the sensory terms or use of different levels of the rating scale (Shamaila et al., 1992). Ear appearance (20%) and kernel color (41%), again accounted for most of the variation in overall quality (data not shown).

Reducing sugar kernel content ranged from 1.3% to 1.7%, total sugar kernel content from 2.5% to 2.8%, and ear moisture at harvest from 68.2% to 70.5%. The three varieties did not differ for these traits.

Conclusions

There has been little evaluation of the three main corn varietal types in Trinidad. In previous studies, the main criterion for performance has been grain yield determined from small-plot on-station trials (Spaner et al., 1995). Extension recommendations generally reflect a bias toward imported hybrid material, although the advantages of hybrid varieties may not be as apparent under the local nonmechanized green corn farming system as under a mechanized grain production system. Our results point towards different recommendations depending on farming system and could be incorporated into breeding strategies for corn in the region. Cash-crop farmers must consider yield and market acceptance of green ears. Although the yield of marketable ears per hectare of the landrace open-pollinated variety was similar to that of the hybrid, the current consumer preference for the ear type of the hybrid would make it difficult for cash-crop farmers to return to open-pollinated varieties. Given the high cost of hybrid seed and the good performance of the open-pollinated landrace variety used here, subsistence farmers might be better served using local open-pollinated saved seed. All

green corn growers would benefit if local plant breeding could incorporate consumer preferences for green corn into breeding strategies to develop locally adapted open-pollinated varieties with the large ears and yellow kernel color currently found only in hybrids.

Literature Cited

International Corn and Wheat Improvement Center. 1984. CIMMYT report on maize improvement 1980–81. CIMMYT, El Batán, Mexico.

Cropper, J. and R.A.I. Brathwaite. 1977. An evaluation of one approach to the promotion of agricultural development in Trinidad and Tobago. The Texaco Food Crops Farm. Proc. Carib. Food Crops Soc. 4:137–164.

Eaton, G.W., Bowen, P.A., and P.A. Jolliffe. 1986. Two-dimensional partitioning of yield variation. HortScience 21: 1053–1054.

Gooding, H.J. 1960. Yields of West Indian maize. Trop. Agr. (Trin.) 37:257–264.

Miller, G.L. 1959. Use of Dinitro salicylic acid reagent for determination of reducing sugars. Anal. Chem. 31:426–428.

Pollack, L.M. 1993. Evaluation of Caribbean maize accessions in Puerto Rico. Trop. Agr. (Trin.) 70(1):8–12.

Shamaila, M., Baumann, T.E., Eaton, W.D., Powrie, W.D., and B.J. Skura. 1992. Quality attributes of strawberry cultivars grown in British Columbia. J. Food Sci. 57(3): 696–699, 720.

Spaner, D., R.A.I. Brathwaite, and D.E. Mather. 1995. Evaluation of open-pollinated maize varieties in Trinidad. Plant Var. Seeds 8:125–134.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill, New York.

Forcing Treatment and Rootstock Affect Budbreak and Growth of Containerized Citrus Nursery Trees

J.G. Williamson¹ and B.E. Maust²

Additional index words. budding, grafting, propagation

Summary. Two experiments were conducted to determine the effects of rootstock and bud-forcing treatment on scion budbreak and nursery tree growth of 'Hamlin' orange. In Expt. 1, 'Carrizo' citrange, 'Swingle' citrumelo, and 'Cleopatra' mandarin were budded with 'Hamlin' orange and forced by one of the following methods: cutting off (pruning away the rootstock top about 2 cm above the inserted scion bud); lopping (cutting half to two-thirds of the way through the rootstock stem 2 cm above the bud union, and breaking over the stem but leaving it attached); or bending (bending the rootstock shoot above the inserted scion bud and tying it to the base of the plant). For 'Swingle' only, percent budbreak was less for bending or lopping compared to cutting off. For 'Carrizo' and 'Swingle', scion dry weights were less when plants were forced by cutting off compared to bending or lopping. For all rootstocks, whole-plant dry weights were greater for plants forced by bending and lopping than for plants forced by cutting off. In Expt. 2, scion buds on 'Swingle' and 'Cleopatra' plants were forced by the three methods in Expt. 1 plus combinations of bending with notching (making an inverted V incision through the bark and into the wood on the rootstock stem directly

Department of Horticultural Sciences, IFAS, University of Florida, Gainesville, FL 32611. Journal series R-05042.

¹Associate professor.

²Graduate research assistant.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulation, this paper must be hereby marked advertisement solely to indicate this fact.

above the scion bud) and/or topping (removing the terminal 2 cm of rootstock shoot tips of plants forced by bending). Percent scion budbreak was high for 'Cleopatra' plants regardless of forcing treatment. For 'Swingle', scion budbreak was greater when bending was combined with notching than for bending alone. For 'Cleopatra', plant dry weight was greatest for plants forced by lopping. When bending was combined with notching, or notching with topping, 'Swingle' scion budbreak was comparable to cutting off, but plant dry weights were greater with these combination treatments than when cutting off was used.

Methods used to force scion bud growth of citrus nursery trees include cutting off, lopping, bending, and sometimes notching (Tucker and Youtsey, 1984; Rouse, 1988). In Florida, lopping is the primary forcing method used in field nurseries, whereas cutting off is preferred for containerized greenhouse-grown trees (Williamson and Castle, 1989). Bending or lopping often result in greater scion growth than cutting off (Amih, 1980; Rouse, 1988; Williamson and Castle, 1989; Williamson et al., 1992). However, in some situations, forcing by bending or lopping results in reduced and/or delayed scion budbreak compared to cutting off (Amih, 1980; Rouse, 1988; Williamson et al., 1992). Amih (1980) reported inconsistent scion budbreak and growth from cutting off, lopping, and bending on several scion/rootstock combinations, depending on growing conditions (field vs. greenhouse) and time of budding (spring vs. fall). In general, scion budbreak was greater for bending than for cutting off for fall-budded, field-grown plants. However, for container-grown plants in a greenhouse, cutting off increased scion budbreak compared to bending or lopping. Rootstocks, or scion/rootstock combinations, appear to be one important factor in the effectiveness of bud-forcing methods on scion budbreak and nursery tree growth. However, we know of no reports that directly compare the response of different citrus rootstocks to different bud-forcing treatments. We have observed particularly low percent budbreak and delayed scion growth of several scion varieties budded on

'Swingle' citrumelo [*C. paradisi* (L.) Osb. x *P. trifoliata* (L.) Raf.] in the greenhouse (J.G. Williamson and B.E. Maust, unpublished data). Use of 'Swingle' citrumelo has increased from about 15% to 51% of all registered citrus propagations in Florida during the last 10 years and is now the major orange and grapefruit rootstock in Florida (Youtsey, 1993). Moreover, there is a trend toward increased containerized citrus nursery tree production in Florida (Castle and Ferguson, 1982; Williamson and Castle, 1989).

Conflicting research results, changes in rootstock use, and increased greenhouse production of containerized citrus nursery trees demonstrate that additional research is needed to compare the effectiveness of bud-forcing method on citrus nursery tree growth, especially for difficult-to-force rootstocks such as 'Swingle' grown as containerized plants in greenhouse nurseries. These experiments were conducted to determine the effects of bud-forcing treatments on scion budbreak and tree growth of 'Hamlin' orange (*Citrus sinensis* Osb.) budded on containerized 'Swingle' citrumelo, 'Carrizo' citrange [*Citrus sinensis* (L.) Osb. x *Poncirus trifoliata* (L.) Raf.], and 'Cleopatra' mandarin (*C. reticulata* Blanco) rootstocks grown in a greenhouse.

Materials and methods

All experiments were conducted in a greenhouse at the Univ. of Florida, Gainesville, Fla. Diurnal maximum and minimum temperatures in the greenhouse ranged from 28 to 36°C and 15 to 22°C, respectively. Maximum photosynthetic photon flux in the greenhouse was 820 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. 'Carrizo' citrange, 'Swingle' citrumelo and 'Cleopatra' mandarin seedlings were grown from certified seed, or purchased as liners from commercial nurseries, and transplanted to 2.8-liter plastic containers with a commercial growing medium consisting of 1 peatmoss : 1 perlite (v/v). Plants were irrigated as needed for two weeks 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 based on N was increased from 100 to 200 $\text{mg}\cdot\text{liter}^{-1}$ 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 about 10 cm above the soil line, and plants were forced 18 to 21 days after budding.

Completely random designs with single-plant plots were used for each experiment. 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 leaf area meter (model LI-300; LI-COR, Lincoln, Neb.). All plant parts were dried at 70°C and weighed. Data were analyzed using SAS's general linear models (GLM) procedure (SAS Institute, Cary, N.C.). Means were separated by Tukey's studentized range test (Steel and Torrie, 1980).

Experiment 1. Budded 'Carrizo', 'Swingle', and 'Cleopatra' plants were forced by one of three bud-forcing treatments: 1) Cutting off (pruning away the rootstock top about 2 cm above the bud union); 2) lopping (cutting half to two-thirds of the way through the rootstock stem about 2 cm above the bud union and breaking over the stem, but leaving it attached; or 3) bending (bending the rootstock shoot above the inserted scion bud and tying it to the base of the plant). Each treatment was replicated 10 times. A factorial arrangement of three rootstocks and three forcing treatments was used. The experiment was concluded after all plants with growing scions had completed three scion-growth flushes, which was about 7 months.

Experiment 2. Budded 'Cleopatra' and 'Swingle' plants were subjected to the three bud-forcing treatments described in Expt. 1, or to one of the following: bending + notching (B+N, bending as described in Expt. 1 plus making an inverted V incision through the bark and into the wood on the rootstock stem above the scion bud); bending + topping (B+T, bending plus removing the terminal 2 cm of rootstock shoot tips); or bending + notching + topping (B+N+T). A factorial arrangement of two rootstocks and six forcing treatments was used. Each treatment was replicated 23 times. The experiment was concluded after all plants with growing scions had completed two scion growth flushes, which was about 5 months.

Results and discussion

Experiment 1. The effect of bud-forcing treatment on scion budbreak of citrus nursery trees varied with rootstock (Table 1). For 'Cleopatra' and 'Carrizo' plants, percent scion budbreak was relatively high for all forcing treatments. However, for 'Swingle' plants, percent budbreak was reduced by bending or lopping compared to cutting off. These results agree with an earlier report (Rouse, 1988) and our prior observation (J.G. Williamson and B.E. Maust, unpublished data) that scion buds on some citrus rootstocks are difficult to force by bending or lopping. The effect of bud-forcing treatment on scion dry weight was also rootstock-dependent. For 'Carrizo' and 'Swingle', scion dry weights were lower for plants forced by cutting off, compared to plants forced either by bending or lopping. However, scion dry weights did not differ among forcing treatments for 'Cleopatra' plants. Previous research showed that citrus scion shoots developed greater leaf area and length (Rouse, 1988) and greater dry weight (Williamson, et al., 1992) in response to lopping or bending compared to cutting off. The previous studies were conducted with sour orange (*C. aurantium* L.) and 'Carrizo' citrange rootstocks. The present study suggests that scion dry weight gain in response to forcing treatment can be rootstock-dependent, since bending or lopping did not result in greater scion dry weight gain than cutting off did for 'Cleopatra' plants. Conversely, whole-plant, root, and scion leaf dry weights and scion leaf area and length were greater for bending and lopping, compared to cutting off, regardless of rootstock (Table 2). This is consistent with earlier findings by Rouse (1988) and Williamson et al. (1992). The only difference found between bending and lopping for nursery tree growth is that root dry weight was greater following bending. Mean scion dry weight was greater for 'Carrizo' plants than for 'Swingle' plants when bending was used to force scion budbreak (Table 1). 'Cleopatra' plants had greater scion dry weight than 'Swingle' plants when cutting off was used.

No differences were found among rootstocks for scion leaf or total plant dry weights (Table 2). After three scion growth flushes, root dry weight was lower in 'Cleopatra' plants than in

'Carrizo' or 'Swingle' plants, and scion length was greater for 'Carrizo' plants than for the other two rootstocks. Scion budbreak occurred sooner after forcing by cutting off compared to bending or lopping. Scion budbreak was delayed in 'Carrizo' rootstock compared to 'Cleopatra' rootstock.

Experiment 2. All growth measurements showed significant interactions among rootstocks and bud-forcing treatments (Table 3). For 'Cleopatra' plants, mean time from forcing until budbreak did not differ among treatments and ranged from 9 to 11 days. Percent budbreak was high ($\geq 90\%$), there being no differences among forcing treatments. All growth measurements for 'Cleopatra' were greater when plants were forced by bending or lopping than when cutting off was used. These results agree with those in Expt. 1, which showed that scion budbreak for 'Cleopatra' was high regardless of forcing treatment and plant growth (except scion dry weight) was greater following lopping or bending than following cutting off. No differences in growth were noted among bending and the combination treatments (B+N, B+T, and B+N+T). Scion dry weights were greater for lopping than for B+T and B+N+T. Root dry weights were greater for lopping than for any of the combination treatments.

For 'Swingle' plants, mean time from forcing until budbreak ranged from 5 to 14 days (Table 4). Plants forced by cutting off grew sooner than plants forced by bending, B+N, or B+N+T. This generally agrees with Expt. 1 in which cutting off resulted in earlier budbreak than lopping or bending. Percent budbreak due to bending and B+T was lower than for other treatments. However, when bending was combined with notching, either as B+N or B+N+T, percent budbreak was greater than for bending alone and not different from cutting off. Lopping generally resulted in the greatest dry weight gain, although differences in lopping and B+T or B+N+T were not significant for whole plant and scion dry weight, respectively. Cutting off resulted in the lowest scion, root, and whole-plant dry weights. This is in general agreement with Expt. 1, in which cutting off resulted in less growth than lopping or bending. For most growth measurements, plants forced by bending did not differ from any of the combination treatments.

Our results are supported by previous work which showed that leaving rootstock shoots attached by bending or lopping resulted in greater growth than cutting off rootstock shoots (Williamson et al., 1990). Generally, this effect of forcing treatment was found for all three rootstocks tested,

Table 1. *Interaction of forcing method and rootstock on percent scion budbreak and scion dry weight of 'Hamlin' citrus nursery trees.*

Forcing method	Percent budbreak			Scion dry wt (g)		
	Cleopatra	Carrizo	Swingle	Cleopatra	Carrizo	Swingle
Bending	100 a ^z A ^y	88 aA	41 bB	34.5 aAB	39.1 aA	30.3 aB
Lopping	98 aA	87 aA	26 bB	31.5 aA	34.9 aA	34.9 aA
Cutting off	100 aA	90 aA	100 aA	25.8 aA	16.4 bAB	15.4 bB

^zMean separation within columns by Tukey's studentized range test, $P = 0.05$.

^yMean separation within rows by Tukey's studentized range test, $P = 0.05$.

Table 2. *Effect of forcing method and rootstock on growth of 'Hamlin' citrus nursery trees.*

Treatment	Days until budbreak	Dry wt (g)			Scion leaf area (cm ²)	Scion length (cm)
		Scion leaf	Root	Plant		
Forcing method						
Bending	17 az	18.7 a	29.8 a	74.9 a	2010 a	90.2 a
Lopping	15 a	19.2 a	26.3 b	71.1 a	2075 a	78.9 a
Cutting	8 b	11.7 b	12 bc	36.1 b	1437 b	68.4 b
Rootstock						
Cleopatra	13 b	17.8 a	22.9 b	64.2 a	1937 a	83.1 b
Carrizo	17 a	17.4 a	27.4 a	68.5 a	1916 a	93.9 a
Swingle	15 ab	17.4 a	27.3 a	69.4 a	1936 a	77.6 b

^zMean separation within columns by Tukey's studentized range test, $P = 0.05$.

although 'Cleopatra' responded more favorably to cutting off than 'Carrizo' or 'Swingle'. Rootstock leaves are probably an important source of recent photosynthates for nursery tree growth following forcing (Williamson, et al., 1992). For optimum nursery tree growth, rootstock shoots should remain attached after forcing (i.e., bending or lopping), provided these treatments result in adequate scion budbreak. With difficult-to-force rootstocks such as 'Swingle', bending and lopping can result in unacceptably low percent scion budbreak (i.e., 41% and 47% scion budbreak from forcing 'Swingle' by bending in Expts. 1 and 2, respectively). For these situations, bending combined with notching above the inserted scion bud could be a useful alternative to cutting off, which is currently the standard forcing treatment for this rootstock. 'Swingle' plants forced by B+N and B+N+T had high percent scion budbreak ($\geq 94\%$) and greater growth than 'Swingle' plants forced by cutting off. In this study, bending combined with notching appeared to provide enough inhibition of apical dominance to allow adequate scion budbreak with the added advantage of leaving rootstock shoots attached resulting in greater plant growth

than was obtained by cutting off.

Bending and lopping were superior bud-forcing treatments compared to cutting off for 'Cleopatra' mandarin (Expts. 1 and 2) and for 'Carrizo' citrange (Expt. 2) rootstocks. Bending or lopping resulted in high percent budbreak and greater plant growth than cutting off. However, percent budbreak of 'Swingle' citrumelo was unacceptably low when bending was used (Expts. 1 and 2), and highly variable when lopping was used (Expt. 1 = 26% budbreak; Expt. 2 = 87% budbreak). We suggest that nursery operators who grow difficult-to-force rootstocks such as 'Swingle' citrumelo try bending combined with notching on a small trial basis to force scion buds. Our results suggest that with 'Swingle' citrumelo, greater nursery plant growth can be achieved with bending + notching than with cutting off without low percent scion budbreak, which is sometimes associated with bending.

Literature Cited

Amih, C.A. 1980. The effects of time and method of forcing on bud survival and scion growth of citrus. MS thesis, Univ. of Florida, Gainesville.

Castle, W.S. and J.J. Ferguson. 1982. Current status of greenhouse and container production of citrus nursery trees in Florida. Proc. Fla. State Hort. Soc. 95:46-52.

Rouse, R.E. 1988. Bud-forcing method affects budbreak and scion growth of citrus grown in containers. J. Rio Grande Valley Hort. Soc. 41:69-73.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and practices of statistics: A biometrical approach. 2nd ed. McGraw Hill, New York.

Tucker, D.P.H. and C.O. Youtsey. 1980. Citrus nursery practices. Fla. Coop. Ext. Serv., Inst. Food Agr. Sci., Univ. of Florida, Circ. 430.

Williamson, J.G. and W.S. Castle. 1989. A survey of Florida citrus nurseries. Proc. Fla. State Hort. Soc. 102:78-82.

Williamson, J.G., W.S. Castle, and K.E. Koch. 1990. Bud-forcing method affects early scion development of container-grown 'Hamlin' nursery trees. Proc. Fla. State Hort. Soc. 103:321-323.

Williamson, J.G., W.S. Castle, and K.E. Koch. 1992. Growth and ^{14}C -photosynthate allocation in citrus nursery trees subjected to one of three bud-forcing methods. J. Amer. Soc. Hort. Sci. 117:37-40.

Table 3. Effect of forcing method on scion budbreak and growth of 'Hamlin'/'Cleopatra' citrus nursery trees.

Forcing treatment ²	Days until budbreak	Percent budbreak	Scion		Dry wt (g)		
			Leaf area (cm ²)	Length (cm)	Scion	Root	Whole plant
Bending	10 a ^y	90 a	463 a	31.3 a	6.1 ab	5.8 ab	14.5 a
B+N	9 a	92 a	439 ab	28.6 ab	4.8 abc	5.0 b	11.9 ab
B+T	9 a	92 a	403 ab	26.6 ab	4.5 bc	4.8 b	12.0 ab
B+N+T	9 a	92 a	403 ab	29.0 ab	4.4 bc	5.0 b	11.7 ab
Lopping	9 a	93 a	529 a	31.4 a	6.5 a	6.3 a	15.8 a
Cutting	11 a	100 a	279 b	20.4 b	2.9 c	3.3 c	8.8 b

²B+N = bending + notching, B+T = bending + topping, and B+N+T = bending + notching + topping.

^yMean separation within columns by Tukey's studentized range test, P = 0.05.

Table 4. Effect of forcing method on scion budbreak and growth of 'Hamlin'/'Swingle' citrus nursery trees.

Forcing treatment ²	Days until budbreak	Percent budbreak	Scion		Dry wt (g)		
			Leaf area (cm ²)	Length (cm)	Scion	Root	Whole plant
Bending	14 a ^y	47.1 b	725 bc	32.9 ab	9.3 c	16.9 b	37.9 b
B+N	10 a	100.0 a	813 b	40.5 a	10.9 bc	17.8 b	39.6 b
B+T	9 ab	52.9 b	1031 ab	49.9 a	10.6 bc	18.0 b	43.2 ab
B+N+T	11 a	94.1 a	828 ab	37.7 ab	13.3 ab	17.9 b	39.6 b
Lopping	9 ab	87.5 a	1099 a	49.4 a	15.9 a	23.8 a	53.8 a
Cutting	5 b	100 a	514 c	26.6 b	5.2 d	10.6 c	23.9 c

²B+N = bending + notching, B+T = bending + topping, and B+N+T = bending + notching + topping.

^yMean separation within columns by Tukey's studentized range test, P = 0.05.