GOOD BUD BAD BUD

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Citrus cultivars produce branches that can be characterized as “floral” and “vegetative”. Both types of mother branches produce the same number of daughter shoots, but floral mother branches produce a greater proportion of inflorescences (>95%) to vegetative shoots. In contrast, vegetative mother branches produce a lower proportion of floral shoots (~50%) and a greater proportion vegetative shoots (~50%) than floral mother branches. The sectors of the tree in which floral branches are found produce a larger proportion of the tree’s total fruit number than the sectors of the tree in which vegetative branches are found. Our hypothesis is that trees propagated from buds taken from floral branches will retain the internal physiological status of the floral mother branches and hence produce a greater proportion of floral branches than trees propagated from buds taken from vegetative mother branches. The greater number of floral branches would result in these trees being more productive. Buds from the two types of mother shoots collected from ‘Tahiti’ lime and ‘Washington’ navel orange were budded on ‘Carrizo’ citrange rootstocks. Ten trees of each cultivar were established in the field at UC-Riverside. Trees were harvested approximately 3 years after being established in the field. Trees propagated with buds from floral mother shoots produced more fruit per tree compared to trees propagated with buds from vegetative mother shoots. For ‘Tahiti’ lime compare 153 fruit (73 kg) per tree to 133 fruit (57 kg) per tree, respectively (P = NS). For ‘Washington’ navel orange compare 67 fruit (83 kg) per tree produced with buds from floral mother shoots to 54 fruit (66 kg) per tree produced with buds from vegetative mother shoots ($P = 0.06$).

Key words: floral shoots, vegetative shoots, tree mapping, epigenetics, topophysis.

Introduction

Plant mapping technology is a method for quantifying tree architecture that has proven to be a sensitive indicator of tree flowering intensity and fruiting potential that might open new approaches to orchard management. Three studies at UCR have applied mapping technology to citrus. Hake (1995) applied the technology to 48 3-year-old container grown 'Limco Lisbon 8-A' lemon trees [*Citrus limon* (L.) Burm. f.] on *C. macraphylla* rootstock. Records of each branch location and morphological traits (length, nodes, thorns, daughter vegetative shoots, daughter inflorescences, both type and number, and fruit number) were collected. From this set of 2142 branches, relatedness of various traits within a branch and between branches was described, along with a generalized diagram of *C. limon* branch and branching structure. From branch to branch the internode length was highly consistent, only decreasing slightly with each younger growth flush. Thorns per branch were significantly positively related to branch length and the number of daughter vegetative shoots produced. The correlation coefficient between thorns and the number of flowers per branch was negative and significant. From one flush to the next, progenitor branches that were long with many thorns tended to produce daughter branches that had many thorns. Progenitor branches with many flowers produced daughter branches with many flowers. Lord and Eckard (1985) used the characteristics listed in Table 1 to distinguish mother branches with a high probability of producing floral shoots from those that would produce fewer floral shoots and more vegetative shoots. Lord and Eckard (1985) also reported a predictability of 90% accuracy for identifying floral mother branches, 70% for vegetative mother branches. Lovatt (unpublished) obtained additional characteristics for floral versus vegetative mother branches based on two separate studies 10 years apart with 'Washington' navel orange (Table 2). There is evidence that branches of citrus trees with specific characteristics may differ in productivity. The mother branches having these specific characteristics are termed “floral” and “vegetative”. Both types of mother branches produce approximately the same number of daughter shoots. However, for floral mother branches, a greater absolute number and proportion (>95%) of the daughter shoots are inflorescences rather than vegetative shoots. In contrast, for vegetative mother branches much fewer daughter shoots are inflorescences in absolute number and proportion (~50%) with vegetative daughter shoots a much greater absolute number and proportion (~50%) than is found on floral mother branches. The sectors of the tree in which floral branches are found produce a larger proportion of the tree’s total fruit load than the sectors of the tree in which vegetative branches are found (Verreynne and Lovatt, 2007). In California, in an orchard with rows that run east-west, floral mother branches are found in greater number in the southwest tree quadrant of citrus trees. In contrast, vegetative mother branches are predominant in the northeast tree quadrant.

Our hypothesis is that trees propagated from buds taken from branches having the characteristics of floral mother branches will retain the internal physiological status of the floral mother branch and hence have a higher proportion of floral branches than trees propagated with buds taken from vegetative mother branches. The higher proportion of floral branches would result in these trees being more productive. If this hypothesis is correct, per tree productivity could be improved by propagating with buds taken from floral mother branches. If the progeny trees have a higher proportion of floral branches, then buds could be taken less discriminatorily from them to produce productive trees with a high proportion of floral branches. The research reported here was performed in order to test and confirm this hypothesis so that nurserymen can take advantage of this information in tree propagation and maintenance of nursery bud wood trees.

Materials and Methods

Trees of ‘Washington’ navel orange (*Citrus sinensis* L. Osbeck) and ‘Tahiti’ lime (*Citrus latifolia* (Yu Tanaka) Tanaka) were budded on *X Citroncirus webberi* (JW Ingram & HE Moore) ‘Carrizo’ in 2005. Ten trees of each cultivar were propagated from buds obtained from each of the two branch types (floral and vegetative) of mature field-grown ‘Washington’ navel trees and mature, potted, lathe-house ‘Tahiti’ lime trees on the campus of the University of California, Riverside (UCR). Vegetative budsticks were selected from the southwest quadrant of the source trees and floral budsticks from the northeast tree quadrant. The trees propagated from these buds were established in the field at UCR in September 2006 (‘Tahiti’ lime) and June 2007 (‘Washington’ navel). The trees were spaced at 7.3 m between rows and 5.2 m within row. The trees were irrigated with mini-sprinklers and otherwise grown with the cultural practices standard in Riverside. Phenotypic characteristics of the young trees were determined in spring and summer of 2009. Yield for 2009-2010 was determined by counting the number of fruit per tree in October and by harvesting the fruit in February.

Results and Discussion

The characteristics of the budsticks used to propagate ‘Tahiti’ lime trees are shown in Table 3. The vegetative budsticks had significantly longer internodes, longer leaves, more thorns, fewer fruit, and fewer daughter branches than the floral budsticks, whereas leaf width did not differ significantly between the two types. This is consistent with the characteristics referred to in the introduction. When the phenotypic characteristics of trees propagated from vegetative and floral budsticks were measured in March 2009, trees propagated from vegetative budsticks had significantly more thorns than did trees propagated from floral budsticks, but the numbers of leaves and nodes as well as leaf length did not differ significantly between trees propagated from the two sources of buds (Table 4). Trees propagated from floral budsticks had significantly more daughter shoots than did trees propagated from vegetative budsticks. This result was due to trees propagated from floral budsticks having significantly more leafless floral daughter shoots, whereas the number of leafy floral and vegetative daughter shoots did not differ significantly between ‘Tahiti’ lime trees propagated from the two types of buds (Table 4). In August 2009, trees propagated from vegetative budsticks had significantly more thorns and nodes and larger leaves than did trees propagated from floral budsticks, whereas trees propagated from floral budsticks had significantly more fruit per branch (Table 5). Trees propagated from floral budsticks yielded significantly more fruit by October 2009 than did trees propagated from vegetative budsticks. However, by February 2010 trees propagated from the two different bud sources did not differ significantly in either number of fruit or total yield in kg of fruit per tree (Table 6).

The characteristics for the budsticks used to propagate the ‘Washington’ navel orange trees are shown in Table 7. Vegetative budsticks had significantly longer internodes and larger leaves than floral budsticks. The leaf length and number of thorns were significantly greater on vegetative budsticks compared to floral budsticks at $P = 0.06$. The number of nodes and fruit did not vary significantly between the two types budsticks but floral budsticks had significantly more daughter shoots. When phenotypic characteristics were measured in March 2009, the only characteristic that differed significantly between trees propagated from vegetative and floral budsticks was the number of thorns, which was significantly greater on trees propagated from vegetative budsticks (Table 8). In August 2009, there were no significant differences between trees propagated from the two bud sources in regard to leaf length and the number of thorns, nodes, and fruit (Table 9). In contrast, trees propagated from floral budsticks produced significantly more fruit per tree by October 2009 ($P = 0.053$) than did trees propagated from vegetative budsticks (Table 10). Additionally, by harvest in February 2010, yields remained greater for trees produced from floral budsticks with regard to both fruit number ($P = 0.057$) and total fruit yield in kg per tree ($P = 0.61$).

Conclusions

The results presented are inconclusive at this time. However, the characteristics of the shoots comprising the young ‘Tahiti’ lime trees propagated from vegetative and floral buds are consistent with the bud sources used and with the general model. In addition, the number of fruit produced by the ‘Tahiti’ lime trees propagated from floral budsticks was significantly greater in October than the number of fruit produced by trees propagated from vegetative budsticks. These data were collected closer to the normal harvest time for lime trees in this growing area. By the late harvest in February, a significant amount of fruit had dropped. Whereas trees propagated from floral budsticks had a greater yield than trees propagated from vegetative budsticks, the difference was not significant. In contrast, the characteristics of the shoots comprising the young ‘Washington’ navel orange trees propagated from vegetative and floral budsticks did not differ significantly but yields were consistently and significantly greater in both October and February (P = 0.06) for trees propagated from floral budsticks. As the trees increase in size, it is possible that the differences and the effect of position (quadrant) will become more pronounced due to shading effects from the larger canopies. The fact that the source budsticks were selected from specific quadrants of mature trees suggests that this may eventually be the case for the trees in our experiment. Overall, the trees in this experiment require additional years of observation and documentation. Our results taken as a whole suggest an interesting relationship between epigenetic changes related to floral development and topophysis (differences in the growth and differentiation potential related to the position of an axillary bud) for buds on floral and vegetative mother branches that when used as bud sticks influences the characteristics of progeny trees. Some researchers have already started noting these characteristics in their investigations and commercial nurseries may want to do the same. For reference, good bud and bad bud characteristics are shown in Figure 1.

Literature Cited

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Table 1. Characteristics used to distinguish floral mother branches, which produce a greater proportion of floral to vegetative daughter shoots, from vegetative mother branches, which produce fewer floral and more vegetative daughter shoots (Lord and Eckard, 1985).

Mother branch type	Branching	Leaf area	Nodes	Thorns
		------ *cm*^{2} ------	------------ *no. per shoot* ------------	
Floral	Frequent[z]	17.59 ± 5.79	5 - 6	Few or absent
Vegetative	Infrequent	27.73 ± 7.34	> 6	Numerous

[z] Data are the mean ± SE for 100 mother branches of each type.

Table 2. Characteristics of floral versus vegetative mother shoots based of 'Washington' navel orange (Lovatt, unpublished data).

					Daughter shoots		
Mother branch type	Branch length	Leaf area	Nodes	Thorns	Total	Floral	Vegetative
	mm	*cm^2*	*no. per shoot*				
Floral	77 ± 2.2[z]	18 ± 0.5	7 ± 0.1	1 ± 0.2	422	411	11
Vegetative	158 ± 5.0	25 ± 0.8	10 ± 0.3	5 ± 0.4	410	208	202

[z] Data are the mean ± SE for 100 mother branches of each type.

Table 3. Characteristics of 'Tahiti' lime floral and vegetative mother branches used as the source of buds (May 2005).

Mother branch type (bud source)	Internode length	Leaf length	Leaf width	Nodes	Thorns	Fruit	Daughter branches
	---------------------- *mm*	----------------------	----------------------	-------------------------- *no. per shoot*			----------------------------
Floral	15 b[z]	67 b	43 a	11 a	2 b	14 a	6 a
Vegetative	27 a	116 a	52 a	10 a	9 a	0 b	0 b
P-value	0.0084	0.0003	0.1104	0.7358	0.0014	0.0175	0.0001

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD test.

Table 4. Effect of the bud source used as the scion on phenotypic characteristics of branches of 3-year-old 'Tahiti' lime trees in March 2009.

Mother branch type (bud source)	Leaf length	Nodes	Leaves	Thorns	Daughter shoots: Vegetative shoots: Total	Daughter shoots: Floral shoots: Leafy	Floral shoots: Leafless	Floral shoots: Single leafless	Floral shoots: Total leafless	Floral shoots: Total
	---- *mm* ----	---- *no. per shoot* ----								
Floral	7.5 a[z]	13.0 a	3.0 a	6.5 b	11.8 a	29.5 a	9.6 a	4.8 a	14.4 a	43.9 a
Vegetative	7.4 a	11.6 a	3.2 a	7.9 a	16.8 a	20.9 a	4.9 b	1.1 a	6.0 b	26.9 b
P-value	0.5717	0.1483	0.2641	0.0480	0.1736	0.0820	0.0209	0.0704	0.0084	0.0042

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD test.

Table 5. Effect of the bud source used as the scion on phenotypic characteristics of branches of 3-year-old 'Tahiti' lime trees in August 2009.

Mother branch type (bud source)	Leaf length	Thorns	Nodes	Fruit
	----- *cm* ----	----------------- *no. per shoot*	------------------	
Floral	6.5 b[z]	3.0 b	7.8 b	0.6 a
Vegetative	7.0 a	3.7 a	9.3 a	0.4 b
P-value	0.0002	0.0535	0.0004	0.0535

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD test.

Table 6. Effect of the bud source on yield of 3-year-old 'Tahiti' lime trees in October 2009 and February 2010.

	October	February	
Mother branch type (bud source)	Total fruit (No.)	Total fruit (No.)	Total fruit (Kg)
	--------------------- *per tree* ---------------------		
Floral	183 a[z]	153 a	14.9 a
Vegetative	120 b	133 a	12.7 a
P-value	0.0529	0.4416	0.7836

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD test.

Table 7. Characteristics of 'Washington' Navel oranges floral and vegetative mother branches used as the source of buds (May 2005).

Mother branch type (bud source)	Internode length	Leaf length	Leaf width	Nodes	Thorns	Fruit	Daughter branches
	---------------------- mm	----------------------		------------------------ no. per shoot	--------------------------		
Floral	15 b[z]	65 b	30 a	8 a	0 b	2 a	6 a
Vegetative	17 a	80 a	36 a	9 a	1 a	3 a	2 b
P-value	0.0470	0.0255	0.0607	0.7526	0.0624	0.6532	0.0289

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD test.

Table 8. Effect of the bud source used as the scion on phenotypic characteristics of branches of 3-year-old 'Washington' navel orange trees in March 2009.

					Daughter shoots					
					Vegetative shoots	Floral shoots				
Mother branch type (bud source)	Leaf length	Nodes	Leaves	Thorns	Total	Leafy	Leafless	Single leafless	Total leafless	Total
	---- *mm* ----	---------- *no. per shoot* ----------								
Floral	8.1 a[z]	11.0 a	3.1 a	1.2 a	33.4 a	26.4 a	1.1 a	1.6 a	2.7 a	29.1 a
Vegetative	8.0 a	11.4 a	2.7 b	1.0 a	21.8 a	40.6 a	4.8 a	1.1 a	5.9 a	46.5 a
P-value	0.6226	0.9401	0.0138	0.5672	0.2805	0.1492	0.2742	0.2178	0.4219	0.1756

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD test.

Table 9. Effect of the bud source used as the scion on phenotypic characteristics of branches of 3-year-old 'Washington' navel orange trees in August 2009.

Mother branch type (bud source)	Leaf length	Thorns	Nodes	Fruit
	---- *cm* ---	------------ *No. per shoot* -------------		
Floral	7.4 a[z]	0.7 a	7.3 a	0.2 a
Vegetative	6.9 a	0.5 b	6.7 a	0.2 a
P-value	0.5949	0.2908	0.6074	0.0757

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD test.

Table 10. Effect of the bud source used as the scion on yield of 3-year-old 'Washington' navel orange trees in October 2009 and February 2010.

	October	February	
Mother branch type (bud source)	Total fruit (No.)	Total fruit (No.)	Total fruit (Kg)
	--------------------- *per tree*	---------------------	
Floral	76 a[z]	67 a	15.0 a
Vegetative	55 b	54 b	13.6 b
P-value	0.0529	0.0571	0.0610

[z] Values in a vertical column followed by different letters are significantly different at *P*-value specified by Fisher's Protected LSD test.

Figure Captions.

Figure 1. Characteristics of Good Buds (left) and Bad Buds (right).