MECHANICAL HARVESTING SYSTEM AND CMNP EFFECTS ON DEBRIS ACCUMULATION IN LOADS OF CITRUS FRUIT

RESEARCH REPORT

FOR

FLORIDA CITRUS HARVESTING RESEARCH ADVISORY COUNCIL

FROM

TIMOTHY M. SPANN, PH.D.
UNIVERSITY OF FLORIDA
CITRUS RESEARCH AND EDUCATION CENTER
spann@ufl.edu
863-956-1151

Purpose: The purpose of this research was to determine the effects of mechanical harvesting systems on the amount of debris accumulated in a harvested load of fruit compared to hand harvesting.

Objectives:

1. Determine the total quantity of debris (primarily stems and leaves) that accumulates in a standard load of harvested fruit for each different mechanical harvesting system and hand harvesting.
2. Characterize the debris accumulated to determine what proportion is leaves, small diameter stems and large diameter stems to aid in the development of debris removal systems.
3. Determine if the abscission compound CMNP can reduce the amount of debris accumulated by different harvest methods.

Methods:

Debris accumulation studies: Debris accumulation studies were conducted using the Oxbo 3210 pull-behind harvester (Mutual Harvesting), and the Oxbo 3220 self-propelled continuous canopy shakers. Models of the Oxbo 3220 with (Lykes Bros.) and without (Circle V Harvesting) the optional destemmer were used. All samples collected from the Oxbo 3210 were from 'Valencia' blocks in Lykes Bros. Camp Mack Grove, Lake Wales. All samples collected from the Oxbo 3220 machines and hand harvested samples were from blocks in Lykes Bros. Ft. Bassinger Grove, Ft. Bassinger.

It was determined that the best point at which to sample for debris is at the point where the goat is dumps harvested fruit into the trailer. This point is common to all harvest methods and it represents the final step before fruit are delivered to the processor, thus any debris still with the fruit at this point will be delivered to the processor. In order to sample at this point it was necessary to develop a system that would allow workers to be at the level of the top of the trailers to facilitate sample collection. This was done by constructing a wooden platform which rests on a ladder rack attached to the bed of a pick-up truck. Once this platform was developed a method needed to be worked out to capture similar samples from each goat as it dumped fruit into the trailer. This was done by constructing a 2 × 4 rail system which lies across the top of the trailer. A plywood carriage rides on these rails and supports a plastic tub 36" × 24" × 8" which is used to catch approximately 50 kg (110 lbs) of fruit and debris from each goat.

Each captured sample is weighed on the platform and then hand sorted to remove all debris. The fruit are returned to the trailer. The debris samples are returned to the laboratory for

further sorting and drying. In the laboratory, the debris is weighed fresh, and then sorted into leaves, small stems and large stems. Our experience has been that stems tend to be either relatively small (pencil diameter) or quite large (> ½ inch diameter). Thus, all sorting is done by eye rather than using calipers and measuring. After sorting, fresh weights of each component are recorded, the samples are dried and dry weights are recorded. All data are reported as dry weight of debris per fresh weight of fruit.

During harvest, the ground speed of each machine is measured by marking a 300' distance on the adjacent row to which the machine(s) is operating. The machine is timed using a stop watch and this value (time per 300') is converted to mph. Three separate speed measurements are made within each harvested block.

The average tree height within each block is measured by measuring the height of 15 randomly selected trees within each block. If a block is particularly variable in tree height trees are selected to represent the range of heights within that block.

CMNP studies: Six separate CMNP studies were sampled during 2007-08. Two of these trials involved 'Parson Brown' in Lykes Bros. Camp Mack Grove, Lake Wales, harvested with the Oxbo 3210 pull-behind machine. The first 'Parson Brown' trial was conducted in December and trees were either treated with 300 ppm CMNP or untreated. The second trial in January was the same as the December trial except that subplots were added for shaker frequency at 230 or 270 cpm. The third and fourth trials were rate trials where CMNP was applied at 0, 100, 200 and 300 gal/acre to 'Valencia.' The first of these trials was also conducted in the Camp Mack Grove and harvested with the Oxbo 3210; the second was conducted in Barron Collier's Oak Hammock Grove and harvested with the Oxbo 3220. The fifth and sixth trials were late-season 'Valencia' trials for ground speed and shaker frequency conducted in the Consolidated Citrus DeSoto Grove. In these studies CMNP was applied at 250 ppm at 100 and 200 gal/acre, respectively. The machine was operated at either 0.5 or 1.0 mph with a shake frequency of 145 or 185 cpm.

Because the fruit treated with CMNP have to be destroyed the fruit are never dumped into the trailer which precludes us from using our sampling method described above. In the CMNP studies, fruit are harvested and placed into field tubs as for standard hand harvest. We sample directly from the field tubs by placing our plastic tub described above on the ground next to the field tub and scooping fruit into our sample tub. This allows us to capture fruit and debris together as opposed to picking individual fruit and pieces of debris from the field tubs.

Debris from CMNP treated fruit is sorted similar to the description above for mechanical harvesting except that the debris is further sorted into loose debris and adhering debris. Adhering debris is that which is still attached to each piece of fruit, generally consisting of a small stem and a few leaves; loose debris is that which is lying loose in the bottom of our

sample tub after the fruit and adhering debris have been removed. Each category, loose and adhering, is then sorted into leaves, small stems and large stems.

Results:

Debris accumulation studies: The results for each individual debris accumulation samplings are shown in Table 1 and are summarized in Figure 1a-d. These data show approximately a 2-3 fold increase in the total amount of debris accumulated (Figure 1d) in mechanically harvested loads compared to hand harvested loads. The bulk of these differences are from small and large stems (Figure 1b and c). However, upon inspection of the data from individual samplings (Table 1) it is apparent that there are large differences between samplings within the mechanically harvested samples; however, the hand harvested samples do not show much variation between samplings. The uniformity within the hand harvested samples indicates that our sample size and method are sufficient. Thus, the variation within the mechanically harvested samples must be related to some factor(s) other than sampling error. Since the fruit harvested with the Oxbo 3210 relies on a hand crew for pick up it is likely that the variation in debris levels from one sample to another is related to the human factor. In theory this fruit should be as clean as hand harvested fruit if each fruit is individually picked up from the ground. The variation among samples collected from the Oxbo 3220 must be related to aspects of grove condition or machine operation that have not yet been determined. The two factors measured to date, ground speed and tree height, do not show any correlation with the debris accumulation variability.

CMNP 'Parson Brown' trials: The data from the December 2007 'Parson Brown' CMNP trial are shown in Table 2. The application of CMNP in this trial was immediately followed by several cold days and efficacy, based on fruit detachment force, was minimal. There were no reductions in the amount of total loose debris or any component of loose debris with the application of CMNP. However, despite the apparent reduction in efficacy from the cold weather, there was a significant reduction in adhering leaves and total adhering debris associated with the use of CMNP. There was a numerical reduction in the total amount of debris when CMNP was applied, although not statistically significant, and this translated into a reduction of nearly 50 lbs of debris in a full load.

The data from the January 2008 'Parson Brown' CMNP trial are shown in Table 3. Unlike in the December trial, the weather conditions following CMNP application in this trial were ideal and efficacy was good based on fruit detachment force data. Also in this trial a hand harvested control from elsewhere in the same block was sampled; however, those data are presented only for comparison and are not included in the statistical analysis. All categories of loose debris were similar for all treatments in this trial with the exception of loose leaves, which were significantly higher in the 230 cpm, -CMNP treatment. The large volume of loose leaves in that treatment accounted for the total loose debris also being higher in that treatment compared to the others. For total loose debris, the 230 cpm, +CMNP treatment was very similar to the hand picked control while both 270 cpm treatments were about 50% greater than the hand picked control. Adhering debris separated nicely among the treatments and none of the treatments

had any adhering large stems. The +CMPN treatments were similar to one another regardless of shaker frequency and significantly lower than both –CMNP treatments. For both categories of adhering debris the 230 cpm, -CMNP treatment contained the greatest amount of debris. This seems to suggest that the low shaker frequency (230 cpm) does not have sufficient force to cleanly separate a strongly adhering variety like 'Parson Brown' without the use of an abscission agent. As previously mentioned, both +CMNP treatments were statistically similar, however, the 270 cpm +CMNP treatment was numerically lower for all categories and was lower than the hand picked comparison. In this study, the use of CMNP equated to nearly a three-fold difference in the amount of debris in a load of fruit (92.4 lbs up to 274.8 lbs).

CMNP 'Valencia' rate trials: The first 'Valencia' rate trial was harvested using the Oxbo 3210 pull behind harvester and those data are shown in Table 4. For all categories of debris, all rates of CMNP numerically reduced the amount of debris relative to the untreated controls. Loose leaves were numerically reduced at all rates of CMNP, but there were no significant differences for this category of debris. Loose small stems were significantly reduced at all rates of CMNP relative to the control, but there were no differences among rates of CMNP. Both adhering leaves and small stems were significantly reduced at the 200 and 300 gal/A rates compared with controls and were numerically lower than the 100 gal/A rate. Total adhering debris and overall total debris followed a similar pattern, 200 and 300 gal/A significantly less compared with controls but only numerically lower compared to the 100 gal/A rate. Overall, the 200 and 300 gal/A rates reduced the total debris in a load by about 64%.

The second 'Valencia' rate trial was harvested using the OXBO 3220 self-propelled harvester and those data are shown in Table 5. The trends are the same in this trial as the one described above. There were no significant differences for any category of loose debris although the 200 and 300 gal/A rates were numerically lower on all cases. For adhering debris the 200 and 300 gal/A rates were significantly lower than the controls for all categories and significantly lower than the 100 gal/A rate for all categories except for adhering leaves. Similar to the previous rate trial there were no significant differences between the 200 and 300 gal/A rates. In this trial the 200 and 300 gal/A rates of CMNP reduced the total debris per load by approximately 60% compared to the control.

Late-season 'Valencia' ground speed x shaker frequency x CMNP trials: The data from the May 13, 2008 late-season 'Valencia' trial are shown in Table 6. By mistake, the CMNP was applied at 100 gal/A on this date. Because of the three factors studied in this experiment and its being designed as a split-plot experiment the statistical significances are not shown in the table; hand harvest debris data are shown for comparison only and are not included in the statistical analysis. Loose leaf and total loose debris was significantly reduced at the 0.5 mph ground speed with CMNP regardless of shaker frequency compared with the 0.5 mph speed without CMNP, but was similar to 1.0 mph ground speed irrespective of CMNP treatment. There were no differences in loose small stems among any of the treatments. For all adhering debris categories (leaves, small stems and total) debris was reduced at the slower shaker frequency (145 cpm) relative to the faster shaker frequency (185 cpm) irrespective of ground speed or

CMNP treatment. Similarly, for all adhering debris categories, CMNP significantly reduced debris irrespective of ground speed or shaker frequency. This same pattern carried over to the overall total debris category, debris reduced by both CMNP and shaker frequency irrespective of the other variables. No combination of factors reduced total debris to levels similar to the hand picked controls in this study, probably because of the misapplication of the CMNP.

The data from the May 27, 2008 late-season 'Valencia' trial are shown in Table 7. In this trial, CMNP was applied at the correct rate of 300 gal/A. For all categories of loose debris (leaves, small stems and total), +CMNP significantly reduced debris compared to –CMNP irrespective of the other factors (ground speed or shaker frequency). And for all categories of loose debris, the amount of debris in +CMNP treatments was similar to or less than the hand picked controls. Adhering leaves followed a similar pattern as loose debris in that +CMNP reduced adhering leaves compared to –CMNP irrespective of the other factors. For adhering small stems and total adhering debris there was an interaction between CMNP and shaker frequency. CMNP treatment always reduced debris relative to –CMNP, but within CMNP treated plots debris was significantly less at the lower shaker frequency. This same pattern carried over to the overall total debris category as well. In general, CMNP reduced all categories of adhering debris to levels similar to the hand picked controls. At the total load level, CMNP reduced debris by about 50%.

Conclusions:

I believe we can confidently say that mechanical harvesting increases the amount of debris in a load of 'Valencia' fruit by 2-3 times. However, we cannot yet determine what other factors may contribute to debris accumulation, but they clearly exist as evidenced by the variation from sample to sample within a machine type. It appears that CMNP can effectively reduce the amount of debris to levels equivalent to hand harvesting and that 200 gal/A at 250 ppm is sufficient to achieve this reduction. However, numerous issues still surround the use of CMNP, not the least of which is unpredictable weather following application.

This season we plan to verify that the debris data collected for 'Valencia' are valid for 'Hamlin'. We also hope to begin to understand what factors outside of the harvester itself affect debris accumulation. We will also continue to collect debris data for all CMNP trials.

Table 1. Amount of individual debris components and total debris (g debris / kg fruit), tree heights and machine ground speed for samples collected from hand harvested fruit and three different mechanical harvesters during the 2008 'Valencia' harvest season.

Sample	Leaves	Small stems	Large stems	Total debris	Estimated lbs debris per 60,000 lb load	Average tree height (m)	Machine ground speed (kph)
	Hand Harvest						
1	0.59	0.45	0	1.04	62.4	2.48	N/A
2	0.70	0.41	0.05	1.16	69.6	3.44	N/A
3	0.72	0.45	0	1.17	70.2	3.58	N/A
	Oxbo 3210 pull-behind						
1	1.89	1.21	0.13	3.23	193.8	3.63	1.14
2	1.57	1.20	0.21	2.95	177.0	4.43	0.78
3	1.40	1.29	0.10	2.80	168.0	3.25	1.27
4*	0.13	0.22	0	0.35	21.0	3.92	0.90
	Oxbo 3220 self-propelled with destemmer						
1	1.28	1.08	0.17	2.53	151.8	2.91	0.69
2	0.74	0.67	0.31	1.72	103.2	4.31	1.97
3	0.56	0.54	0.11	1.21	72.6	4.09	ND**
	Oxbo 3220 self-propelled without destemmer						
1	0.84	0.72	0.15	1.72	103.2	3.61	2.63
2	0.56	0.57	0.06	1.19	71.4	4.30	2.43
3	0.71	0.77	0.47	1.55	93.0	3.37	2.19

*This sample was picked up using the Oxbo 3200 pickup unit. The ground speed given is the speed of the harvester.

**ND = no data, no speed data were collected for this sample.

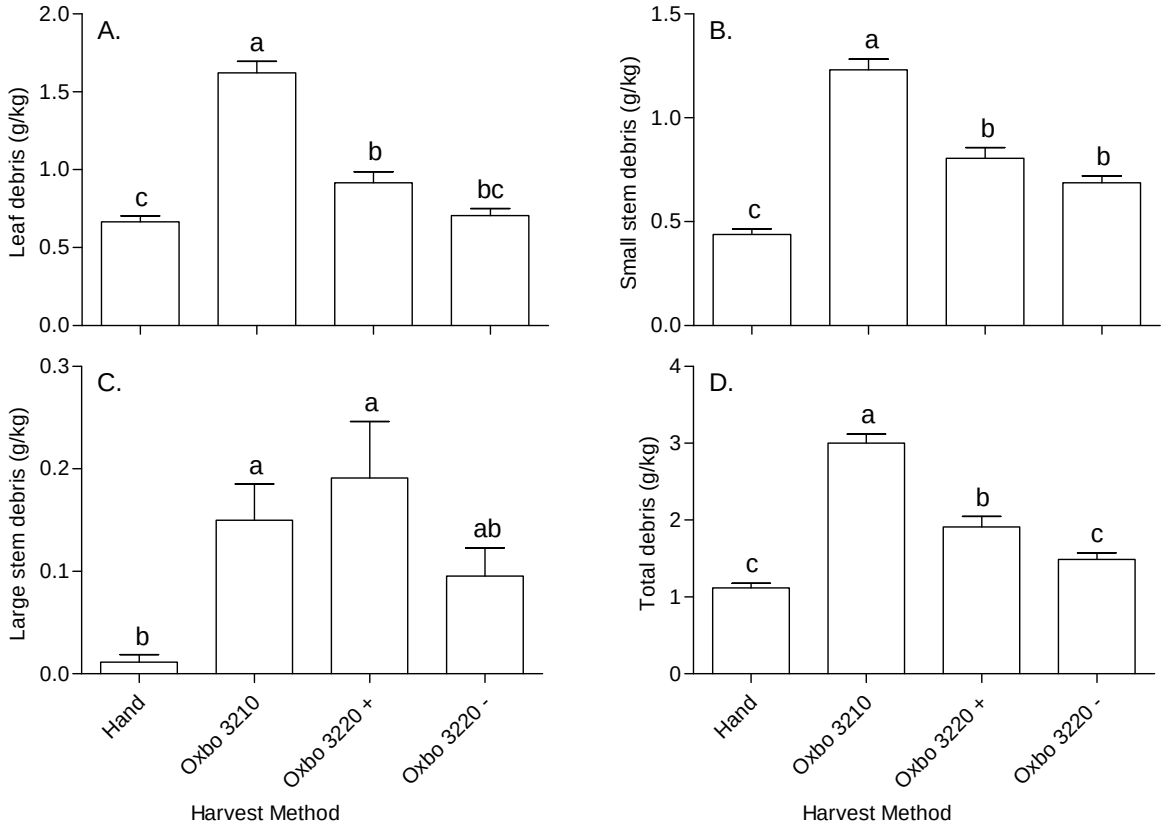

Figure 1. Leaves (A.), small stems (B.), large stems (C.) and total debris (D.) (g debris / kg fruit) averaged over three samplings of each of four harvest methods. Bars with different letters are significantly different within a debris category.

Table 2. Amount of loose and adhering debris (g debris / kg fruit) in mechanically harvested loads of 'Parson Brown' oranges either treated with 300 ppm CMNP or untreated in December 2007.

	Loose Debris				Adhering Debris				
Treatment	Leaves	Small stems	Large stems	Total	Leaves	Small stems	Total	Overall Total	Estimated lbs debris per 60,000 lb load
- CMNP	0.833	0.410	0.375	1.32	1.24	0.723	2.06	3.38	202.8
+ CMNP	0.760	0.318	0.245	1.18	0.978	0.605	1.58	2.76	165.6
Significance[z]	NS	NS	NS	NS	*	NS	*	NS	

[z] Significance based on *t*-test: NS = not significant, * = significant at P=0.05.

Table 3. Amount of loose and adhering debris (g debris / kg fruit) in mechanically harvested loads of 'Parson Brown' oranges either treated with 300 ppm CMNP or untreated and harvested with a shaker frequency of 230 or 270 cpm compared to a hand picked control in January 2008.

		Loose Debris				Adhering Debris				
Shaker frequency (cpm)	CMNP	Leaves	Small stems	Large stems	Total	Leaves	Small stems	Total	Overall Total	Estimated lbs debris per 60,000 lb load
230	-	1.17a	0.570	0.363	2.09a	1.54a	0.943a	2.48a	4.58a	274.8
230	+	0.465b	0.220	0.060	0.743b	0.588c	0.403b	0.990c	1.73c	103.8
270	-	0.683b	0.255	0	0.935b	1.03b	0.753a	1.79b	2.73b	163.8
270	+	0.600b	0.258	0.055	0.915b	0.380c	0.240b	0.618c	1.54c	92.4
Hand harvest		0.560	0.098	0	0.660	0.513	0.440	0.960	1.61	96.6

[z] Lowercase letters within a column indicate significant differences by Duncan's multiple range test, P=0.05.

Table 4. Amount of loose and adhering debris (g debris / kg fruit) in loads of 'Valencia' oranges harvested with the Oxbo 3210 pull-behind harvester treated with 300 ppm CMNP applied at 0 (control), 100, 200 or 300 gal/acre in April 2008.

	Loose Debris			Adhering Debris				Estimated lbs debris
Treatment	Leaves	Small stems	Total	Leaves	Small stems	Total	Overall Total	per 60,000 lb load
100 gal/A	0.374[z]	0.131b	0.551	0.704ab	0.720ab	1.42ab	1.97ab	118.4
200 gal/A	0.341	0.142b	0.483	0.377b	0.445b	0.822b	1.30b	78.2
300 gal/A	0.440	0.178b	0.649	0.283b	0.317b	0.600b	1.25b	74.9
control	0.621	0.532a	1.02	0.923a	0.916a	1.84a	2.93a	202.9

[z] Lowercase letters within a column indicate significant differences by Duncan's multiple range test, P=0.05.

Table 5. Amount of loose and adhering debris (g debris / kg fruit) in loads of 'Valencia' oranges harvested with the Oxbo 3220 self-propelled harvester treated with 300 ppm CMNP applied at 0 (control), 100, 200 or 300 gal/acre in April 2008.

	Loose Debris				Adhering Debris				Estimated lbs debris
Treatment	Leaves	Small stems	Large stems	Total	Leaves	Small stems	Total	Overall Total	per 60,000 lb load
100 gal/A	1.38[z]	1.71	0.145	3.47	0.448ab	0.713a	1.16a	4.63a	277.8
200 gal/A	0.488	1.06	0.383	1.55	0.135b	0.240b	0.375b	1.92b	115.2
300 gal/A	0.500	1.02	0	1.52	0.005b	0.020b	0.025b	1.54b	92.6
control	1.10	1.72	0	2.96	0.623a	0.638a	1.27a	4.23a	253.5

[z] Lowercase letters within a column indicate significant differences by Duncan's multiple range test, P=0.05.

Table 6. Effects of harvester ground speed, shaker frequency and CMNP on loose and adhering debris in loads of 'Valencia' oranges mechanically harvested with the Oxbo 3210 pull-behind canopy shaker compared to hand harvested controls on May 13, 2008.

			Loose Debris			Adhering Debris				
Ground speed (mph)	Shaker speed (cpm)	CMNP[z]	Leaves	Small stems	Total	Leaves	Small stems	Total	Overall total	Estimated lbs debris per 60,000 lb load
0.5	145	-	0.21	0.29	0.50	0.32	0.49	0.80	1.30	78.0
0.5	185	-	0.27	0.20	0.47	0.47	0.75	1.22	1.69	101.4
0.5	145	+	0.11	0.18	0.29	0.13	0.28	0.41	0.70	42.0
0.5	185	+	0.19	0.22	0.40	0.19	0.35	0.54	0.95	57.0
1.0	145	-	0.14	0.19	0.37	0.22	0.46	0.68	1.05	63.0
1.0	185	-	0.11	0.07	0.18	0.43	0.68	1.10	1.29	77.4
1.0	145	+	0.18	0.20	0.37	0.17	0.35	0.52	0.89	53.4
1.0	185	+	0.17	0.28	0.46	0.31	0.52	0.83	1.29	77.4
Hand		-	0.09	0.15	0.24	0.04	0.10	0.13	0.38	27.8
Hand		+	0.17	0.25	0.42	0.07	0.12	0.18	0.61	36.6

[z] CMNP applied at 250 ppm at 100 gal / acre.

Table 7. Effects of harvester ground speed, shaker frequency and CMNP on loose and adhering debris in loads of 'Valencia' oranges mechanically harvested with the Oxbo 3210 pull-behind canopy shaker compared to hand harvested controls on May 27, 2008.

			Loose Debris			Adhering Debris				
Ground speed (mph)	Shaker speed (cpm)	CMNP[z]	Leaves	Small stems	Total	Leaves	Small stems	Total	Overall total	Estimated lbs debris per 60,000 lb load
0.5	145	-	0.12	0.16	0.27	0.34	0.50	0.84	1.11	66.6
0.5	185	-	0.06	0.08	0.14	0.23	0.39	0.62	0.76	45.6
0.5	145	+	0.04	0.05	0.09	0.08	0.17	0.25	0.33	19.8
0.5	185	+	0.02	0.01	0.03	0.12	0.20	0.33	0.36	21.6
1.0	145	-	0.10	0.12	0.22	0.19	0.40	0.59	0.81	48.6
1.0	185	-	0.06	0.08	0.14	0.14	0.31	0.46	0.60	36.0
1.0	145	+	0.03	0.03	0.06	0.10	0.19	0.28	0.34	20.4
1.0	185	+	0.04	0.06	0.10	0.13	0.22	0.35	0.45	27.0
Hand		-	0.12	0.07	0.19	0.10	0.17	0.27	0.47	28.2
Hand		+	0.10	0.09	0.19	0.05	0.07	0.12	0.30	18.0

[z] CMNP applied at 250 ppm at 300 gal / acre.