Reprinted from
Proc. Fla. State Hort. Soc. 113:93-96. 2000.

ABSCISSION CHEMICALS AFFECT TRUNK SHAKER ORANGE REMOVAL

J. D. WHITNEY, U. HARTMOND, W. J. KENDER, M. SALYANI
AND J. K. BURNS
University of Florida, IFAS
Citrus Research and Education Center
700 Experiment Station Road
Lake Alfred, FL 33850

Additional index words. Mechanical harvesting, citrus, harvest efficiency.

Abstract. **Trunk shake-catch systems have been used commercially to a limited extent to mechanically harvest Florida oranges for processing for the past five seasons. In most cases, oranges left on the trees by the shakers and missing the catchframes must be gleaned by hand harvesters and the cost of gleaning reduces or eliminates the profit for the mechanical harvesting operation. During the 1997-1998 and 1998-1999 seasons, abscission chemicals under development to reduce the detachment force of oranges have been tested to determine to what extent they increase the removal efficiency of the shakers. This paper will discuss orange removal results with various chemicals. In general, removal efficiencies were increased 10 to 15 percentage points when orange detachment forces were reduced 50 to 80%.**

Trunk shakers and abscission chemicals for citrus harvesting were first investigated in the 1960s (Whitney, 1995). A five-year study (Hedden et al., 1988) found that abscission chemicals increased fruit removal (including pre-harvest fruit drop by abscission chemicals) of trunk shakers by 17 to 26 percentage points over harvest without abscission chemicals with little apparent effect on yield and tree growth. In 1986, however, the experimental use permits and registration of abscission chemicals for citrus expired. Fruit Harvesters International, Inc. (Alva, FL) initiated the development of a trunk shake-catch mechanical harvester in 1993 and has been keenly interested in developing an abscission chemical to improve harvester efficiency since then. 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 has been the trunk shaker (Whitney, 1999).

With renewed interest in abscission chemicals to aid mechanical harvesting, we began field testing candidate abscission chemicals with trunk shakers in 1997, and continued these tests in 1998. The objectives of these tests were to determine how effectively the abscission chemicals loosened oranges for processing and how they improved the fruit removal efficiency of trunk shakers.

Florida Agricultural Experiment Station Journal Series No. N-01939. The authors would like to acknowledge the funding support of the Florida Department of Citrus in conducting these tests, the Florida Department of Agriculture and Consumer Services—Division of Plant Industry for providing some of the trees, and the technical assistance of David Noxel, Roy Sweeb, and Angela Grant. Mention of products if for information only and does not imply endorsement by the University of Florida over products not mentioned.

Materials and Methods

Three abscission chemicals and four different trunk shakers with scissors-type clamps were used in eight replicated field tests. In each test, abscission chemical treatments were applied to three replicate trees and an adjuvant (Kinetic, Setre Chemical Co., Memphis, TN) was added at 0.1% to the abscission chemical and water mixture. The trees were shaken 3 to 8 d post spray when fruit loosening was judged to be optimum and minimum pre-harvest fruit drop had occurred. Within each test, each tree was shaken for approximately the same length of time at the same frequency. Length of shaking time was set as the minimum which maximized fruit removal from the trees having the loosest fruit (defined as the lowest fruit detachment force and/or highest pre-harvest fruit drop), and thus maximize differences in fruit removal related to fruit looseness. To establish fruit looseness, fruit detachment forces were measured with a Model FDV-50 electronic scale (Wagner Instruments, Greenwich, CT) on 10 fruit per tree, and pre-harvest fruit drop was determined by weighing the fruit on the ground for each tree just prior to harvest. Tree trunk and shaker head motion were measured with instrumentation described by Whitney et al. (2000). After shaking each tree, both fruit removed by the shaker fruit left on the tree were weighed. The height above ground at which the shaker clamp pads contacted the trunk and the trunk circumference at that height were measured.

Test 1. A new abscission chemical, prosulfuron (Peak, Novartis, Greensboro, NC) was applied 20 Feb. 1997 to 'Hamlin' orange trees spaced 7.3 m × 7.3 m and 4.5 m tall. The chemical, which was named Transfer by Wilcox and Taylor (1996), was reported to have promise for loosening citrus. The four abscission chemical treatments [0 (control), 15, 30, and 45 ppm] were each applied using water at 2330 liters/ha with a pto airblast sprayer. Each tree was shaken on 28 Feb. with a FMC Model 729 shaker (FMC Corp., Madera, CA) for 5 sec. The shaker head, described by Whitney et al. (1988), had two 30.9 kg unbalanced masses rotating in the same direction with one mass rotating 15% faster than the other. Each mass had an eccentricity of 114 mm and was mounted on a separate vertical shaft.

Test 2. Another new abscission chemical, metsulfuron-methyl (Ally, DuPont Co., Wilmington, DE) was applied 6 Jan. 1998 to 'Hamlin' orange trees spaced 7.3 m × 7.3 m and 4.5 to 6 m tall. Twelve abscission chemical treatments were applied with a pto airblast sprayer. The treatments were 0 (control), 1, 2, and 4 ppm each applied using water at 467, 1870, and 4670 liters/ha. Each tree was shaken on 16 Jan. with a Fruit Harvesters International (FHI) trunk shaker for 12 to 15 sec. The shaker used two sets of unbalanced masses and specifications were proprietary information.

Tests 3-5. These tests were conducted in 1998 using 'Hamlin' orange trees spaced 6.1 m × 4.6 m and 4 m tall. Each test corresponded to a harvest date (Test 1, 16 Jan.; Test 2, 30 Jan.; Test 3, 13 Feb.) for which abscission chemical treatments were applied with a handgun sprayer using water at 6800 liters/ha on 6 Jan., 20 Jan., and 6 Feb., respectively. The three treatments were a control, metsulfuron-methyl at 2 ppm, and CMN-pyrazole [Release (previously tested, see Hedden et al.,

Table 1. Harvest results with treatments prosulfuron and FMC 729 shaker head (5 sec shake) in Hamlin oranges, Test 1.

Prosulfuron treatment (ppm)	Fruit detachment force (N[y])	Pre-harvest fruit drop (%)	Shaker fruit removal (%)	Total fruit removal (%)	Trunk circumference (mm)	Shaker clamp pad height (mm)	Tree fruit yield (kg)
0 (control)	73 a[z]	3.8 a	57.2 a	61.0 a	600 a	500 a	357 a
15	50 b	16.6 a	61.9 a	78.5 a	570 a	460 a	313 a
30	46 b	17.5 a	68.0 a	85.5 a	590 a	460 a	295 a
45	51 b	16.1 a	71.2 a	87.2 a	480 a	450 a	217 a

[z]Mean separation in each column by Duncan's Multiple Range Test, 5% level.
[y]N = newton = 0.23 lb.

1988), Abbott Laboratories, Chicago, IL] at 100 ppm. On the date of harvest, the trees were shaken for 5 sec. In Test 3, a FHI shaker was used and in Tests 4 and 5, a Compton (Compton Enterprises Inc., Chico, CA) side-mount shaker was used. The Compton shaker, described by Whitney (1999), had two sets of unbalanced masses totaling 125 kg mounted on one vertical shaft. The masses (220 mm eccentricity) rotated in the same direction with one set rotating 15% faster than the other.

Tests 6-8. These tests were conducted in 1998 using 'Valencia' orange trees spaced 6.1 m × 4.6 m and 3 m tall. Each test corresponded to a harvest date (Test 6, 20 Apr.; Test 7, 7 May; Test 8, 21 May) for which abscission chemical treatments were applied with a handgun sprayer using water at 6800 liters/ha on 15 Apr., 1 May, and 18 May, respectively. The four treatments were a control, metsulfuron-methyl at 0.5 ppm, CMN-pyrazole at 50 ppm, and CMN-pyrazole at 100 ppm. On the date of harvest, the trees were shaken for 5 sec with an experimental Compton (Compton Enterprises Inc., Chico, CA) monoboom-mounted shaker. This shaker, different than the one used in Tests 4 and 5, had two sets of unbalanced masses totaling 130 kg mounted on a single shaft to one side of the parallel clamp pads and centered on the length of the longitudinal axes of the pads. The masses (220 mm eccentricity) rotated in the same direction with one set rotating 15% faster than the other.

All data were statistically analyzed using the GLM procedure in SAS (SAS Institute, Cary, NC). Duncan's Multiple Range Test was used to determine mean separation at the 5% level of significance.

Results and Discussion

Shaker fruit removal was defined as the fruit removed by the shaker, whereas total fruit removal was defined as pre-harvest fruit drop plus shaker fruit removal. All percentage calculations were referenced to the total fruit yield of the tree.

Test 1. Table 1 shows that 8 d after application, all prosulfuron treatments significantly reduced the detachment force of 'Hamlin' oranges about 30% compared with the control. Even though there were trends in the other dependent variables, the differences were not statistically significant at the 5% level. Pre-harvest fruit drop with the prosulfuron treatments averaged 16.7%. Shaker and total fruit removal increased with prosulfuron concentration, averaging 67 and 83.7%, respectively (9.8 and 22.7 percentage points higher than the control). These results were similar to those reported in 'Hamlin' oranges by Hedden et al. (1988). The FMC 729 shaker head, not used commercially in Florida citrus, developed a maximum displacement of 30 to 35 mm at 15 to 18 Hz on a trunk of 570 mm circumference.

Test 2. Table 2 summarizes the harvest results for each metsulfuron-methyl concentration averaged over application rate (liters/ha). All concentrations of metsulfuron-methyl significantly reduced fruit detachment forces and significantly increased total fruit removal. In general, these effects were related to metsulfuron-methyl concentration. Pre-harvest fruit drop was significantly increased only by metsulfuron-methyl at 4 ppm. Shaker fruit removal was not significantly affected by any of the metsulfuron-methyl treatments. Although the values are not shown, increasing the application rate had a similar effect as increasing metsulfuron-methyl concentration (Kender et al., 1999). Compared to all other tests, tree sizes and fruit yields were considerably greater and more variable. The FHI shaker head operated at 6 Hz while the displacement was 50 mm on a trunk with an 860 mm circumference and 80 mm on a trunk with a 560 mm circumference.

Test 3-5. Table 3 shows that compared with the control in Test 3, metsulfuron-methyl and CMN-pyrazole significantly reduced fruit detachment forces, and significantly increased the percentage of shaker and total fruit removals. Further, fruit removals with metsulfuron-methyl were significantly greater than those obtained with CMN-pyrazole. The FHI shaker operated at 6 Hz and 80 mm displacement on a trunk of 450 mm circumference.

In Test 4, both metsulfuron-methyl and CMN-pyrazole provided a significant reduction (80%) in fruit detachment force and significantly increased pre-harvest fruit drop. Both

Table 2. Harvest results with metsulfuron-methyl treatments and FHI trunk shaker (12-15 sec shake) in Hamlin oranges, Test 2.

Metsulfuron-methyl treatment (ppm)	Fruit detachment force (N[y])	Pre-harvest fruit drop (%)	Shaker fruit removal (%)	Total fruit removal (%)	Trunk circumference (mm)	Shaker clamp pad height (mm)	Tree fruit yield (kg)
0 (control)	73 a[z]	1.1 a	71.2 a	72.3 a	650 a	370 a	443 a
1	43 b	3.4 a	79.5 a	82.9 b	740 ab	360 a	562 ab
2	43 b	10.0 ab	76.4 a	86.4 b	710 ab	350 a	521 ab
4	38 b	16.2 b	70.6 a	86.8 b	820 b	350 a	652 b

[z]Mean separation in each column by Duncan's Multiple Range Test, 5% level.
[y]N = newton = 0.23 lb.

Table 3. Harvest results with metsulfuron-methyl and CMN-pyrazole treatments with FHI (Test 3) and Compton (Tests 4 and 5) shakers (5 sec shake) in Hamlin oranges, Tests 3-5.

Abscission chemical treatment	Fruit detachment force (N[y])	Pre-harvest fruit drop (%)	Shaker fruit removal (%)	Total fruit removal (%)	Trunk circumference (mm)	Shaker clamp pad height (mm)	Tree fruit yield (kg)
			Test 3				
Control	76 a[z]	1 a	78.2 a	79.2 a	450 a	280 a	207 a
Metsul. 0.5	27 b	4.8 a	93.0 c	97.8 c	450 a	280 a	186 a
CMN-P 100	43 b	4.8 a	83.4 b	88.2 b	480 a	290 a	238 a
			Test 4				
Control	85 a	4.9 a	79.0 a	83.9 a	530 a	310 a	246 a
Metsul. 0.5	18 b	25.9 b	73.2 a	99.1 b	550 a	330 a	273 a
CMN-P 100	13 b	31.7 b	66.3 a	98.0 b	530 a	310 a	274 a
			Test 5				
Control	61 a	0.8 a	80.7 a	81.5 a	540 a	290 a	269 a
Metsul. 0.5	26 b	1.1 a	94.9 b	96.0 b	500 a	280 a	237 a
CMN-P 100	24 b	3.4 b	94.2 ab	97.6 b	570 a	210 b	271 a

[z]Mean separation in each column within each test by Duncan's Multiple Range Test, 5% level.
[y]N = newton = 0.23 lb.

abscission chemical treatments significantly increased total fruit removal by 14 percentage points, and shaker fruit removals were less, but not significant. In Test 5, both metsulfuron-methyl and CMN-pyrazole significantly reduced fruit detachment forces (60%) and significantly increased total fruit removals about 14 percentage points. Only metsulfuron-methyl significantly increased shaker fruit removal. The Compton shaker operated at 10 Hz and a displacement of 50 mm on a trunk of 540 mm circumference in both tests.

Tests 6-8. Table 4 summarizes the results. In Test 6, only the CMN-pyrazole treatments significantly reduced fruit detachment force, and only metsulfuron-methyl and CMN-pyrazole at 100 ppm significantly increased total fruit removal by 10 to 13 percentage points. Shaker fruit removal was not significantly changed by any of the abscission chemical treatments. CMN-pyrazole at 100 ppm was superior to CMN-pyrazole at 50 ppm in decreasing detachment force and increasing pre-harvest drop. The shaker was operated at 8 Hz and had a maximum displacement of 80 mm on a trunk of 480 mm circumference.

In Test 7, only CMN-pyrazole at 100 ppm significantly decreased fruit detachment force and significantly increased shaker and total fruit removal. This date of application corresponded to the time when the Valencia orange was less responsive to abscission chemicals (Hartmond et al., 2000). Shaker frequency and displacement results were similar to those in Test 6.

The results in Test 8 showed that only the CMN-pyrazole treatments significantly reduced fruit detachment force and significantly increased shaker and total fruit removal. Overall, CMN-pyrazole provided superior results by increasing fruit removals by 12 to 15 percentage points. Shaker frequency and displacement results were similar to those in Test 6.

Prosulfuron and metasulfuron-methyl provided orange loosening at low concentrations and are cleared for other uses, but they were phytotoxic to the tree. Whitney (1998) and

Table 4. Harvest results with metsulfuron-methyl and CMN-pyrazole treatments and experimental Compton trunk shaker (5 sec shake) in Valencia oranges, Tests 6-8.

Abscission chemical treatment	Fruit detachment force (N[y])	Pre-harvest fruit drop (%)	Shaker fruit removal (%)	Total fruit removal (%)	Trunk circumference (mm)	Shaker clamp pad height (mm)	Tree fruit yield (kg)
			Test 6				
Control	99 a[z]	0.0 a	85.6 ab	85.6 a	380 a	270 a	130 a
Metsul.	83 a	10.2 a	85.6 ab	95.8 b	410 a	260 a	127 a
CMN-P 50	49 b	2.6 a	91.2 a	93.8 ab	380 a	290 a	134 a
CMN-P 100	21 c	24.5 b	74.2 b	98.7 b	420 a	260 a	101 a
			Test 7				
Control	101 a	0.0 a	87.8 a	87.8 a	340 a	240 b	156 ab
Metsul.	100 a	0.0 a	83.3 a	83.3 a	350 a	230 ab	171 a
CMN-P 50	92 a	0.0 a	87.5 a	87.5 a	470 a	200 a	173 a
CMN-P 100	76 b	0.0 a	95.3 b	95.3 b	410 a	270 c	129 b
			Test 8				
Control	101 a	0.0 a	79.7 a	79.7 a	480 a	260 a	202 a
Metsul.	78 ab	0.0 a	88.2 ab	88.2 ab	440 a	320 a	180 a
CMN-P 50	66 b	0.0 a	92.4 b	92.4 b	450 a	250 a	190 a
CMN-P 100	28 c	3.2 b	92.3 b	95.5 b	440 a	280 a	191 a

[z]Mean separation in each column within each test by Duncan's Multiple Range Test, 5% level.
[y]N = newton = 0.23 lb.

Kender et al. (1999) reported twig dieback and injury to young Valencia fruit. On the other hand, CMN-pyrazole required higher concentrations to be effective, but has been field tested over several seasons (Hedden et al., 1988) and has shown no significant phytotoxic effects on orange trees. Its clearance by the EPA for use on citrus is unknown at this time. Detailed discussions of the results with trunk shakers and abscission chemicals can be found in Whitney et al. (2000).

Conclusions

1. Abscission chemicals usually loosened 'Hamlin' and 'Valencia' oranges and increased shaker and total (pre-harvest fruit drop + shaker fruit removal) fruit removals up to 14 and 30 percentage points, respectively. Maximum shaker and total fruit removals were 95 and 99%, respectively.

2. Abscission chemicals tended to increase total orange removal of trunk shakers with 30 mm displacement at 15 to 18 Hz more than trunk shakers with 50-80 mm displacement at 6 to 10 Hz.

Literature Cited

Hartmond, U., J. D. Whitney, J. K. Burns and W. J. Kender. 2000. Seasor variation in response to two abscission compounds. HortScien 35(2):226-229.

Hedden, S. L., D. B. Churchhill and J. D. Whitney. 1988. Trunk shakers f citrus harvesting-Part II: Tree growth, fruit yield, and removal. Appl. Er Agr. 4(2):102-106.

Kender, W. J., U. Hartmond, M. Salyani, J. K. Burns and J. D. Whitney. 19! Injurious effects of metsulfuron-methyl when used to stimulate abscissi of Hamlin oranges. HortScience 34(5):904-907.

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

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

Whitney, J. D. 1999. Field test results with mechanical harvesting equipme in Florida citrus. Appl. Eng. Agr. 15(3):205-210.

Whitney, J. D., D. B. Churchill, S. L. Hedden and G. H. Smerage. 1988. Tru shakers for citrus harvesting—Part I: Measured trunk shaker and tr trunk motion. Appl. Eng. Agr. 4(2):93-101.

Whitney, J. D., U. Hartmond, W. J. Kender, J. K. Burns and M. Salyani. 20 Orange removal with trunk shakers and abscission chemicals. Appl. Er Agr. 16(4):367-371.

Wilcox, M. and J. B. Taylor. 1996. Transfer: A new abscission agent. Proc. I Soc. Citricult. 1996(2):1013-1016.