Table 6. Mean number (±SEM) live, parasitized and percent parasitized 2nd and 3rd instar CRS per 20 fruit collected on 27 July 2000.

	CRS		
	(No. Live)	(No. Parasitized)	(% Parasitized)
Diflubenzuron + HMO	16.0 ± 4.6 a	3.1 ± 0.9	16.0 ± 2.7 a
Pyridaben + Pyriproxyfen	3.6 ± 1.1 b	0.2 ± 1.2	4.1 ± 2.6 b
Pyridaben + HMO	4.1 ± 1.0 b	0.13 ± 0.09	2.2 ± 1.6 b

Means within columns followed by the same letter are not significantly different (LSD, $P < 0.05$).

In the aftermath of a favorable CRS year, infestations increased with a single spring application of pyridaben in 1999. The effect was enhanced by an additional application in the fall, although a single fall application was not sufficient to cause an increase. No increase with pyridaben was observed in 2000, although CRS populations were successfully reduced to extremely low levels with pyriproxyfen. Thus, we should not expect pyridaben to exacerbate CRS populations under typical Florida conditions. However, if the climate again approaches a Mediterranean rainfall pattern, we might again see increases in CRS populations in response to applications of pyridaben. Under such conditions, pyridaben would best be reserved for fall applications, and pyriproxyfen could be used effectively for CRS suppression if necessary.

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Literature Cited

Browning, H. W. 1994. Classical biological control of citrus scale insects. In Pest management in the subtropics: biological control—a Florida perspective. D. Rosen, F. D. Bennett and J. L. Capinera (eds.). Intercept, Andover.

Cardwell, E. E. and C. A. Reagan. 1999. California red scale insecticide efficacy trial, 1997. Arthropod Management Tests. 24:91.

DeBach, P. 1950. Natural control of citrus pests in Texas and Florida. California Citrograph 35:410, 434.

Dekle, G. W. 1976. Florida armored scale insects, Arthropods of Florida and neighboring land areas, 3:30. Florida Dept. Agric. And Consumer Svcs, Div. Plant Ind., Gainesville.

Krombein, K. V. P. D. Hurd, D. R. Smith, and B. D. Burks. 1976. Catalogue of Hymenoptera of North America North of Mexico, 1:894. Smithsonian Institution Press, Washington.

Stansly, P. A. 2000. California red scale outbreak in Florida. Citrus Industry. 81:25-26.

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TRUNK SHAKER AND ABSCISSION CHEMICAL EFFECTS ON YIELDS, FRUIT REMOVAL, AND GROWTH OF ORANGE TREES

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Abstract. **In a 5-year study, available abscission chemicals were applied to 'Hamlin', 'Pineapple', and 'Valencia' orange trees, which were harvested with commercially available trunk shakers. In the first 2 years, abscission chemicals prosulfuron and metsulfuron-methyl were applied and loosened mature fruit, but were phytotoxic to the trees and young 'Valencia' fruit. Abscission chemical CMN-P (5-chloro-3-methyl-4-nitro-1H-pyrazole) was applied the last 3 years and it provided better loosening of mature fruit without being phytotoxic to the trees, young 'Valencia' fruit, or reducing yields. Trunk circumference growth was not affected by shaker and/or abscission chemicals. CMN-P increased total fruit removal of the trunk shaker an average of 9%. Trunk shakers did not significantly reduce total yields compared to conventional manual harvesting methods.**

Trunk shakers have been utilized as fruit removal devices in Florida citrus for at least three decades. The initial work was done in the early 1970s (Whitney, 1975, 1995; Whitney and Sumner, 1977). Trunk shakers that had been developed for prune and nut harvesting in California were modified for use in Florida. Their shake frequencies and displacements were 15 to 20 Hz and 1 inch, respectively. Normally, abscission chemicals were applied before shaking because fruit removal was generally too low without fruit loosening. A 5-yr

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study in South Florida in the early 1980s (Whitney et al., 1986) showed that abscission chemicals increased total fruit removals (including preharvest fruit drop by abscission chemicals) of the trunk shaker an average of 26 and 17% in 'Hamlin' and 'Valencia' oranges, respectively. In addition, fruit yields and trunk growth were not affected.

In the early 1990s, low fruit prices and increasing industry concerns that the projected larger crops could not be harvested at a competitive cost caused renewed interest in mechanical harvesting. In 1993, Fruit Harvesters International, Inc. (Alva, Fla.) initiated the development of a trunk shake-catch mechanical harvesting system. In 1994, the Florida citrus industry initiated a harvesting research and development program administered by the Florida Department of Citrus to ensure that the harvesting of future crops would be done at a competitive cost. One of the mechanical fruit removal methods under development was the trunk shaker (Whitney, 1997). Without abscission chemicals, it was found that more aggressive shaking (larger displacements up to 2 inches) at lower frequencies (8 to 10 Hz) was required to achieve fruit removals in the 90% range.

With renewed interest in abscission chemicals to aid mechanical harvesting, field testing of candidate abscission chemicals with trunk shakers began in 1997 (Whitney et al., 2000). It was found that total orange removals by trunk shakers were increased by 10 to 15% when the fruit detachment forces were reduced 50 to 80% with abscission chemicals. Growers continued to be concerned about the long-term effects of trunk shakers and abscission chemicals on tree productivity. The objectives of this study were to measure the effects of trunk shakers and abscission chemicals on the yield, fruit removal, and trunk growth for Florida oranges over a 5-yr period.

Materials and Methods

In 1997, five replicated field experiments were initiated in a grove between Sebring and Arcadia, Fla. The trees were planted in 1988 on two-row beds with between-row spacings of 22 ft (across bed) and 26 ft (across ditch) and an in-row spacing that was alternately 10 and 15 ft. Each experiment was replicated six times with two-tree plots (paired trees at 10 ft in-row spacing) with four treatments as described in Table 1. The experimental design was split plot with abscission chemical (C) and no abscission chemical (NC) as the two whole-plot treatments and shaker (SK) and handpick (HP) as the two split-plot or subplot treatments or a total of 48 trees per experiment.

Different trunk shakers and abscission chemicals were used during the experiments and are shown in Table 2. In addition to the 'Hamlin' and 'Pineapple' experiments, there were three 'Valencia' experiments (1, 2, 3) corresponding to three dates of harvest with each successive date separated by 2 to 3 weeks when the immature (young) fruit for next year's crop were increasing in diameter. Compton (Compton Enterprises, Inc., Chico, Calif.) and FHI (Alva, Fla.) trunk shakers were used in 1997 through 1999 while Orchard Rite (Orchard Rite Ltd., Inc., Yakima, Wash.) trunk shakers were used in 2000 and 2001. These shakers are described in more detail in Whitney (1997) and Whitney et al. (2000, 2001). Prosulfuron (Peak, Novartis, Greensboro, N.C.) was applied to 'Valencia' only in 1997. Metsulfuron-methyl (Ally, DuPont, Wilmington, Del.) was applied in 1998 and CMN-P (5-chloro-3-methyl-4-nitro-1H-pyrazole, Release, Abbott Laboratories, Chicago, Ill.) was applied in 1999 through 2001.

All trees designated for the mechanical harvester treatments were shaken for five consecutive years, 1997-2001. Likewise, all trees designated for abscission chemicals (except for the 'Hamlin' and 'Pineapple' orange trees in 1997 when no abscission chemical was available) were sprayed for the same five consecutive years. Each year the abscission chemical was applied with an airblast sprayer. When fruit loosening was judged to be adequate, the fruit was harvested. Just prior to harvest, fruit drop was counted and fruit detachment forces (FDF) were measured on 10 fruit in each of three abscission and no-abscission chemical trees, and the 10 fruit were weighed to determine an average fruit weight. All trees designated for trunk shaking were shaken for approximately the same length of time (usually between 5 and 10 sec) based on optimum fruit removal on the trees sprayed with the abscission chemical. On two or three representative trees, simultaneous acceleration measurements were made on the shaker head and tree trunk, and were subsequently mathematically integrated to quantify shaker/tree displacements and shaking frequencies. These measurements were made to verify that the shaker displacements and frequencies were similar for most of the experiments. The fruit removed by the shaker in each two-tree plot (including fruit drop) were weighed with an electronic scale on a goat truck. Fruit left on the trees in each plot were gleaned manually, weighed in the same manner, and added to the fruit removed by the shaker to obtain yield. In 'Valencia' 1, 2, and 3, the young 'Valencia' fruit (equal to or greater than 0.3 inch diameter) removed by the shaker were counted and the range of diameters measured. All plot trees designated for handpicking were manually harvested and the fruit weighed in a similar manner to obtain yield. After harvesting, the shaker clamp pad mark was usually visible on the trunk and the shaker clamp height was measured above ground level to the center of the mark. Each year, the trunk circumference of each tree in the experiment was measured at the same height (marked by a nail driven into the trunk in 1997). In 2002, the fruit on all experimental trees were harvested by handpicking to obtain yield data, and trunk circumferences were measured.

All trunk circumference and fruit removal data were statistically analyzed using the GLM procedure in SAS, and all yield data were analyzed using MIXED procedure (Littell, et al., 2002). Mean differences were indicated at the 5% level of significance.

Table 1. Description of treatments in experiments.

Treatment	Description
HPNC	Handpick with no abscission chemical (check)
SKNC	Trunk shaker with no abscission chemical
HPC	Handpick with abscission chemical
SKC	Trunk shaker with abscission chemical

Results and Discussion

Trunk circumference. Table 3 summarizes the trunk circumference measurements for all experiments and treatments. Trunk circumferences grew an average of 5.1 inches over the 5-yr period or about 1 inch per year. For each year and each experiment, analysis of the trunk circumference data indicated no effects by any of the treatments. Average trunk size was largest in 'Hamlin' and smallest in 'Pineapple'.

Table 2. Trunk shaker and abscission chemical attributes in the five experiments.

Attribute	Experiment (Scion)[z]				
	'Hamlin'	'Pineapple'	'Valencia' 1	'Valencia' 2	'Valencia' 3
			1997		
Abscission chemical	None	None	Prosulfuron	Prosulfuron	Prosulfuron
Date applied			April 9	April 30	May 15
ppm			30	30	30
gpa			250	250	250
Trunk shaker	Compton	Compton	Compton	FHI	FHI
Harvest date	February 14	February 13	April 28	May 16	May 29
Shake time per tree, sec.	5-10	4-8	5	5	5
			1998		
Abscission chemical	Metsulfuron-methyl	Metsulfuron-methyl	Metsulfuron-methyl	Metsulfuron-methyl	Metsulfuron-methyl
Date applied	January 19	January 19	April 14	May 6	May 18
ppm	2	2	0.5	0.5	0.5
gpa	250	250	500	500	500
Trunk shaker	Compton	Compton	Compton	Compton	FHI
Harvest date	January 28	January 28	April 22	May 15	May 26
Shake time per tree, sec.	5	5	5	5-7	5
			1999		
Abscission chemical	CMN-P	CMN-P	CMN-P	CMN-P	CMN-P
Date applied	January 22	January 29	April 9	April 23	May 7
ppm	100	100	150	150	150
gpa	450	450	450	450	450
Trunk shaker	FHI	FHI	FHI	FHI	FHI
Harvest date	January 27	February 2	April 13	April 27	May 11
Shake time per tree, sec.	5-8	5-8	5-8	5-8	5-8
			2000		
Abscission chemical	CMN-P	CMN-P	CMN-P	CMN-P	CMN-P
Date applied	February 18	February 18	April 7	April 28	May 19
ppm	100	100	250	250	250
gpa	450	450	465	465	465
Trunk shaker	Orchard Rite	Orchard Rite	Orchard Rite	Orchard Rite	Orchard Rite
Harvest date	February 22	February 22	April 12	May 2	May 23
Shake time per tree, sec.	3-5	3-5	5-10	5	5
			2001		
Abscission chemical	CMN-P	CMN-P	CMN-P	CMN-P	CMN-P
Date applied	February 9	February 9	April 20	May 4	May 18
ppm	100	100	250	250	250
gpa	450	450	450	450	450
Trunk shaker	Orchard Rite	Orchard Rite	Orchard Rite	Orchard Rite	Orchard Rite
Harvest date	February 12	February 13	April 24	May 8	May 22
Shake time per tree, sec.	8-10	5-8	5	5	5

[z]'Hamlin' and 'Pineapple' oranges were budded on Bittersweet rootstock; 'Valencia' oranges were budded on Cleopatra rootstock; 1, 2, and 3 refer to harvest dates 1, 2, and 3.

Fruit removal. Total mature fruit removal by the trunk shakers as discussed in this paper included any fruit drop that had occurred naturally and/or from abscission chemicals. Table 4 shows total fruit removal results and related attributes measured in the 'Hamlin' and 'Pineapple' orange experiments. Shaker clamp heights (data not shown) ranged from 9 to 15 inches and were generally not significantly different between shaker treatments SKNC and SKC. On average in 'Hamlin', abscission chemicals reduced FDF by one-half, increased fruit drop by 3%, and increased total fruit removal by trunk shaker about 9%. In 'Pineapple', FDF were reduced on average by two-thirds by abscission chemicals, and fruit drop and total fruit removal were increased 6 and 8%, respectively.

Table 5 shows the results in 'Valencia' oranges. Abscission chemicals in the date 1 harvest of 'Valencia' resulted in an average two-thirds reduction in FDF. Fruit drop and total fruit removal were increased an average of 4 and 6%, respectively. In two of the 5 yr when the young fruit were >0.3 inch in diameter, young fruit removals were similar for the trunk shaker with and without abscission chemicals. In the date 2 harvest of 'Valencia', abscission chemicals reduced FDF an average of about 50%, and resulted in a 3 and 7% increase in fruit drop and total fruit removal, respectively. Average young fruit removals by the shaker (~60 per tree) were similar with and without abscission chemicals, and young fruit diameters ranged from 0.3 to 2 inches. In the date 3 harvest of 'Valen-

Table 3. Trunk circumferences in 1997 and trunk circumference growths from 1997-2002, in inches.

	'Hamlin'		'Pineapple'		'Valencia' 1		'Valencia' 2		'Valencia' 3		Avg. Gr. 97-02
Treatment[z]	1997	Gr.,[y] 97-02	1997	Gr., 97-02	1997	Gr., 97-02	1997	Gr., 97-02	1997	Gr., 97-02	all treatments
HPNC	23.6	4.9	18.9	5.3	21.7	4.7	22.8	5.3	22.8	4.6	5.0
SKNC	22.8	4.8	19.3	5.2	22.4	5.2	22.8	5.1	23.2	4.7	5.0
HPC	23.6	4.5	18.9	5.5	23.2	5.2	22.4	5.1	23.6	5.6	5.2
SKC	25.6	5.4	19.3	4.9	22.4	5.4	22.4	4.5	22.4	5.6	5.2

[z]HPNC—handpick with no abscission chemical (check); SKNC—trunk shaker with no abscission chemical; HPC—handpick with abscission chemical; SKC—trunk shaker with abscission chemical.
[y]Tree trunk growth between 1997 and 2002.

cia', abscission chemicals reduced FDF about 50% while increasing fruit drop and total fruit removal by 4 and 7%, respectively. Total fruit removals were lower in 2001 than in the other years and was thought to result from the trees being shaken when they were very wet from rainfall, and the water on the leaves, etc., damped the vibration input to the fruit. Young fruit removals averaged 70 per tree with abscission chemicals and 98 per tree without. Young fruit diameters ranged from 0.3 to 2.1 inches.

The time required for fruit loosening after application varied considerably with the three abscission chemicals. Prosulfuron, applied to 'Valencia' in 1997, required 2 weeks while metsulfuron-methyl, applied in 1998, required in excess of 1 week. CMN-P, on the other hand, required 3 to 5 d. In general, fruit loosening was better with CMN-P than with prosulfuron or metsulfuron-methyl. Overall, abscission chemicals increased total fruit removal by the shakers by 7.4%, 90.2 vs. 82.8. During 1997 and 1998, prosulfuron and metsulfuron-methyl increased total fruit removal by the shakers by 5%, 87.0 vs. 82.0. From 1999 through 2001, CMN-P increased total shaker fruit removal by 8.7%, 91.6 vs. 82.9. Preharvest fruit drop from CMN-P during those 3 yr averaged 7% vs. 2% for the unsprayed trees. The FDF data in Tables 4 and 5 may or may not be representative as 10 fruit per tree were measured.

Shaker head and trunk displacements were generally in the 2-inch range at shaking frequencies from 6 to 10 Hz. The shake patterns of the Compton and FHI trunk shakers were multidirectional, whereas a linear shake pattern was developed by the Orchard Rite trunk shakers. The linear shake pattern was developed perpendicular to the shaker clamp pads and resulted in less bark damage than the multidirectional pattern. For given shaking displacements, frequencies, and shaking times per tree, Whitney et al. (2001) reported the linear shake pattern was equal or superior to the multidirectional shake pattern in removing oranges from the tree.

Fruit yields. Table 6 shows the mean fruit yields for the whole plot [no abscission chemical (NC) vs abscission chemical (C) averaged over handpick and shaker harvest methods] and subplot [handpick (HP) vs shaker (SK) averaged over no abscission chemical and abscission chemical] effects. Means are shown for individual years 1997-2002, for 1998-2002, and for 2000-2002, which were subsequent to initial trunk shaking and abscission chemical applications in 1997.

In 1998, there were no treatment effects in 'Hamlin' and 'Pineapple' (no abcsission chemicals were applied in 1997). In 'Valencia' 1, 2, and 3, however, there were treatment effects. In 'Valencia' 1 and 2, the abscission chemical reduced yields. At harvest time in 1997, prosulfuron had abscised many of the young 'Valencia' fruit (1998 crop) and had resulted in some twig dieback (Whitney et al., 1998). Young 'Valencia' fruit in 1997 were up to 2.0-inch diameter in 'Valencia' 2, and 70 to 80 fruit per tree were removed (Table 5) by the shaker, and probably contributed to the shaker yield reduction in 1998. In 'Valencia' 3, the shaker reduced 1998 yields and was probably the result of young 'Valencia' fruit (100+ per tree) up to 2.1-inch diameter being removed from the trees in 1997. Although prosulfuron did not reduce 1998 'Valencia' 3 yield, there was evidence of phytotoxicity to the young 'Valencia' in

Table 4. Mature fruit detachment force, fruit drop, total fruit removal by trunk shaker in 'Hamlin' and 'Pineapple' orange experiments.

	1997		1998		1999		2000		2001		1997-2001 avg.[w]	
Attribute	SKNC	SKC	SKNC	SKC	SKNC	SKC	SKNC	SKC	SKNC	SKC	SKNC	SKC
						'Hamlin'						
FDF,[z] lb	22 a	22 a[y]	nd	nd[x]	20 a	11 b	21 a	6 b	19 a	9 b	20	9
Drop, %	0 a	0 a	2 b	3 a	nd	nd	3 b	11 a	2 a	3 a	2	5
Total removal, %	85.4 a	73.6 b	78.4 a	87.7 a	75.9 b	92.5 a	89.1 a	92.6 a	84.6 a	91.9 a	82.5	91.2
						'Pineapple'						
FDF, lb	26 a	26 a	18 a	4 b	23 a	6 b	24 a	7 b	19 a	10 b	21	7
Drop, %	0 a	0 a	3 b	5 a	3 b	11 a	6 b	17 a	3 b	6 a	4	10
Total removal, %	95.4 a	90.6 a	88.3 b	92.3 a	90.2 b	98.1 a	91.0 b	96.4 a	75.9 b	91.1 a	86.4	94.5

[z]Mature fruit detachment force.
[y]Abscission chemicals not applied to 'Hamlin' and 'Pineapple' in 1997. Means followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.
[x]nd—no data were collected.
[w]Averaged for years when data available.

Table 5. Mature fruit detachment force, fruit drop, total mature and young fruit removal by trunk shaker, and young fruit diameter range in 'Valencia' orange experiments.

	1997		1998		1999		2000		2001		1997-2001 avg[x]	
Attribute	SKNC	SKC	SKNC	SKC	SKNC	SKC	SKNC	SKC	SKNC	SKC	SKNC	SKC
						'Valencia' 1						
FDF,[z] lb	27 a[y]	22 b	26 a	3 b	27 a	8 b	21 a	2 b	17 a	6 b	24	8
Drop, %	0 na[w]	3 na	nd[v]	5	0 na	4 na	1 b	11 a	2 b	4 a	1	5
Total removal, %	83.7 a	87.3 a	80.1 a	85.2 a	83.7 b	93.7 a	84.7 b	94.4 a	93.1 a	94.9 a	85.1	91.1
Yfr,[u] no./tree	31 a	33 a	nd	nd	nd	nd	nd	nd	10 a	16 a	21	25
Diam range,[t] inches	0.3-1.3	0.3-1.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.3-0.8	0.3-0.8	nd	nd
						'Valencia' 2						
FDF, lb	21 a	7 b	27 a	22 b	23 a	10 b	23 a	8 b	24 a	10 b	24	11
Drop, %	0 na	6 na	nd	nd	2 na	7 na	2 a	6 a	2 b	3 a	2	5
Total removal, %	83.9 b	92.4 a	86.7 a	87.5 a	85.9 b	96.0 a	86.9 a	91.9 a	75.3 a	86.3 a	83.7	90.8
Yfr, no./tree	84 a	73 a	11 a	14 a	nd	nd	25 a	9 b	132 a	134 a	63	58
Diam range, inches	0.5-2.0	0.5-2.0	0.4-1.2	0.4-1.2	<0.3	<0.3	0.3-1.0	0.3-1.0	0.5-1.5	0.5-1.5	nd	nd
						'Valencia' 3						
FDF, lb	32 a	23 b	27 a	18 b	24 a	15 b	23 a	6 b	23 a	7 b	26	14
Drop, %	0 na	4 na	nd	nd	2 na	6 na	2 b	5 a	1 b	5 a	1	5
Total removal, %	79.0 a	83.4 a	75.7 a	80.1 a	73.2 a	81.9 a	85.8 a	92.6 a	67.5 a	78.9 a	76.2	83.4
Yfr, no./tree	169 a	108 a	94 a	77 a	<10 na	<10 na	53 a	39 a	166 a	116 a	98	70
Diam range, inches	0.8-2.1	0.8-2.1	0.8-2.0	0.8-2.0	0.3-1.3	0.3-1.3	0.3-1.8	0.3-1.8	0.8-2.0	0.8-2.0	nd	nd

[z]Mature fruit detachment force, n = 30.
[y]Means followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.
[x]Averaged for years when data available.
[w]na—no statistical analysis was made of the data.
[v]nd—no data were collected.
[u]Yfr—young fruit removed by shaker at harvest.
[t]Diameter range of young fruit removed by shaker.

1997 by the ring on many of the mature 'Valencia' rinds in 1998. The ring resulted from rind damage to the young 'Valencia' fruit from the concentration of prosulfuron as it accumulated and dried after the spray application.

In 1999, there were no treatment effects in 'Hamlin' even though there was evidence in 1998 that metsulfuron-methyl had caused some twig dieback. In 'Pineapple', however, metsulfuron-methyl reduced yield. Metsulfuron-methyl also reduced 'Valencia' 1 and 2 yield and was the result of the abscission chemical abscising many of the young 'Valencia' fruit in 1998. Shaker yields were greater than the handpick yields in 'Valencia' 1 and 2. Increased yields could have been due to stimulating effects similar to girdling by the shaker bark damage in 1998. In addition, the young 'Valencia' fruit were small in 'Valencia' 1 and small numbers were removed by the shaker in 'Valencia' 2. In contrast, the shaker reduced 'Valencia' 3 yield and was probably due to the shaker removing an average of 85 young 'Valencia' fruit per tree with diameters up to 2 inches.

Following the application of CMN-P for the first time in 1999, the shaker reduced 'Hamlin' and 'Pineapple' yield in 2000. In 'Valencia' 1 and 3, CMN-P increased yield over unsprayed trees. The yield of the shaker trees were greater than the handpicked trees in both 'Valencia' 2 and 3 following minimal shaker removal of young 'Valencia' fruit in 1999.

In 2001 following the application of CMN-P for the second year, there were no treatment effects on yield in 'Hamlin'. In 'Pineapple' and 'Valencia' 1, CMN-P reduced yield compared to the unsprayed trees. There were no treatment effects in 'Valencia' 2. In 'Valencia' 3, however, the shaker reduced yield compared to the handpicked trees and may have been due, in part, to the shaker removing 40 to 50 young 'Valencia' fruit per tree up to 1.8-inch diameter in 2000.

Again in 2002, there were no treatment effects in 'Hamlin'. However, in 'Pineapple', the yield of shaker trees was less than the handpicked trees. In 'Valencia' 2 and 3, there were no treatment effects even though in 2001 the shaker removed over 100 young 'Valencia' fruit per tree up to 1.5 and 2-inch diameters.

Within each experiment, multiple year effects of C vs. NC and HP vs. SK were considered. The use of prosulfuron in 1997 and metsulfuron-methyl in 1998 was terminated because of phytotoxicity to the trees and young fruit. Averaging the yields for all five experiments in 1998 and 1999, subsequent to the application of both these abscission chemicals, resulted in with (C) and without (NC) abscission chemical yield means of 2.9 and 3.7 boxes per tree, respectively (means not shown in Table 6). Except for 'Hamlin', the NC means were significantly greater than the C means. In contrast, the effects of CMN-P applied in 1999-2001 were markedly different. There was no visual evidence of phytotoxicity, and the mean yield for all five experiments of the CMN-P (C) trees for 2000-2002 was 3.9 boxes per tree compared to 3.7 boxes per tree for the trees not sprayed (NC). Means for the individual experiments are shown in the last column of Table 6 and indicate that CMN-P had no detrimental effect on yield, and in some cases, improved it. For 'Valencia' 1 and 3, yields of the CMN-P or C

Table 6. Means of orange yields in boxes/tree for the whole plot (no abscission chemical vs abscission chemical) and subplot (handpick vs shaker) effects in the five experiments.

Whole plot or subplot[z] effect	1997	1998	1999	2000	2001	2002	1998-2002	2000-2002
				'Hamlin'				
NC	4.5	6.5 a[y]	5.7 a	5.5 a	6.5 a	4.4 a	5.7 a	5.5 a
C	4.2	5.8 a	5.2 a	5.7 a	6.2 a	4.8 a	5.5 a	5.6 a
HP	4.3	6.2 a	5.4 a	6.2 a	6.5 a	4.6 a	5.8 a	5.8 a
SK	4.4	6.1 a	5.5 a	4.9 b	6.7 a	4.6 a	5.6 a	5.4 a
				'Pineapple'				
NC	1.6	5.0 a	3.4 a	4.6 a	3.1 a	4.1 a	4.0 a	3.9 a
C	1.7	4.9 a	2.5 b	4.9 a	2.3 b	4.4 a	3.8 a	3.9 a
HP	1.6	5.0 a	2.8 a	5.0 a	2.8 a	4.6 a	4.0 a	4.1 a
SK	1.6	4.9 a	3.1 a	4.5 b	2.6 a	3.9 b	3.8 a	3.7 b
				'Valencia' 1				
NC	3.5	4.0 a	3.8 a	2.2 b	3.8 a	3.1 a	3.4 a	3.0 b
C	3.5	3.4 b	2.0 b	3.2 a	3.4 b	3.3 a	3.1 b	3.3 a
HP	3.5	3.8 a	2.5 b	2.8 a	3.7 a	3.5 a	3.3 a	3.3 a
SK	3.5	3.6 a	3.4 a	2.6 a	3.5 a	3.0 a	3.2 a	3.0 a
				'Valencia' 2				
NC	3.6	3.2 a	3.8 a	2.5 a	4.1 a	3.1 a	3.3 a	3.2 a
C	3.5	2.4 b	3.1 b	2.9 a	4.1 a	3.2 a	3.1 a	3.4 a
HP	3.6	3.1 a	3.1 b	2.4 b	4.2 a	3.3 a	3.2 a	3.3 a
SK	3.5	2.4 b	3.7 a	3.0 a	4.0 a	3.0 a	3.2 a	3.3 a
				'Valencia' 3				
NC	4.0	2.7 a	2.8 a	3.1 b	2.7 a	2.8 a	2.8 a	2.9 b
C	4.0	2.6 a	2.3 a	3.7 a	2.8 a	3.1 a	2.9 a	3.2 a
HP	4.0	3.0 a	2.8 a	3.0 b	3.0 a	3.0 a	3.0 a	3.0 a
SK	4.0	2.3 b	2.3 b	3.8 a	2.5 b	3.0 a	2.8 a	3.1 a

[z]NC—no abscission chemical mean averaged over handpick (HPNC) and shaker (SKNC) harvest methods; C—abscission chemical mean averaged over handpick (HPC) and shaker (SKC) harvest methods; HP—handpick harvest method mean averaged over abscission chemicals (HPC) and no abscission chemicals (HPNC); SK—trunk shaker harvest method mean averaged over abscission chemicals (SKC) and no abscission chemicals (SKNC).
[y]Means (NC vs. C or HP vs. SK) followed by the same letter are not significantly different by mixed model t-tests at the 5% level.

trees were higher than the NC trees. These observations and data are in agreement with a 5-yr study on trunk shakers and CMN-P by Whitney et al. (1986).

The effect of harvest method (HP vs SK) was considered over the 5-yr period, 1998-2002. Analysis of the yields for each experiment indicated there were no significant differences in the means (Table 6) of the HP and SK trees.

Bark damage was often severe on the 'Valencia' trees in 1997-1999 because of the multidirectional shaking pattern. In addition, after the initial bark damage on the trunks in 1997, the use of different shakers in 1998 and 1999 often meant clamping the trunks in different places and sometimes caused additional damage. By the end of the experiment, most of the shaker trees had some bark damage. The linear shaker pattern used in 2000 and 2001 reduced bark damage significantly. However, it was difficult to prevent bark damage in 2000 and 2001 because of the bark damage in the three previous years. Another contributing factor to the bark damage in 'Valencia' was the trees were often shaken while the bark was being wetted with microsprinklers being operated by the grower.

Conclusions

1. Abscission chemicals prosulfuron and metsulfuron-methyl increased total fruit removal by the trunk shaker an average of 5%, but were phytotoxic to orange trees and reduced yields.
2. Abscission chemical CMN-P increased total fruit removal by the trunk shaker by an average of 9%, was not phytotoxic to orange trees, and did not reduce yields.
3. Orange tree trunk growth was not affected by the use of trunk shakers and/or abscission chemicals.
4. Trunk shakers did not significantly reduce orange yields over a 5-yr period compared to handpick checks.

Literature Cited

Littell, R. C., W. W. Stroup, and R. J. Freund. SAS for Linear Models, 4th ed. 2002. SAS Institute Inc., Cary, NC.

Whitney, J. D. 1975. Orange yield and removal studies with air and trunk shakers using abscission chemicals. Proc. Fla. State Hort. Soc. 88:120-124.

Whitney, J. D. 1995. A review of citrus harvesting in Florida. Trans. Citrus Eng. Conf., Florida Section, ASME. 41:33-59.

Whitney, J. D. 1997. Field test results with mechanical citrus fruit removal devices. Proc. Fla. State Hort. Soc. 110:89-92.

Whitney, J. D. 1998. Prosulfuron affects trunk shaker efficiency and yields of 'Valencia' oranges. Proc. Fla. State Hort. Soc. 111:106-107.

Whitney, J. D. and H. R. Sumner. 1977. Mechanical removal of fruit from citrus trees. Proc. Intern. Soc. Citricult. 2:407-412.

Whitney, J. D., D. B. Churchill, and S. L. Hedden. 1986. A five-year study of orange removal with trunk shakers. Proc. Fla. State Hort. Soc. 99:40-44.

Whitney, J. D., U. Hartmond, W. J. Kender, M. Salyani, and J. K. Burns. 2000. Abscission chemicals affect trunk shaker orange removal. Proc. Fla. State Hort. Soc. 113:93-96.

Whitney, J. D., E. BenSalem, and M. Salyani. 2001. The effect of trunk shaker patterns on Florida orange removal. Appl. Eng. Agr. 17(4):461-464.