Citrus Rootstock Acquisition and Evaluation — 2016[1]

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Introduction

There is no disputing the importance of citrus rootstocks and scions to desert citrus production. Rootstocks must be adaptable to 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. New rootstocks will improve the profitability of the Arizona citrus industry.

C. macrophylla and *C. volkameriana* are the standard, vigorous rootstocks used widely across the Arizona and California desert lemon industry. They are both vigorous, and produce high-yielding trees with fruit of excellent size. Lemon trees on both rootstocks are relatively cold-sensitive and are susceptible to the brown wood rot fungi (*Coniophora eremophila* and *Antrodia sinuosa* that plague desert lemons. Also, *C. volkameriana* is susceptible to "winter yellows", and tends to produce excessive numbers of trunk suckers.

Many years ago, sour orange (*Citrus aurantium* L.) was the common rootstock for lemon in Arizona as it was the only rootstock available and is quite adaptable to the highly alkaline desert soil. Sour orange is of medium vigor and may be used to reduce the vigor of lemon scions (Ferguson *et al*., 1990, Roose 2014). However, it fell out of favor because its yields are less than more recently introduced rootstocks, such as Carrizo. Carrizo (*Citrus sinensis* x *Poncirus trifoliata*) is commonly used as a rootstock for oranges, mandarins and lemons in Central California, and for oranges and mandarins in the desert. It is not commonly used for lemons in Arizona because yield and fruit size are less than for trees budded to *C. macrophylla* and *C. volkameriana*, and because it is not particularly tolerant of alkaline soils. Trees on Carrizo are known to have bud unions with a shoulder, where the scion diameter is smaller than the rootstock diameter. This condition is sometimes indicative of delayed incompatibility (Roose, 2014). Rangpur lime (*Citrus limonia*) has never been widely used in the United States, but it is quite common in Brazil, where it is used as a rootstock for oranges. In Brazil, Rangpur is known to confer drought tolerance on the scion. Rangpur lime is vigorous and produces well on deep sandy soils.

Bitters (C-22), Carpenter (C-54) and Furr (C-57) citrandarin (*Citrus sunki* x Swingle citrumelo [*Citrus paradisi* x *Poncirus trifoliata*]) are hybrids of 'Sunki' mandarin and Swingle citrumelo. All three were developed at the USDA citrus breeding program in Indio, CA and were released by the University of California in 2009. According to Siebert *et al.*, (2010), Bitters produces a small tree with high yield relative to canopy volume. Trees budded to Bitters are freeze tolerant, CTV tolerant, *Phytophthora* tolerant, and adaptable to high pH soils. Bitters is not tolerant of citrus nematode. Carpenter produces medium to large trees with good yield that are freeze tolerant. This rootstock is tolerant of CTV, and citrus nematode and moderately tolerant of *Phytophthora* and calcareous soils. Trees budded to Furr are similar to those on Carpenter, but are more tolerant of *Phytophthora* and citrus nematode.

In January 2016, we initiated a new lemon rootstock trial, the first to be planted at the University of Arizona's Yuma Mesa farm since 1993. The purpose of the trial was to evaluate the effect of the above-mentioned rootstocks on yield, fruit size, precocity, tree size, interior and exterior fruit quality and disease tolerance (especially tolerance to brown wood rot – *Antrodia sinuosa*). High yielding, precocious trees with large fruit size are favored by the desert lemon industry. Desert lemons are marketed from mid-August to February. During the early and middle part of that window, lemons from other suppliers can be limited and sizes can be small, so high quantities of large fruit translate to good

[1] The author wishes to thank Mr. Arturo Moreno and Mr. Hector Inzunza for their assistance in completing this project. Also, the author thanks the staff at Lyn Citrus Seeds, Mr. Mark Loghry of Sunset Nursery and Mr. Roger Smith of TreeSource nursery for producing the trees. The author would also like to thank the Arizona Citrus Research Council for supporting this research. This is a final report for project 2016-02 entitled "*Citrus Rootstock Acquisition and Evaluation — 2016*". Information presented here is from January 1, 2016 through June 30, 2017.

returns to the grower. Rootstocks are also known to affect drought tolerance, peel thickness, peel smoothness, fruit total soluble solids and acid levels, and percentage of juice in the fruit (Ferguson *et al*., 1990). Also, rootstocks can affect the growth of the brown wood rot fungi, *Antrodia sinuosa*, in the scion (Matheron and Porchas, unpublished data).

Following the presentation of the project to the Arizona Citrus Research Council in November 2015, the Council requested that the project be replicated using flood irrigation, which was the original irrigation method, and using pressurized irrigation. The Council's rationale for the change was that although flooding is the common method of irrigation for the Arizona lemon industry, a block of lemons on pressurized irrigation will demonstrate that high-quality lemons can be grown using less water, and that the water savings versus flood can then be documented. Also, growers and the authors suspect that high orchard humidity due to flood irrigation may be one of the causes of the growth of the *Antrodia sinuosa* in the orchards. It is possible that the use of pressurized irrigation will reduce the orchard humidity and slow the spread of this serious disease. The changes were made to the original plan of work, and the project was resubmitted and approved in January 2016.

Materials and Methods

Planning for the trial was started in October 2015. The lemon scion selected for the trial was 'Corona Foothills', because of its popularity among Arizona lemon growers. The rootstocks selected in the original work plan were *Citrus macrophylla* (Macrophylla) as a control, Brazilian Sour orange, Carrizo citrange, Rangpur Lime, Bitters citrandarin, Carpenter citrandarin, and Furr citrandarin. *Citrus volkameriana* (Volkameriana) was added as a control rootstock in the revised plan of work in January 2016. Macrophylla, Volkameriana, Carrizo citrange and Brazilian sour orange rootstocks were grown from seed at Sunset Nursery, Yuma, AZ. Seeds of Rangpur lime were purchased from Lyn Citrus Seed (formerly Willits and Newcomb, Inc.) of Arvin, CA, and were delivered to Sunset Nursery in February 2016 for planting. The three citrandarin rootstocks were grown to a height of 10 to 15 inches at TreeSource Nursery, Exeter, CA. They were then delivered to Sunset Nursery in July 2016 for budding. Trees were budded and hardened off at Sunset Nursery and were ready for planting in May 2017.

The experimental site is Block 6 of the Yuma Agriculture Center, Mesa Farm. This block is divided into an east section (Block 6E) and a west section (Block 6W) by a small irrigation canal, as seen in Fig. 1.

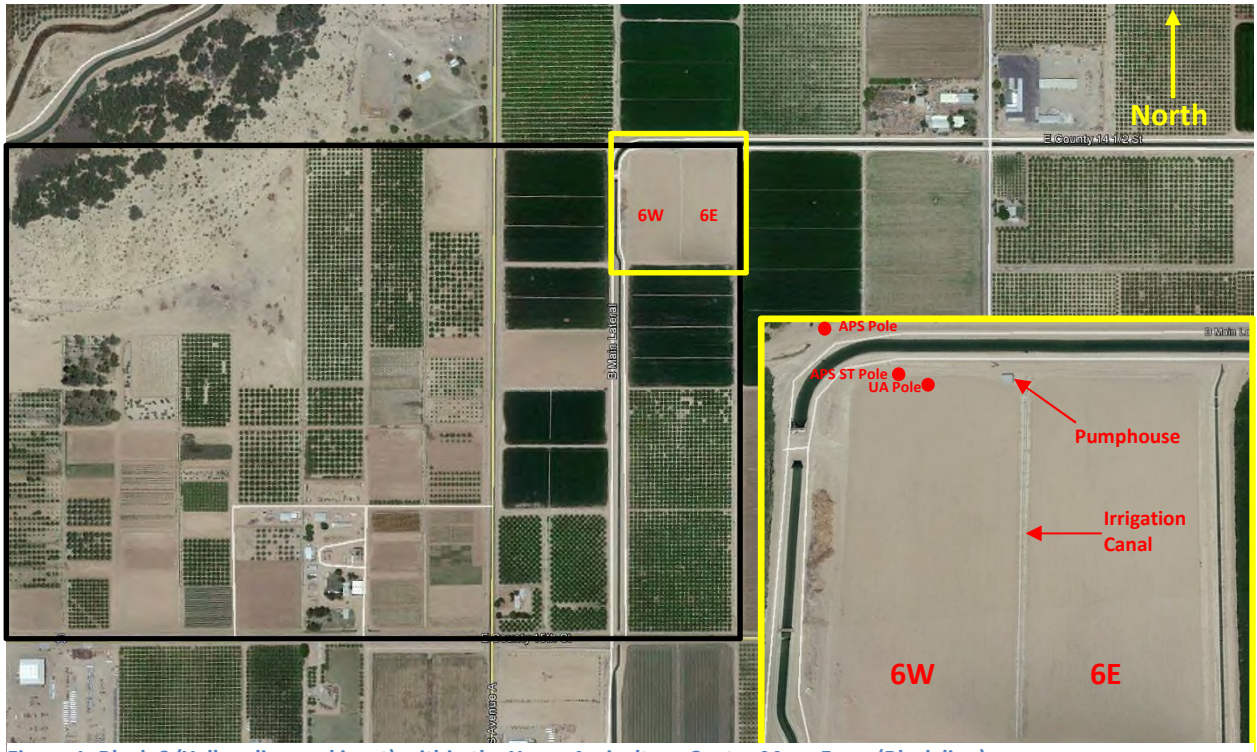

Figure 1. Block 6 (Yellow line and inset) within the Yuma Agriculture Center Mesa Farm (Black line).

There is also a small pumphouse at the north end of the irrigation canal that we planned to use to house the pump, filters, injectors and controllers for the pressurized irrigation system to be established in field 6W (Fig. 2). The UA built this structure in the 1970's for another pressurized irrigation study, but it fell into disrepair because it had not been in use for at least 25 years. We spent considerable time cleaning out the structure, improving its stability, patching the roof, installing new walls made of corrugated metal, and installing new doors made of expanded steel. Also, the pumphouse was not connected to any source of electricity, therefore we contacted Arizona Public Service (APS) to have the connection made from a pole on the north side of the B Main Lateral canal (APS pole as seen in the inset) to transformer on an APS subtransmission line pole (APS ST pole as seen in the inset) on the south side of the Lateral, and finally to a pole and meter box that we installed on the south side of the canal (UA pole – Fig. 3). From the pole, the electric line passes underground to the pumphouse. Bureaucracy and red tape at APS and the UA slowed the electrification process; eighteen months passed from the first contact with APS to completion of the job.

Figure 2. Pumphouse at the north end of Block 6.

Figure. 3. UA Pole and APS High Transmission pole that holds a transformer on the south side of the B Main Lateral canal.

Parts for the pressurized system were ordered just before June 30, 2017 through Sprinkler World (Tucson, AZ). These parts include the pump, filters, valves, injectors, flow meters, drip tube, cellular-connected weather station, soil moisture station, and soil moisture probe. Many of the parts are manufactured by Rainbird.

Water from the B Main Lateral canal can flow through a slide gate into the small canal that bisects the block, and the flood irrigation side of the experiment, in Block 6E, would be irrigated using the canal. From the outset, it was unclear how water from the Lateral was to enter the pumphouse to supply block 6W. A few UA employees who had seen the previous pressurized system in action recalled that there was a pipe extending from the wall of the Lateral canal to the pumphouse, but no one remembered its exact location. We spent considerable time digging around the pumphouse, but initially did not find anything. However, we found the pipe in November 2016, when the Lateral was drained for annual maintenance by the Unit B Irrigation and Drainage District. The pipe was cleaned out, extended to the pumphouse and capped with a valve in anticipation of connecting it to a pump. It is important to note that although block 6W will be primarily irrigated using pressurized irrigation, there will be the ability to flood this block until the pressurized system is installed and subsequently in case extra water is needed for fruit sizing in the late summer or for a freeze event.

While all this preparatory was progressing, block 6 contained alfalfa. The final cutting was taken in May 2017, and the alfalfa was disked under. Then we irrigated the field, laser-leveled it with a slight slope and irrigated again. Seventy-five trees budded to each of the eight rootstocks were picked up from Sunset Nursery on June 12, 2017 and moved to a lath house at the Mesa Farm. Tree height, scion and rootstock trunk diameter measurements were taken for each tree, then 561 trees were planted on June 15th. Thirty-nine trees were kept on reserve in case there were any mortalities. Tree trunks were wrapped with cardboard tree wraps in the field the following week.

Tree spacing is 22 ft. between rows and 22 ft. within the row. There are 11 trees per row. Block 6E has 26 rows while block 6W has 25, due to the need to maintain space on the north end of the block for the UA pole and the underground electrical line that is connected to the pumphouse. For the experiment, there are 27 'Corona Foothill' trees of each of the eight rootstocks planted in rows 2 through 25 of both block 6W and 6E, giving 216 experimental trees in block 6W and 6E, for 432 experimental trees in total. The statistical design of the experiment is Randomized Complete Block. Within 6W and 6E, there are nine replications, each including eight groups of three trees, one for each of the eight rootstocks. Each three-tree group is randomized within a replication, thus there are 24 trees within each replication.

There are guard rows around the experimental trees in 6W and 6E encompassing all of rows one and 26, as well as all trees nearest and farthest from the small irrigation canal. In total, 129 trees are used as guard trees. and all the trees appear to be healthy (Figs. 4 and 5). Each tree was assigned a number and a color, which can be seen in the plot plan (Fig. 6).

Figure 4. Panorama of the experimental plot, looking from the southwest corner.

Figure 5. Representative tree in the experiment after about 100 days.

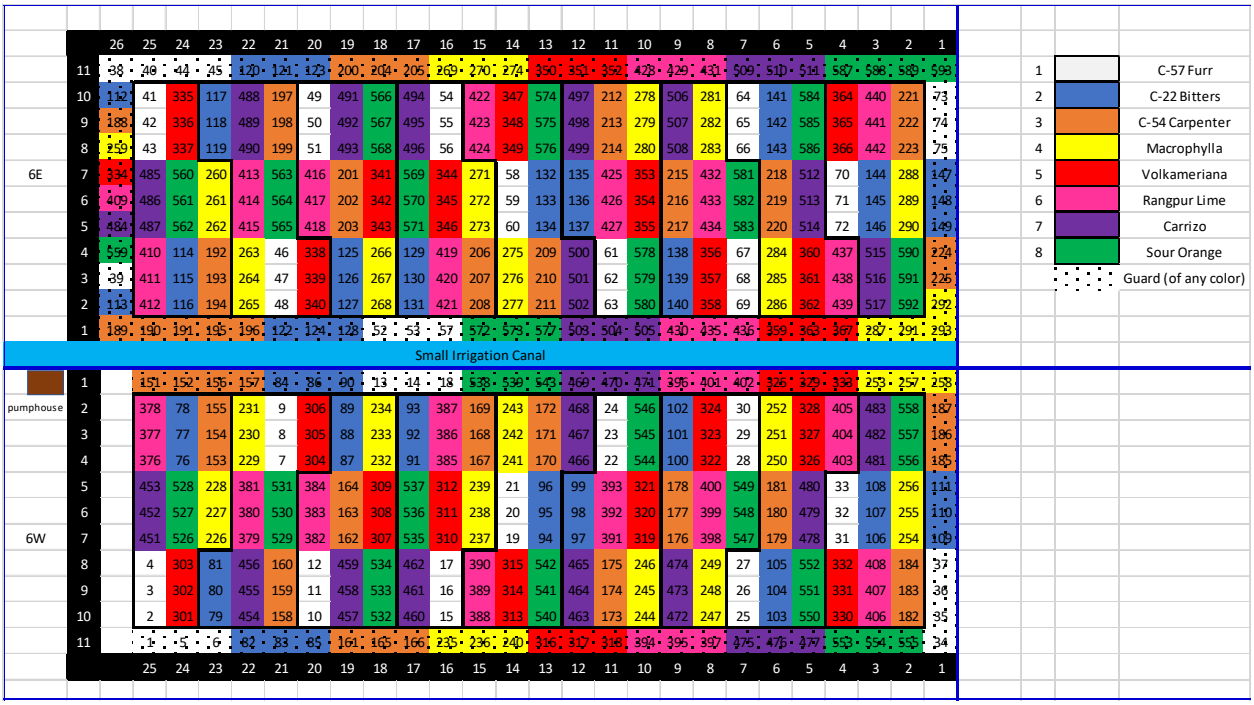

Figure 6. Experimental plot plan.

Results and Discussion

The only data collected so far has been the tree height and scion and rootstock trunk diameters (Table 1). From the diameter data, we also calculated a scion:rootstock diameter ratio. Height of the seedlings ranged from about 88 to 96 cm. Lemons budded to Macrophylla, Rangpur Lime and Volkameriana were significantly taller than all the other rootstocks, from 94 to 96 cm, while Furr was significantly shorter than the rest, at just under 88 cm. Carrizo, Bitters, Sour Orange and Carpenter were intermediate in height. Scion diameter ranged from about 5.6 to just over 6.5 cm. Volkameriana has the greatest scion diameter of just over 6.5 cm., followed by Rangpur lime and Carpenter, both at least 6 cm. Macrophylla was next at 5.9 cm, followed by Carrizo, Bitters, and Sour Orange, at about 5.6 to 5.7 cm.,

and Furr, at less than 5.6 cm. Rootstock diameter was larger than scion diameter, ranging from about 6.8 cm to 8 cm. Volkameriana and Carrizo had the greatest rootstock diameter, at 7.9 to 8.0 cm., followed by Macrophylla and Carpenter at about 7.6 cm. Furr and Rangpur lime followed with diameters between 7.1 and 7.2 cm., while Bitters and Sour Orange had the smallest rootstock diameters – less than 6.9 cm. Scion to Rootstock Diameter ratio ranged from 0.72 to 0.87. Trees on Rangpur lime rootstock had the greatest ratio of 0.87, indicating that there is little evidence of a shoulder forming at the bud union of these trees. Sour Orange, Bitters, Volkameriana and Carpenter all had ratios between 0.84 and 0.8. Furr and Macrophylla had lower ratios of 0.79 and 0.78 respectively. The diameter ratio of trees budded to Carrizo was the least, at 0.72, suggesting that a shoulder is most likely to develop on this scion/rootstock combination as was reported by Roose (2014).

Table 1. Height, scion and rootstock trunk diameter and scion to rootstock trunk diameter ratio of 'Corona Foothills' lemon trees budded to eight rootstock selections.

Rootstock	Height (cm)	Scion Diameter (mm)	Rootstock Diameter (mm)	Scion:Rootstock Ratio
Macrophylla	95.75 a	5.91 c	7.62 b	0.78 e
Rangpur Lime	94.65 a	6.14 b	7.11 c	0.87 a
Volkameriana	93.93 a	6.52 a	8.03 a	0.82 cd
Carrizo	90.93 b	5.66 d	7.90 a	0.72 f
Bitters (C-22)	90.88 b	5.59 d	6.77 d	0.83 bc
Sour Orange	89.81 bc	5.73 d	6.86 d	0.84 b
Carpenter (C-54)	88.69 bc	6.00 bc	7.57 b	0.80 de
Furr (C-57)	87.85 c	5.63 d	7.15 c	0.79 e

Plans for the Next Fiscal Cycle

Some of the activity for the next fiscal cycle, January 2017 to March 2018 is reported here since there is overlap in the ACRC project fiscal cycles. Beginning in July 2017, we expect to receive the remaining parts for the pressurized system and begin installation. We expect that installation will be complete by December 2017. After a training session conducted by Rainbird, we will begin to operate and monitor the pressurized system in Block 6W. We will begin to collect data on water use at that time. Meanwhile, we will carry out normal fertilization, pest control and weed control in both blocks, apply flood irrigation in Block 6E in accordance with normal horticultural practices.

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