a sealable door cut into one side, with vents on the top and all sides covered with 0.1-mm^2 meshed cloth. Each cage was illuminated for the entire test period using two 40 watt incandescent light bulbs. Treatments consisted of choice tests where each cage contained a terminal treated with Surround or Snow and an untreated terminal, no choice tests where each cage consisted of two terminals treated with either Surround or Snow, or the control treatment consisting of two untreated terminals. Each treatment was replicated four times. Each insectary cage was infested with 200 field collected adult citrus thrips, released in the bottom of the cage. After 24 hours, each terminal was carefully cut and tapped on a beat pan with a yellow sticky card in the bottom to trap the thrips which were then counted. Data from all the preference tests were converted to percentages and analyzed using ANOVA and an F protected LSD, $P<0.05$.

Results and Discussion

Citrus thrips were extremely low among all plots in this study throughout the season. Based on an action threshold of 10% infested fruit, thrips populations never reached damaging levels during the period of fruit susceptibility (Figure 1). Because Surround and Snow are thought to act primarily as a repellent, treatments were applied preventively being initiated just prior to full petal fall on 9 April, additional applications of Surround and Snow were made to insure coverage of new growth. Although, the commercial standard never exceeded the action threshold, an initial application at petal fall on 9 April was made as is often a standard practice even as low population density early in the season. Applications of Danitol were applied on 11 and 21 May primarily for control of Yuma spider mites, *Eotetranychu yumensis* (McGregor) (Figure 2). Since the Danitol did not appear to effectively control citrus thrips which continued to rise to almost 8% infestation, Success was applied on 8 June. Statistically, differences in thrips infestation were observed on 9, 18 and 25 May, and on 4 June. On all of these sample date, the Surround and the Snow treatments contained significantly fewer infested fruit than the commercial standard, but did not differ from each other (Figure 1). The Yuma spider mite population was variable and we could not detect any difference among any of the treatments. Thus we are not certain from this test whether or not Surround or Snow is efficacious against Yuma spider mite. As expected due to the low thrips populations and effective treatment regimes, there were no statistical differences among treatments in fruit scarring (Figure 3). None of the treatments contained fewer than 95% fancy grade fruit due to thrips scarring.

Following the first harvest, plots treated with Surround produced a significantly higher yield than those treated with Snow, but did not differ from the commercial standard, but we could not detect any benefit in yield by making an additional application of Surround or Snow post thrips season in July (Figure 4). There were no significant differences in yield among treatments for the 2nd or 3rd harvests or for total yield (Figure 4). When comparing percentage of fruit harvested during the first harvest relative to the stripped harvests, the Surround plots produced a significantly higher proportion of its yield during the first pick than Snow, but did not differ from the commercial standard (Figure 5). The fact that Surround increased yields during the first harvest over Snow but not the commercial standard suggests that Surround may increase earliness to some extent through reduction of leaf temperature and subsequent increase in stomatal conductance and photosynthesis and that Snow may have a slight negative impact. Temperatures during 2001 were relatively cooler than normal particularly in June. These sub-normal temperatures may have lessened the potential impact Surround might have on yield or fruit earliness relative to the commercial standard. Snow may have had a slight negative impact on yield and fruit earliness relative to Surround because it contains higher percentages of inert ingredients such as silica, which could adversely influence photosynthesis and/or stomatal conductance by clogging the stomata. We did not detect any differences in fruit sizes frequency or fruit quality among any of the treatments (Figures 6, 7, 8, and 9).

In the Munger cell choice test, a greater percentage of nymph and adult citrus thrips preferred to settle on a lemon leaf surface without Surround or Snow relative to an untreated surface, but Surround and Snow treatments did not differ from each other (Table 1). This supports the theory that both citrus thrips nymphs and adults will avoid settling on a leaf surface treated with either particle film. Thus, on a tree where Surround or Snow is applied, citrus thrips will avoid moving onto treated portions from untreated portions. In addition to repellency, both Surround and Snow induced significant nymphal mortality after 24 hours, but only Surround induced significant mortality to adults (Table 2). In the no choice Munger cell test where the thrips did not have an untreated leaf surface to settle on but had to either settle on the particle film or on the cage surface, Surround had the lowest percentage of nymph citrus thrips settle on the treated surface, but Surround did not differ from Snow or the untreated for adults (Table 1.) Snow had significantly fewer adult thrips settle on its surface than the untreated (Table 1). Surprisingly, in the no choice test there was no significant differences in nymph mortality among treatments, yet Surround induced higher mortality of adult thrips than either the untreated or Snow (Table 2).

In the terminal preference test, citrus thrips adults preferred to infest untreated foliage over foliage treated with either Surround or Snow when given a choice, and preferred to settle on the cage surface or were killed when forced to select a treated terminal over nothing at all (Table 3). These data demonstrate that both Surround and Snow have good repellency qualities to adult thrips, thus suggesting that adult citrus thrips moving into a grove from outside or from weeds in the grove may be effectively repelled for the treated surfaces. These preference test data suggest that most of Surround and Snow's activity comes from the repellency of the products to both immature and adult citrus thrips. Additionally, Surround and Snow also appear to cause some direct mortality of citrus thrips.

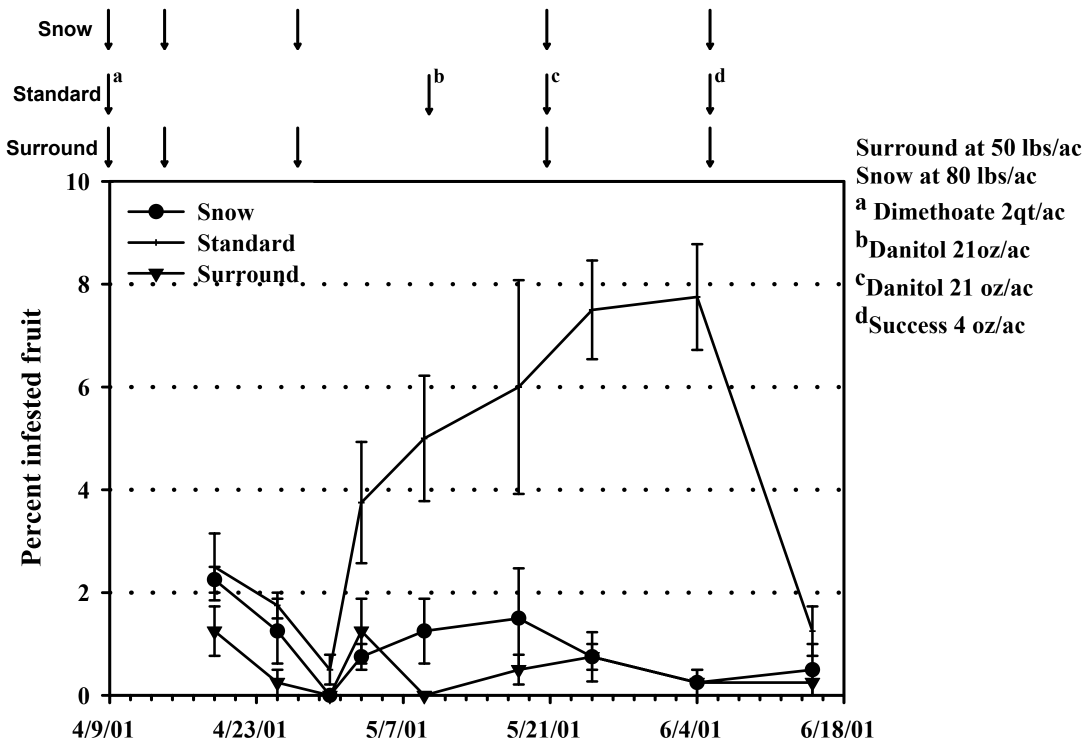

Figure 1. Percentages of lemon fruit infested with at least one immature citrus thrips.

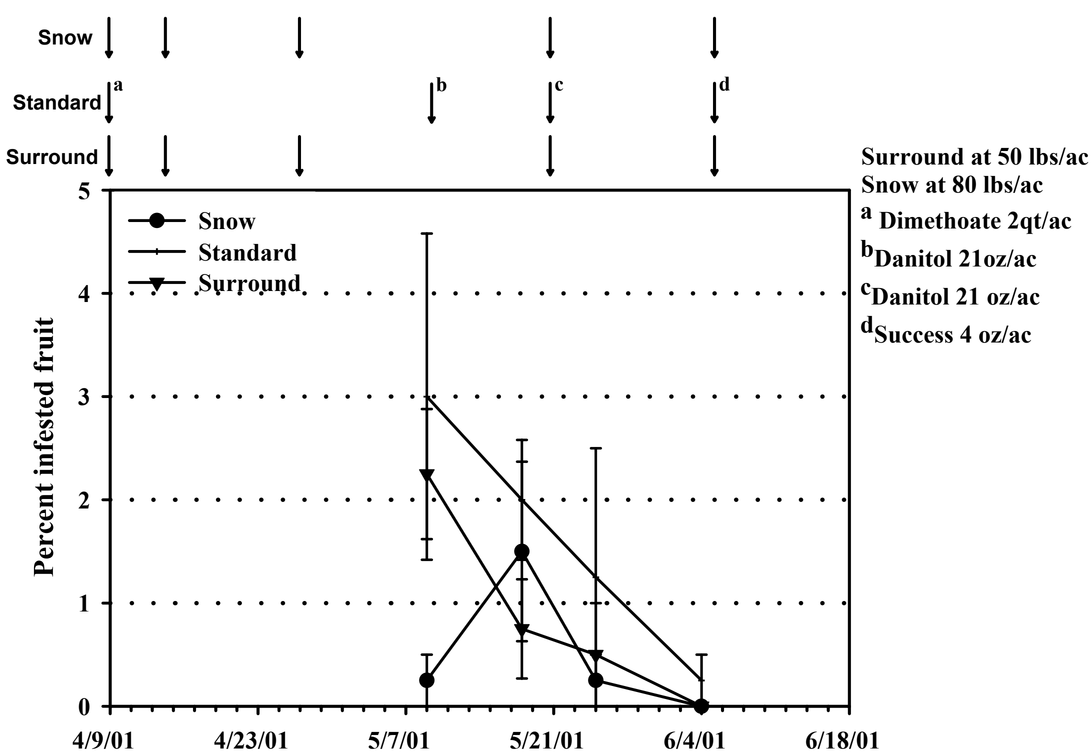

Figure 2. Percentages of lemon fruit infested with at least one Yuma spider mite.

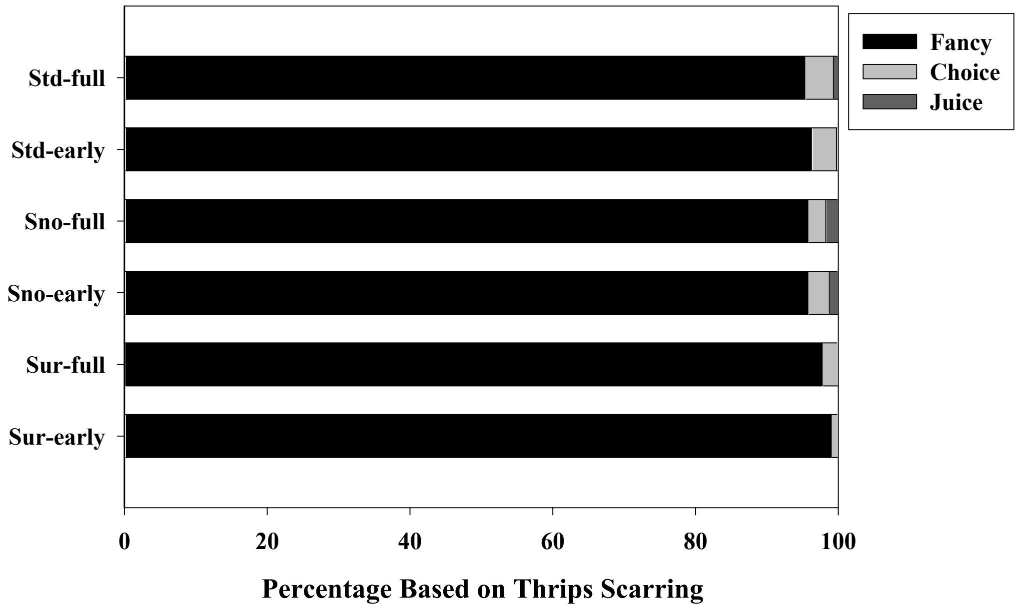

Figure3. Percentage of fancy, choice and juice grade lemons due to thrips scarring.

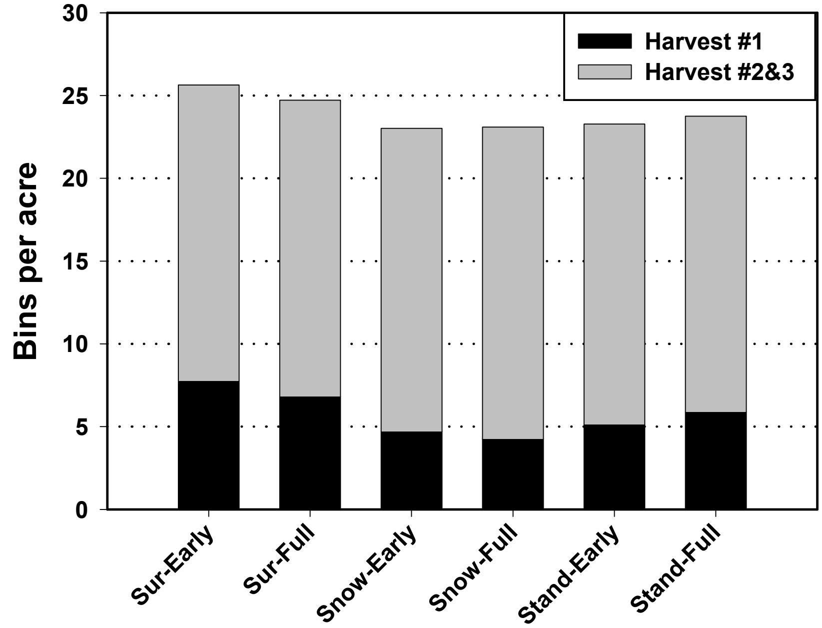

Figure 4. Yield of lemons from plots treated with Surround or Snow particle films, or with commercial standard insecticides (first harvest on 9 October 2001, second harvest on 24 November 2001 and third harvest on 4 February 2002).

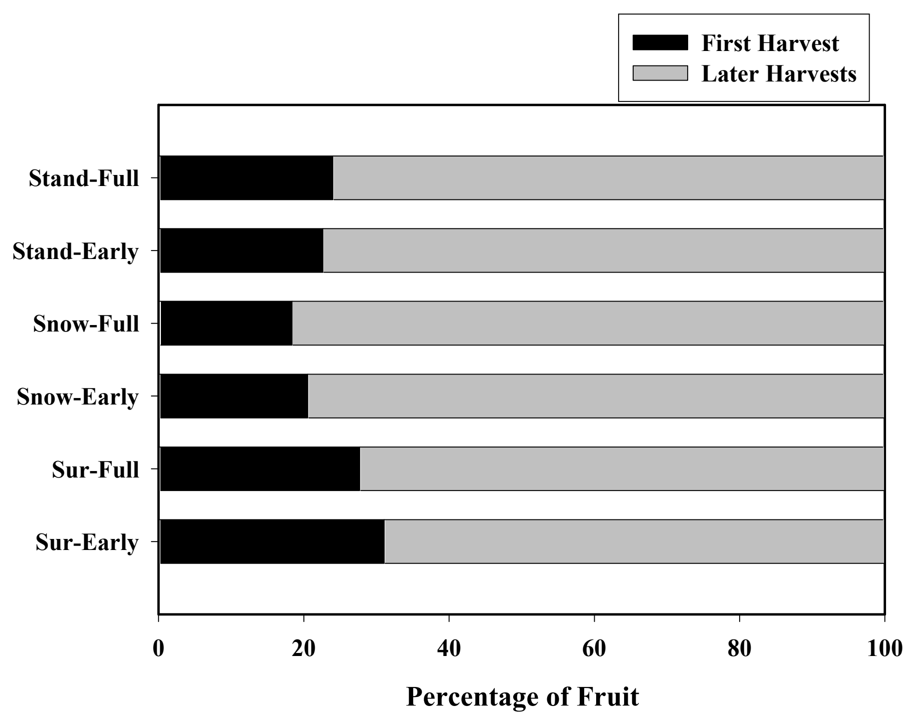

Figure 5. Percentage of lemon fruit picked during the first harvest (#8 ring, on 9

October 2001) relative to a combination of the second and third harvests (24 November 2001 and 4 February 2002).

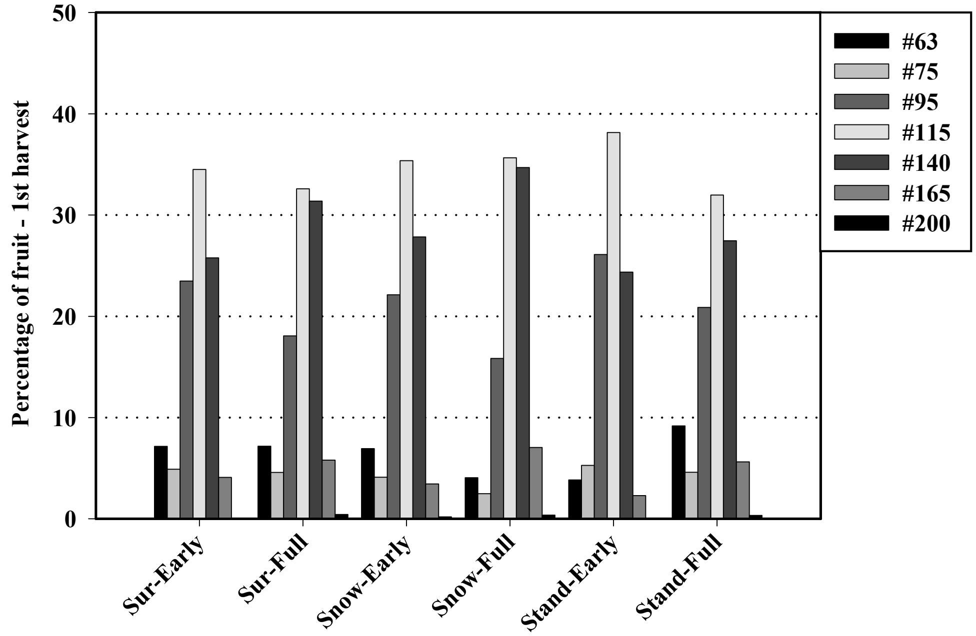

Figure 6. Effects of Surround and Snow particle films on fruit size at first harvest (#8 ring), on 9 October 2001.

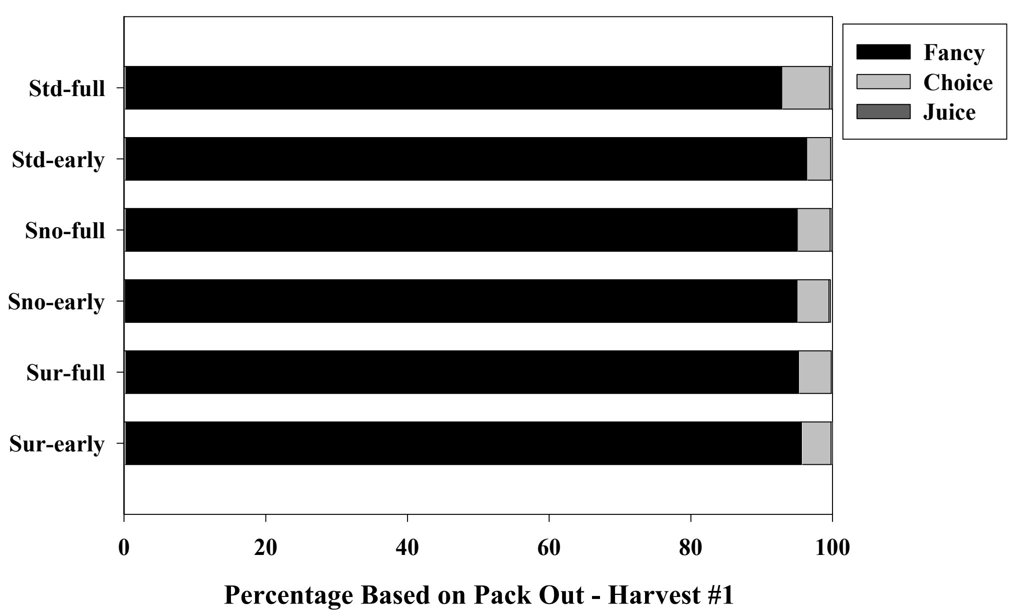

Figure 7. Effects of Surround and Snow particle films on fruit quality at first harvest (#8 ring), on 9 October 2001.

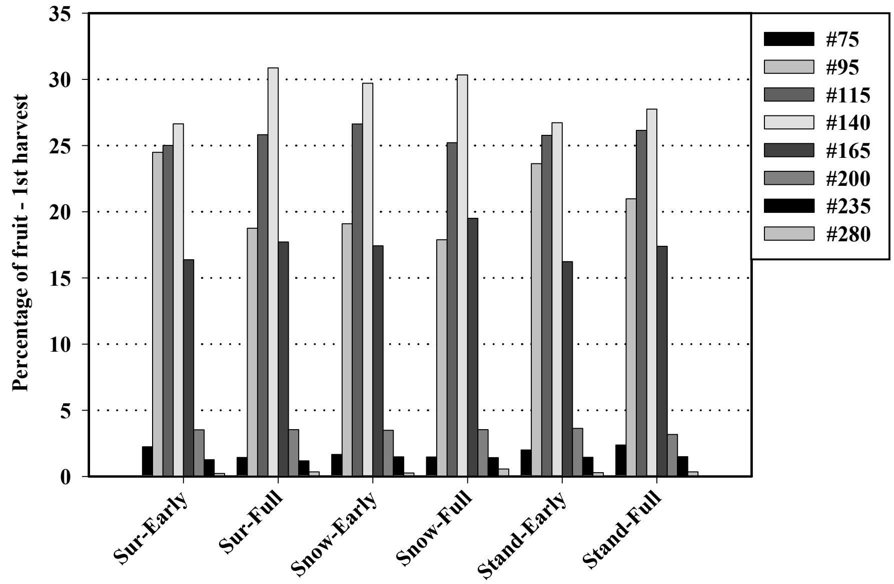

Figure 8. Effects of Surround and Snow particle films on fruit size at second and third harvest (stripped), on 24 November 2001 and 4 February 2002.

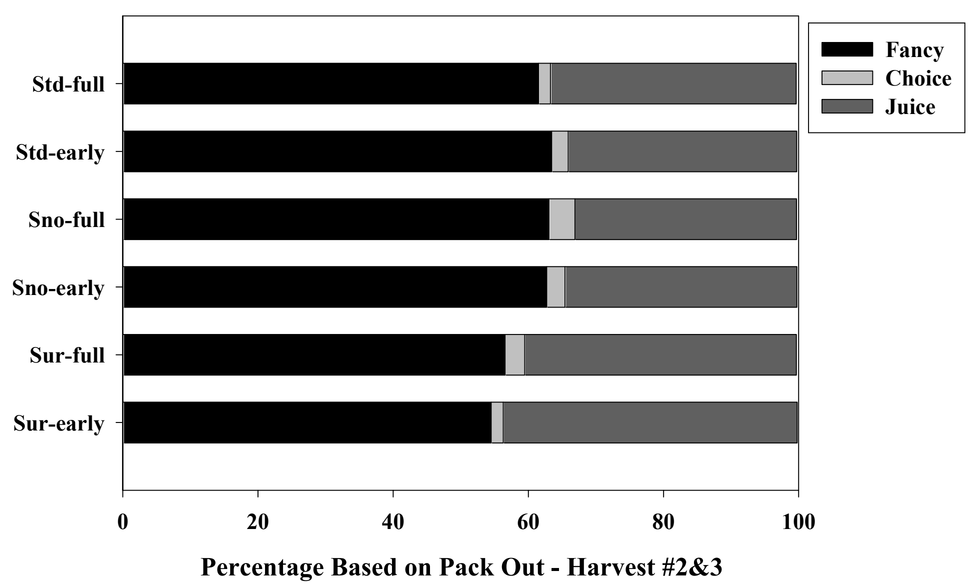

Figure 9. Effects of Surround and Snow particle films on fruit quality at the second and third first harvests (stripped), on 24 November and 4 February 2002.

Table 1. Percentage of surviving adult and immature citrus thrips settling on lemon leaves treated with Surround or Snow relative to untreated foliage in choice and no choice tests after 24 hours.

	Choice test		No choice test	
Treatment	Nymphs	Adults	Nymphs	Adults
Surround	16.67 ± 11.79 a	18.93 ± 8.32 a	52.50 ± 3.84 a	81.25 ± 11.97 ab
Snow	6.25 ± 6.25 a	9.13 ± 5.51 a	80.42 ± 7.08 b	50.00 ± 17.32 a
Untreated	100.00 ± 0.00 b	100.00 ± 0.00 b	100.00 ± 0.00 c	100.00 ± 0.00 b

Means in a column followed by the same letter are not significantly different based on an F protected LSD ($P \leq 0.05$).

Table 2. Percent mortality of adult and immature citrus thrips on lemon leaves treated with Surround or Snow relative to untreated foliage in choice and no choice tests after 24 hours.

	Choice test		No choice test	
Treatment	Nymphs	Adults	Nymphs	Adults
Surround	39.58 ± 11.47 a	18.95 ± 3.94 a	23.06 ± 10.28 a	44.55 ± 6.89 a
Snow	11.25 ± 6.57 a	11.70 ± 1.05 ab	25.48 ± 8.81 a	19.29 ± 6.74 b
Untreated	0.00 ± 0.00 b	4.58 ± 2.67 b	0.00 ± 0.00 a	4.58 ± 2.67 b

Means in a column followed by the same letter are not significantly different based on an F protected LSD ($P \leq 0.05$).

Table 3. Percentage of surviving adult citrus thrips settling on lemon flush growth treated with Surround or Snow relative to untreated foliage in choice and no choice tests after 24 hours.

Treatment	Choice test	No choice test
Surround	2.88 ± 1.07 aA	15.36 ± 2.22 aB
Snow	1.75 ± 0.52 aA	14.45 ± 2.42 aB
Untreated	70.19 ± 1.33 bA	70.19 ± 1.33 bA

Means in a column followed by the same lower case letter and means in a row followed by the same upper case letter not significantly different based on an F protected LSD ($P \leq 0.05$).