

Early Results of Scion and Rootstock Trials for Lemon in Arizona¹

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Abstract

Four 'Lisbon' lemon selections from the University of Arizona Citrus Budwood Certification plot were selected for evaluation on Citrus rootstock. 'Frost Nucellar', 'Corona Foothills', 'Limoneira 8A' and 'Prior' were selected because of their popularity among Arizona growers or because of the lack of information about their performance under Arizona climactic and edaphic conditions. Trees were planted in 1993. Early results indicate that the 'Limoneira 8A Lisbon' selection is outperforming the other selections in both growth and yield.

In a similar trial, five rootstocks were selected for evaluation using 'Limoneira 8A Lisbon' as the scion. Carrizo citrange, Citrus macrophylla, Rough lemon, Swingle citrumelo and Citrus volkameriana were chosen. Trees were planted in 1993. Early results indicate that trees on C. volkameriana are superior to those on other rootstocks in both growth and yield.

Introduction

There is no disputing the importance of lemon cultivars and rootstocks to desert citrus production. A successful lemon cultivar must be adaptable to the harsh climate, (where average high temperatures are often greater than 40°C), must be vigorous and must produce high yields of good quality fruit of marketable size. Likewise, the ideal lemon rootstock must be compatible with the scion, be adaptable to the appropriate soil and climactic factors and should also improve one or more of the following characteristics: pest and disease resistance, cold tolerance, harvest date, internal and external fruit quality,

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yield and post-harvest quality. Ultimately, the value of a rootstock for lemon lies in its ability to improve production and/or quality of the lemon fruit.

Unfortunately, there is no one perfect lemon scion rootstock combination. Information as to the suitability of scions and rootstocks in non-desert areas of California is often not applicable to desert citrus growing areas. The Arizona citrus industry has suffered because of the shortfalls of certain scion-rootstock combinations that were recommended for California but have shown themselves to be incompatible. Proper evaluation of both cultivar and rootstock in the desert is necessary before they are widely planted throughout the industry.

Few Arizona lemon trials have been conducted, and data is old and/or incomplete. The most recent rootstock trial for lemons was using 'Frost Nucellar Lisbon' lemon and was published by Rodney and Harris in 1976. This study indicated that greatest yield was for *C. macrophylla*, rough lemon, 'Rangpur' lime, 'Troyer' citrange, and 'Carrizo' citrange. There were no trees planted on *C. volkameriana*, and there was no comparison of the effect of rootstock on fruit size or earliness. Additionally, Fallahi *et al.* (1990) published some work comparing five 'Lisbon' lemon cultivars with two 'Eureka' varieties and 'Villafranca', all on *C. macrophylla* rootstock. 'Prior Lisbon' had the greatest cumulative yield after 6 years, while the 'Foothills Lisbon' had the largest fruit size. There has been no work on recent releases, such as 'Limoneira 8A Lisbon'.

Therefore, we have initiated two trials using scion and rootstock cultivars that are widely planted in the Arizona citrus industry today and using cultivars that are new. The lemon scion trial includes 'Limoneira 8A Lisbon', 'Prior Lisbon', 'Frost Nucellar Lisbon', and 'Corona Foothills Lisbon' lemon on *C. volkameriana* as the rootstock. A lemon rootstock trial is also underway. This trial includes rough lemon (*C. jambhiri*), *C. volkameriana*, *C. macrophylla*, 'Carrizo' citrange and 'Swingle' citrumelo as the rootstocks and 'Limoneira 8A Lisbon' lemon as the scion. Data collected from these trials includes tree growth, mineral nutrition, fruit quality, fruit size and total yield

Materials and Methods

These experiments were established in March 1993 in Block 26 of the Yuma Mesa Agricultural Center, near Yuma, Arizona. The land was laser leveled and fumigated prior to planting. Trees were planted on a 10 m x 10 m spacing. Ten replicates of each of the 5 rootstocks were planted, and 12 replicates of each of the 4 scions were planted, for a total of 98 trees. Experimental design is randomized complete block.

Irrigation is border flood, and normal cultural practices are used. Growth data, expressed as trunk diameter, is taken annually in March. Measurements are taken about 5 cm inches below the scion-rootstock interface (bud union), and about 10 cm above. These locations are permanently marked with paint. Diameters were taken of both the scion and rootstock, during 1994 and 1995 so as to quantify and differential growth rates that might have occurred. These differences were less apparent during 1996, so only scion trunk diameter data was collected. Leaves are collected annually in August for mineral analysis, however there have been no significant differences. Fruit diameter data was collected semiweekly in 1995 and 1996. One fruit of a representative size per tree was tagged, and was measured until harvest. Replacement fruits of approximately the same size were selected if a fruit was harvested or if it abscised. Yield data is collected during the fall and winter. Trees are ring or strip-picked as noted below. Cull fruits are then removed, and the remaining fruits are then sized, and reported as the number of fruit in a typical 17.2 kg box. Fruit quality data was collected at each harvest time. These data include °brix, peel thickness, percentage juice, pH, and total soluble solids to total acid ratio. Data was analyzed using SPSS for Windows (SPSS Inc., Chicago, Illinois).

Results and Discussion

Trunk Diameter and Canopy Volume. Trunk diameters of 'Limoneira 8A Lisbon' trees on *C. volkameriana* were the greatest at planting (Table 1), followed by 'Carrizo' citrange, Rough lemon, *C. macrophylla* and 'Swingle' citrumelo. Lemons on *C. volkameriana* have had the greatest trunk growth each of the following years, while trees on *C. macrophylla* and rough lemon have been close behind. These rates resulted in cumulative trunk growth increases that were greatest for *C. volkameriana*, *C. macrophylla* and rough lemon, and less for trees on 'Carrizo', and 'Swingle'. Canopy volumes taken during 1997 show similar trends, although trees on *C. volkameriana* are significantly larger than those on *C. macrophylla* or rough lemon.

During 1994 and 1995, there were little growth differences among the four lemon scions tested, however by 1996, differences were apparent (Table 2). 'Prior Lisbon' trees had significantly larger trunk diameters than 'Frost Nucellar Lisbon' trees, while 'Limoneira 8A Lisbon' and 'Corona Foothills Lisbon' were intermediate. These differences did not translate into larger yields (See below). There was no difference in canopy volume among the four scions.

Fruit Diameter. Fruit diameter increase from June 1995 until December 1995 is shown in Figure 1. When fruit diameter decreases following a selective harvest, only smaller fruits remain. During 1995, fruit diameter of trees on *C. volkameriana* was usually larger than any other scion-rootstock combination, until the first harvest on 26 September. For 1995, these data suggest that fruit of trees on *C. volkameriana* are larger because they are "set" earlier, and thus have longer growing periods. Alternatively, these fruits may benefit from greater water intake typical of *C. volkameriana*, which would lead to increased fruit cell growth. Fruit diameter of trees on *C. macrophylla* was slightly less, beginning in late July, a time that was notable for extremely high temperatures (< 45°C). This suggests that young trees on *C. macrophylla* are less able to withstand those high temperatures. Rough lemon led to intermediate fruit diameters, but 'Swingle' and 'Carrizo' led to smaller diameter fruit. After the first harvest, fruit diameters of trees on the three lemon rootstocks were virtually identical, but fruit diameter of 'Swingle' and 'Carrizo' trailed.

Figure 2 is an expanded view of Figure 1, that shows only fruit diameters above 50 mm, and indicates the relationship between fruit size expressed in mm (right axis) and the fruit per box count (left axis). Early fruit sizing is especially important in Arizona because demand for large fruit by both the US and export lemon market is high during the late summer and fall. In this figure, it becomes clear that fruits of trees on *C. volkameriana* reach size 115 sooner than any other, and that *C. macrophylla* and rough lemon fruit size equals that of *C. volkameriana* only after 9 October. In contrast, fruit of trees on 'Swingle' and 'Carrizo' seldom average above size 200.

For 1996, fruit diameter data (not shown) was similar, but differences between *C. volkameriana*, rough lemon and *C. macrophylla* were not as apparent. This may be because the summer of 1996 was not as hot, and these trees were able to withstand the heat.

Figure 3 is the equivalent of Figure 1, but for the lemon scion trial, and Figure 4 is its expanded view. These graphs indicate that fruit of 'Limoneira 8A' was larger than the fruit of the other three scions until after the second harvest on 8 November. Fruit of 'Frost Nucellar' trees were generally smaller than the others until the second harvest. The expanded graph (Figure 4) indicates that 'Limoneira 8A' trees produced fruit that was larger than size 200 by 25 September, about one month earlier than any other cultivar tested. Data from 1996 showed the same trend.

Yield. Yield of trees in both studies was quite limited during the 1994-95 season. Nonetheless, significant yield differences appeared in the rootstock trial (Table 3), where trees on *C. volkameriana* rootstock had four to twelve times the yield of any other scion rootstock combination. During 1995-96 and 1996-1997, both *C. macrophylla* and *C. volkameriana* gave the best yield (80% more than 'Carrizo' or 'Swingle'). Trees on Rough lemon produced intermediate yields, while those on 'Carrizo' and 'Swingle' produced the

least. This is due to the reduced vigor of these two rootstocks. When the yield is expressed as kg fruit per m³ of canopy, *C. macrophylla* performs best, because of its smaller size. All three lemon-type rootstocks had significantly more fruit harvested early than did 'Carrizo' or 'Swingle'.

There were no yield differences among the scions tested during the 1994-95 harvest season (Table 4). Yields across the entire experiment in 1995-96 were light, but 'Limoneira 8A Lisbon' trees had 2 to 2.5 times the yield of the other scion cultivars. This same trend was repeated in 1996-97. 'Frost Nucellar' in particular appears to be performing poorly as far as early fruit sizing. This is surprising because this cultivar was originally planted in Arizona because of its early sizing capabilities.

Fruit Grade and Size. There was no significant difference in fruit grade due to rootstock (Table 5), however differences in fruit size did occur. Not surprisingly, trees on 'Carrizo' and 'Swingle' had smaller size fruit, while those trees on the three lemon rootstocks had larger size. *C. volkameriana* trees had significantly more fruit of size 95 or better than did any other rootstock tested. For the scions tested (Table 6), 'Limoneira 8A' had significantly less cull fruit than did 'Frost Nucellar'. This may be due to reduced amount of foliage on 'Frost Nucellar' that leads to more sand damage to the peel. Additionally, 'Limoneira 8A' had significantly more large fruit than did the other cultivars tested.

Conclusions

It is apparent that 'Carrizo' and 'Swingle' are unsuitable as rootstocks for lemon in Arizona. Reduced vigor, late fruit sizing and ultimate small fruit size are characteristics that cannot be overcome. Differences between *C. volkameriana*, *C. macrophylla* and rough lemon are not yet clear, although it appears as if trees on rough lemon may not be as vigorous as those on the other two lemon rootstocks. It remains to be seen if yield or fruit size will decrease, especially for *C. macrophylla*, as has occurred on older groves in Arizona.

For the scions, 'Limoneira 8A' appears to be superior to the others at this point. Whether it will remain superior will not be known for several years.

Literature cited

- Fallahi, E., D.R. Rodney and Z. Mousavi. 1990. Growth, yield and fruit quality of eight lemon cultivars in Arizona. *J. Amer. Soc. Hort. Sci.* 115:6-8.
- Rodney, D.R. and D.E. Harris. 1976. Rootstocks for lemons. University of Arizona Yuma Branch Experiment Station, Citrus Field Day Report. Series P-38.

Table 1. Trunk diameter and canopy volume of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Scion Trunk Diameter (mm)					Canopy Volume (m ³) 1997
	1993 ^y	1994	1995	1996	Growth Increase (mm) 1993-96	
'Carrizo' Citrange	17.39 b ^x	23.02 b	40.07 c	75.76 c	58.37 b	5.23 c
<i>C. macrophylla</i>	15.12 c	21.12 c	43.41 b	88.17 ab	67.08 a	11.87 b
Rough Lemon	17.17 b	22.70 b	44.59 b	82.20 abc	71.00 a	12.29 b
'Swingle' Citrumelo	14.50 c	19.48 d	34.97 d	79.71 bc	65.22 ab	4.81 c
<i>C. volkameriana</i>	20.81 a	27.80 a	50.71 a	91.00 a	70.19 a	14.61 a

^z Values are the means of 10 trees.

^y March 1993 trunk diameter measurements were collected at planting.

^x Means separation in columns by Duncan's Multiple Range Test, 5% level.

Table 2. Trunk diameters of four 'Lisbon' lemon cultivars budded to *C. volkameriana* rootstock.

Cultivar ^z	Scion Trunk Diameter (mm)					Canopy Volume (m ³) 1997
	1993 ^y	1994	1995	1996	Growth Increase (mm) 1993-96	
'Corona Foothills Lisbon'	11.04 b ^x	21.29 a	47.56 a	82.80 ab	71.76 a	16.07 a
'Frost Nucellar Lisbon'	12.98 a	22.29 a	45.63 a	78.24 b	65.26 b	12.98 a
'Limoneira 8A Lisbon'	12.34 a	21.81 a	47.20 a	81.17 ab	68.82 ab	14.13 a
'Prior Lisbon'	12.89 a	22.20 a	48.90 a	86.47 a	73.57 a	15.94 a

^z Values are the means of 12 trees.

^y March 1993 measurements were collected at planting.

^x Means separation in columns by Duncan's Multiple Range Test, 5% level.

Table 3. Yields, yield per m³ canopy and percentage of fruit harvested early of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Yield per tree (kg)			Kg fruit per m ³ of Canopy 1997	Pct. Fruit Harvested Early ^y
	1994-95	1995-96	1996-97		
'Carrizo' Citrange	0.15 b ^x	4.61 c	5.35 c	1.11 c	41.04 b
<i>C. macrophylla</i>	0.05 b	13.47 a	26.42 a	2.21 a	70.33 a
Rough Lemon	0.06 b	8.89 b	18.38 b	1.47 bc	65.38 a
'Swingle' Citrumelo	0.07 b	5.29 c	5.05 c	0.96 c	40.97 b
<i>C. volkameriana</i>	0.58 a	16.42 a	26.18 a	1.85 ab	74.36 a

^z Values are the means of 10 trees.

^y Fruit harvested on 26 September 1995 and 12 November 1996 as a percentage of the entire yield 1995-1997.

^x Means separation in columns by Duncan's Multiple Range Test, 5% level.

Table 4. Yields, yield per m³ canopy and percentage of fruit harvested early of four 'Lisbon' lemon cultivars budded to *C. volkameriana* rootstock.

Scion ^z	Yield per tree (kg)			Kg fruit per m ³ of Canopy 1997	Pct. Fruit Harvested Early ^y
	1994-95	1995-96	1996-97		
'Corona Foothills Lisbon'	0.06 a ^x	2.26 b	5.14 b	0.34 b	60.96 ab
'Frost Nucellar Lisbon'	0.03 a	1.80 b	6.57 b	0.56 b	51.14 b
'Limoneira 8A Lisbon'	0.06 a	4.79 a	12.57 a	0.93 a	70.27 a
'Prior Lisbon'	0.00 a	1.77 b	6.89 b	0.42 b	55.31 ab

^z Values are the means of 12 trees.

^y Fruit harvested on 26 September 1995 and 21 November 1996 as a percentage of the entire yield 1995-1997.

^x Means separation in columns by Duncan's Multiple Range Test, 5% level.

Table 5. 1996-97 harvest fruit grade and fruit size, expressed as fruit per 17.25 kg. box, of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Fruit Grade (%)			Fruit Size (%)					
	Cull	2nd Grade	First Grade	235 or less	200	165	140	115	95 or more
'Carrizo' Citrange	60.5 a ^y	19.8 a	19.7 a	18.2 b	4.3 a	2.8 a	8.1 a	4.6 a	62.1 c
<i>C. macrophylla</i>	60.5 a	15.9 a	23.6 a	5.5 c	1.9 b	1.2 ab	9.7 a	4.8 a	76.9 b
Rough Lemon	57.3 a	17.9 a	24.8 a	4.2 c	1.7 b	1.3 ab	7.8 a	5.6 a	79.5 ab
'Swingle' Citrumelo	58.0 a	15.9 a	26.1 a	27.9 a	2.6 b	2.6 a	6.0 a	4.9 a	56.0 c
<i>C. volkameriana</i>	57.4 a	21.2 a	21.4 a	2.7 c	1.2 b	0.3 b	5.6 a	3.9 a	86.4 a

^z Values are the means of 10 trees.

^y Means separation in columns by Duncan's Multiple Range Test, 5% level.

Table 6. 1996-97 harvest fruit grade and fruit size, expressed as fruit per 17.25 kg. box, of four 'Lisbon' lemon cultivars budded to *C. volkameriana* rootstock.

Rootstock ^z	Fruit Grade (%)				Fruit Size (%)				
	Cull	2nd Grade	First Grade	235 or less	200	165	140	115	95 or more
'Corona Foothills Lisbon'	58.1 ab ^y	18.3 a	23.7 a	4.1 a	1.8 b	1.7 a	3.6 b	2.2 a	85.9 a
'Frost Nucellar Lisbon'	61.8 a	16.4 a	21.8 a	6.8 a	1.5 b	0.9 a	11.7 a	2.5 a	75.5 b
'Limoneira 8A Lisbon'	55.2 b	20.9 a	23.8 a	3.4 a	0.8 b	0.7 a	4.6 b	3.2 a	85.1 a
'Prior Lisbon'	60.4 ab	16.5 a	23.1 a	4.3a	4.1 a	0.8 a	7.5 ab	1.9 a	79.8 ab

^z Values are the means of 12 trees.

^y Means separation in columns by Duncan's Multiple Range Test, 5% level.

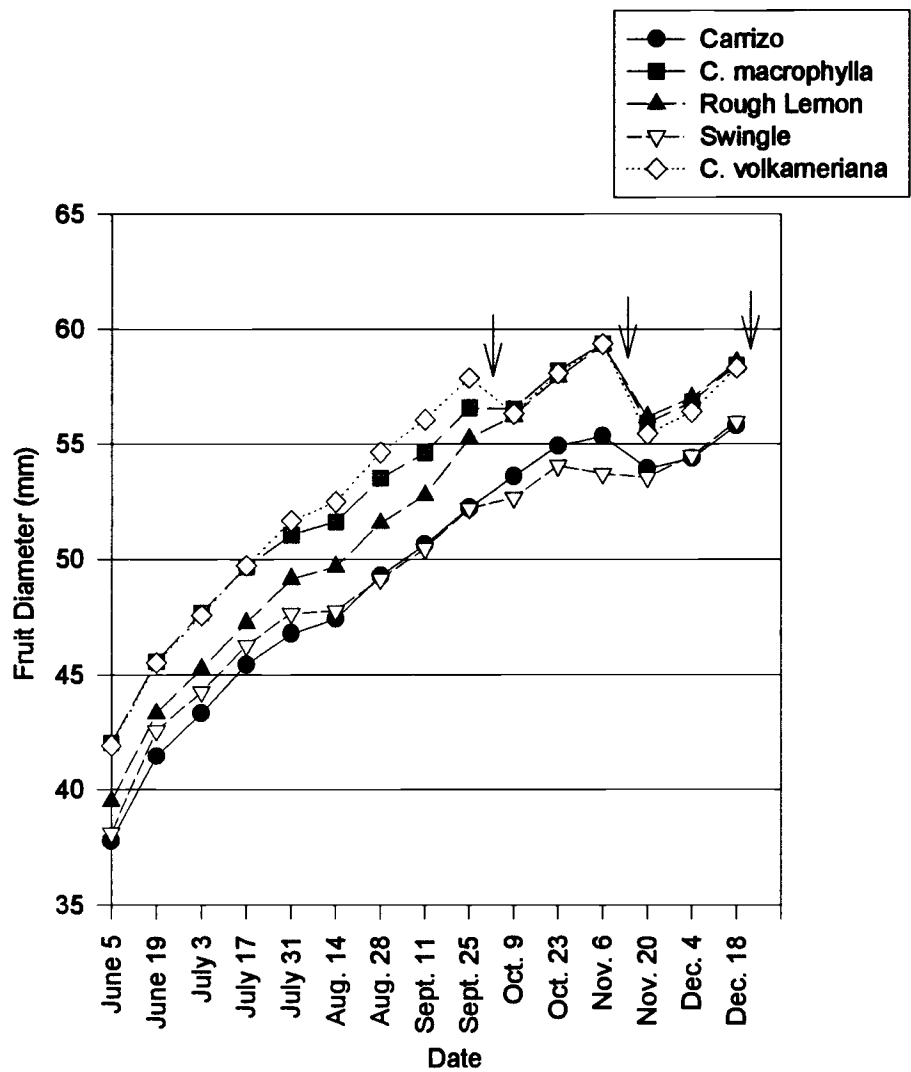


Figure 1. Biweekly fruit diameter of 'Limoneira 8A Lisbon' lemons on five rootstocks.

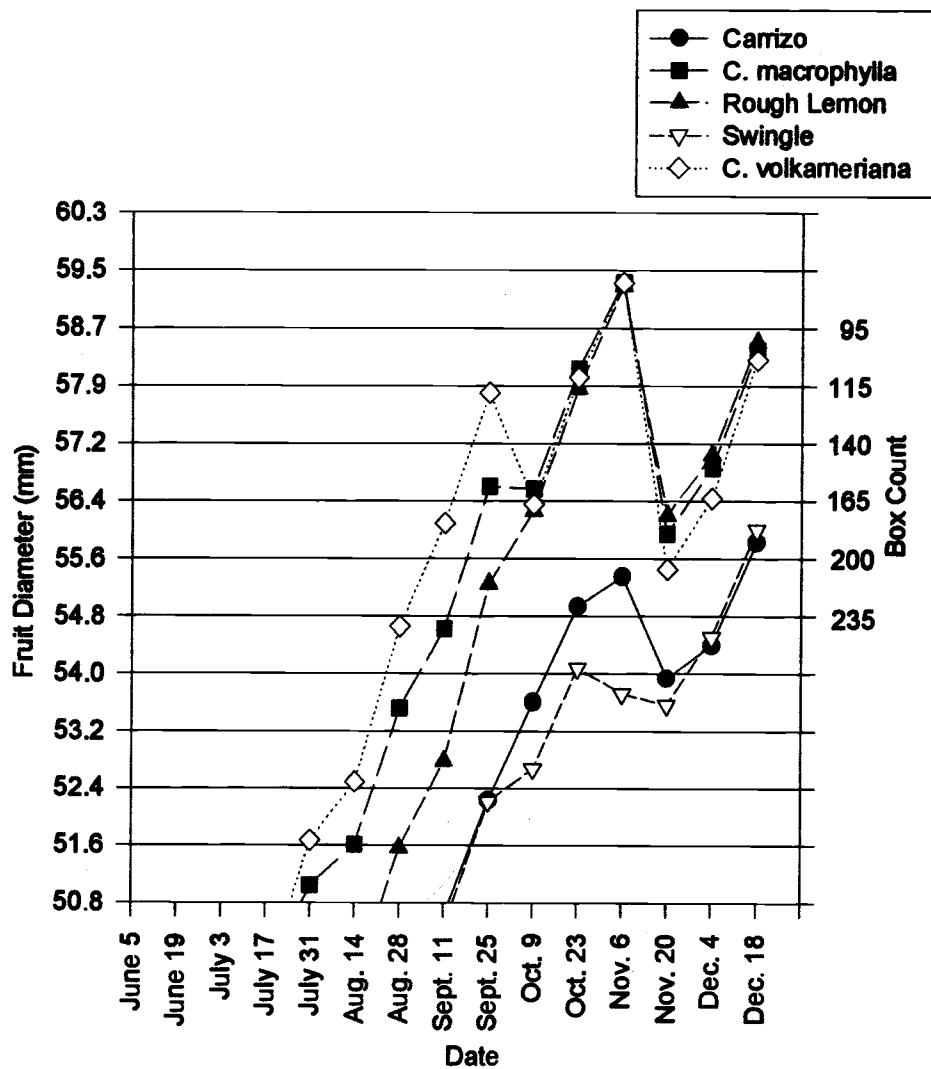


Figure 2. Biweekly fruit diameter of 'Limoneira 8A Lisbon' lemons on five rootstocks after July 31, 1995. Values on the right Y axis correspond to box counts.

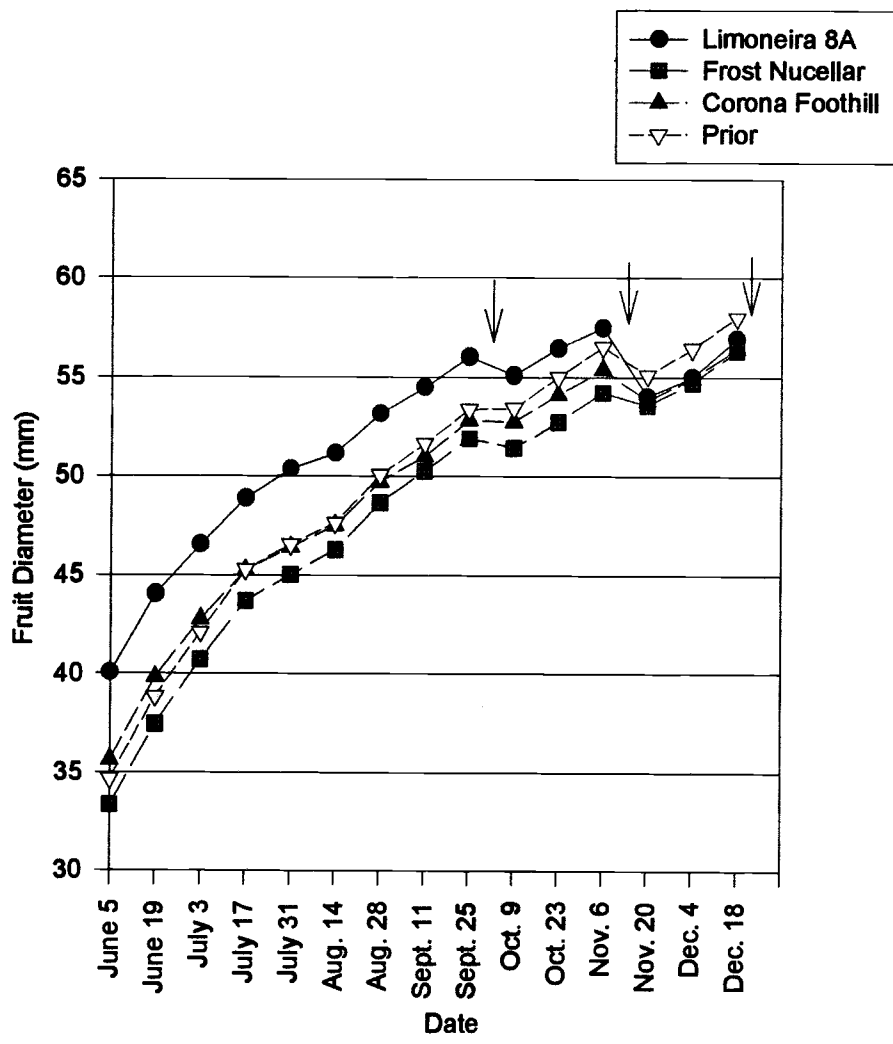


Figure 3. Biweekly fruit diameter of four 'Lisbon' lemon scion cultivars on *C. volkameriana* rootstock.

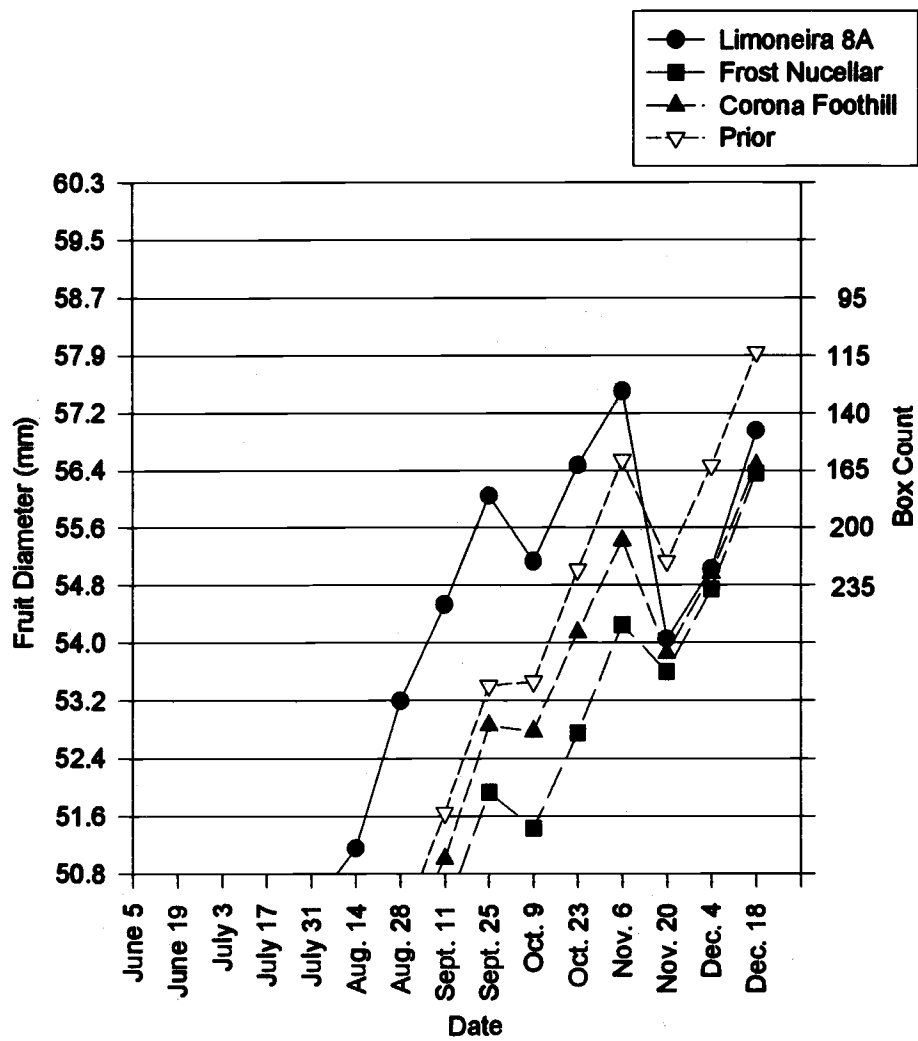


Figure 4. Biweekly fruit diameter of four 'Lisbon' lemon scion cultivars on *C. volkameriana* rootstock, after July 31, 1995. Values on the right Y axis correspond to box counts.