Girdling 'Fairchild' Mandarins and 'Lisbon' Lemons to Improve Fruit Size

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Abstract

'Fairchild' mandarins in the Phoenix area and 'Lisbon' lemons in Yuma were girdled beginning in November 1996. November, March and May girdling of the mandarins led to the greatest yield the first year, while March and May girdling led to the greatest yield in years 2 and 3. March girdling yield increases were generally due to greater fruit numbers, while in May, yield increases were due to greater fruit numbers and fruit size. Returns per acre suggest that March and or May girdling of mandarins will lead to greater profits for the grower. Like mandarins, lemon yields were greater following November, or November and March girdling after one year of the experiment. However, yields of these trees dropped considerably the second year, and the trees appear to be in an alternate bearing cycle. No lemon girdling treatment appears to be better than the untreated trees after three years.

Introduction

It is well recognized that medium to large fruit size is one key to profitable citrus production in Southwest Arizona. Although extra large sized mandarins are sometimes hard to market due to the potential for granulation, small sized fruit receive poor prices throughout the season, except when there is a fruit shortage. Prices for medium to large sized fruit, on the other hand, remain strong during the entire harvest season from October until February. Los Angeles Terminal Fruit Market FOB prices for 1st grade mandarins of large and mammoth size and above is seldom below $8.00, while for smaller sizes, the price may drop below $5.00 per box.

For lemons, medium and small size lemons command good prices early in the season, but these prices drop precipitously during the late fall. Prices for large fruit, on the other hand, remain strong during the desert lemon harvest season from August until February. Los Angeles Terminal Fruit Market FOB prices for 1st grade lemons of size 140 and above are seldom below $15.00, while for smaller sizes, the price may drop below $6.00 per box.

Fruit growth of citrus can be subdivided into four phases. Cell division occurs primarily in phase I. This phase lasts from 1 to 1½ months following anthesis (flowering), and final fruit size is at least partly dependent on the number of cells produced during this period. Following phase II, a period of cell differentiation, phase III occurs when those cells begin to enlarge. This phase generally lasts between 2 and 3 months. Final fruit size also depends upon the magnitude of that enlargement, as cells may increase in volume up to 1000 percent. Phase IV occurs when the peel begins to color, fruit solids increase and fruit acids decrease.

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The three principal factors influencing fruit growth rate are soil moisture, temperature during the growing season and carbohydrate partitioning to the fruit. The citrus grower can influence soil moisture through proper irrigation, but it is difficult to affect orchard temperature. Carbohydrate partitioning to the fruit, however, can be altered. It is commonly accepted that the carbohydrates available to any particular fruit are dependent upon the presence of carbohydrate sources (leaves), and the number of competitive carbohydrate sinks such as other fruit, rapidly growing shoots and the roots. Elimination of competitive sinks is one of the primary methods for improving fruit size. Thinning is practiced in deciduous fruit crops to eliminate competition by other fruits, but is not usually practiced in citriculture. Pruning to eliminate competitive shoots has not been studied in citrus. The practice of girdling to temporarily remove the competition from roots, however, is an old horticultural technique that may hold promise. Temporary removal of the roots as a competitive sink for available carbohydrates may improve fruit size and returns to the grower without harming the tree.

Effects of girdling on fruit size are mixed. Both Shamel and Pomeroy (1944) and Ghayur and Khan (1962) reported smaller fruit size of 'Washington Navel' orange and mandarin, respectively. Krezdorn (1960) and Krezdorn *et al.* (1968), working with 'Orlando' tangelo, and Shamel and Pomeroy (1934), working with 'Washington Navel' orange reported no change in fruit size. In contrast, Cohen (1984) reports that early summer (June) girdling tended to increase fruit size (+15%), compared with mid-bloom girdling on 'Shamouti' mandarin. Cohen (1984) also suggests that the number of leaves from which a fruit can draw carbohydrates affects fruit size. Girdling too early will lead to too many fruits per leaf, thus reducing fruit size. Girdling too late will lead to a smaller increase in fruit size. Summer girdling should be after 'June drop' but as soon as possible after it (phase III) to achieve the greatest effect. Mataa *et al.* (1998) reported that July and September improved fruit size, but November girdling did not. Alternatively, local reports indicate that girdling mandarins in November lead to greater fruit size, because more fruit is set in the interior of the tree during phase I (H. Ormsby -- personal communication).

While girdling studies have been conducted on some varieties of mandarins, we have been unable to find any investigations of the practice on 'Fairchild' mandarins or any evidence of a study of the practice on bearing lemons. Because the studies cited indicate that the effects of girdling vary depending on the citrus variety or species we feel that additional work on 'Fairchilds' and on lemons is necessary.

Therefore, our objective in this study is to determine the effect of girdling time on fruit size, fruit quality and yield of 'Fairchild' mandarins and 'Lisbon' lemons.

Materials and Methods

We recognized that girdling has the potential to injure the tree, and followed procedures that minimize that possibility. Therefore, girdling was done only on healthy trees. Studies show that trees that are improperly irrigated show more injury than to trees that are properly irrigated (Cohen 1981; Cohen, 1984). Research also shows that thin girdling (2.5-4 mm cut) is less likely to be injurious than a thicker girdle.

'Fairchild' Mandarins – This portion of the research was conducted at the University of Arizona Citrus Agriculture Center at Waddell, AZ. Ninety-six 'Fairchild' mandarin trees on three different rootstocks were included in this study. Trees were subject to one of 4 treatments, March girdling, May girdling, November girdling or an untreated control.

A treatment unit in this study was a pair of trees, one on 'Carrizo rootstock' and the other on either 'Rough lemon' or *'C. volkameriana'* rootstock. There were four treatment units, eight trees per block, one treatment unit (2 trees) for each of the four treatments, and 12 blocks (replications) in the experiment. All trees, except the control were girdled by a spiral, single cut between the 10th and the 30th of the specified month using a 3/16-inch wide double-bladed girdling knife. For the 1997 harvest season, girdling began in November 1996.

Trees were harvested on 12/4/97, 12/17/98 and 12/28/99. For the first two years fruit was weighed and then sized using a circular, rotating fruit sorting table (GREEFA Machinebouw B.V., Tricht, Netherlands). Fruit was then graded manually. For both 1997-98 and 1998-99 harvest seasons, fruit quality measurements (juice content, total solids, total acid, solid to acid ratio were collected on a 15 fruit sample per tree. For 1999, the fruit was passed through an automated electronic eye sorter (Autoline, Inc., Reedley, CA), which provides weight, color, exterior quality and size data for each fruit. No interior fruit quality measurements were collected in 1999/2000.

Economic impact was calculated using a weighted average price net return per carton figure from a commercial Yuma packinghouse. The receipts per acre are gross returns that do not include any pre-harvest costs. Per acre estimates were based on 109 trees per acre (20 x 20 spacing).

Data was analyzed by analysis of variance, and treatment means separation using the General Linear Model found in SPSS for Windows (SPSS Inc., Chicago, IL). Experimental design was randomized complete block

'Lisbon Lemons' - This portion of the research was conducted at the University of Arizona Yuma Mesa Agriculture Center at Yuma, AZ. Thirty 'Limoneira 8A Lisbon' lemon trees on *Citrus volkameriana* rootstock were included in this study. Trees were subject to one of 5 treatments, March girdling, May girdling, November girdling November and March girdling or an untreated control.

A treatment unit in this study was one tree. There were five treatment units per block, one treatment unit for each of the five treatments, and 6 blocks (replications) in the experiment. All trees, except the control were girdled by a spiral, single cut between the 10^{th} and the 30^{th} of the specified month using a 3/16-inch wide double-bladed girdling knife.

Trees were harvested on 10/24/97, 1/8/98, 11/2/98, 1/14/99, 9/29/99, 11/6/99 and 2/3/00. For the first two years fruit was weighed and then sized using metal fruit sizing rings commonly used by fruit pickers. Fruit was then graded manually. For 1999, the fruit was passed through an automated electronic eye sorter (Autoline, Inc., Reedley, CA), which provides weight, color, exterior quality and size data for each fruit. No interior fruit quality measurements were collected.

Data was analyzed by analysis of variance, and treatment means separation using the General Linear Model found in SPSS for Windows (SPSS Inc., Chicago, IL). Experimental design was randomized complete block.

In both locations, trees were watered and fertilized according to normal horticultural practices common to the desert southwest.

Results and Discussion

'Fairchild' Mandarins – For the 1997-98 harvest season, all treatments led to improved yield, compared to the control (Table 1). Improved yield ranged from a 49% increase for the May girdled trees, to a 141% increase for the November girdled trees, to a 217% increase for the March girdled trees.

For the November and March girdled trees, fruit size was generally smaller than for the other treatments. Both these treatments had greater numbers of small and medium sized fruits, and smaller numbers of jumbo and mammoth sized fruit. This suggests that these two treatments led to increased fruit set and/or fruit retention, perhaps through improved carbohydrate allocation to the developing fruitlets. Nonetheless the larger population of fruit on the tree also led to smaller fruit size. There was no effect of girdling on the percentage of large sized fruits, but May girdled trees had a greater percentage of mammoth, jumbo and colossal-sized fruits. This suggests that the May girdling treatment led to improved cellular growth of fruits that survived the post-anthesis drop. Since we did not actually count fruit numbers, it is difficult to know if the improved yield for the May girdled trees is also due to improved fruit retention.

Gross receipts per acre were greater for any of the girdling treatments compared to the control. For the November and the March girdled trees the impact of smaller fruit size was offset by larger yields. This impact was more pronounced for the March girdled trees. For the May girdled trees, despite a smaller yield than the November and March treatments, comparatively larger fruit size led to greater returns per acre.

Juice content of control tree fruit was significantly greater than that of the girdle treatments (Table 2). This may be because the girdling did not inhibit root growth of these trees, thus hydraulic conductivity was greater. Total acid percentage of the control fruit was also greater than that of the girdled trees fruit, while there was no difference in the total soluble solid percentage between any of the treatments. Thus, the solid to acid ratio of the control fruits was less. This result is in contrast with that of Damigella *et al. (*1970) who found that girdling 'Clementine' mandarins had no effect on fruit ripening. There was no effect of the treatments upon peel thickness.

For the 1998-99 harvest season, the March and May treatments led to improved yield, compared to the control, while the November yield was significantly reduced (Table 3). Yields showed a 35% increase for the March girdled trees, and a 46% increase for the May girdled trees compared to the control. In contrast to the previous season, trees girdled in November had 43% less yield than the control. Although tree canopy volume data has not yet been collected, it appears as though trees girdled in November are smaller than the others. This may account for the reduced yield of this treatment.

The 1998-99 harvest was characterized by a smaller fruit size in general, compared with the previous season, especially when one compares the percentage of jumbo and mammoth sized fruit. For the November girdled trees, fruit size was generally larger than for the other treatments, which is to be expected since the smaller population of fruit on the tree led to larger fruit size. Ungirdled, May and March girdled trees had generally smaller fruit size compared with the November treatment. In the case of all treatments, this is most likely due to the larger fruit number.

Because of the small fruit size for this year, the economic impact of the treatments is not as great as the previous year. An acre of ungirdled trees would have cost the producer almost $53.00 even before costs of production were included. Trees girdled in May were barely profitable, while those girdled in November and March returned about $200.00 per acre before pre-harvest costs.

Unlike the previous season, there was little effect of treatment upon fruit quality in 1998-99 (Table 4).

For the 1999-2000 harvest season, yield of all trees increased regardless of treatment, compared with 1998-99 (Table 5). Like the previous year, the March and May treatments led to improved yield, compared to the control, while the November yield was reduced compared to the control. Yields showed an 11.5% (non-significant) increase for the March girdled trees, and a 21% increase for the May girdled trees compared to the control. In contrast to the previous season, trees girdled in November had only 13% less yield than the control.

Fruit size was much greater in 1999-2000 than in 1998-99. Just as in 1997-98, for the November and March girdled trees, fruit size was generally smaller than for the other treatments. Both these treatments had greater numbers of small and medium sized fruits, and smaller numbers of jumbo and mammoth sized fruit. Since the November trees had both low yield and small fruit size, it is possible that this treatment is harming the trees. The May treatment had large fruit size and high yield, suggesting again that girdling at this time of the year improves fruit cell growth.

The economic impact of the treatments for 1999-2000 was varied. Unlike 1997-98 and 1998-99, the November and March girdling treatment had lower returns than the control treatment because the yields were similar to control trees, but there was more small fruit. In contrast, the May treatment had higher yields than the control and had similar to larger fruit size, which led to the greatest return per acre of the four treatments.

The average gross return per acre of the four treatments for the three year period of this study are as follows: Control - $518.67; November girdling - $498.49; March girdling - $715.53; May girdling - $741.26. Based on the these figures it is apparent that, for the three years of this study, girdling in March or May is preferable to girdling

in November, or to not girdling at all. Although March girdling led to smaller fruit size than in the control in 2 of the 3 years of this study, greater yields propelled this treatment to the forefront. May girdling yields were also always greater than the control trees, but returns in this case were due to larger fruit size.

'Lisbon Lemons' – Lemons had a very different response to girdling than did the 'Fairchild' mandarins (Table 6). Like the mandarins, yield of girdled trees was significantly larger than the control trees the first harvest following treatments. However, the second year, those trees that had large yields the first year had much reduced yield the next. The third year, yields for those same trees increased. Thus, girdling seems, up to this point, to put the trees into a mild alternate bearing cycle that is not apparent in the 'Fairchilds'. Also unlike the mandarins, we saw no effect of the girdling treatments upon fruit size or exterior fruit quality (data not shown). Thus, girdling appears to only affect fruit set or fruit retention in lemons.

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Table 1. 1997-98 Yield and packout of 'Fairchild' mandarins subject to girdling treatments.

Girdling Time	Yield (lbs. per tree)	Fruit Size (%)							Economic Impact	
		Small	Medium	Large	Jumbo	Mammoth	Colossal	Super-Colossal	Net Returns per carton[y] ($)	Gross Receipts per acre ($)
Control	50.4 d[z]	6.2 b	23.9 b	39.7 a	23.2 b	8.4 b	0.1 b	0.0 a	$3.40	$497.81
November	121.5 b	17.8 a	44.6 a	30.2 b	6.8 c	0.8 c	0.0 b	0.0 a	$1.76	$622.57
March	159.8 a	14.7 a	41.1 a	32.2 b	11.1 c	1.9 c	0.1 b	0.0 a	$2.16	$1,005.06
May	75.0 c	2.8 b	17.4 b	32.1 b	28.9 a	18.0 a	1.5 a	0.1 a	$4.07	$886.52

[z] Means separation by Duncan's Multiple Range Test, α=0.05. Values within the same column with different letters are significantly different.

[y] This figure calculated as a weighted average of the returns per carton of first grade fruit less the cost of picking, hauling and packing the fruit. In this case, the figures are based on a return of $0.79 per 37.5 lb. carton for small, colossal and super-colossal fruit,, $5.87 for medium, $7.18 for large, $8.28 for jumbo, $11.86 for mammoth fruit, and $3.82 per carton for picking, hauling and packing.

Table 2. 1997-98 Fruit Quality of 'Fairchild' mandarins subject to girdling treatments.

Girdling Time	Juice Content (%)	Total Soluble Solids (%)	Total Acid (%)	TSS:TA	Peel Thickness (mm)
Control	48.3 a	12.8 a	0.92 a	14.2 c	2.6 b
November	43.6 c	12.8 a	0.80 b	16.3 a	2.6 b
March	46.5 ab	13.0 a	0.82 b	16.0 ab	2.9 a
May	46.1 b	12.5 a	0.85 ab	15.0 bc	2.7 b

[z] Means separation by Duncan's Multiple Range Test, α=0.05. Values within the same column with different letters are significantly different.

Table 3. 1998-99 Yield and packout of 'Fairchild' mandarins subject to girdling treatments.

Girdling Time	Yield (lbs. per tree)	Fruit Size (%)							Economic Impact	
		Small	Medium	Large	Jumbo	Mammoth	Colossal	Super-Colossal	Net Returns per carton[y] ($)	Gross Receipts per acre ($)
Control	96.68 b[z]	29.5 a	40.7 a	21.6 c	2.3 b	0.0 b	0.0 a	0.0 a	-$0.19	-$52.91
November	55.18 c	12.0 c	35.9 b	37.2 a	5.8 a	0.4 a	0.0 a	0.0 a	$1.17	$188.25
March	141.69 a	21.1 b	38.1 ab	31.5 b	3.2 b	0.1 b	0.0 a	0.0 a	$0.53	$216.36
May	130.55 a	25.4 b	40.5 a	25.5 c	2.5 b	0.0 b	0.0 a	0.0 a	$1.10	$38.12

[z] Means separation by Duncan's Multiple Range Test, α=0.05. Values within the same column with different letters are significantly different.

[y] This figure calculated as a weighted average of the returns per carton of first grade fruit less the cost of picking, hauling and packing the fruit. In this case, the figures are based on a return of $1.06 per 37.5 lb. carton for small, colossal and super-colossal fruit, $5.00 for medium, $7.98 for large, $13.65 for jumbo, $18.12 for mammoth fruit, and $4.57 per carton for picking, hauling and packing.

Table 4. 1998-99 Fruit Quality of 'Fairchild' mandarins subject to girdling treatments.

Girdling Time	Juice Content (%)	Total Soluble Solids (%)	Total Acid (%)	TSS:TA	Peel Thickness (mm)
Control	50.2 a	14.7 a	1.47 a	10.0 a	2.7 a
November	50.5 a	14.0 b	1.43 a	10.1 a	2.7 a
March	49.4 a	14.5 ab	1.40 a	10.6 a	2.8 a
May	50.9 a	14.4 ab	1.39 a	10.1 a	2.7 a

[z] Means separation by Duncan's Multiple Range Test, α=0.05. Values within the same column with different letters are significantly different.

Table 5. 1999-2000 Yield and packout of 'Fairchild' mandarins subject to girdling treatments.

Girdling Time	Yield (lbs. per tree)	Fruit Size (%)							Economic Impact	
		Small	Medium	Large	Jumbo	Mammoth	Colossal	Super-Colossal	Net Returns per carton[y] ($)	Gross Receipts per acre ($)
Control	199.0 bc[z]	4.2 b	21.5 b	47.7 a	21.1 a	4.7 a	0.9 a	0.0 a	$1.92	$1,111.13
November	175.7 c	9.5 a	28.0 a	45.1 ab	14.1 b	2.1 b	1.1 a	0.0 a	$1.34	$684.65
March	221.9 ab	8.9 a	31.4 a	40.7 b	13.9 b	4.0 ab	1.2 a	0.0 a	$1.43	$925.18
May	240.2 a	4.5 b	22.9 b	47.2 a	19.9 a	4.5 a	1.0 a	0.0 a	$1.86	$1,299.14

[z] Means separation by Duncan's Multiple Range Test, α=0.05. Values within the same column with different letters are significantly different.

[y] This figure calculated as a weighted average of the returns per carton of first grade fruit less the cost of picking, hauling and packing the fruit. In this case, the figures are based on a return of $2.00 per 37.5 lb. carton for small, and super-colossal fruit, $5.38 for medium, $6.53 for large, $8.28 for jumbo, $12.21 for mammoth fruit, $10.85 for colossal fruit and an estimated $4.85 per carton for picking, hauling and packing.

Table 6. Lemon yield, fruit size and packout of lemon trees subject to girdling treatments.

	Yield per tree (lb)				
Girdling Month	1997-98	1998-99	1999-2000	Total	Average
November	42.12 a	45.17 b	84.87 b	172.16 b	57.38 b
March	28.77 b	153.33 a	92.73 b	274.83 a	91.61 a
May	27.48 b	153.83 a	72.46 b	253.77 a	84.59 a
November and March	49.57 a	54.00 b	132.18 a	235.75 a	78.58 a
Control	28.80 b	155.17 a	98.66 b	282.63 a	94.21 a