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DEFOLIATION AFTER HARVEST WITH A TRUNK SHAKER DOES NOT AFFECT CANOPY LIGHT INTERCEPTION IN ORANGE TREES

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Abstract. **Tree productivity can be directly related to light interception by the canopy. To determine the effects of defoliation during mechanical harvesting on canopy light interception, we measured midday interception of direct light with a 16.3 m² point grid system and of photosynthetically active radiation (PAR) with a ceptometer in mature 'Hamlin' and 'Valencia' sweet orange trees (*Citrus sinensis*). Light interception measurements were made near solar noon on trees before and after hand harvesting or trunk shaking harvesting with a linear-type trunk shaker in 2005 and 2006. Leaves removed during harvest were collected to estimate percentage defoliation. Canopy volume and leaf area the following year were estimated. Before harvest, well-developed citrus tree canopies intercepted 80% of the direct light and >88% of PAR per projected area of canopy. Although excessive trunk shaking can remove up to 15% of the leaf area compared to 2% by hand harvesting (Li et al., 2005), little change in canopy leaf area index (LAI) or midday light interception occurred after harvest using the trunk shaker. Canopy volume and total leaf area the following year were not correlated to previous harvest methods.**

Partial defoliation during harvest with a canopy or trunk shaker is one of the visible physical injuries to citrus trees by mechanical harvesting machines (Li and Syvertsen, 2004). Regardless of the type of harvest machines, the aggressiveness and duration of machine operation can inevitably remove a number of leaves and twigs along with mature fruit. Our previous study indicated that while achieving commercially acceptable harvest efficiency with a linear-type trunk shaker, up to 15% of leaves were removed (Li et al., 2005). Growers' concerns about this defoliation and other potential effects of mechanical harvesting on citrus trees health limit the adoption of mechanical harvesting by Florida's citrus industry (Brown, 2005).

If the lost leaf surface area negatively impacts citrus tree productivity, it would likely occur through diminished photosynthetic activity. Assessing canopy photosynthesis by measuring whole canopy gas exchange (Li et al., 2003) is technically feasible but would be time- and labor-consuming on relatively large citrus trees. Canopy photosynthesis can be estimated using individual leaf gas exchange, but it is difficult to obtain a sample size large enough to represent the diversity of leaf age, location, and canopy microclimate, and the integration of single leaf measurements over a whole tree canopy presents many problems (Miller et al., 1996). Alternatively, since the ultimate limit on productivity of citrus or any other agricultural crop is the amount of photosynthetically active radiation intercepted by the canopy (Jackson, 1980; Tucker et al., 1991), measuring canopy light interception is a simple approach to evaluate canopy photosynthetic function.

On clear days, measuring direct light interception with a point grid provides a simple and inexpensive estimate of canopy light interception (Wünsche et al., 1995). These results have been highly correlated to those obtained with other more expensive devices. Thus, total light interception can be used as a surrogate for potential canopy productivity. An issue is that citrus trees have a relatively high leaf area index (LAI; Jahn, 1979; Syvertsen and Lloyd, 1994) so there are multiple layers of leaves per unit ground surface area to absorb available light. Our objective was to compare canopy light interception before and after harvest by hand or with a trunk shaker to identify any relationship between mechanical harvesting-induced partial defoliation and canopy light interception. We hypothesized that healthy citrus trees can sustain some partial defoliation by mechanical harvesting without reducing light interception by the canopy.

Materials and Methods

Healthy, uniform and mature 13-year-old 'Hamlin' and 14-year-old 'Valencia' sweet orange [*Citrus sinensis* (L.) Osb.] trees on Swingle citrumelo [*C. paradisi* Macf. × *Poncirus trifoliata*] rootstock at the UF/IFAS Citrus Research and Education Center were used in this study. Harvesting trials were established in winter 2003. Trees were either harvested by hand or with a linear-type trunk-shaking system (FMC Corp., Lakeland, Fla.) for 10 or 20 s of shake time. The padded clamp shaker head was equipped with 70.8 kg (156 lbs) of unbalanced weight and connected by a power take-off to a tractor engine operating at 2100 rpm. This weight and power combination was selected to generate a shaking frequency of 4 Hz with a maximum trunk displacement of 13 cm (5 in) at 45 cm (18 in) aboveground. From 2004 to 2006, individual trees were harvested with the same harvest treatment. Leaves and twigs removed during harvest were collected and leaf area was measured. Canopy volume was measured after harvest and canopy leaf area was estimated by frame count (Albrigo et al., 1975). Defoliation attributable to mechanical harvesting was then estimated from removed leaf area and remaining canopy leaf area.

Direct light interception at midday was measured in the 'Hamlin' trial in 2005 harvest season using a custom-made 16.3 m² (175 ft²) point grid on a tarpaulin placed on the ground. There were 440 red dots evenly distributed on the grid. Twenty-five trees in one east-west row were divided into five blocks of five trees. On 6 Jan., two trees in each block were harvested by hand, two trees harvested with the trunk shaker for 10 s shaking duration, and one harvested with the trunk shaker for 20 s. The percentage area of the grid occupied by

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the canopy shade near solar noon was measured on 4 Jan. and 8 Jan. by recording the number of shaded and sun exposed dots on the grid. Midday canopy PAR interception was measured in the 'Valencia' trial in 2005 and 2006 using a PAR ceptometer (AccuPAR, Decagon Devices, Inc., Pullman, Wash.). In this case, 20 trees in a north-south row were divided into five blocks. On 15 Mar. 2005, one tree in each block was harvested by hand, two trees with the trunk shaker for 10 s, and one with the trunk shaker for 20 s. Midday PAR interception by the canopy was recorded on 14 Mar. and 18 Mar. In 2006, trees were harvested on 23 Mar. Midday canopy PAR interception was measured and LAI estimated from the PAR readings on 22 and 24 Mar.

A randomized block design with three treatments and 5 or 10 replicates was applied in each trial. Data were subjected to analysis of variance (ANOVA). Significant differences between means were tested using Duncan's multiple range test at $P \leq 0.05$.

Results and Discussion

Leaf removal and canopy midday direct light interception. In the 'Hamlin' trial, harvest by trunk shaking removed more than 12% of the leaf area in 2004 harvest season (Fig. 1A). By the 2005 harvest season, midday canopy light interceptions by trees harvested with the trunk shaker were similar to those harvested by hand (Fig. 1B). Before harvest again on 6 Jan. 2005, these trees intercepted nearly 80% of the direct sunlight per projected canopy area at solar noon regardless of the harvest methods used in the previous year. The second year of trunk shaking removed 6% to 7% of the leaf area compared to <1% by hand harvest. However, there were no significant changes in canopy light interception attributable to harvest treatment (Fig. 1B). The slight numeric reduction in midday light interception was possibly due to removal of fruit and increase in branch angles after harvest.

Leaf removal and midday canopy PAR interception. Similar to canopy interception of direct light, the moderate defoliation by mechanical harvesting had little effect on PAR interception in the 'Valencia' trial (Fig. 2). Trunk shaking removed 15% leaf area in 2004 (Fig. 2A). By Mar. 2005, canopy PAR interception was similar among all trees regardless of the previous harvest method (Fig. 2B). Mechanical harvesting again on 15 Mar. 2005 removed about 7% and 13% of leaf area by trunk shaking for 10 or 20 s (respectively, Fig. 2A) but did not cause any substantial reduction in midday PAR interception (Fig. 2B). By Mar. 2006 after 2 years of harvesting, trees har-

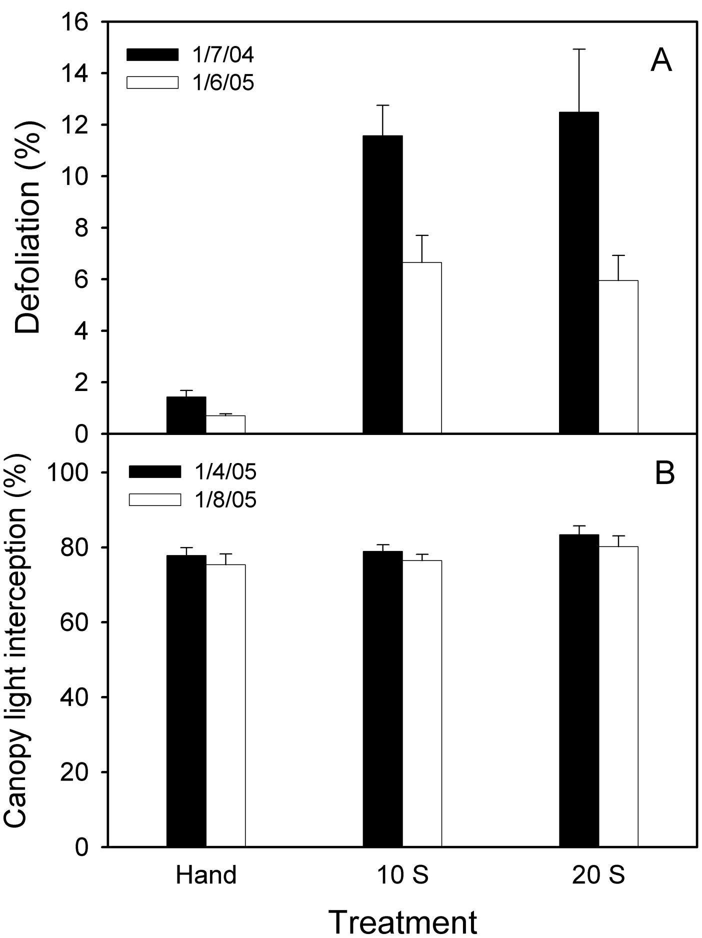

Fig. 1. A) Defoliation and B) midday interception of direct light by 'Hamlin' trees harvested by hand or by trunk shaker. Trees were harvested on 7 Jan. 2004 and 6 Jan. 2005. Canopy light interception was measured on 4 and 8 Jan. 2005. Treatments: Hand = hand harvest; 10 S = 10 s trunk shaking; and 20 S = 20 s trunk shaking. Values represent mean of 10 (Hand and 10S) or 5 (20S) trees. Vertical bars represent standard error.

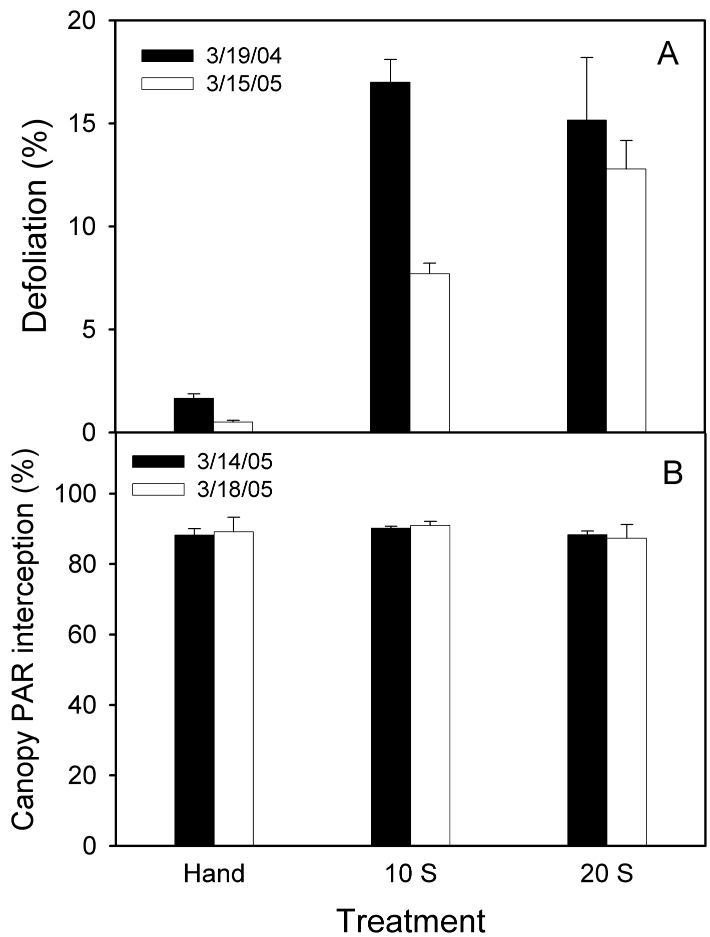

Fig. 2. A) Defoliation and B) midday photosynthetically active radiation (PAR) interception of hand harvested and trunk shaker harvested 'Valencia' trees. Trees were harvested on 19 Mar. 2004 and 15 Mar. 2005. Canopy PAR interception was measured on 14 and 18 Mar. 2005. Treatments: Hand = hand harvest; 10 S = 10 s trunk shaking; and 20 S = 20 s trunk shaking. Values represent mean of 10 (10S) or 5 (Hand and 20S) trees. Vertical bars represent standard error.

vested by excessive trunk shaking (20 s) had a slightly lower LAI than other trees harvested by hand or by normal trunk shaking (10S, Fig. 3A). Nevertheless, with an LAI close to 4, these well-developed canopies intercepted up to 95% PAR around solar noon (Fig. 3B). Similar to the previous year's result, mechanical harvesting in 23 Mar. 2006 did not change canopy LAI or midday PAR interception.

Overall, defoliation caused by mechanical harvesting did not reduce canopy light interception in well-developed citrus tree canopies. This means that more light penetrated into the canopy impinging on shaded inner leaves after mechanical harvesting. Thus, the partial removal of leaves and twigs after

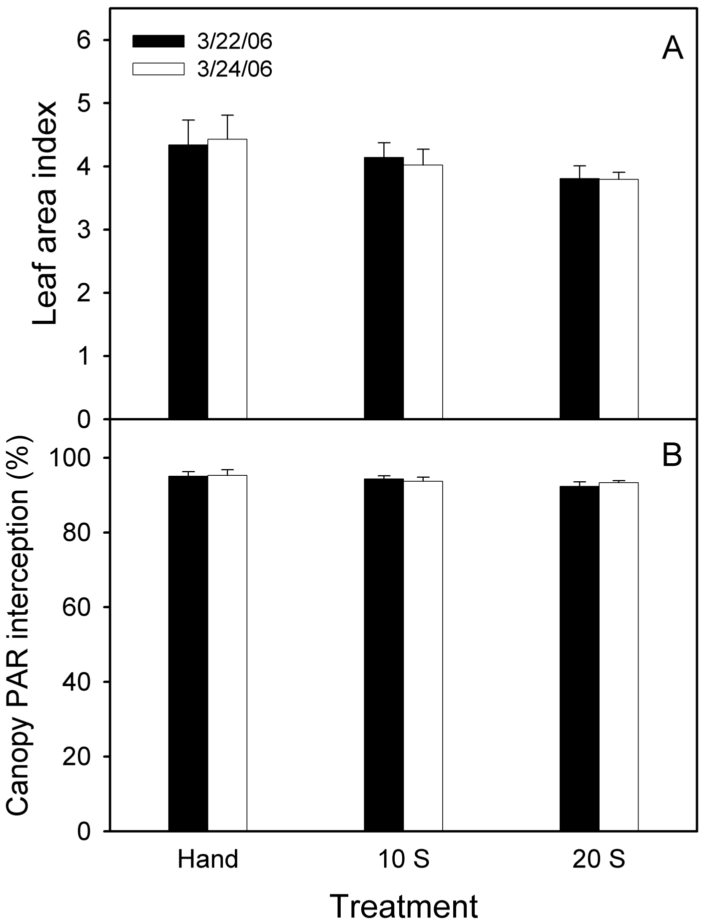

Fig. 3. A) Leaf area index (LAI) and B) midday interception of photosynthetically active radiation (PAR) by hand harvested and trunk shaker harvested 'Valencia' trees. Trees were harvested on 23 Mar. 2006. Canopy LAI and PAR interception were measured on 22 and 24 Mar. 2006. Treatments: Hand = hand harvest; 10 S = 10 s trunk shaking; and 20 S = 20 s trunk shaking. Values represent mean of 10 (10S) or 5 (Hand and 20S) trees. Vertical bars represent standard error.

mechanical harvesting could improve light penetration to the inner canopy and consequently increase the gas exchange rate of the leaves inside the canopy. Healthy citrus trees can sustain up to 25% defoliation without reducing the crop the following year (Yuan et al., 2005) and citrus can partially compensate for leaf loss by increasing leaf photosynthesis of remaining leaves (Syvertsen, 1994). The defoliation by mechanical harvesting, however, did not induce such compensation on exposed sun leaves in mature citrus trees (Li and Syvertsen, 2005). Instead, some compensation may have occurred in the previously shaded leaves inside the canopy after mechanical harvesting due to increasing PAR availability. Although mechanical harvesting reduced total canopy leaf area by up to 15%, trees were apparently able to maintain a canopy photosynthetic activity sufficient to maintain subsequent yield.

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