PROHEXADIONE CALCIUM (APOGEE®) REDUCES GROWTH OF CONTAINER GROWN CITRUS ROOTSTOCK SEEDLINGS

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ABSTRACT

Prohexadione calcium (Pro-Ca, Apogee®, BASF Corp.) was applied to ‘Carrizo’ citrange and ‘Swingle’ citrumelo rootstock seedlings as a foliar spray (100 and 200 ppm) or a soil drench (100 ppm). At all application rates, Pro-Ca significantly reduced stem elongation compared to control plants. The growth reduction from Pro-Ca was similar to that achieved with moderate drought stress. However, unlike drought stress, Pro-Ca did not reduce the number of new leaves formed, average leaf area or average leaf dry weight. Additionally, oviposition by the Asian citrus psyllid, the insect vector of Huanglongbing (HLB, citrus greening disease) was reduced by more than 50% on Pro-Ca treated seedlings compared with untreated controls. This suggests that Pro-Ca may be a beneficial tool the in management of HLB. However, at the rates tested, Pro-Ca was ineffective at controlling vegetative growth of field-grown ‘Hamlin’ sweet oranges.

INTRODUCTION

Huanglongbing (HLB, citrus greening disease) has been described as the most serious disease of citrus in the world. HLB is believed to be caused by the uncultured bacteria Candidatus Liberibacter spp. and is vectored by the Asian citrus psyllid (ACP, Diaphorina citri Kuwayama). New flush is required by the ACP for oviposition which occurs only on the tips of growing shoots or on the feather-like flush. The survival of the immature stages of ACP declines when leaves mature and harden off. Thus, one way to slow the spread of HLB is to reduce the number of new flushes annually and/or reduce the period of time from leaf emergence to hardening off (flush duration) of each new flush to reduce psyllid populations.

Long-lived evergreen citrus trees in Florida produce an excess of leaves above that required to support maximum fruit yield (Yuan et al., 2005). This excess growth primarily arises from the more-or-less continuous flushing that can occur any time of the year, but especially during the warm summer rainy season. Control of this excess growth is commonly achieved by hedging, the practice of mechanically pruning the sides of tree canopies to maintain between row spacing. However, in general, pruning is considered to be an invigorating practice (Harris, 1983) despite the fact that leaves and branches are removed and citrus yields can decline for a year or two after extensive hedging. Summarizing numerous pruning studies across multiple tree fruit crop species, Mika (1986) concluded that pruning always induces the development of longer shoots that grow more rapidly and for a longer period of time than when pruning does not occur. Studies in citrus tend to support this generalization (Bacon and Bevington, 1978; Bacon, 1981).

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In other fruit crops such as apple where excessive vegetative growth can be problematic, plant growth regulators (PGRs) are routinely used to limit vegetative growth (Petracek et al., 2003). However, the use of PGRs in citrus has been limited to influencing fruit development and for maintaining post-harvest quality (El-Otmani et al., 2000). Plant growth regulators not only control vegetative growth, but PGRs also offer potential to reduce insect pest populations (Hall, 1972; Westigard et al., 1980). These effects may be directly related to reduction of vegetative growth, as in the case of insect pests like ACP which prefer newly developing leaves and shoots, or indirectly related to an alteration of host plant metabolites or nutrition (Paulson et al., 2005). In addition, PGRs may help to increase pesticide efficacy on leaf surfaces since it is difficult to maintain effective pesticide residue levels on vigorously growing tissues (Cooley et al., 1997). A recent study found a synergistic effect between the plant growth inhibitor prohexadione-calcium and the systemic pesticide imidacloprid in the control of leafroller \textit{(Choristoneura rasaceana)} in apple (Paulson et al., 2005).

We investigated the potential for prohexadione calcium (Pro-Ca, Apogee®, BASF Corp., Agricultural Products Division, Research Triangle Park, NC) to reduce the growth of greenhouse-grown citrus rootstock seedlings and field grown ‘Hamlin’ sweet orange trees. We also studied the effects of Pro-Ca application on ACP oviposition citrus rootstock seedlings.

**MATERIAL AND METHODS**

Five-month-old seedlings of ‘Carrizo’ citrange were obtained from a commercial citrus nursery in May 2008. The seedlings were planted into 164 ml cone-tainers (Stuewe & Sons, Inc., Corvallis, OR), using Fafard 2 soilless potting medium (Conrad Fafard, Inc., Agawam, MA), and allowed to recover from transplant for 2 weeks. On 30 May 2008, the 120 seedlings were randomly assigned to one of four treatments. Treatments consisted of two foliar applications of pro-cal, one soil drench application and an untreated control. Foliar applications were applied at 100 and 200 mg L-1 (ppm) a.i. mixed with 2.5 mL L-1 (0.32 oz gal-1) non-ionic surfactant (Induce®, Helena Chemical Company, Collierville, TN), and 5 mL L-1 (0.64 oz gal-1) of 0.5% citric acid (per manufacturer’s recommendation). Seedlings were sprayed to thoroughly wet upper and lower leaf surfaces while the soil surface was covered during application and until the product dried to avoid soil contamination. Soil drench applications were applied at 100 mg L-1 (ppm) a.i. mixed with 5 mL L-1 (0.64 oz gal-1) of 0.5% citric acid. Each cone-tainer received a total of 40 mL (1.4 oz.) of solution applied as two 20 mL (0.7 oz) applications. Some leaching occurred following the second 20 mL (0.7 oz) application. Foliar treated seedlings and control seedlings all received 40 mL (1.4 oz) of de-ionized water at the time of treatment.

On 2 June, the initial height of each seedling was recorded. All seedlings were watered on Monday, Wednesday and Friday each week with 40 mL of a dilute nutrient solution (8N-2P-8K plus minors) so that each seedling received 15 mg of N per week. Final seedling heights were recorded on 7 July.

On 2 September the experiment was repeated using 5 mo-old seedlings of ‘Swingle’ citrumelo (C. paradisi Macfad. × P. trifololiata). Final seedling heights were recorded on 3 October.

For the evaluation of the effect of pro-cal on psyllid oviposition, 10 additional ‘Carizzo’ seedlings were treated as previously described for each of the treatments. Seedlings were
selected to have young, newly expanded flush. Two pairs of psyllids were caged on each seedling using transparent plastic cylinder cages [33 cm (13 in) long x 7 cm (2.75 in) diameter] with their tops covered with thin muslin. The seedlings were placed in growth chambers (Percival, Boone, IA) at 25 °C, 65-75% RH, and a 12 h photoperiod. After 10 days, all pairs were removed and the laid eggs were counted.

Following the initial greenhouse trials, pro-ca was tested in the field in an existing hedging trial. The trial was composed of mature ‘Hamlin’ sweet orange trees (Citrus sinensis (L.) Osbeck.) on ‘Cleopatra’ mandarin rootstock (C. reticulata Blanco), that were hedged at bi-weekly intervals from late-summer through fall. Foliar applications of pro-ca at 200 ppm were made to trees that were hedged the 13th and 27th of August and the 10th of September 2008. Applications were made approximately two weeks after hedging (29 August, 12 and 24 September) when regrowth averaged about 2 cm. Three 5-tree plots were treated at each application date, and shoot growth was measured for all shoots within a 1 m² frame on the north and south side at the mid-height in the canopy for the three middle trees of each plot. Untreated trees were hedged at the same dates were measured as controls. Approximately one gallon of pro-ca was applied to each tree using a hand-gun type sprayer. The volume was sufficient to thoroughly wet all foliage. Since the trees were planted in east-west rows, data are presented for shoot growth from the north and south sides of the tree separately.

RESULTS AND DISCUSSION

The ‘Carrizo’ seedlings were overall much more vigorous than the ‘Swingle’ seedlings as can be seen from the final heights for the control plants at 80 and 90 DAT (Figure 1B, 1D). At 30 DAT all pro-ca applications significantly reduced ‘Carrizo’ shoot growth relative to the control plants (Figure 1A). The 200 ppm foliar application and 100 ppm soil drench were significantly better at reducing overall growth of ‘Carrizo’ seedlings 30 DAT compared with 100 ppm foliar application, but were similar to the growth reduction achieved through moderate drought stress. Presumably due to seedling vigor, the ‘Carrizo’ seedlings outgrew all pro-ca treatments by 80 DAT and were no longer significantly different from the control plants (Figure 1B).

At 30 DAT, the 100 ppm foliar application of pro-ca was ineffective at reducing growth of ‘Swingle’ seedlings (Figure 1C). However, the 200 ppm foliar spray and 100 ppm soil drench both significantly reduced growth to levels equal to or less than that of the drought stress treatment. At 90 DAT, the 200 ppm foliar application and 100 ppm soil drench were still effectively controlling the growth of ‘Swingle’ seedlings (Figure 1D). This more prolonged period of efficacy on ‘Swingle’ compared to ‘Carrizo’ seedlings was likely a result of the lower vigor of the ‘Swingle’ seedlings.

The number of leaves per length of stem for the ‘Carrizo’ seedlings harvested 80 DAT is shown in Figure 2. The pro-ca 200 ppm foliar application and 100 ppm drench application had significantly more leaves per length of stem than the control, 100 ppm foliar spray or drought stress seedlings. This indicates that the growth reduction achieved with pro-ca was a result of reduced internode elongation, which effectively spaced the leaves more closely. This is in contrast to the drought stress treatment, which reduced growth by a similar amount as the 200 ppm foliar application and 100 ppm soil drench, but maintained the same number of leaves per
length of stem as the control trees. This indicates that the drought treatment reduced growth by reducing new leaf initiation.

In the field the efficacy of pro-ca was much more variable than in the greenhouse. When applied on 2 September to trees hedged the second week of August pro-ca had no effect on growth of shoots on the north side of trees and significantly increased growth of shoots on the south side of trees (Figure 3A). Application of pro-ca on 16 September to trees hedged the fourth week of August resulted in a modest reduction of shoot growth on both the north and south side of the canopy, although this reduction was not statistically significant (Figure 3B). Application on September 26 to trees hedged the second week of September resulted in no growth effect for shoots on the south side of the canopy, but resulted in a significant increase in growth of shoots on the north side (Figure 3C).

All application rates and methods of pro-ca numerically reduced psyllid oviposition by more than 50%; however, variability was high and no treatments were statistically different (Figure 4). The reduction in oviposition by Asian citrus psyllid, although not statistically significant in this study, indicates the potential use of the pro-cal treatments described, to impact the reproductive biology of this insect pest. This effect on psyllid behavior may be a due to reduced flush growth and oviposition sites, or by some change in plant chemistry. However, the leaves per length of stem data indicate that the effect on psyllid behavior is not likely a result of reduced oviposition sites. In a similar study of pear psyllid, Paulson et al. (2005) found that psyllid nymph populations continued increasing after the application of the pesticide imidacloprid, but declined when imidacloprid was combined with pro-ca. Thus, pro-ca and other PGRs may increase the efficacy of systemic pesticides, like imidacloprid, by reducing their dilution within the plant by reducing growth.

LITERATURE CITED
Figure 1. Effect of prohexadione calcium (Apogee®) on stem growth of ‘Carrizo’ citrange (A. & B.) and ‘Swingle’ citrumelo (C. & D.) seedlings 30 days after treatment (A. & C.) and 80 (B.) and 90 DAT (D.).
Figure 2. Effect of prohexadione calcium application on the number of leaves per length of stem for ‘Carrizo’ citrange seedlings 80 days after treatment.
Figure 3. Effect of Apogee (200 ppm foliar spray) on vegetative re-growth of 'Hamlin' sweet orange following hedging. Hedging and Apogee treatment dates were, August 13 and August 29 (A), August 27 and September 12 (B), and September 10 and September 24 (C), respectively. Squares (□ ■) represent shoot growth on the south side of the canopy and circles (○ ●) represent shoot growth on north side of the canopy.
Figure 4. Prohexadione calcium (Apogee) reduced oviposition of Asian citrus psyllids on citrus rootstock seedlings. Apogee was applied as a single foliar spray or as a soil drench.