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ROOTSTOCK SHOOT CONTRIBUTIONS TO SCION GROWTH OF CONTAINERIZED CITRUS NURSERY TREES

JEFFREY G. WILLIAMSON AND BRIAN E. MAUST
University of Florida, IFAS
Horticultural Sciences Department
Gainesville, FL 32611-0690

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Abstract. **Two experiments were conducted to determine whether rootstock contributions to scion and root growth were primarily from current photosynthates, or from stored reserves. Both experiments were conducted in the greenhouse with Swingle citrumelo [*Citrus paradisi* (L.) Osb. × *Poncirus trifoliata* (L.) Raf.] and Cleopatra mandarin (*C. reticulata* Blanco) seedlings budded with 'Hamlin' orange [*C. sinensis* (L.) Osb.]. Plants were forced by cutting off the rootstock above the bud union (C), or by bending the rootstock shoot above the bud union and tying it to the base of the plant (B). In experiment 1, rootstock shoots of Swingle citrumelo and Cleopatra mandarin forced by bending were subjected to 4 levels of defoliation. For Cleopatra, the defoliation treatments were no defoliation, 39%, 58%, and 84% defoliation. For Swingle, defoliation treatments were no defoliation, 29%, 58% and 98% defoliation. In experiment 2, rootstock leaves for B plants were subjected to 4 levels of shade: (1) no shade; (2) 72% shade; (3) 89% shade; or (4) 96% shade. All recorded measures of plant growth for Cleopatra declined linearly with increasing levels of rootstock top defoliation. Plant dry weight was greater for no defoliation and 39% defoliation than for cutting off. For Swingle, plant dry weight responded quadratically to increasing rootstock top defoliation. For both rootstocks, high levels of shade reduced whole plant and root dry weights when compared to low, or no shade. For Cleopatra, scion dry weight was greater for unshaded plants than for all levels of shade. For both rootstocks, plant dry weight was greater for B plants with no shade or 72% shade than for C plants. Both experiments suggest that current rootstock photosynthates are the primary source of greater nursery plant dry weight gain from bending when compared to cutting off rootstock tops.**

Methods to induce scion budbreak and growth of citrus nursery trees usually consist of complete removal of the rootstock shoot top (cutting off), or modification of the attached rootstock shoot in a manner which reduces apical dominance such as lopping, bending or notching (Rouse, 1988; Tucker and Youtsey, 1980; Williamson and Castle, 1989). Studies have shown that forcing methods which leave the rootstock shoots attached (bending or lopping) result in greater nursery tree growth (Moore, 1978; Rouse, 1988; Williamson et al., 1992). Moreover, current rootstock photosynthates were translocated to scions and roots of young budded nursery trees forced by lopping or bending (Williamson et al., 1992). However, the relative contributions of current rootstock photosynthates and stored rootstock shoot reserves to nursery tree growth have not been determined. If current rootstock photosynthates contribute significantly to nursery tree growth, treatments which reduce the photosynthetic capacity of rootstock shoots, such as rootstock shoot shading or defoliation, should reduce growth of nursery trees forced by bending or lopping. The following experiments were conducted to determine the effects of rootstock shoot defoliation and shading on growth of containerized citrus nursery trees forced by bending. Defoliation and shading treatments were also compared to complete rootstock shoot removal (cutting off).

Materials and Methods

All experiments were conducted in a greenhouse on the campus of the University of Florida, Gainesville, Fla. Typical diurnal maximum and minimum temperatures ranged from 27 to 35°C and 15 to 22°C, respectively. Maximum photosynthetic photon flux was 820 μmol/s/m². Swingle citrumelo and Cleopatra mandarin seedlings were grown from registered seed and transplanted to 2.8 liter plastic citripots containing a growing medium consisting of peat moss and perlite (1:1 V/V). Plants were irrigated as needed for 14 days following transplanting. Thereafter, a water soluble fertilizer (20N-8.8P-16K), (Peters Fertilizer Products, W.R. Grace, Fogelsville, Pa) was applied at 2- to 5-day intervals with each irrigation. Fertilizer concentration was increased from 100 to 200 ppm N 21 days after transplanting and maintained at that concentration for the duration of the experiment. Seedlings were budded with 'Hamlin' orange using inverted T-buds inserted approximately 10 cm above the soil line. Plants were forced 18 to 21 days after budding.

Randomized complete block designs with single-plant plots were used for both experiments. Scion bud break was determined daily for all plants in both experiments. At the conclusion of each experiment, all plants were harvested and separated into scion leaves and stems (by growth flush), rootstock trunks, and fibrous and structural roots. Leaf areas were measured with a model LI-300 LI-COR leaf area meter (LI-COR, Lincoln, Neb.). All plant parts were dried at 70°C and weighed. Data were analyzed using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS Institute, 1987).

Defoliation experiment. Swingle and Cleopatra plants were budded with 'Hamlin' orange and forced by cutting off the rootstock tops approximately 2 cm above the bud union, or by bending the rootstock shoots to the base of plants and tying them into position. Swingle plants forced by bending were subjected to one of the following rootstock shoot defoliation treatments; no defoliation, 29%, 58%, or 98% defoliation. Cleopatra plants forced by bending were subjected to one of the following defoliation treatments; no defoliation, 39%, 58% or 84% defoliation. All defoliation treatments were applied immediately after

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bending. Plants were harvested after two scion growth flushes. SAS was used for regression analysis and Dunnett's T-tests (Steel and Torrie, 1980) were used to compare the cut off treatment with defoliation treatments.

Rootstock shading experiment. Swingle and Cleopatra plants budded with 'Hamlin' orange were forced by cutting off or bending as described above. Plants forced by bending were subjected to one of the following levels of rootstock shoot shading: 1) no shade [Photosynthetic photon flux (PPF)=820 μmol/s/m²]; 2) low shade (PPF=226 μmol/s/m²); moderate shade (PPF=89 μmol/s/m²); or high shade (PPF=30 μmol/s/m²). Rootstock shade treatments were applied by placing rootstock shoots in horizontal cylinders made of one, two, or three layers of black 60% shade cloth. Leaf and air temperatures were measured inside and outside the cylinders. Air temperatures inside the cylinders did not vary by more than 2°C from ambient greenhouse temperatures. Plants were harvested after two scion growth flushes. Treatment means were compared using Duncan's Multiple Range test and Dunnett's T-test was used to compare the cut off treatment with all shade treatments.

Results and Discussion

Rootstock shoot defoliation. Plant dry weights for Cleopatra and Swingle plants are shown in Figures 1 and 2, respectively. With Cleopatra plants, whole plant dry weight decreased linearly with increasing rootstock top defoliation (Fig. 1). A linear decline in scion and root dry weights also occurred with increasing levels of rootstock top defoliation (data not shown). Plant dry weight, scion dry weight, length and leaf area were greater for no defoliation and 39% defoliation when compared to cutting off the rootstock top (Table 1). Root dry weights were greater for bent plants than for cut off plants when rootstock top defoliation was ≤ 58%.

Swingle plant dry weight responded quadratically to increasing levels of rootstock top defoliation (Fig. 2). For plant dry weight and most other growth measurements, low (29%) and moderate (58%) defoliation resulted in no reduction of plant growth compared with no defoliation. However, 98% defoliation resulted in a large reduction in growth compared with other defoliation treatments. Scion dry weights were greater for the 29 and 58% defoliation treatments than for the cut off treatment. Alternatively, root and whole plant dry weight were greater for the 0%, 29%, and 58% defoliation treatments than for plants forced by cutting off (data not shown).

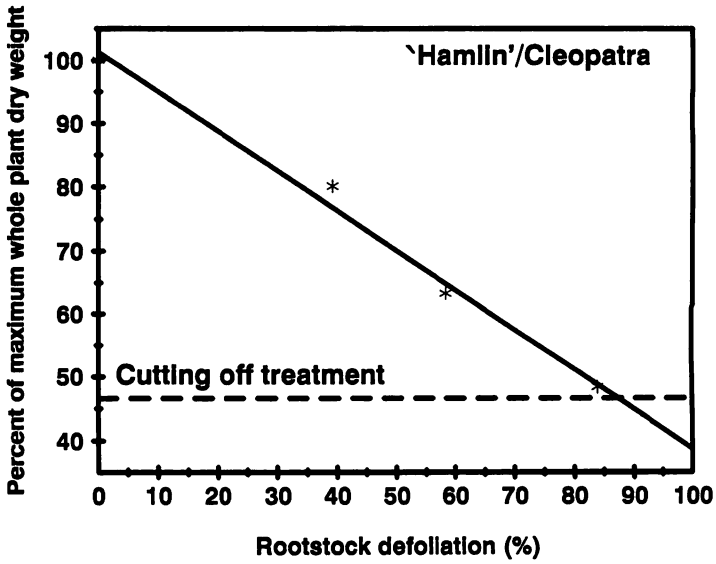

Fig. 1. The relationship between whole plant dry weight and rootstock top defoliation of 'Hamlin'/Cleopatra citrus nursery plants forced by bending. Plant dry weight of the cutting off treatment is shown as a dashed line.

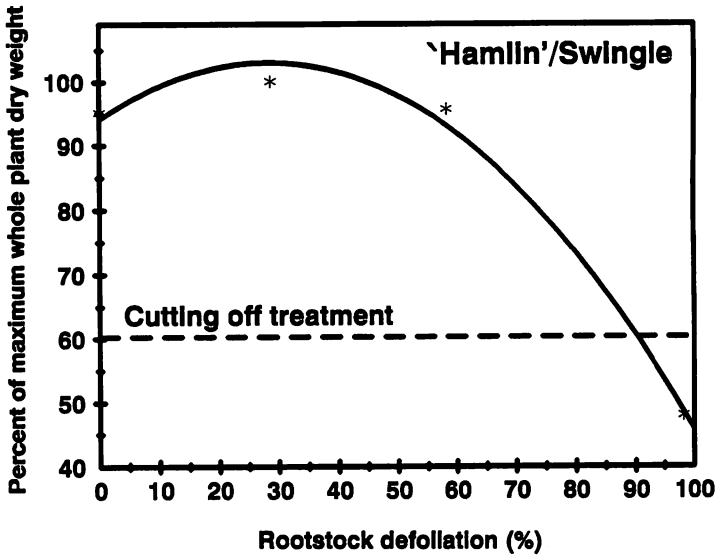

Fig. 2. The relationship between whole plant dry weight and rootstock top defoliation of 'Hamlin'/Swingle citrus nursery plants forced by bending. Plant dry weight of the cutting off treatment is shown as a dashed line.

Table 1. Effect of rootstock top defoliation on scion length and leaf area and scion, root, and whole plant dry weight of 'Hamlin'/Cleopatra citrus nursery trees.

Rootstock top defoliation[z]	Percent of maximum (%)				
	Scion		Dry weight (g)		
	Length (cm)	Leaf area (cm²)	Scion	Root	Whole plant
0	100.0*[y]	100.0*	100.0*	100.0*	100.0*
39	84.1*	83.6*	72.3*	87.7*	80.0*
58	66.8	65.1	53.2	71.9*	63.2
84	43.3	43.2	33.6	58.3	48.3
Cutting off	53.1	45.8	35.1	50.8	46.5

[z]Percent of rootstock top leaf area removed at bud forcing.
*[y]Differs from cut off treatment, Dunnett's T test, P = 0.05.

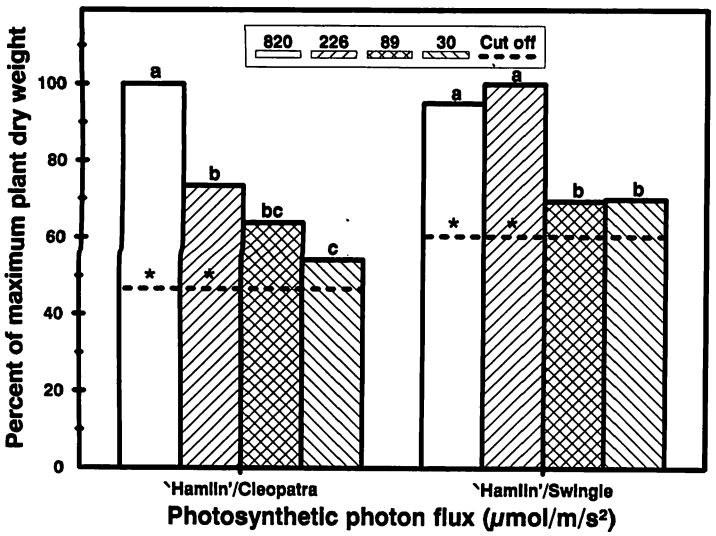

Fig. 3. Effect of photosynthetic photon flux applied to rootstock tops on whole plant dry weight of 'Hamlin'/Cleopatra and 'Hamlin'/Swingle citrus nursery plants forced by bending. Plant dry weight of the cutting off treatment is shown as a dashed line. Small letters indicate mean separation by Duncan's Multiple Range test P=0.05. * Differs from the cutting off treatment, Dunnett's t Test, P=0.05.

Rootstock shoot shading. Whole plant dry weight for Cleopatra plants was less for all shade levels when compared to the unshaded controls (Fig. 3). The highest level of shade (PPF=30 μmol/m's²) reduced whole plant dry weight when compared to the lowest shade level (PPF=226 μmol/s/m²). Scion length, leaf area and scion and root dry weights were also reduced by all shade levels when compared to the unshaded controls (data not shown). For Swingle plants, whole plant dry weight was reduced at the 2 highest shade levels (PPF=89 μmol/s/m² and PPF=30 μmol/s/m²), but not at the lowest shade level (PPF=226 μmol/s/m²), when compared to unshaded controls (Fig. 3). Scion dry weight, length and leaf area were not reduced by shading when compared to the controls, but root dry weight followed a trend similar to that shown for Swingle whole plant dry weight in Figure 3. For both Cleopatra and Swingle plants, unshaded controls and the lowest level of shade resulted in greater whole plant dry weights than the cut off treatment (Fig. 3).

Our results agree with earlier reports (Moore, 1978; Rouse, 1988, Williamson et al., 1992) which show enhanced growth of citrus nursery plants by leaving rootstock shoots attached following bud forcing. The reduction in scion, root and whole plant dry weight associated with shading and defoliating rootstock shoots suggests that current rootstock photosynthates are the primary source of increased nursery plant growth from bending. Furthermore, moderate to severe rootstock shoot shading or defoliation usually resulted in no increase in plant growth compared to cutting off. This suggests that stored reserves in the rootstock shoot stem are of minor importance to increased plant growth from bending compared to cutting off. Current rootstock photosynthates are probably also largely responsible for enhanced growth of lopped nursery trees over those forced by cutting off. Shading and defoliation of rootstock shoots reduced nursery tree growth for both rootstocks. However, plant growth responses to rootstock shoot shading and defoliation appear to be rootstock dependent. Generally, plant growth was reduced by lower levels of shade and defoliation for Cleopatra than for Swingle. Other rootstocks would probably respond similarly, but critical threshold levels for shading and defoliation may vary.

Greenhouse structures often reduce photosynthetically active radiation by 50% or more. Additional shading from adjacent plants in high-density greenhouse nurseries can reduce the effectiveness of rootstock shoots at enhancing nursery plant growth. Some nursery managers position rootstock shoots of bent or lopped plants between or below the containers rather than tying them to the lower plant stem. Rootstock shoots of bent and lopped plants are sometimes pruned back because of space constraints in high-density nurseries. These practices probably reduce the effectiveness of bending or lopping by reducing light exposure to rootstock leaves, or by reducing the total leaf surface area of rootstock shoots available for photosynthesis.

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