

Lemon Rootstock Trials in Arizona – 2001-02¹

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Abstract

In a rootstock evaluation trial planted in 1993, five rootstocks, 'Carrizo' citrange, Citrus macrophylla, 'Rough Lemon', Swingle citrumelo and Citrus volkameriana were selected for evaluation using 'Limoneira 8A Lisbon' as the scion. 1994-2002 yield and packout results indicate that trees on C. macrophylla, C. volkameriana and 'Rough Lemon' are superior to those on other rootstocks in both growth and yield. C. macrophylla is outperforming C. volkameriana. For the second year in a row, 'Rough Lemon' trees performed similarly to C. macrophylla and better than C. volkameriana. 'Swingle' and 'Carrizo' are performing poorly. In two other rootstock evaluation trials, both planted in 1995, C. macrophylla and/or C. volkameriana are outperforming other trifoliolate and trifoliolate-hybrid rootstocks under test.

Introduction

There is no disputing the importance of citrus rootstocks to desert citrus production. The ideal citrus 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, yield and post-harvest quality. Ultimately, the value of a rootstock lies in its ability to improve production and/or quality of the fruit.

Climactic and edaphic characteristics of the desert citrus growing regions impose stress upon a citrus tree. Many times, rootstocks that are suitable for other areas are not suitable in the desert. Conversely, rootstocks that may be of limited value in other citrus growing areas might be more useful under desert conditions. It cannot be assumed that rootstocks will perform similarly across all climactic and edaphic conditions.

The first rootstock trial that we planted in 1993 was established to fill a large knowledge gap as to which were the appropriate lemon rootstocks for the Arizona industry. This trial includes rough lemon (*C. jambhiri*), a vigorous and formerly popular rootstock that is susceptible to *Phytophthora* root rot, and *C. macrophylla*, also popular, but susceptible to brown wood rot (*Coniophora eremophila*. and *Antrodia spp.*) and *Macrophylla* decline. Also included are *C. volkameriana*, a newly popular but untested rootstock, as well as 'Carrizo' citrange and 'Swingle' citrumelo as experimental rootstocks (although 'Carrizo' is commonly used as a rootstock for lemon in coastal California). 'Limoneira 8A Lisbon' lemon is the scion. Data collected from these trials includes tree growth, mineral nutrition, fruit quality, fruit size and total yield. Previous results from this trial have been reported in

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Wright and Peña (2001), Wright and Peña (2000), Wright *et al.* (1999), Wright (1998), Wright (1997), Wright (1996) and Wright (1995). This trial is hereafter referred to as the 1993 Lemon Rootstock Trial.

Two additional rootstock trials, planted in 1995, are now in production. The first of these has 'Limoneira 8A Lisbon' lemon as the scion, with the experimental rootstocks 'African' Shaddock x 'Rubidoux' trifoliolate orange, 'C-35 Citrange', 'Citremón 1449', *C. taiwanica*, and 'Yuma Citrange'. *C. volkameriana* is also included as a standard. This trial is hereafter referred to as 1995 'Limoneira 8A' rootstock trial.

The second trial planted in 1995 has 'Limonero Fino 49' lemon as the scion. Fino 49 is the common fall and winter harvested lemon grown in Spain. Rootstocks in this trial include 'African' Shaddock x 'Rubidoux' trifoliolate orange, 'C-35' Citrange, 'Carrizo' Citrange, 'Citremón 1449', *C. macrophylla*, *C. taiwanica*, *C. volkameriana*, 'Rough Lemon' (*C. jambhiri*), or 'Swingle' citrumelo. This trial is hereafter referred to as 1995 'Limonero Fino 49' rootstock trial.

Materials and Methods

1993 Lemon Rootstock Trial. This trial was 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 for a total of 50 trees. Experimental design is randomized complete block.

Irrigation is border flood, and normal cultural practices are used. Growth data, expressed as trunk diameter, was taken annually through 1997. Measurements were taken about 4 inches above the bud union. These locations are permanently marked with paint. Trunk diameters were taken annually in March, so as to quantify any differential growth rates that might have occurred. Leaves are collected annually in August for mineral analysis; however there have been no significant differences in leaf nutrient content. Yield data is collected during the fall and winter. Trees were ring or strip-picked as noted below. Prior to 1999-2000, about 30 lbs of fruit was sampled from each tree, and fruits were sized by hand and graded by observation. Since 1999-2000, the entire harvest from each tree has been passed through an automated electronic eye sorter (Autoline, Inc., Reedley, CA), which provides weight, color, exterior quality and size data for each fruit. Fruit packout data is reported on a percentage basis. 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. There was no effect of rootstock on fruit quality (data not shown).

1995 'Limoneira 8A' Rootstock Trial. This trial was established in June 1995 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. There are five complete blocks containing each of the six rootstocks, additionally, there are four blocks that lack only the 'African' Shaddock x 'Rubidoux' trifoliolate orange, and the 'Yuma' Citrange. Yields are expressed as lb. fruit per tree. Yield, packout and fruit quality data are collected as described above for the 1993 lemon trials.

1995 'Limonero Fino 49' Rootstock Trial. This trial was established in June 1995 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. There are ten complete blocks containing each of the nine rootstocks. Yields are expressed as lb. fruit per tree. Yield, packout and fruit quality data are collected as described above for the 1993 lemon trials.

All data was analyzed using SPSS 8.0 for Windows (SPSS Inc., Chicago, Illinois).

Results and Discussion

1993 Lemon Rootstock Trial. Yield of trees on the five rootstocks was quite limited during the 1994-95 season. Nonetheless, significant yield differences appeared (Table 1), and trees on *C. volkameriana* rootstock had four to

twelve times the yield of any other scion rootstock combination. From 1995-96 through 1997-98, both *C. macrophylla* and *C. volkameriana* produced the best yield (three to five times more than ‘Carrizo’ or ‘Swingle’). It is notable that 1996-97 was the first year that trees on *C. macrophylla* had more yield than those trees of *C. volkameriana*, although the difference was not significant. This trend continued in 1997-98, 1998-99 and 1999-2000, when trees on *C. macrophylla* had 22%, 16% and 35% respectively more yield than trees on *C. volkameriana*. Trees on ‘Rough Lemon’ produced intermediate yields, less than *C. macrophylla* and *C. volkameriana*, but more than ‘Swingle’ or ‘Carrizo’, from 1994-95 through 1999-2000.

Total yields in 2000-01 were about 50 to 300 % greater than the previous year, but the general trends of the previous years remained unchanged (Table 2). For 2000-01, trees on *C. macrophylla* had the greatest yield for the first harvest, about 30% more than trees on *C. volkameriana*, and about 55% greater than trees on ‘Rough Lemon’. The earliness of *C. macrophylla* is reflected in the fact that over 60% of the crop for that rootstock was harvest during the first harvest. ‘Rough Lemon’ and *C. volkameriana* had the greatest yields for the second pick, while *C. macrophylla* lagged. Thus, the overall yield for these three rootstocks was statistically the same. This is the first time since the 1996-97 season that yields for these trees have been statistically the same. As in previous years, ‘Carrizo’ and ‘Swingle’ produced the least fruit. This is due to the reduced vigor of these two rootstocks.

Total yields in 2001-02 were up to 38% greater than the previous year, depending on rootstock (Table 3). This year was the first in which any rootstock produced yields of over 500 lbs. per tree. Many of the trends from previous years continued. For 2001-02, total yields of trees on *C. macrophylla* were about 18% greater than those on ‘Rough Lemon’, and about 26% more than trees on *C. volkameriana*. These differences were statistically significant. This continues the trend first noted in 1996-97. All three rootstocks had about 23% of the fruit being harvested early in the first pick. Yield of trees on ‘Swingle’ and ‘Carrizo’ were much less than the other three; yields were only 23% to 27% of that of *C. macrophylla*.

For ease of viewing, annual yields in lbs and field boxes per acre for trees on the five rootstocks tested can be seen graphically in Figure 1.

Packout for the September 27th 2001 harvest is shown in Figure 2. Trees on all five rootstocks had fruit that peaked on sizes 140 and 165. However, *C. macrophylla*, *C. volkameriana* and ‘Rough Lemon’ trees had somewhat more 95 and 115 size fruit than did the others tested, while Carrizo and Swingle trees had more size 165 and 200 size fruit. There was no effect of rootstocks on fruit grade (data not shown). There was no effect of rootstock on packout for the November 28th harvest.

1995 ‘Limoneira 8A’ Rootstock Trial. 1998-99 through 2001-02 yields of ‘Limoneira 8A Lisbon’ on the five rootstock cultivars are shown in Table 4. For the first three seasons, yields of trees on *C. volkameriana* were 2 ¼ to 9 times greater than yields on any of the other rootstocks. For 2001-02, there was no significant difference between the yields of *C. volkameriana* and ‘Citremón 1449’ for the first harvest, but the trees on *C. volkameriana* had significantly greater yields than the others tested for the second harvest, which led to significant differences for the total 2001-02 yield. There was no effect of rootstock upon packout or fruit quality in this trial.

1995 Limonero Fino 49’ Rootstock Trial. 1998-99 through 2001-02 yields of ‘Limonero Fino 49’ scions on the nine rootstock cultivars are shown in Table 5. For 1998-99, yields of trees on *C. macrophylla* were 2 ½ to 8 times greater than yields on any of the other rootstocks. However, for 1999-2000, trees on *C. volkameriana* and ‘Citremón 1449’ rootstock were statistically the equal of *C. macrophylla*. For 2000-01 and 2001-02, *C. macrophylla* regained its prominence with yields 2 to 8 times the yield of the other rootstocks tested.

Packout for the September 27th 2001 harvest is shown in Figure 3. Trees on all five rootstocks had fruit that peaked on sizes 115, 140 and/or 165. However, *C. macrophylla*, *C. volkameriana* and ‘Rough Lemon’ trees had somewhat more size 95 and fewer size 165 fruit than did the others tested. There was no effect of rootstocks on fruit grade (data not shown). There was no effect of rootstock on packout or fruit grade for the November 28th harvest.

Conclusions

It is still apparent that all rootstocks other than *C. macrophylla*, *C. volkameriana* and 'Rough Lemon' are unsuitable as rootstocks for lemon in Arizona in high pH soils. Reduced vigor, late fruit sizing and ultimate small fruit size are characteristics that have not yet been overcome.

Differences between *C. volkameriana* and *C. macrophylla* are becoming increasingly clear. For six of the past seven years, yield of trees on *C. macrophylla* has equaled or surpassed the yield of trees on *C. volkameriana*. There is no clear trend as to which of these rootstocks produces earlier fruit, and overall fruit size appears to be similar. Arizona packinghouse managers report that fruit of trees on *C. macrophylla* have a smoother peel, which leads to better overall fruit quality. Growers also report that *C. volkameriana* produces more water sprouts on the trunk than does *C. macrophylla*, and that trees on *C. volkameriana* show more transient nutrient deficiencies in the winter (winter yellows), than do trees on *C. macrophylla*. It remains to be seen if yield or fruit size for *C. macrophylla* will decrease, as has occurred on older groves in Arizona. After a slow start, 'Rough Lemon' has equaled or surpassed *C. volkameriana* for the past two years. It remains to be seen if this is a long-term phenomena. 'Rough Lemon' has not typically produced as well as *C. macrophylla*, nor has it produced as much early-season fruit as the other two vigorous rootstocks tested. 'Rough Lemon' is more difficult to grow in the nursery due to its greater susceptibility to Phytophthora root rot, so its availability is somewhat limited unless trees are special ordered on this rootstock.

Based on the results thus far, *C. macrophylla* appears to be the superior rootstock for lemons in Arizona; although the possibility exists that it may decline sooner than 'Rough Lemon' or *C. volkameriana*. It is probably not a good idea to plant all ones acreage on only one rootstock, thus either *C. volkameriana* or 'Rough Lemon' would be a good complementary rootstock as well.

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Table 1. 1994-99 yields of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Yield per tree (lb.).					
	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
'Carrizo' Citrange	0.33 b ^y	10.16 c	11.80 c	23.61 c	71.51 c	29.4 c
<i>C. macrophylla</i>	0.11 b	29.70 a	58.25 a	103.47 a	415.20 a	273.2 a
'Rough Lemon'	0.13 b	19.60 b	40.52 b	53.54 b	323.58 b	187.3 b
'Swingle' Citrumelo	0.15 b	11.66 c	11.13 c	37.96 bc	105.81 c	34.5 c
<i>C. volkameriana</i>	1.28 a	36.20 a	57.71 a	84.62 a	356.51 b	201.4 b

^z Values are the means of 10 trees.

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

Table 2. 2000-01 yields and percentage of fruit harvested early of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Yield per tree (lb.).			Pct. Fruit Harvested Early ^x
	9-28-00	12-4-00	Total Yield	
'Carrizo' Citrange	35.4 c	96.5 c	131.9 b	25.1 c
<i>C. macrophylla</i>	254.9 a	179.3 b	434.2 a	60.1 a
'Rough Lemon'	164.5 b	255.4 a	419.9 a	38.9 bc
'Swingle' Citrumelo	32.3 c	75.0 c	107.3 b	30.1 c
<i>C. volkameriana</i>	197.2 b	198.3 ab	395.5 a	47.7 ab

^z Values are the means of 10 trees.

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

^x Fruit harvested on 9/28/00 as a percentage of the total fruit harvested during the season.

Table 3. 2001-02 yields and percentage of fruit harvested early of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Yield per tree (lb.).			Pct. Fruit Harvested Early ^x
	9-27-01	11-28-01	Total Yield	
'Carrizo' Citrange	34.8 b	135.9 c	170.8 c	21.2 a
<i>C. macrophylla</i>	145.8 a	454.8 a	600.1 a	23.6 a
'Rough Lemon'	112.1 a	397.7 ab	509.8 b	22.8 a
'Swingle' Citrumelo	29.6 b	109.1 c	138.7 c	27.3 a
<i>C. volkameriana</i>	130.9 a	344.8 b	475.7 b	27.7 a

^z Values are the means of 10 trees.

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

^x Fruit harvested on 9/27/01 as a percentage of the total fruit harvested during the season.

Fig. 1 1995 -2002 'Limoneira 8A Lisbon' Lemon Yields on Five Rootstocks

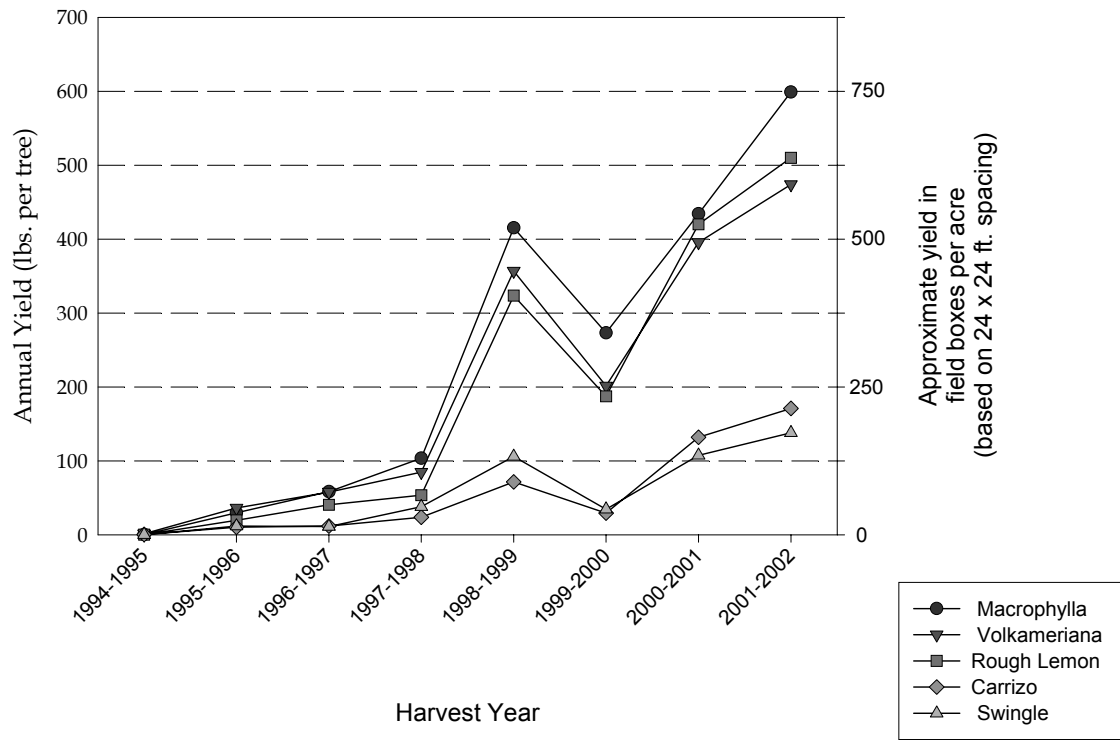
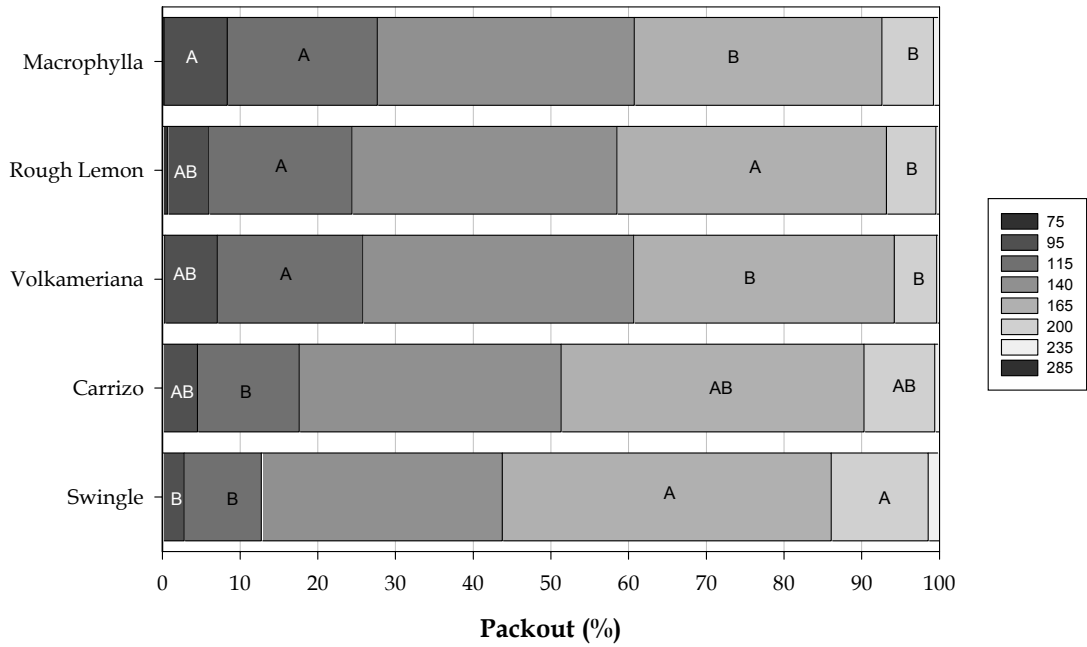


Fig. 2. 2001-02 'Limoneira 8A Lisbon' Lemon Packout on Five Rootstocks
 - 9/27/01 Harvest
Cultivar



Letters indicate significant differences within fruit sizes. Within a fruit size, letters that are the same indicate no significant effect of rootstock upon percentage of fruit within that size category.

Table 4. Yields from 1998-2002 of 'Limoneira 8A Lisbon' lemon trees on six different rootstocks.

Rootstock ^z	Yield per tree (lb.).					
	Total 1998-99 Yield (lbs.)	Total 1999-2000 Yield (lbs)	Total 2000-01 Yield (lbs.)	9-27-01 Harvest Yield (lbs.)	11-28-01 Harvest Yield (lbs.)	Total 2001-02 Yield (lbs.)
<i>C. volkameriana</i>	18.64 a	121.01 a	143.32 a	27.60 a	231.48 a	259.08 a
C-35 Citrange	7.21 b	49.15 b	68.42 b	5.22 b	69.38 b	74.60 bc
Citremon 1449	5.14 b	47.13 b	83.61 b	24.86 a	90.25 b	115.11 b
<i>C. taiwanica</i>	4.69 b	33.13 b	53.61 b	4.82 b	57.41 b	62.23 c
African Shaddock x Rubidoux trifoliolate.	2.20 b	23.38 b	58.42 b	16.44 ab	74.17 b	90.61 bc

^z Values are the means of 9 to 15 trees.

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

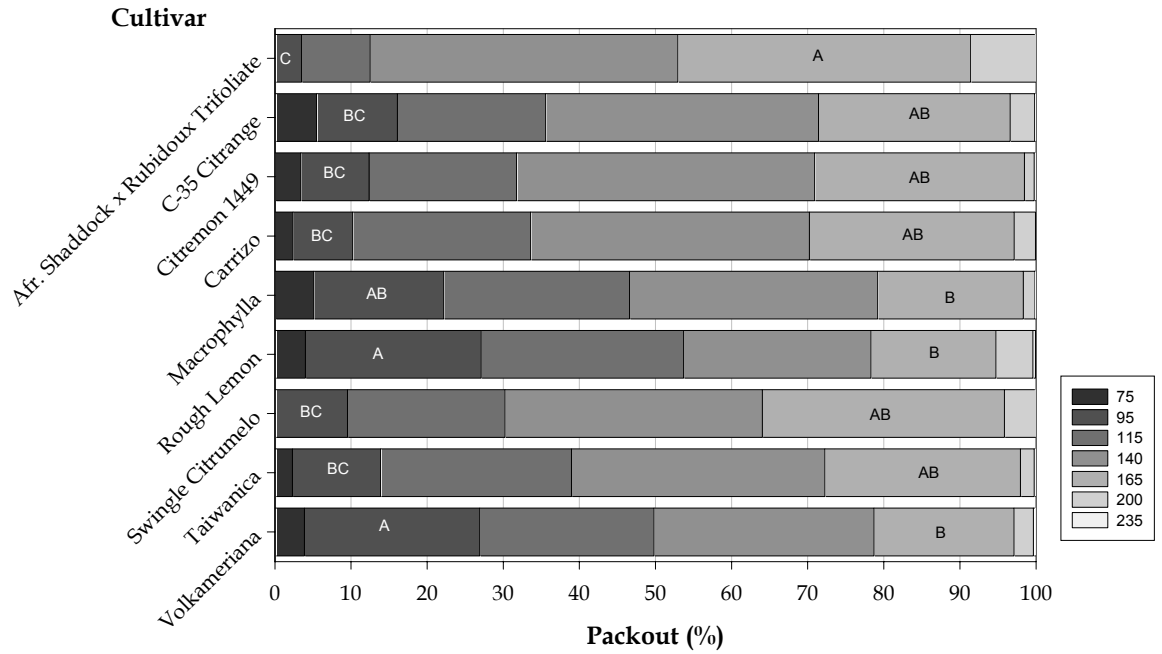
Table 5. Yields during 1998-2002 of 'Limonero Fino 49' lemon trees on nine different rootstocks.

Rootstock ^z	Yield per tree (lb.).					
	Total 1998-99 Yield	Total 1999-2000 Yield	Total 2000-01 Yield	9-27-01 Yield	11-28-01 Yield	Total 2001-02 Yield
<i>C. macrophylla</i>	21.46 a	38.75 a	102.8 a	71.40 a	181.72 a	253.12 a
C-35 citrange	6.26 a	12.43 bc	31.2 b	19.97 bc	58.69 bc	78.67 bc
Swingle Citrumelo	8.70 a	20.57 abc	40.8 b	2.00 c	38.31 c	40.31 c
Carrizo Citrange	8.49 a	7.56 bc	32.0 b	17.52 bc	52.98 bc	70.50 c
Citremon 1449	5.69 a	23.74 abc	52.8 b	16.53 bc	77.24 bc	93.77 bc
<i>C. volkameriana</i>	4.21 a	28.79 ab	50.9 b	41.96 b	94.67 b	136.63 b
Afr. Shaddock x Rubidoux trifoliolate.	5.65 a	4.34 bc	13.1 b	5.78 c	43.15 c	48.92 c
<i>C. taiwanica</i>	3.51 a	2.62 c	26.4 b	3.88 c	31.40 c	35.28 c
'Rough Lemon'	2.04 a	3.44 c	32.2 b	32.56 bc	62.68 bc	95.24 bc

^z Values are the means of 9 to 15 trees.

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

Fig. 3. 2001-02 Packout of 'Limonero Fino 49' Lemon on Nine Rootstocks
9/27/01 Harvest



Letters indicate significant differences within fruit sizes. Within a fruit size, letters that are the same indicate no significant effect of rootstock upon percentage of fruit within that size category.