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EFFECTS OF CONCENTRATION AND APPLICATION TIME OF 'PROSULFURON' ON THE ABSCISSION OF 'HAMLIN' AND 'VALENCIA' ORANGES

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Abstract. **The effects of Prosulfuron, an experimental abscission chemical, on the loosening of 'Hamlin' and 'Valencia' oranges for mechanical harvesting were studied. Foliar applications of Prosulfuron were effective in loosening 'Hamlin' oranges, an early season cultivar, at 30 and 45 ppm. The optimum window for harvesting was 8 to 11 days after application. When applied during the bloom period, Prosulfuron caused complete abscission of exposed 'Hamlin' flowers. Pitting of the peel was observed at the 3 concentrations tested (15, 30, and 45 ppm).**

Although Prosulfuron loosened 'Valencia' fruit, a late season cultivar, the response was erratic depending on the time of application. Twenty-one days after treatment of Prosulfuron at 30 ppm the percent drop of mature fruit was 6.8%, 31.0%, and 11.0% when applied on April 7, April 30, and May 15, respectively. Starting 8 days after application, Prosulfuron induced excessive drop of immature fruit, which severely reduced the next year's crop.

Prosulfuron was an effective agent for loosening the early season cultivar, 'Hamlin', for harvesting but was erratic and unpredictable for 'Valencia' the late season cultivar.

Efficiency of mechanical shakers for harvesting citrus trees for processing varies from 60 to 95% fruit removal (Wilson, 1978). In most cases an undesirable number of fruit remains on the tree following shaking. Several abscission chemicals have been shown to effectively loosen citrus fruit (Wilson et al., 1981). Abscission agents expedite mechanical fruit removal because the fruit can be detached in a shorter shake time and with less energy and less wear of the shaker and tree. For example, abscission chemicals increased harvest speed of limb shakers and fruit removal efficiency (Coppock, 1975). Air shaker capacity was increased up to 400% and fruit removal efficiency up to 60% (Whitney and Sumner, 1977).

Wilson and Coppock (1981) showed that abscission chemicals can be safely used as an aid to a shaker-catchframe harvest system without loss in yields of early and midseason oranges in subsequent years. However, Sumner and Churchill (1980), reported that yields of 'Valencia' oranges were reduced by the same abscission chemical treatments due to the excessive drop of young fruit. Early and midseason orange varieties differ in response to abscission agents from those of late varieties such as 'Valencia'. When a desired sugar/acid ratio is reached (i.e., 13.0) 'Hamlin' fruit are physiologically responsive to abscission chemicals and remain so through the harvest season.

In preliminary tests, Prosulfuron (1-(4-methoxy-6-methyl-triazin-2-yl)-3-[2-(3, 3, 3-trifluoropropyl) phenylsulfonyl] urea) (WTX100), a new abscission chemical, was reported to effectively loosen orange fruit (Wilcox and Taylor, 1996). The primary advantages of Prosulfuron were it's low application rates, no damage to immature 'Valencia' fruit and a wider window between application and harvesting than previously tested compounds.

The objectives of this research were to determine the effects of concentration and time of Prosulfuron application on loosening of 'Hamlin' (early) and 'Valencia' (late) orange fruit under grove conditions.

Materials and Methods

Concentration

Two separate field experiments were initiated to compare 3 concentrations of the abscission chemical Prosulfuron on loosening of 'Hamlin' and 'Valencia' oranges. Spray mixtures containing Prosulfuron at 15, 30, and 45 ppm plus a nonionic silicone copolymer surfactant (Silwet L-77) at 300 ppm were applied at 2,375 l/ha and 2.4 km/hr using a PTO-driven airblast sprayer. A solution containing only Silwet L-77 served as a control treatment.

Treatments were applied to 22-yr-old 'Hamlin' trees on Swingle, F-80-3, and F-80-8 rootstocks growing in the Florida Division of Plant Industry's budwood grove in Dundee, Fla. on February 20, 1997. Tree spacing was 7.3×7.3 m. The same treatments were applied to 9-yr-old 'Valencia' trees on sour orange rootstocks spaced at 4.5×6.0 m at the University of Florida's Citrus Research and Education Center in Lake Alfred, Fla. on April 30, 1997.

The 4 treatments were applied to pairs of trees in 3 blocks for a total of 24 trees for each cultivar arranged in a randomized complete block design. The ground under the trees was cleared and one Hamlin tree in each pair was sampled every 2 to 4 days to measure fruit detachment force (FDF), fruit weight, sugar, acid, sugar/acid ratio, peel disorders, fruit drop, flower drop, and leaf drop. Sugar and acid contents were measured using standard juice analysis procedures (Wardowski et al., 1995). FDF of mature fruit was measured using a digital force gauge ('Force Five', Wagner Instr., Greenwich, Conn.). Fruit were clipped with the stem, inserted into the gauge and the stem was pulled parallel to the fruit axis until it separated from the peduncle. The same measurements were made on both trees of each pair of 'Valencia' trees. At 8 days post spray, one 'Hamlin' tree in each pair was shaken for 5 sec with an FMC trunk shaker (729 Shaker Head). In the 'Valencia' study, ethylene production of subsamples of mature fruit was monitored and young fruit drop and leaf drop were recorded.

Timing

To study the effects of date of application on the efficacy of Prosulfuron, 9-yr-old 'Valencia' orange trees were sprayed with Prosulfuron on April 7, April 30, and May 15, 1997 in 3 separate

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experiments. Prosulfuron at 30 ppm containing Silwet L-77 adjuvant was applied with an airblast sprayer at 2,375 l/ha. Control trees were sprayed with Silwet L-77 adjuvant at 300 ppm. Sugar/acid ratio on the dates of application were 11.8, 12.2, and 13.5, respectively. The 2 treatments were replicated 5 times on each date. On a total of 40 trees, arranged in a randomized complete block design, FDF, rate of fruit drop, sugar, acid, sugar/acid ratio, fruit weight, and diameter, and ethylene concentration in the fruit was measured over a 3-wk period.

Temperature, relative humidity, leaf wetness, and precipitation were monitored with an automated weather station within the grove in each experiment. All data were tested by analysis of variance and treatment means separated by Duncan's Multiple Range test at P = 0.05 using SAS analysis software.

Results

Effect of concentration

'Hamlin' orange. Six days after Prosulfuron application, the FDF of treated fruit on the tree decreased from the original range of 7.7-8.2 kg to 4.8-5.2 kg (Fig. 1A). The FDF of the control fruit was 7.2 kg. There were no significant differences in FDF among the 15, 30, and 45 ppm concentrations during the course of this experiment. FDF of treated fruit continued to decrease and reached a low point on March 3 (11 days after treatment) at 2.3 to 2.8 kg whereas the FDF of control fruit averaged 5.4 kg. Between the March 3 and March 12 harvest dates, the FDF of all treated fruit increased to a range of 3.6 to 4.6 kg. The control was 5.1 kg.

By the end of the measurement period (March 12) 65 to 75% of the total fruit dropped as a result of the 45 and 30 ppm Prosulfuron treatment, respectively, compared to 12% for the control (Fig. 1B). Of the total fruit that dropped 20 to 25% abscised between 8 and 11 days after application of Prosulfuron (Fig. 1C).

Prosulfuron had no significant effect on fruit quality except that it induced significant levels of peel pitting at 15, 30, and 45 ppm. Trunk shaking removed between 60 to 84% of the fruit. There were no significant differences between concentrations of Prosulfuron on fruit removal by the trunk shaker. All 3 concentrations, caused complete flower abscission from the pinhead to fully open stages, but had no apparent effect on the abscission of leaves.

No correlations of chemically-induced abscission and the weather parameters were established. Mean temperatures were stable at 22°C with daily minimum and maximum temperatures of 16°C and 30°C, respectively. No significant precipitation or strong winds occurred during the 'Hamlin' study. Relative Humidity averaged 70 to 80%.

'Valencia' orange. FDF of Prosulfuron-treated 'Valencia' fruit on the trees was significantly reduced compared to control fruit starting 5 days after treatment (Fig. 2A). There were no differences in FDF between the 3 Prosulfuron concentrations. This trend continued at 10 and 12 days after treatment. At days 15 to 19, fruit treated with 30 and 45 ppm had significantly lower FDF than fruit on trees sprayed with 15 or 0 ppm. On day 19 all 4 treatments were significantly different from each other, and the mean FDF reached the lowest point (3.7 kg) at 45 ppm Prosulfuron. After day 19 FDF of Prosulfuron-treated fruit increased slightly because nearly all loose fruit had dropped.

Significant mature fruit drop did not begin until 12 days after treatment, when 30 and 45 ppm concentrations had 20% drop of the total yield (Fig. 2B). The peak fruit drop occurred with the 45 ppm treatment on day 19 when 50% of the mature fruit dropped.

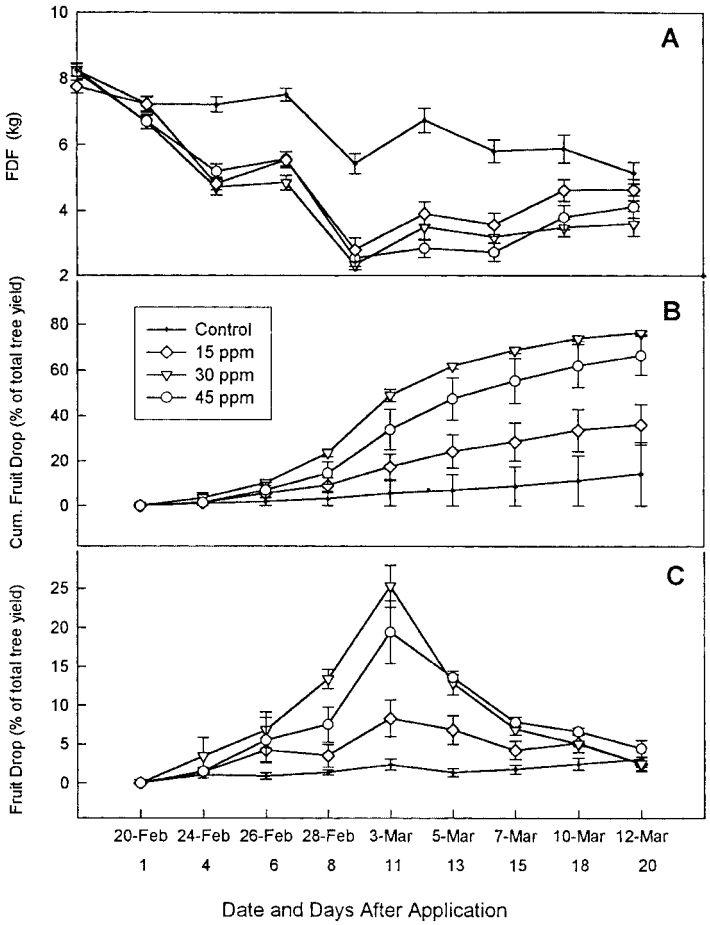

Figure 1. Effect of Prosulfuron concentration on (A) fruit detachment force, FDF, (B) cumulative mature fruit drop and (C) daily mature fruit drop of 'Hamlin' orange fruit. Dundee, Fla. 1997.

The cumulative mature fruit drop at 0, 15, 30, and 45 ppm was 3, 11, 42, and 60%, respectively, on day 21.

Immature developing 'Valencia' fruit were also loosened by Prosulfuron treatment (Fig. 2C). Normal cumulative young fruit drop in control trees during the 21 days of this study was 106 per tree compared to 445, 702, and 810 for the 15, 30, and 45 ppm treatments, respectively. The peak drop of immature fruit occurred during a 2-day period prior to May 12 when over 326 young fruit dropped from the 30 ppm Prosulfuron-treated trees.

In 'Valencia' trees, Prosulfuron caused significant abscission of young leaves. The total dry weight of leaves that abscised as a result of Prosulfuron treatments on day 21 was 28, 118, 342, and 650 g at 0, 15, 30, and 45 ppm, respectively (Fig. 3). The peak leaf drop occurred on day 12, coinciding with the peak young fruit drop.

Effect of timing

Valencia' orange. April 7 application. Although the overall response was poor on mature fruit, Prosulfuron-treated trees had significantly lower FDF than control trees starting on April 21 (14 days after application; Fig. 4A). FDF on treated trees did not fall below 7.5 kg and dropped to this level on day 16 (April 23). The number of fruit that dropped in this experiment peaked on April 25 (day 18, Fig. 4B). Only 6.8% fruit drop of the total yield occurred by day 21.

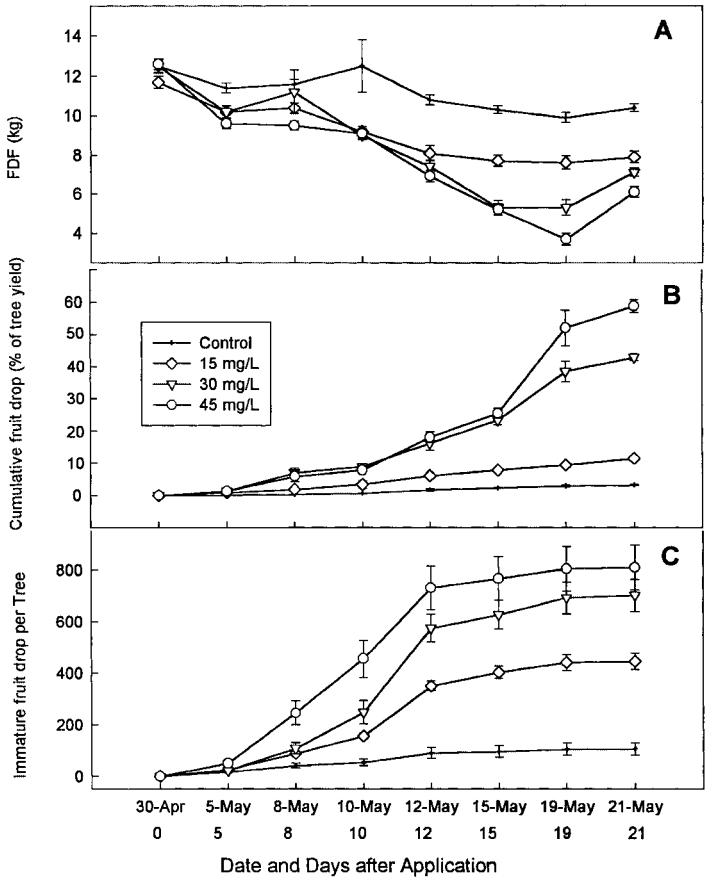

Figure 2. Effect of Prosulfuron concentration on (A) fruit detachment force, FDF, (B) cumulative mature fruit drop and (C) number of immature fruit drop per tree of 'Valencia' orange fruit. Lake Alfred, Fla. 1997.

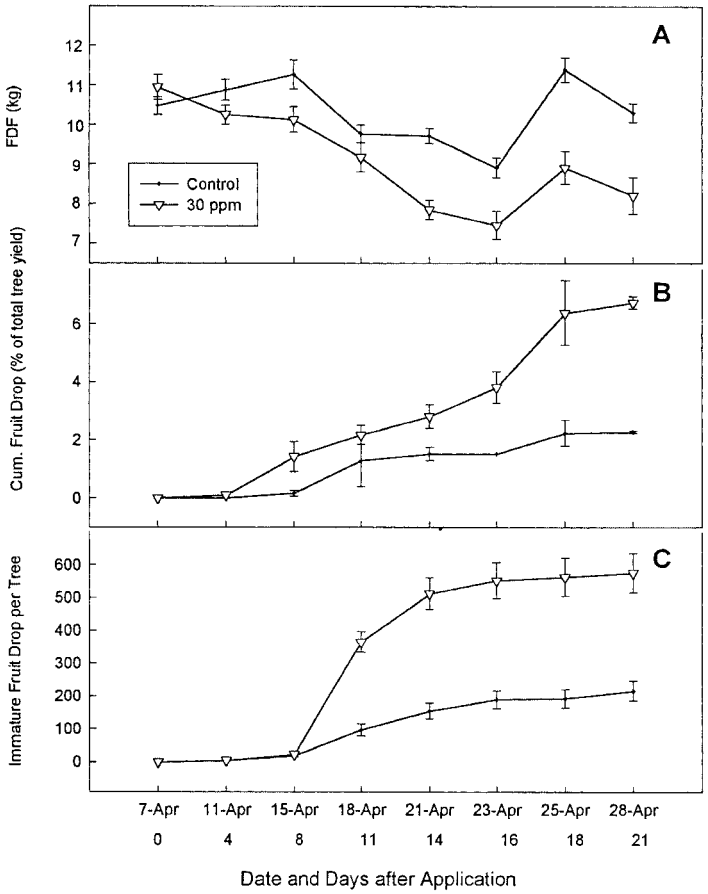

Figure 4. Effect of Prosulfuron applied on April 7 at 30 ppm on (A) fruit detachment force, FDF, (B) cumulative mature fruit drop, and (C) cumulative number of immature fruit drop per tree of 'Valencia' orange fruit. Lake Alfred, Fla. 1997.

Prosulfuron at 30 ppm caused significant abscission of immature fruit when compared to control trees. By day 11, 341 young fruit dropped, reaching a maximum of 575 fruit on day 21 (Fig. 4C).

April 30 application. The FDF of control trees decreased over the 21 days of this experiment, from 12.3 kg on day 8 to 9.2 kg on day 21 (Fig. 5A). The FDF of Prosulfuron-treated fruit decreased significantly from 11.3 kg on day 8 to 5.1 kg on day 19. Later it increased slightly to 6.1 kg on day 21 when most loose fruit had dropped.

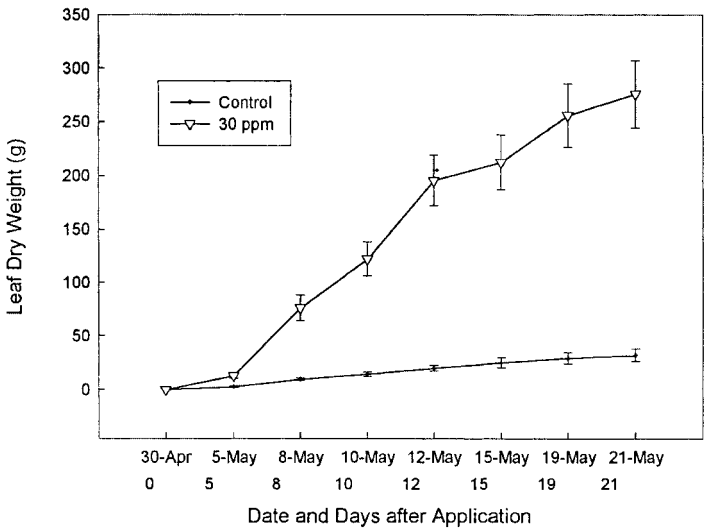

Figure 3. Effect of Prosulfuron applied on April 30 at 30 ppm on the cumulative leaf drop of 'Valencia' orange trees. Lake Alfred, Fla. 1997.

On day 12 the drop of Prosulfuron-treated fruit was significantly greater than that of the controls (Fig. 5B). By the end of the experiment, the cumulative fruit drop was 31% of the total tree yield, the highest level reached in this series of experiments.

Initial drop of immature fruit occurred in large numbers on day 8 as a result of Prosulfuron treatment (Fig. 5C). On day 12, an average of 276 immature green fruit dropped compared to only 27 on control trees. On days 15, 19, and 21, the number of immature fruit that dropped was relatively low, averaging 38, 48, and 6, respectively. A total of 591 young fruit dropped by day 21. The chemical-induced leaf drop was significant on all sampling dates. The total dry weight of fallen leaves, however, was insufficient to cause concern for tree productivity.

May 15 application. Response of mature 'Valencia' fruit to the May 15 application was poor and variable, reaching only 11% drop of the total tree yield (Fig. 6B). FDF of control and treated mature fruit were similar up to day 7 (Fig. 6A). On May 27 (12 days after treatment), treated fruit were significantly looser than control fruit, although the FDF never fell below 7.0 kg during the test. On days 12, 14, 18, and 21, the drop of immature fruit treated with Prosulfuron was 10 times higher than the controls (Fig. 6C), but substantially less than the cumulative fruit drop in the April 30

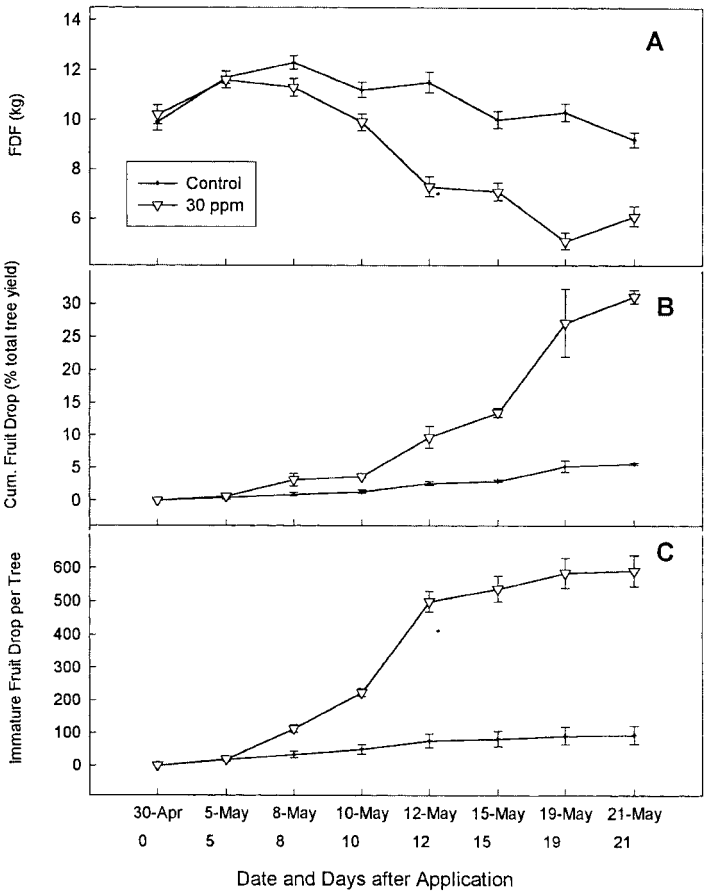

Figure 5. Effect of Prosulfuron applied on April 30 at 30 ppm on (A) fruit detachment force, FDF, (B) cumulative mature fruit drop, and (C) cumulative number of immature fruit drop per tree of 'Valencia' orange fruit. Lake Alfred, Fla. 1997.

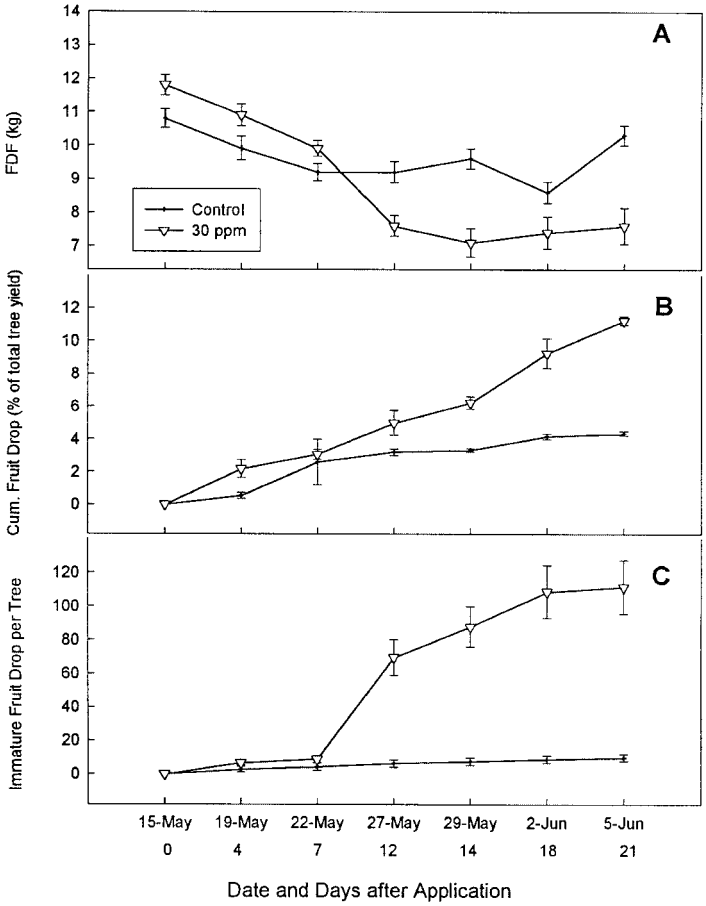

Figure 6. Effect of Prosulfuron applied on May 15 at 30 ppm on (A) fruit detachment force, FDF, (B) cumulative mature fruit drop, and (C) cumulative number of immature fruit drop per tree of 'Valencia' orange fruit. Lake Alfred, Fla. 1997.

experiment. The peak drop of immature fruit was on May 27 (12 days after treatment). Leaf drop was significantly higher in chemical-treated trees than in control trees but was not detrimental in either case.

Peel disorder. A thin necrotic ring was detected on immature fruitlets both on abscised fruit and those on the tree. From 5 to 50% of the fruitlets per tree showed this symptom. It occurred on fruit from trees treated with Prosulfuron solution containing Silwet L-77, as well as on fruit from control trees treated with Silwet alone. Unsprayed fruit did not have this disorder indicating that the organosilicone-based adjuvant caused this superficial injury on immature fruit.

Crop loss. On June 25, after the end of the natural drop period, the immature fruit remaining on the trees were counted. Prosulfuron at 15 ppm reduced the 1997-98 crop by 22%, and by 74% and 91% at 30 and 45 ppm, respectively. Prosulfuron at 30 ppm usually gave adequate loosening of mature fruit, but it also caused an 84% loss of immature fruit in the April 30 experiment.

Discussion

'Hamlin' orange

Prosulfuron at 30 and 45 ppm was very effective in loosening 'Hamlin' fruit. FDF was reduced to 50% of the control 11 days after treatment, causing heavy fruit drop. Based on this experiment, the optimum window for effectiveness of Prosulfuron was from 8 to 13 days after application. Further studies are needed to link loosening magnitude with efficient mechanical fruit removal prior to chemical-induced fruit drop. Preharvest drop will be lost with a shake-catch harvesting operation.

Under the conditions of this experiment, pitting of the peel was evident in the late stages of maturity at all concentrations of Prosulfuron but not on the control fruit. If chemical-induced pitting is a common occurrence the fruit would not be acceptable for fresh fruit marketing. All flowers that received Prosulfuron at 30 and 45 ppm abscised confirming that this chemical should not be applied during the bloom period. In contrast, Wilcox and Taylor (1996) reported no phytotoxicity to flowers or fruit.

'Valencia' orange

Prosulfuron applied to 'Valencia' oranges at the same concentrations was less effective in loosening mature fruit. When applied on April 7 there was very little response by mature fruit. Only 7% of the fruit dropped after 3 wk and the FDF was reduced by a maximum of 16%. Immature fruit, however, dropped readily at 30 ppm. On April 30, Prosulfuron was more effective in loosening mature fruit than earlier (April 7) or later (May 15). Unfortunately,

immature fruit were also responsive. Of the 3 dates of application to Valencia trees, only the April 30 treatment successfully loosened fruit.

Similar results were found by Wilson et al. (1977) and Wheaton et al. (1977) where 'Valencia' oranges were not responsive to abscission chemicals during periods of regreening. This period of low response usually occurs in early May and lasts for 2 to 3 wk depending on the age of the tree (Holm and Wilson, 1976). In their studies, Holm and Wilson (1976) found that optimal response to abscission chemicals by 'Valencia' oranges is from mid-February through April followed by the period of reduced response.

Mature 'Valencia' orange harvest begins before bloom, but continues after bloom and fruit set when the developing fruit for next year's crop is on the tree. It is important that the immature fruit are not damaged or removed in the harvesting process. Furthermore, the successful use of abscission chemicals to aid citrus harvest precludes the removal of young fruit requiring a differential selectivity between the two stages of fruit maturity. Subsequent fruit yields will determine the efficacy of the abscission chemical if it offers marginal selectivity.

Immature fruit consistently started dropping 1 wk earlier than mature fruit (12 vs. 19 days). Prosulfuron did not demonstrate selectivity between mature and immature fruit as reported by Wilcox and Taylor (1996).

Morphological and physiological changes occur in the young fruit which are associated with a period of natural young fruit drop following bloom and ending in mid-May (Wheaton et al., 1977). Such erratic responses make the optimal use of such chemicals unpredictable.

In previous studies it was necessary that mature fruit be thoroughly covered by Prosulfuron solution for effective loosening. Adequate wetting of the abscission zone is especially effective (Kender et al., 1998).

The heavy drop of immature fruit in April as a result of Prosulfuron treatment raises questions as to its commercial use. Before Prosulfuron can be recommended as a potential abscission agent for citrus several questions must be answered: How much young fruit removal can be tolerated to retain a commercial crop? What can be done to manipulate the conditions in which Prosulfuron is applied? What basic physiological and molecular factors regulate the abscission process in citrus? Is FDF an adequate indicator of optimum mechanical fruit removal? Future research should be directed at spray volume, fruit maturity and date of application, possible use of other adjuvants, weather conditions, varietal responses, and hormonal factors that may affect the efficacy of Prosulfuron. Based on this study, the use of Prosulfuron as an abscission agent for 'Hamlin' oranges was encouraging. However, on 'Valencia' oranges it can not be recommended until conditions for its safe use can be determined.

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