Proc. Fla. State Hort. Soc. 123:59–61. 2010.

Interaction of CMNP Application and Harvest Date of 'Hamlin' Sweet Orange

ROBERT C. EBEL*, KELLY T. MORGAN, AND FRITZ M. ROKA

University of Florida, IFAS, Southwest Florida Research and Education Center, 2685 SR 29 N., Immokalee, FL 34142

ADDITIONAL INDEX WORDS. mechanical harvesting, abscission, harvest efficiency, 5-chloro-3-methyl-4-nitro-1*H*-pyrazole

This study was conducted to determine the change in mechanical harvest efficiency over time of sweet orange treated with the abscission agent 5-chloro-3-methyl-4-nitro-1*H*-pyrazole (CMNP). CMNP was applied in December on 'Hamlin' at 0 and 300 mg·L^{-1} in a carrier volume of 2806 L·ha^{-1}. The trees were harvested 2, 3, 4, and 6 d after CMNP application with a pull-behind canopy shaker operating at 3.7 Hz and with a tractor speed of 1.6 km·h^{-1}. Fruit detachment force of CMNP-treated fruit declined to 39 N, which was 40% lower than the controls, by 4 d after CMNP application. The percent of fruit drop increased to 5% for CMNP treated fruit by 4 d compared to the controls that were significantly lower with 1% drop. The CMNP × harvest day interaction for the percentage of the crop removed by the harvester was not significantly different. The CMNP main effect mean was significant with CMNP removing 73% of the crop compared to 68% for the controls. The widest separation between CMNP treated and controls trees for the amount of fruit left in the trees after mechanical harvest occurred on day 4, where only 23% of the crop had to be gleaned for CMNP-treated trees compared to the controls that required 36% of the crop to be removed by hand. This study demonstrated that CMNP was active up to 4 d after CMNP application with the concentration and carrier volume of CMNP as used here and with air temperatures optimum for loosening (>15.6 °C) for most of the loosening period.

An Experimental Use Permit (EUP) for 5-chloro-3-methyl-4-nitro-1*H*-pyrazole (CMNP) as an abscission agent for sweet orange [*Citrus sinensis* (L.) Osbeck] to aid mechanical harvesting in Florida was submitted to the EPA in Dec. 2009. If successful, CMNP will be available for the 2011–12 harvest season. Incorporation of CMNP into mechanical harvesting of sweet oranges has stimulated research to understand the most significant factors affecting efficacy, including concentration, carrier volume, coverage, air temperature, and time of year (Alferez et al., 2005; BenSalem et al., 2001; Burns et al., 2005, 2006; Ebel and Burns, 2008; Ebel et al., 2009; Farooq et al., 2003; Freeman and Sarooshi, 1976; Kender and Hartmond, 1999; Koo et al., 1999, 2000; Salyani et al., 2002; Yuan and Burns, 2004). Research has also been conducted to determine settings of canopy shakers, the most commonly used mechanical harvesters, that would maximize removal including shaker frequency (Ebel et al., 2010).

CMNP has been shown to promote abscission for up to 5 d after CMNP application (Burns et al., 2005), but it is not known how preharvest fruit drop and fruit removal by the mechanical harvesters would change over the 5-d period. This information is critical for understanding how to best time harvesting by machines equipped with decks that capture the fruit that is loaded via a conveyor into transport equipment to remove the fruit from the grove. The goal of harvesting with machines equipped with catch frames is to maximize recovery, defined as the percent of the entire crop that is removed from the grove by the harvest process without the use of hand labor (Sharma et al., 2010). This study was conducted to determine the pattern of fruit drop and percent of total fruit harvested by CMNP application and a canopy shaker over a 6-d period.

Materials and Methods

PLANT MATERIAL AND CULTURE. This study was conducted in the Flatwoods region of southern Florida on fully mature, 'Hamlin' sweet orange [*Citrus sinensis* (L.) Osbeck] trees on Carrizo citrange (*C. sinensis* × *Poncirus trifoliata* (L.) Raf.] rootstock during the 2009–10 harvest season. The trial was conducted in a commercial grove that used standard commercial practices owned and operated by Cooperative Producers Incorporated Ranch One Grove near Immokalee, FL. The trial was located at latitude 26N 20'05" and longitude 81W 22'22" (block P-25) on trees planted in 1987. At the time of the trial the trees averaged 4.4 m high (SE = 0.028), 5.1 m wide (SE = 0.038), and were skirted to 0.8 m (SE = 0.015) above the soil. The soil type was an Immokalee Fine Sand (siliceous, hyperthermic Arenic Alaquods). The trees were mechanically pruned (hedged) every year to maintain tree size within a very narrow range as indicated by the low SE for height, width and skirt height.

TREATMENTS. Trees were sprayed on 13 Dec. 2009 with a multi-head air-blast sprayer (model T1000, OXBO International, Clear Lake, WI) a vertical 5.5-m boom oriented parallel to and arched over the outer part of the canopy (Ebel et al., 2009). Each boom had six equally spaced fan/nozzle assemblies and each fan assembly had eight Conejet #12 nozzles (Spraying Systems Col., Wheaton, IL) operating at 1.5 MPa. The tractor speed during application was 2.7 km·h^{-1}. The sprayer was calibrated immediately before CMNP application. CMNP (17% a.i.) was applied at 300

Acknowledgments. This research was funded by the Florida state legislature through the Citrus Initiative. We would like to thank the Citrus Harvesting Research and Advisory Council and Agrosource, Inc., for their helpful advice. We thank Peter Newman, Lisa Cushman, and Naveen Kumar (Citrus Physiology Laboratory, SWFREC, IFAS, UF, Immokalee, FL for technical assistance.
*Corresponding author; phone: (239) 658 3400; email: rcebel@ufl.edu

mg·L^{-1} a.i. in a volume of 2806 L·ha^{-1} with 0.55 mg·L^{-1} of the adjuvant Activator 90 (Alkylphenol ethoxylate, alcohol ethoxylate and tall oil fatty acid, Loveland Products, Inc. Greeley, CO). The trees were sprayed from 1 to 2 PM. Relative humidity was 51% to 55% and air temperature was between 31.4 and 32.2 °C during CMNP application. Air temperature stayed above 16 °C for the first 24 h after application. There was also an unsprayed control.

The trees were mechanically harvested using a pull-behind canopy shaker (model 3210, OXBO International) 2, 3, 4, and 6 d after application. The shaker cycle frequency was 3.7 Hz and the tractor speed was 1.6 km·h^{-1}. A significant rain event occurred 5 d after application and harvest was delayed in order to reduce the spread of bacterial canker.

Data collected. Before each harvest, fruit detachment force (FDF) was determined from 10 randomly selected fruit per plot. FDF was measured using a force gauge (Force One digital force gauge, Wagner Instruments, Greenwich, CT) as described previously (Pozo et al., 2004).

Fruit beneath each tree (preharvest fruit drop) were collected and the total weight determined. Fruit harvested by machine were collected into commercial bins that held approximately 450 kg of fruit and were weighed on a 5.6-t capacity, 1.2 × 1.2 m electronic floor scale (Gator Deck, Avery Weigh-Tronix, Livonia, MI). Fruit remaining in the canopy after shaking were removed by hand and weighed. Total yield was determined by adding the weights of the preharvest drop fruit, the fruit dropped to the ground by the mechanical harvester, and the fruit gleaned. The percent removed was the sum of preharvest fruit drop and mechanically harvested fruit.

Statistical analysis. The study was conducted as a randomized complete-block design with four blocks. The experimental unit or plot consisted of three adjacent trees. There were at least two buffer trees between plots and a buffer row between treatment rows. The study was a 2 (CMNP treatment) × 4 (harvest date) split-plot design, with CMNP treatment as the whole plot and harvest date as the subplots. Data were analyzed using the General Linear Models procedure of the Statistical Analysis System (SAS, Carey, NC).

Results and Discussion

The CMNP × harvest day interaction was significant at $P = 0.0999$ for FDF. FDF of CMNP-treated fruit declined steadily after CMNP application up to day 4 where it reached 39 N, which was 40% lower than the controls (Fig. 1). FDF appeared to increase to that of the controls 6 d after treatment, which is in part related to drop and perhaps to cooler temperatures that occurred after the low-pressure front moved through the region the previous day. The CMNP × harvest day interaction for the percentage of the crop that dropped before harvest was significant at the $P = 0.0474$ level. The percent drop was similar to the controls 2 d after CMNP application, but increased to 5% by 4 d for CMNP-treated trees and remained at that level at 6 d. The controls had about 1% drop on all harvest dates.

The CMNP × harvest day interaction for the percentage of the crop removed by the canopy shaker was nonsignificant ($P = 0.3790$). The CMNP and harvest day main effect means were significant at $P = 0.0204$ and $P = 0.0022$, respectively, indicating that the percentage of total yield mechanically harvested was higher for CMNP-treated trees and that the percentage of the crop that was removed by the harvester increased over time. The fruit that was left in the trees and had to be gleaned also did not have a significant CMNP × harvest day interaction ($P = 0.2737$). The CMNP and harvest day main effect means for the percent of fruit gleaned were significant at $P = 0.0002$ and $P = 0.0047$, respectively. The widest separation between CMNP-treated and control trees occurred on day 4, where only 23% of the crop had to be gleaned for CMNP-treated trees compared to the controls that required 36% of the crop to be removed by hand.

In previous work it has been established that a decrease in FDF to 50% of the controls leads to maximum removal (Ebel et al., 2010). In the current study, FDF for CMNP-treated fruit declined to its lowest point by day 4, which was 60% of the controls. Fruit drop was low for all harvest dates, which was similar to that shown in previous studies for 'Hamlin' harvested in December (Ebel et al., 2010). Also in our earlier study, fruit drop plus fruit harvested was 90% when using the same CMNP rates, tractor settings, and time window between CMNP application and harvest as used in the current study, whereas only 80% of the fruit was removed without CMNP. In the current study, fruit drop plus fruit harvested was 63% without CMNP and 77% with CMNP 4 d after CMNP application. Thus, although both studies were conducted in the same block of trees but only one year apart, removal was about 13% less in the current study than our previous study (Ebel et al., 2010). Weather conditions were similar in both studies and so would not be considered to have explained the variation in removal for the two years. One fac-

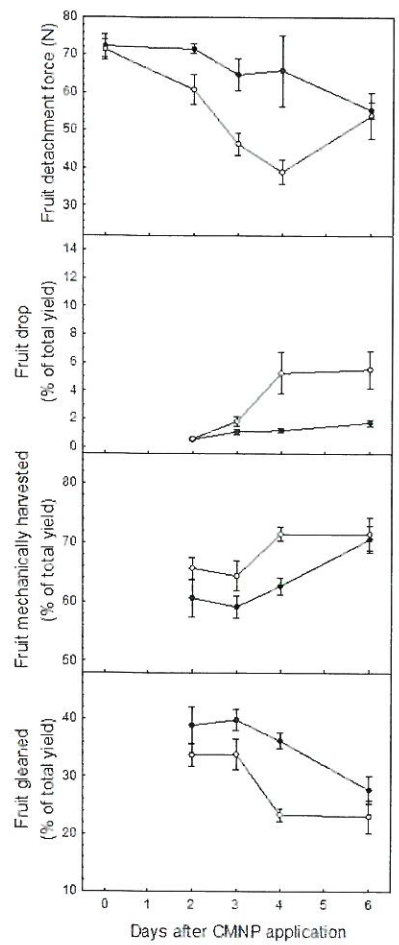

Fig. 1. Interaction of the abscission agent CMNP and harvest date on fruit detachment force and harvest components of 'Hamlin' sweet orange.

tor in both studies that is difficult to control is the depth of the shaker mechanism penetration into the canopy, which can have a large effect on removal rates (Whitney and Hedden, 1973). The shaker equipment is on a boom that is manually moved into the canopy at depths determined by the operator. Studies need to be conducted to determine the relationship of the depth of the shaking mechanism into the canopy on removal rates.

Although we used a pull-behind canopy shaker, most of the commercial sweet orange industry in Florida utilizes a self-propelled canopy shaker that is equipped with catch frames. These systems include two canopy shakers that run on either side of the row with the catch frames attached under the trees to maximize fruit capture. With this equipment, there is a trade-off between harvesting before fruit drop increases above unsprayed controls, and loosening that would allow more removal of fruit from the tree. As we noted in another study (Sharma et al., 2010), self-propelled canopy shakers should optimize efficiency by minimizing the sum of drop and fruit that is left in the tree. In this earlier study, the sum of drop and gleaned fruit was 36% at 3d and 29% at 4 d after CMNP application, indicating that the latter date would provide a greater opportunity to maximize recovery.

This study demonstrated that CMNP was active up to 4 d after CMNP application with the concentration and carrier volume of CMNP as used here and with air temperatures optimum for loosening (>15.6 °C) for most of the loosening period. Fruit drop was low throughout the study for CMNP-treated (<6%) and control fruit (<2%). Removal was higher for CMNP-treated trees with the maximum separation with untreated trees occurring 4 d after CMNP application.

Literature Cited

Alferez, F., S. Shila, A.L. Umback, B. Hockema, and J.K. Burns. 2005. Citrus abscission and arabidopsis plant decline in response to 5-chloro-3-methyl-4-nitro-1*H*-pyrazole are mediated by lipid signaling. Plant Cell Environ. 28:1436–1449.

BenSalem, E., M. Salyani, and J.D. Whitney. 2001. Spray variable effects on deposition and harvesting efficacy of CMN-pyrazole. Proc. Fla. State Hort. Soc. 114:111–118.

Burns, J.K., R.S. Buker III, and F.M. Roka. 2005. Mechanical harvesting capacity in sweet orange is increased with an abscission agent. HortTechnology 15:758–765.

Burns, J.K., F.M. Roka, K.T. Li, L.V. Pozo, and R.S. Buker, III. 2006. Late-season 'Valencia' orange mechanical harvesting with an abscission agent and low-frequency harvesting. HortScience 49:341–346.

Ebel, R.C. and J.K. Burns. 2008. Incorporation of air temperature into a model that predicts loosening of sweet oranges by CMNP. Fla. State Hort. Soc. Proc. 121:160–163.

Ebel, R.C., J.K. Burns, and K. Morgan. 2009. Spray volume distribution and effect of 5-chloro-3-methyl-4-nitro-1*H*-pyrazole for loosening sweet oranges using a vertical, multiple fan. HortScience 44:1895–1899.

Ebel, R.C., J. Burns, K. Morgan, and F. Roka. 2010. Abscission agent application and canopy shaker frequency effects on mechanical harvest efficiency of sweet orange. HortScience 45:1079–1083.

Farooq, M., M. Saylani, and J.D. Whitney. 2003. Effect of application techniques on abscission chemical deposition and mechanical harvesting of 'Valencia' oranges. HortTechnology 13:344–350.

Freeman, B. and R.A. Sarooshi. 1976. Abscission chemicals for Valencia oranges in New South Wales. Austral. J. Expt. Agr. Animal Husb. 16:943–949.

Kender, W.J. and U. Hartmond. 1999. Variability in detachment force and other properties of fruit within orange tree canopies. Fruit Var. J. 53:105–109.

Koo, Y.M., M. Salyani, and J.D. Whitney. 1999. Effects of abscission chemical spray deposition on mechanical harvest efficacy of 'Hamlin' orange. Proc. Fla. State Hort. Soc. 112:28–33.

Koo, Y.M., M. Salyani, and J.D. Whitney. 2000. Spray variable effects on abscission of orange fruit for mechanical harvesting. Trans. Amer. Soc. Agr. Eng. 43:1067–1073.

Pozo, L., R. Yuan, I. Kostenyuk, F. Alferez, G.Y. Zhong, and J.K. Burns. 2004. Differential effects of 1-methylcyclopropene on citrus leaf and mature fruit abscission. J. Amer. Soc. Hort. Sci. 129:473–478.

Sharma, S., R.C. Ebel, and K.T. Morgan. 2010. Modeling loosening of sweet orange with CMNP: Variation in fruit detachment force. Proc. Fla. State Hort. Soc. 123:39–43.

Salyani, M., E. BenSalem, and J.D. Whitney. 2002. Spray deposition and abscission efficacy of CMN-pyrazole in mechanical harvesting of Valencia orange. Trans. Amer. Soc. Agr. Eng. 45:265–271.

Whitney, J.D. and S.L. Hedden. 1973. Harvesting Valencia oranges with a vertical foliage shaker. Proc. Fla. State Hort. Soc. 86:41–48.

Yuan, R. and J.K. Burns. 2004. Temperature factor affecting the abscission response of mature fruit and leaves to CMNP-pyrazole and ethephon in 'Hamlin' orange. J. Amer. Soc. Hort. Sci. 129:287–293.