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BUD FORCING METHOD AFFECTS EARLY SCION DEVELOPMENT OF CONTAINER-GROWN 'HAMLIN' NURSERY TREES

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Abstract. **Greenhouse-grown Carrizo citrange [*Citrus sinensis* (L.) Osb. x *Poncirus trifoliata* (L.) Raf.] seedlings were budded with 'Hamlin' orange [*Citrus sinensis* (L.) Osb.]. Three treatments were used to force bud growth: (a) cutting off [C] the seedling above the bud union; (b) lopping [L] by cutting half way through the seedling above the bud union and breaking the seedling top over; or (c) bending [B] the seedling top over and tying it to the base of the plant. Plants were harvested, dried and weighed as scions grew following forcing. Seedling tops of L and B plants were labeled with $^{14}CO_2$ at 3 stages of scion development and plants were harvested 24 hr after labeling. Plants with seedling tops attached (L,B) gained more scion and whole plant dry weight than C plants. Root dry weight gain, shoot length, leaf number and leaf area were greater for B plants than for C plants. During early stages of scion development, a greater percent of labeled photosynthate was translocated from seedling leaves of B plants than from seedling leaves of L plants. Movement of ^{14}C photosynthate within nursery plants was primarily to shoots during growth flushes, and to roots during periods between growth flushes.**

Reducing, or eliminating, rootstock apical dominance is a standard nursery practice which allows the bud, inserted during grafting, to develop the upper portion of the tree. The methods commonly used in citrus nurseries to force scion bud growth are: (a) cutting off, (b) lopping and, (c) bending/tying (looping). While each method is used in Florida, lopping and "cutting off" are most popular in field and greenhouse nurseries, respectively (1,5). Claims have been made that bending/tying and lopping are superior to "cutting off" because the rootstock top may serve as a source of photosynthate for developing scions (2,3). Moore (2) reported faster growth from bending/tying and lopping than from "cutting off", and described scion growth as continuous rather than cyclic as with "cutting off". However, Moore reported no data. Amih's (1) studies of the effects of forcing method on nursery tree growth were inconclusive. Amih suggested that such factors as scion and rootstock cultivar, environment, and season may affect plant response to forcing method. Rouse (4) reported that bending/tying with seedling leaves remaining below the bud union was superior to other forcing methods for 'Rio Red' grapefruit [*Citrus paradisi* (Macf.)] budded on sour orange [*Citrus aurantium* (L.)] rootstock. Bending/tying has resulted in lower percent bud break than has "cutting off" when seedling leaves below the bud were removed (4).

Bud forcing method probably affects many physiological processes which may directly, or indirectly, influence growth and development of nursery trees. Understanding the contributions of seedling tops to the growth of citrus nursery plants may enable nursrey managers to achieve more rapid and uniform growth of nursery scions following bud forcing. The purpose of this study was to quantify the effects of seedling tops on the dry weight gain and scion development of nursery plants and to evaluate the extent of photosynthate transfer from seedling tops to other plant parts at several stages of scion growth following bud forcing.

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Materials and Methods

Bare-rooted Carrizo citrange [*Citrus sinensis* (L.) Osb. x *Poncirus trifoliata* (L.) Raf.] seedlings were purchased from a commercial nursery and potted 17 August, 1989, in 1-gal containers using a commercial growing medium consisting of peat moss, vermiculite and perlite. Plants were grown in the greenhouse and irrigated as needed for 10 days following transplanting. Thereafter, a water soluble fertilizer (20.0N:8.8P:16.6K) was applied at each irrigation. Fertilizer concentration was increased from 100 ppm N to 200 ppm N after 14 days and maintained at that level for the duration of the experiment. Seedling height ranged from 24-43 inches and stem diameters 3 inches above the soil line ranged from 0.2-0.3 inches at time of budding. Seedlings were budded 5 October with 'Hamlin' orange [*Citrus sinensis* (L.) Osb.] approximately 4 inches above the soil line using the inverted T-bud procedure. Plants were forced on 30 October using three bud forcing treatments: (a) cutting off [C] the seedling top about 1.5 inches above the bud union; (b) lopping [L] by cutting half way through the seedling stem about 1.5 inches above the bud union and breaking the seedling top over; or (c) bending/tying [B] the seedling top over to the base of the plant.

A randomized complete block design was used with 20 single-plant replications of each treatment divided into five blocks of plants with similar stem diameters. One plant per treatment was harvested from each block at 7, 18, 32, and 122 days after forcing. Harvest dates corresponded with the initiation of the first scion growth flush, mid-way through the first scion growth flush, between the first and second scion growth flushes, and following the second growth flush. Dry weights were determined for scion leaves and stems, fibrous and structural roots, and rootstock stems (between the bud union and roots). Scion length, leaf area and leaf number were also measured. Scion length was determined for all plants at 3-4 day intervals.

Seedling tops of 3 plants forced by lopping or bending/tying were sealed in clear, polyethylene bags and exposed to $^{14}CO_2$ at 18, 32, and 89 days after bud forcing. Plants were harvested and divided into leaves, stems and roots 24 hr after exposure to $^{14}CO_2$. Labeling periods corresponded with the first scion growth flush, between the first and second scion growth flushes, and during the second scion growth flush. Scions of 12 plants (3 groups of 4 plants) forced by "cutting off" were labeled with $^{14}CO_2$. Each group corresponded with a different stage of scion development during the initial scion flush: (a) scion stem elongating and the uppermost 4 leaves 25 percent fully expanded, (b) scion stem fully elongated and uppermost 4 leaves 50 percent fully expanded, and (c) scion stem fully elongated and leaves fully expanded.

All plants were harvested 24 hr after labeling and divided into scion leaves and stems for each growth flush, roots, seedling leaves, seedling stem and lower seedling stem (between the bud union and roots). Tissue subsamples (1 mg) were oxidized in a model 306 Packard oxidizer (Packard Instruments, Downer's Grove, IL) using Carbosorb 2 (Packard Instruments) as a carbon trapping agent. Total isotopic activity was determined with an LKB scintillation counter (Pharmacia LKB, Gaithersburg, MD) using an internal quenching curve specific for Carbosorb.

Table 1. Effect of bud forcing treatment on the initiation and duration of scion growth.

Forcing method	First growth flush: Initiation (days after forcing)	First growth flush: Duration (days)	Second growth flush: Initiation (days after forcing)	Second growth flush: Duration (days)
Cutting	7.4 b[z]	15.4 b	77.8 a	18.3 a
Lopping	10.0 a	17.9 b	79.2 a	20.3 a
Bending	8.9 ab	24.1 a	79.8 a	22.6 a

[z]Means separation by Duncan's multiple range test, 5% level.

Results and Discussion

Percent bud break exceeded 90 percent for all treatments (data not reported), but scion growth began sooner for plants forced by "cutting off" (C) than by lopping (L) (Table 1). The duration of the initial flush was greater for plants forced by bending/tying (B) than for C or L plants. No differences were observed among treatments for the initiation or duration of the second scion flush. Scion leaf and stem dry weights, and total scion dry weight were greater for B plants than for C or L plants following the first growth flush (Table 2). After the second scion growth flush, leaf, shoot and whole plant dry weights did not differ for treatments where rootstock tops were left attached (L and B treatments), however, both were significantly greater than for C plants. Root dry weight was greater for B plants than for C plants following each growth flush. Scion shoot length, leaf number and leaf area were greater for B plants than for C plants following each growth flush (Table 3).

Extent of ^{14}C photosynthate export from labeled scions was not affected by the 3 stages of scion development based on stem elongation and leaf expansion (data not reported). Considerable movement of ^{14}C photosynthate from scions to roots (8.6-12.9% of total ^{14}C) was noted 24 hr. after labeling at all scion growth stages.

A greater percentage of total ^{14}C photosynthate was translocated from rootstock leaves of B plants than L plants during the first scion growth flush (Table 4). More ^{14}C photosynthate was translocated to roots ($P = 0.06$) and scion stems ($P = 0.08$) of B plants than C plants during the

Table 2. Effect of bud forcing method on dry weight gain of container-grown citrus nursery trees.

Forcing method	Scion dry weight (oz x 10^{-2}): Stem	Leaf	Leaf and stem	Root dry wt (oz x 10^{-2})	Whole plant dry wt (oz x 10^{-2})
	32 days after forcing[z]				
Cutting	0.7 c[y]	3.8 b	4.4 b	15.6 b	30.1 b
Lopping	1.1 b	4.3 b	5.3 b	17.8 ab	34.1 b
Bending	1.8 a	6.8 a	8.6 a	19.2 a	40.2 a
	122 days after forcing[x]				
Cutting	3.6 c	18.6 b	12.9 b	27.3 b	63.4 b
Lopping	7.6 b	26.5 a	34.1 a	31.5 ab	82.8 a
Bending	9.9 a	31.2 a	41.3 a	35.3 a	93.7 a

[z]Corresponds with the period following the first scion growth flush.
[y]Means separation by Duncan's multiple range test, 5% level.
[x]Corresponds with the period following the second scion growth flush.

Table 3. Effect of bud forcing method on scion length and leaf characteristics.

Forcing method	Length (in)	Leaf number	Leaf area (in^2)
	32 days after forcing[z]		
Cutting	4.0 b[y]	11.6 b	26.9 b
Lopping	4.5 b	11.0 b	32.0 ab
Bending	7.0 a	13.7 a	42.7 a
	122 days after forcing[x]		
Cutting	10.5 b	18.2 b	83.4 c
Lopping	13.4 b	21.7 ab	121.8 b
Bending	18.1 a	24.9 a	158.6 a

[z]Corresponds with the period following the first scion growth flush.
[y]Means separation by Duncan's multiple range test, 5% level.
[x]Corresponds with the period following the second scion growth flush.

first scion growth flush. Between scion growth flushes, no treatment differences were noted for ^{14}C photosynthate partitioning among plant parts. However, more ^{14}C was found in roots, and less in scions, than when scions were actively growing. During the second scion growth flush, more photosynthate moved out of rootstock leaves (P = 0.06) and into elongating scion stems (P = 0.09) for B plants than for L plants.

Amounts of ^{14}C photosynthate translocated from rootstock tops were consistent with the effects of rootstock tops on nursery tree growth and dry weight gain. More ^{14}C photosynthate moved from rootstock tops of B plants than L plants during the initial scion growth flush. Moreover, more ^{14}C photosynthate appeared to be directed to roots and scion stems of B plants where dry weight gain was greater than for other treatments.

During periods of scion growth, more photosynthate moved to scions than to roots while the opposite was true during periods between scion growth flushes, when roots presumably were growing.

In this study, advantages in growth were obtained from leaving rootstock tops attached to nursery trees (bending/tying and lopping). Gain in scion dry weight and whole-plant dry weight was greater for L and B plants than for C plants even though scion growth began sooner for C plants. Some advantages of bending/tying over lopping were observed. Following the initial scion growth flush, plants with buds forced by bending/tying had greater scion shoot, root, and whole plant dry weight than plants with buds forced by lopping. Scion stem length and leaf number were also greater for B plants than for L plants. After the second growth flush, few differences in dry weight gain were apparent between these treatments (only scion stem dry weight) although scion stem length and leaf area were greater for B plants than for L plants. Growth measurements and ^{14}C partitioning suggest that bending/tying may allow for greater contributions from seedling tops to nursery tree growth than lopping. However, both procedures resulted in increased nursery tree growth when compared to "cutting off" seedling tops to force scion growth.

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Table 4. Effect of bud forcing method on ^{14}C photosynthate distribution (% of total ^{14}C by plant part).

Forcing method	Rootstock leaves	Rootstock stem	Lower rootstock[z]	Roots	Scion leaves	Scion stem	First scion flush	Second scion flush
				18 days after forcing[y]				
Lopping	87.12	1.71	4.05	1.54	3.79	1.79		
Bending	68.25	5.62	7.15	8.68	5.65	4.64		
P>F	0.028	0.086	0.124	0.055	0.640	0.081		
				32 days after forcing[x]				
Lopping	75.39	12.37	3.72	8.82	1.33	0.53		
Bending	63.00	8.76	7.53	18.88	1.23	0.64		
P>F	0.137	0.425	0.400	0.265	0.884	0.580		
				89 days after forcing[w]				
Lopping	65.78	9.39	3.25	4.00	9.28	8.34	6.98	10.61
Bending	48.80	8.49	6.00	5.05	21.72	9.95	4.59	27.07
P>F	0.064	0.828	0.353	0.800	0.137	0.675	0.230	0.090

[z]Rootstock between bud union and root system.
[y]Corresponds to the first growth flush.
[x]Corresponds with the period following the first growth flush.