Spray Deposition and Abscission Efficacy of CMN–Pyrazole in Mechanical Harvesting of Valencia Orange

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Abstract. *Tests were conducted to investigate the efficacy of an experimental abscission chemical, CMN–Pyrazole (CMN–P), in a commercial orange grove in south Florida. Application variables included sprayer type, spray volume rate, spray release height, and application time. Spray deposition was assessed by fluorometry and the chemical efficacy was quantified by measuring fruit detachment force and fruit removal by a trunk shaker.*

CMN–P deposition decreased when spray volume increased. However, high volume applications produced better loosening effects and fruit removal. At low volumes, nighttime application resulted in higher depositions than daytime application. Spray release height had significant effects on spray penetration within the canopy, fruit detachment force, and fruit removal. Depositions on the outside and at lower canopy locations were generally higher than those on the inside and at higher canopy locations.

Keywords. *Spray, CMN–pyrazole, Pyranine, Fruit detachment force, Trunk shaker, Citrus.*

The effects of application variables on spray deposition and pesticide efficacy in citrus tree canopies have been studied by several researchers. Salyani et al. (1988) analyzed the effect of spray volume on deposition, using a copper tracer. The study showed that spray volume had no significant effects on mean deposition, but higher spray volumes resulted in more uniform coverage than low volume rates. Salyani and Whitney (1990, 1991) investigated the effects of air–carrier sprayer ground speed and oscillators on spray deposition. They concluded that neither ground speed nor operation of the oscillators influenced spray deposition. Hoffmann and Salyani (1996) studied the effects of spray volume rate and application time on spray deposition. Nighttime applications (lower temperature and higher relative humidity) resulted in a higher deposition than daytime applications (higher temperature and lower relative humidity). When spray volume decreased, mean and variability of deposition increased.

Several studies have evaluated the efficacy of abscission chemicals in relation to mechanical harvesting of oranges. Hedden et al. (1988) reported 17 to 26 percentage points increase in fruit removal efficiency of trunk shakers when using abscission chemicals. Whitney et al. (2000b) studied the fruit removal efficiency of different abscission chemicals and trunk shakers on Hamlin and Valencia oranges. The shaker efficiency increased by 10 to 15 percentage points when fruit detachment force was reduced by 50% to 80%. Investigating the effects of spray variables and CMN–P application rate on spray deposition and abscission efficacy, Koo et al. (1999, 2000) found that lower spray volumes gave more deposition than the higher volume rates, but the latter resulted in more effective fruit loosening and removal. Whitney et al. (2000a) suggested that variable spray release to the top and bottom half of the tree canopy could affect fruit loosening and removal. In the same study, a linear shaking pattern resulted in 1 to 6 percentage points better fruit removal than a multidirectional pattern.

The objectives of this study were:

- To determine the effects of sprayer type, application volume, application time, and spray release height on CMN–pyrazole deposition.
- To establish the relationship between spray deposition and harvesting efficacy of the abscission chemical in mechanical harvesting of Valencia orange.

Materials and Methods

An experimental abscission chemical, CMN–pyrazole (CMN–P), was applied to Valencia orange trees in two field tests on April 27 and May 19, 2000. The trees were 4.6 to 5.5 m high, set on 2–row beds, and alternately spaced at 3.0 and 4.6 m in the row, and at 6.7 and 7.8 m between the bed

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Product and company names used in this article are to provide specific information only. Their mention does not imply an endorsement or recommendation over others not mentioned.

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and water furrow rows, respectively (fig. 1). In both tests, spray treatments and an unsprayed control (check) were assigned to 4–tree plots, in a randomized complete block design with four replications. The trees were sprayed on both sides. Spray mixtures contained the CMN–P active ingredient (5–chloro–3–methyl–4–nitro–1H–pyrazole), adjuvant Kinetic (Helena Chemical Co., Memphis, Tenn.), and a fluorescent deposition tracer (Pyranine–10G, Keystone Aniline Inc., Chicago, Ill.). The formulated active ingredient (17.18% a.i. w/w) was developed by Abbott Laboratories (Chicago, Ill.) in the early 1970s. The sprayers were a Titan 1093 (John Bean Sprayers, Hogansville, Ga.) and a standard 8–fan Curtec (BEI, Inc., South Haven, Mich.). The former was an air-blast tower sprayer equipped with an axial–flow fan, tower air–duct, and hydraulic nozzles (fig. 1). The latter was an air–curtain sprayer using cross–flow fans and rotary atomizers. Spray application variables and deposition sampling procedure were different for each test.

First Test

Spray treatments included four combinations of the volume rate and application time: low volume–daytime (LV–D), low volume–nighttime (LV–N), high volume–daytime (HV–D), and high volume–nighttime (HV–N). All treatments were applied with both the Curtec and Titan sprayers. Application related parameters are presented in table 1.

Shortly after spraying, leaf samples were collected from the two middle trees of each plot at three heights (1.5, 3.0, and 4.5 m) outside and at 60 to 80 cm inside the tree canopy. Since earlier experiments (Koo et al., 1999) had shown a strong correlation between leaf and fruit depositions, only leaves were used for deposition assessment. The samples were washed with 100 mL of de–ionized water, and fluorescence levels were measured with a fluorometer (Model 111, Sequoia–Turner Co., Mountain View, Cal.). The surface areas of the leaves were measured with an area–meter (Delta–T Devices Ltd., Cambridge, U.K.). Using the Pyranine/CMN–P ratio, the tracer deposition was converted into the active ingredient deposition and expressed in ηg a.i./cm^2. During the day, the temperature, relative humidity, and wind velocity varied from 23°C to 29°C, 32% to 37%, and 1.9 to 4.7 m/s, respectively. At night, air temperature dropped to 12°C, relative humidity reached saturation, and wind velocity averaged 0.3 m/s.

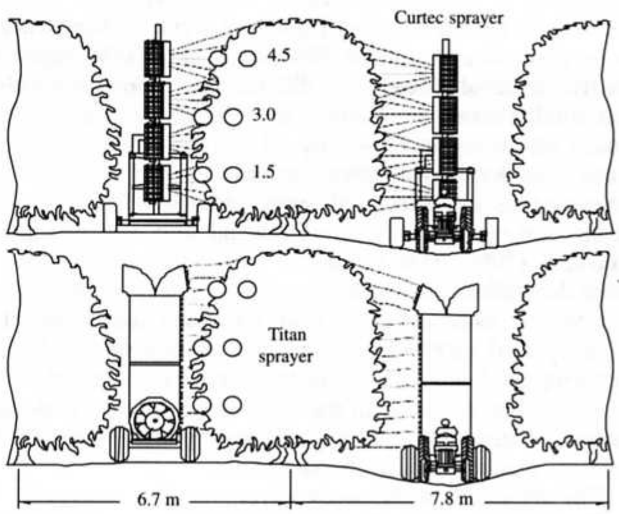

Figure 1. Schematic views of the sprayers and sample locations.

Four days after spraying, the two middle trees of each plot were used for harvesting measurements. First, fruit detachment force (FDF) was measured on five fruit at each of the 1.5 and 4.5 m high sample locations, using a force gauge (Model FDV–50, Wagner Instrument, Greenwich, Conn.). Then, the trees were shaken by a trunk shaker (Orchard Rite, Yakima, Wash.). The shaker was operated for 5 s, at 7 Hz frequency and 6 cm trunk displacement, using 205 kg of unbalanced mass in a linear pattern (Whitney et al., 2000a). Trunk displacements were measured on representative trees with an accelerometer–data–acquisition system (PCB piezotronics, Inc., Depew, N.Y.) and a DaqBook software (Iotech, Cleveland, Ohio). Fruit removed by the shaker and fruit that remained on the tree were weighed separately, and the percent of fruit removal was determined. Trunk circumference and the shaker clamp height were measured for each shaken tree.

Second Test

Using both the Curtec and Titan sprayers, a constant amount of the abscission chemical was applied to tree canopies in three release patterns:

- Released uniformly along the sprayer height to the entire tree canopy (T2B2).
- Released from the upper nozzles to the upper half of the tree (T4B0).
- Released from the lower nozzles to the lower half of the tree (T0B4).

All treatments were applied at 1030 L/ha and 4.8 km/h ground speed. The concentrations of the CMN–P a.i. and Pyranine–10G in the tank mix were 375 and 350 mg/L, respectively. The Titan sprayer was operated with 20 D6–23 disc–core nozzles (Spraying Systems Co., Wheaton, Ill.) at 690 kPa. Depending on the treatment, the nozzles were positioned equidistantly along the entire sprayer height

Table 1. Spray application variables in first test.

Treatment Code[a]	Application Volume Rate (L/ha)	Application Time	Sprayer Output[b] (L/min)	Ground Speed (km/h)	CMN–P A.I. Concentration (mg/L)	Pyranine Concentration (mg/L)
LV–D	234	Day	6.9	4.8	1650	1500
LV–N	234	Night	6.9	4.8	1650	1500
HV–D	1540	Day	30.3	3.2	250	227
HV–N	1540	Night	30.3	3.2	250	227

[a] Applied with both Curtec and Titan sprayers.
[b] Sprayer output per side from:
Curtec: four BEI rotary atomizers at 1.8 (LV) and 11.2 (HV) flow index settings.
Titan: 12 ConeJet TXVK–6 at 795 kPa (LV), and 12 ConeJet TXVK–6 plus 13 TeeJet disc–core D4–25 at 1050 kPa (HV).

(T2B2), the upper half manifolds (T4B0), or the lower half manifolds (T0B4). Similarly, for the Curtec, the spray was discharged from all four atomizers (T2B2), the upper two atomizers (T4B0), or the lower two atomizers (T0B4). In the latter two cases, spray applications were made in two passes on each side (because of flow rate limitation of rotary atomizers).

Spray penetration was sampled with absorbent cotton ribbons (2.5 cm wide) placed at the tree row line about 30 and 120 cm from the tree trunk. The ribbons were stretched from ground level to the canopy top. After spraying, the cotton ribbons were cut into 60 cm long segments and stored individually in sampling bags. Only the samples from 0.6 to 4.2 m heights were used in data comparisons. Samples were washed with 150 mL of de–ionized water, and spray deposition was quantified by fluorometry. Fruit detachment force and other harvesting variables were measured as described in the first test.

Data Analyses

Data collected from both tests were analyzed using the General linear Models (GLM) procedure in SAS (SAS, 1990). Means were separated by the Duncan's multiple range test at the 5% level. Variability of the data was expressed as the coefficient of variation (CV). Fruit removal data were correlated with fruit detachment force, spray deposition, trunk circumference, and clamp height data using the Pearson correlation coefficients.

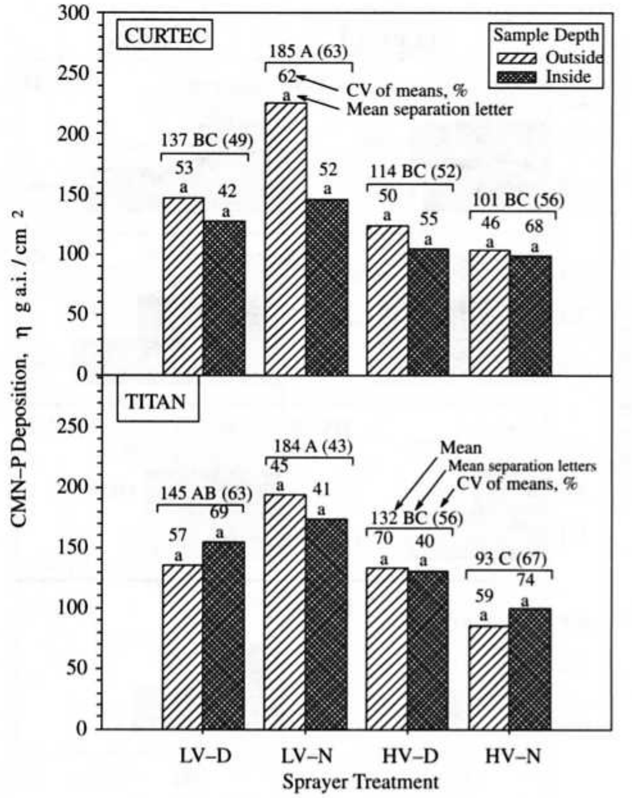

Figure 2. Mean CMN–P deposition of the two sprayers in the first test (LV = low volume, HV = high volume, D = day, N = night).

Results and Discussion

First Test

Spray Deposition

Overall, CMN–P deposition mean and variability (CV) of different treatments were comparable in magnitude and trend for both sprayer types (fig. 2). The low volume (LV) applications resulted in higher depositions than the high volume (HV) applications; however, the differences were not significant for daytime (D) applications. Deposition was highest for the low volume–nighttime (LV–N) treatments and lowest for the high volume–nighttime (HV–N) treatments. The higher humidity at night, which reached saturation, probably enhanced the low volume deposition by providing a better leaf retention capacity for the finer droplets of the low volume sprays. On the other hand, the wet leaves could have provided less retention capacity for the coarser sprays produced in high volume applications, causing increased runoff from the leaf surface. Hoffmann and Salyani (1996) observed similar trends and referred to Larcher (1975) and Syvertsen and Albrigo (1980) for leaf spray retention and nighttime dew formation arguments, respectively. Mean depositions inside the canopy tended to be generally lower than those on the outside for both sprayers; however, the differences were not statistically significant.

Except for the Curtec LV–D and LV–N and the Titan HV–D applications, deposits were significantly higher at the lower canopy than at the upper locations (fig. 3). Koo et al. (1999) reported similar results. The higher amounts of deposits at the lower canopy locations could in part be attributed to the lower leaf density at those locations. Under such canopy conditions, spray deposits could come from both sides of the tree.

It should be noted that the Curtec is commonly used at low volume rates (140–280 L/ha, 3.2–8.0 km/h) in citrus pesticide applications. In this experiment, we used the sprayer beyond its recommended parameters to explore its utility for abscission chemical applications, which are usually more effective at high volume rates. The use of the Curtec at the higher volume might have caused pump cavitations and lower flow rates from the upper atomizers, although there was no evidence of that during the sprayer calibration. It should also be noted that, during the HV–N applications with the Titan sprayer, we experienced some valve opening delay problems. The effect of the sprayer malfunction is evident in the lower–than–expected magnitudes of the deposits at the upper canopy levels (fig. 3).

On average, low volume treatments (LV = 235 L/ha) deposited 1.4 times more chemical than high volume (HV = 1540 L/ha) applications (fig. 4). Overall, there was no significant difference between the Curtec and Titan sprayers in spray deposition. In addition, the differences within either low or high volume rates were not significant. Mean deposits of the daytime and nighttime sprays were not significantly different; however, LV–N treatments resulted in significantly higher deposits than LV–D treatments, and the trend was reversed for high volume treatments. These results confirm the influence of relative humidity (dew formation on leaf surfaces) on the retention capacity of the canopy for lower and higher spray volumes.

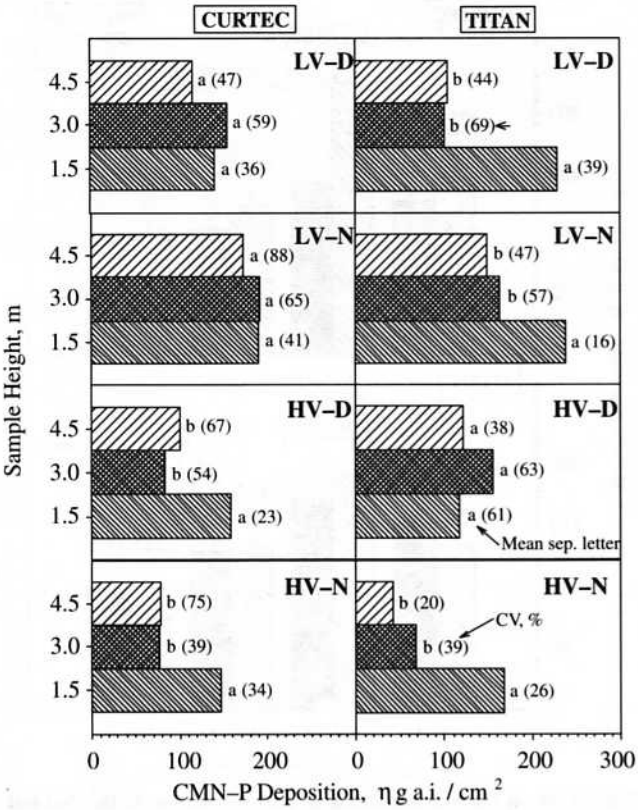

Figure 3. Mean CMN–P deposition at the three heights (first test).

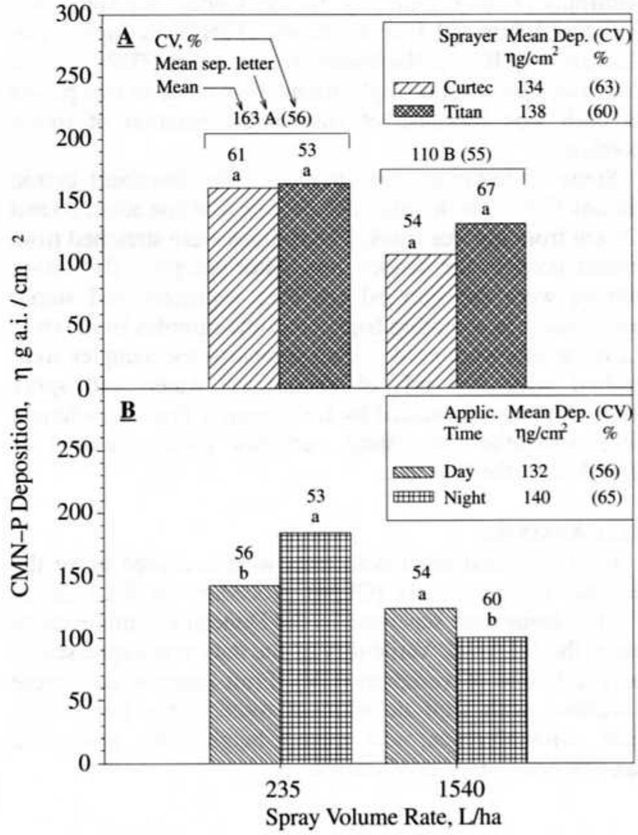

Figure 4. Overall mean CMN–P deposition for (A) the two sprayers and (B) two application times in the first test.

Fruit Loosening and Shaker Efficiency

The effects of spray application variables on fruit detachment force are shown in figure 5. All spray treatments showed some reduction in FDF as compared to the unsprayed control (check); however, the differences were not significant for most low volume applications. In general, the response (reduction in FDF) was stronger at the lower half of the tree than in the upper half, but the differences were not significant for most treatments. Overall, high volume treatments resulted in better fruit loosening than low volume treatments, and the differences were significant with the Curtec sprayer. The results agree with those of Kender and Hartmond (1999) and Koo et al. (1999). Application time did not appear to affect fruit loosening. Compared to the unsprayed check, FDFs were reduced by 12% to 30% by low volume treatments and by 34% to 50% by high volume treatments.

Figure 6 shows the results of the harvesting variables. Except high volume–nighttime applications with the Titan, none of the spray treatments resulted in significant improvement in fruit removal, as compared to the unsprayed check (83%). Despite having the lowest overall deposition, the HV–N applications gave the highest reduction in FDF and resulted in the highest fruit removal (Curtec: 90%, Titan: 91%). Again, high volume application along with dew formation during nighttime could have resulted in better fruit coverage and allowed better action of the abscission agent. Fruit yields were not significantly different. However, there were some significant differences in trunk circumference and shaker clamp height, which may partly explain some of the differences in fruit removal. In general, fruit removal increases with the shaker clamp height but decreases with yield and tree trunk circumference.

Table 2 relates fruit removal to spray deposition and harvesting parameters. Fruit removal was positively correlated with total fruit yield and shaker clamp height, and it was negatively correlated with fruit detachment force and tree trunk circumference. There was no significant correlation with CMN–P deposition.

SECOND TEST

Spray Deposition

Overall, spray release height had a significant effect on deposition; however, the effects were different for the two sprayers (fig. 7). While the T0B4 treatment (all spray discharged from the lower nozzles) gave the highest mean deposit with the Curtec, the T4B0 treatment (all spray discharged from the upper nozzles) gave the highest mean deposit with the Titan. Mean depositions of the three spray treatments were significantly different with the Curtec but not with the Titan. For both sprayers, spray deposition at the tree center (30 cm from tree trunk) was generally lower than that at the canopy edge (120 cm from tree trunk), but the differences were not significant.

The effects of spray treatments on deposition within the tree canopy are presented in figure 8. Depositions produced by each spray treatment were comparable in trend for both sprayer types. However, treatment T4B0 of the Curtec sprayer resulted in much lower magnitudes than those of the Titan sprayer. This may be attributed to the possibility of