FINAL REPORT Covering FY2011

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Project Title: Citrus Rootstock Breeding and Evaluation

Project Objectives and Timetable: *(from original proposal milestones; and justify any revisions to milestones)*
The original proposal outlined 9 major objectives for 2011. These are listed below with summaries of results. Most objectives were completed, but we did not screen new hybrids for nucellar embryony or initiate the salinity tolerance test. Other activities required more effort than planned and we decided that these tests could be delayed.

FY2011 Progress and Findings*:*
1) Evaluation of existing rootstock trials. Nine trials were scheduled for evaluation (tree size measurements, health, budunions etc.) during the current year and 6 have been completed.
a) The three **lemon rootstock trials** in Ventura Co. have not yet been measured.
b) The large **South Coast tristeza trial** was measured as planned. A full summary of the results is shown in Tables 1 and 2 below. Survival of trees on most rootstocks was 100% or nearly so, whereas that of trees on Brazil sour orange and 7 hybrids of Chandler pummelo x trifoliate orange was much lower (44-73%). Trees on these rootstocks and a few others also had low tree health ratings, and trees were small. These trees are either CTV susceptible or poorly adapted to this site. Trees on Carrizo and several other released rootstocks were among the largest and healthiest in the trial. Trees on ASRT, which are large and vigorous at most other sites, had high survival and fair-good tree health ratings, but were small in size, suggesting a stunting effect of CTV as reported by others. Dwarfing rootstocks with good tree health include Flying Dragon, several selections that originated as self-pollinated seedlings of trifoliate orange, Bitters (C22) and some hybrids from the USDA breeding program in Florida including US942, US896, and US812. Several experimental rootstocks appear quite promising.
c) For the **Lindcove mandarin scion-rootstock tr**ial, we collected tree size, health, and yield data on all trees, packline data on all 6 satsuma selections, and fruit quality data on S9 satsuma. The two imported selections Miyanchi Lyokah tangor and Soh Himtra mandarin do not appear to have acceptable fruit quality and are not reported here. Soh Himtra may have compatibility issues with these rootstocks based on pitting and shoulder bark cracking on many trees. Trees on Rubidoux trifoliate and Rich 16-6 trifoliate were smaller than those on Carrizo with trees on C35 intermediate in size (Table 3). 2010 yield was higher for the larger trees on Carrizo and C35 than those on the trifoliate orange rootstocks. Yield relative to tree size was highest for trees on C35. When averaged over rootstocks trees of S2 and Iveriya were largest, followed by S6 and S7, with S9 and Aguzdera producing the smallest trees (Table 4). Tree health ratings were approximately proportional to tree size, with trees of Aguzdera having the lowest rating and highest sucker count. Aguzdera appears to have a compatibility problem with Carrizo and the trifoliate oranges (Table 5). Based on packline data, in the 2010-11 crop, S2 had the largest fruit size, followed by Aguzdera, and then the other four selections (Table 6 and figures). Among rootstocks, fruit from trees on Carrizo was smaller than that from trees on the other three stocks. Fruit quality characteristics were determined for S-9 satsuma only in October 2010 and November 2011. Fruit from trees on trifoliate had slightly higher soluble solids than that from trees on Carrizo or C35. In 2010,

acid was slightly higher in fruit from trees on trifoliates, but then was not observed in fruit harvested relatively late in 2011 (Table 7).
d) For the **Lindcove Fukumoto trial**, we collected new tree size data in 2010-11 and additional yield and packline data in 2011-12. Based on packline fruit counts, trees on Volk had more fruit in 2009 and 2010 than those on Carrizo or C35 (Table 8). Trees propagated from different bud sources did not differ in tree size, health, or yield (Table 9). November 2010 fruit quality data (Table 10) show that the largest fruit were from trees on C35 and the smallest from trees on Carrizo. Rind color was deeper orange for Carrizo and Volk. Fruit from trees on Volk had thicker rinds, lower Brix, and lower acidity than those from trees on Carrizo and C35. Trees propagated from different bud sources did not differ in fruit quality characters (Table 11). The 2011 data have not yet been analyzed.
e) Three **rootstock trials for Tango** mandarin were planted in 2008 and 2009. Trees in the 2009 trials are rather young to measure canopy volume. For the 2008 trial on a clay soil near Porterville, the largest trees were on Yuma Ponderosa, Volk and Schaub rough lemon (Table 12). Trees on trifoliate orange selections were very chlorotic and grew poorly. Trees on Bitters and Carpenter were among those with low chlorosis and good tree health. Fruit counts were collected in Dec. 2011 on trees in all of these trials to evaluate early fruiting, but these have not yet been analyzed.
f) Trial site characterization: We have maintained the dataloggers at each site and downloaded data. Additional soil samples were collected at the new UCR trial (see 2 below) and the Woodlake Moro trial.

2) Propagate trees for new trial to test early bearing and adaptation to high intensity management. Trees of Washington navel orange on 28 rootstocks were planted at UCR on September 14, 2011 using a randomized complete block design with 10 single-tree replicates and guard rows. Tree spacing is 6.5 foot within rows. The trial was planted on berms about 16 inches high, after amending the soil with compost and gypsum according to a soil test. John Deere Water generously provided two CropSenseTM monitors that were placed adjacent to trees on Carrizo and Rubidoux trifoliate to measure soil moisture on a continuous basis and optimize irrigation. The trial also uses a weed block fabric cover on the beds. Nearly all trees grew well after planting. Rootstocks included in this trial are listed below:

Af. Shad. X Rub. trif (ASRT)
Argentine sweet orange
Bitters (C22)
Brazil sour
C146
C35
Carpenter (C54)
Carrizo
Cleopatra mandarin
Flying Dragon
Furr (C57)
Macrophylla
Obovoidea
Pomeroy trifoliate
Rangpur x Marks trifoliate
Rangpur x Shekwasha
Rangpur x Swingle trifoliate
Rich 16-6 trifoliate
Rubidoux trifoliate
Schaub rough lemon
Shekwasha x Eng.trifoliate
Santa Barbara Red Lime
Sun Chu Sha
Sunki X Flying Dragon
Swingle
Tosu
Volkameriana
Yuma Ponderosa Lemon

3) Propagate trees for trials of Clementine and DaisySL. Trees were budded at Lindcove in September 2011. DaisySL buds were tracked by budsource-branch so we can determine whether production of seedy fruit (if any) is related to the bud source used. The experimental trees will be Nules Clementine, with guard row trees of Sidi Aissa to allow comparison of these varieties. We thank B&Z Nursery for providing help with the budding. The rootstocks grown for this trial are similar to those listed above. The Clementine buds have pushed and grown well, but many of the DaisySL buds have not and many of the DaisySL trees are fairly chlorotic. We will assess this in more detail in spring when the fate of all buds has become clear. With researchers from Florida, Texas and Arizona, we have applied for USDA-SCRI program funding to explore high-density plantings and high-intensity management of citrus. If this proposal is funded, we will likely plant the Clementine trial at Lindcove (as planned) but using high density, berms, and more sophisticated irrigation and fertigation controls (similar to the new Washington navel trial at UCR). The DaisySL trial may be planted at the UCR CVARS

station instead of Borrego Springs because data collection and tree management will be easier at the nearer field station location.

4) Screen selected new hybrids for nucellar embryony. We did not collect seed of new hybrids for screening in fall 2010. Seedlings for the Clementine and DaisySL trials were not growing well at Lindcove and it appeared that we might have to replant all of the rootstocks for this trial, so we recollected seed of the selections included in this trial. Leaching and additional fertilizer application eventually resulted in reasonable seedling growth at Lindcove, but we had already collected seed of the trial seedlings and were unable to do more.

5) Iron chlorosis tolerance screening. We screened 26 rootstocks for iron chlorosis tolerance. Most of these are standard rootstocks or advanced selections, essentially the same set as included in the trials listed above. The most susceptible rootstocks were trifoliate orange selections, which were slightly chlorotic even in normal greenhouse soil. X639 showed as much chlorosis as the trifoliates. C35 and Swingle were also quite susceptible. The most tolerant rootstocks based on chlorosis ratings were Macrophylla, Brazil sour orange, Bitters trifoliate hybrid (C22), ASRT, Volk, and Cleopatra. For growth, measured as change in total shoot length (including branches), there were significant differences among rootstocks but the interaction between calcium carbonate level and rootstock was not significant (all rootstocks responded similarly). Possibly a more sophisticated analysis of growth will show significant interaction. It should be interesting to compare the chlorosis observed on budded DaisySL trees with that seen on rootstock seedlings.

6) Test hybrids for Phytophthora root rot resistance. A total of 27 rootstock hybrids were tested for tolerance to *P. citrophthora* as planned. The rootstocks tested are essentially the same as listed in section 2) above. The trial was completed and each plant photographed, but we have not completed rating the root systems.

7) Test rootstocks for salinity tolerance. Seedlings were grown for the planned salinity test, and some of the necessary equipment was obtained, but the experiment has not been initiated. The Washington navel orange rootstock trial at UCR became much more complex to set up than we had expected and no time was left to initiate the salinity trial. We hope to initiate this trial in spring 2012.

8) New hybridization. Crosses were made onto three females that have previously demonstrated low levels of nucellar embryony and other traits of interest: 2 hybrids of Tahitian Pummelo X Flying Dragon, and 1 hybrid of Tahitian Pummelo X Carrizo. We used pollen from Shekwasha X English trifoliate, Furr (C57), and Bitters (C22), all of which have high levels of nucellar embryony. At least two pollen parents were used on each female. Several hundred seeds were obtained.

9) Investigate compatibility problems. We consulted with other researchers and nurseries regarding compatibility problems in satsuma, Beck navel, and Fukumoto. No new experiments were initiated this year.

Funding:

Carryin Agency Funds 0 **Agency Funds Used** 22,000 **Agency Funding** 22,000

Carryover Agency Funds 0 **Non-Agency Funds Used** 150,000 (UC and CRB)

Signature _____ **Date** _____

Table 1. 2006 Tristeza Trial at South Coast Research and Extension Center. Trees inoculated with 4 isolates of CTV at planting. Measured in Sept. 2011. Ranked by 2011 tree health rating which used a 0-5 scale with 0=dead and 5=excellent. Fruit count is a visual estimate. Dead trees treated as missing except for Health Rating =0. See next page for stock codes.

Stock	Survival (%)	2007 Health	2008 Health	2011 Health	2008 Canopy Vol. (m3)	2011 Canopy Vol. (m3)	2011 Union Rating	2011 Fruit Count
RR86-10-12 (ChxTf)	43.8	2.63	1.94	0.64#	0.29	0.70	4.83	10.3
Brazil sour	56.3	2.31	1.75	0.88#	0.31	0.31	4.56	12.7
RR86-10-35 (ChxTf)	53.8	2.96	2.15	1.12#	0.50	1.17	5.00	16.4
RR86-10-54 (ChxTf)	60.0	3.17	2.15	1.28#	0.75	1.72	3.67	22.5
RR86-10-46 (ChxTf)	68.8	2.81	2.09	1.31#	0.39	0.61	5.27	13.8
RR86-10-77 (ChxTf)	72.7	3.27	2.50	1.43#	0.71	1.20	4.69	39.9
RR86-10-84 (ChxTf)	72.7	2.86	2.09	1.55#	0.52	0.97	3.86	33.3
RR86-10-89 (ChxTf)	73.3	2.83	2.60	1.58#	0.51	1.26	4.00	48.1
RR86-10-94 (ChxTf)	92.3	3.00	2.58	1.62#	0.43	0.71	4.50	30.9
RR83-9-48 (FD self)	100.0	3.13	3.21	2.06#	0.36	0.63	2.33	11.7
RR84-6-14 (FD self)	100.0	3.00	3.30	2.12#	0.32	0.64	2.13	18.8
RR85-8-3 (FD self)	92.3	3.35	3.38	2.23#	0.50	0.79	2.27	23.1
US897 (CleoxTf)	93.8	3.75	3.31	2.36	0.94	1.15	3.93	37.8
Flying Dragon	100.0	3.57	3.63	2.72	0.54	0.89&	1.93	32.4
RR84-8-23 (Rt self)	100.0	3.28	3.22	2.80	0.72	1.92&	3.00	69.3
US942 (SkxTf)	100.0	3.88	4.13	2.94	1.41	2.44	4.03	109.6
RR83-2-1 (FD self)	100.0	3.63	3.41	2.97	0.75	1.93&	2.60	59.3
RR83-1-101 (Pt self)	100.0	3.50	3.35	3.04	0.80	2.19	3.12	62.6
RR83-02-74 (FD self)	100.0	3.70	3.77	3.07	0.81	2.50	3.20	83.3
RR84-1-8 (Pt self)	100.0	3.43	3.61	3.11	0.69	2.37	2.50	78.0
US896 (CleoxRtf)	100.0	3.94	4.03	3.11	1.13	2.44	4.59	85.1
RR83-2-64 (FD self)	100.0	3.46	3.61	3.16	0.60	1.80&	2.50	72.4
US812 (SkxBTf)	100.0	3.86	4.21	3.18	1.33	3.54	3.86	113.2
RR85-13-15 (Rt self)	100.0	3.43	3.70	3.25	0.75	2.49	3.77	103.8
RR85-12-25 (Pt self)	100.0	3.59	3.59	3.27	0.83	2.01&	2.31	67.8
Bitters (C22)	100.0	3.97	4.09	3.28	1.32	2.74	4.88	109.4
RR84-2-7 (Pt self)	100.0	3.66	3.69	3.31	0.95	3.01	2.72	107.5
Rubidoux trifoliate	100.0	3.82	3.91	3.32	1.18	2.94	3.73	156.5
6A,38,05 (SkxFD)	100.0	3.83	4.03	3.33	1.25	3.03	4.17	100.1
Pomeroy trifoliate	100.0	3.83	4.00	3.40	1.01	2.93	2.92	138.0
6A,38,3 (SkxFD)	100.0	3.97	4.10	3.40	1.30	2.84	3.93	113.5
RR83-1-33 (Pt self)	100.0	3.75	3.72	3.41	0.85	2.70	2.78	84.7
ASRT	100.0	3.54	3.50	3.44	0.77	2.74	4.12	97.7
C35	100.0	3.94	4.19	3.50	1.72	3.71	3.94	151.6
RR86-10-15 (ChxTf)	100.0	3.88	4.13	3.58	1.29	4.50	4.33	147.9
LC53,19,13 (SkxJTf)	100.0	3.81	4.19	3.64	1.54	4.13	3.97	138.9
RR86-10-4 (ChxTf)	100.0	3.69	4.03	3.64	1.58	4.46	3.47	167.1
RR85-12-27 (Pt self)	100.0	3.68	3.89	3.64	1.22	3.22	3.04	136.9
RR86-10-72 (ChxTf)	100.0	3.67	4.25	3.65	1.23	4.32	3.08	142.4
Siam.Pum x R. trif.	100.0	3.80	4.00	3.65	1.61	5.87	3.95	174.4
C32	100.0	3.82	4.18	3.66	2.16	5.73	4.14	165.7
Furr (C57)	100.0	4.06	4.22	3.67	1.66	4.39	3.97	139.2
6A,38,07 (ShxEt)	100.0	3.75	4.06	3.75	1.33	3.93	4.25	126.5
LC53,19,08 (SkxPSO)	100.0	3.94	4.16	3.80	1.64	5.24	5.78	222.0
US802 (SPxTf)	100.0	3.47	3.72	3.83	1.09	4.10	2.56	114.3
Carpenter (C54)	100.0	3.90	4.17	3.88	1.76	5.93	4.43	245.0
Carrizo	100.0	3.67	4.03	3.90	1.63	6.33	4.03	196.1
RR86-10-19 (ChxTf)	100.0	3.90	4.10	3.90	1.86	5.29	4.77	187.1
RR86-10-38 (ChxTf)	100.0	3.84	4.09	3.98	1.94	6.51	3.59	179.6
RR86-10-60 (ChxTf)	100.0	3.97	4.30	4.00	2.35	6.67	4.33	242.7
Mean	93.9	3.56	3.58	2.97	1.09	2.91	3.65	104.1
LSD(0.05)		0.35	0.41	0.44	0.13	0.78	0.51	48.7

rootstocks with low health rating and tree size suggesting stunting or decline from CTV.

& - apparently dwarfing rootstock or one stunted by CTV with little effect on tree health.

Table 2. 2006 Tristeza trial at South Coast REC. Trees inoculated with 4 isolates of CTV at planting. Trees measured in Sept. 2011. Average over all CTV-positive trees.

CTV isolate	2011 Survival (%)	2007 Health Rating	2008 Health Rating	2011 Health Rating	2008 Canopy Vol. (m^3)	2011 Canopy Vol. (m^3)	2011 Union Rating	2011 Fruit Count
366	93.7	3.54	3.61	3.03	1.18	3.47	3.67	116.4
440	96.4	3.57	3.71	3.03	0.97	2.57	3.64	91.0
46	90.6	3.61	3.50	2.86	1.12	3.11	3.59	103.5
514	94.3	3.51	3.49	2.96	1.10	3.22	3.69	108.1
F-test		ns	*	*	*	***	*	ns

Analyzing only data on CTV-positive trees, the CTV isolate x stock interaction was statistically significant for tree health rating in 2008 and 2011, and for canopy volume and bud union rating in 2011, but not for 2007 tree health rating or 2011 fruit count. This indicates that the effects of CTV isolates varied among rootstocks. If all trees (any rootstock) testing negative for CTV (inoculated or not) are included as a fifth treatment, these 38 trees have significantly larger canopy volume and fruit counts than those of trees inoculated with any of the CTV isolates, but their 2011 tree health ratings do not differ from those in CTV-positive trees. This suggests that these CTV isolates reduce tree size and yield, but this might be due to reactions of susceptible combinations. There are too few negative trees on individual rootstocks and they are not randomly distributed in the field, so comparison of CTV-positive and CTV-negative trees within rootstocks is not possible.

Codes

RR86-10 = Chandler pummelo x trifoliate
RR83-1, RR84-1, RR84-2, RR85-12 = Pomeroy trifoliate x open pollinated
RR83-2, RR84-6, RR85-8, RR85-9 = Flying Dragon trifoliate x open pollinated
RR84-8, RR85-13 = Rubidoux trifoliate x open pollinated
6A,38,05 = Sunki mandarin x Flying Dragon trifoliate I-62-109-19
6A,38,07 = Shekwasha x English trifoliate
6A,38,3 = Sunki mandarin x Flying Dragon trifoliate I-62-109-1

LC53-19-8 = Sunki mandarin x Palestine sour orange
LC53-19-13 = Sunki mandarin x Jacobsen trifoliate
US802 = Siamese pummelo x trifoliate
US812 = Sunki mandarin x Beneke trifoliate
US896 = Cleopatra mandarin x Rubidoux trifoliate
US897 = Cleopatra mandarin x trifoliate
US942 = Sunki mandarin x trifoliate

Satsuma mandarin rootstock – scion trial at Lindcove, planted in July 2003. 8 trees per scion-rootstock combination. Tree size and health data recorded in April 2011. 2010 yield recorded in 2010-11 season. Dead trees were treated as missing in this analysis. There were only 5 dead trees in the trial: 2 of Aguzdera on Rich 16-6, and one each of Aguzdera on Rubidoux, S2 on Rich 16-6, and S7 on C35. F-tests indicate statistical significance in a General Linear Model analysis.

Trees on Carrizo were largest and those on the two trifoliate orange rootstocks were smallest. Trees on C35 were intermediate in size. Trees on the two trifoliate orange selections had somewhat lower tree health ratings than those on Carrizo and C35. Bud unions of trees on Carrizo were somewhat smoother, but differences among rootstocks were not significant. There were no significant differences among rootstocks in the number of suckers present. Trees on C35 and Carrizo had higher yields in 2010 than those on the trifoliate orange selections, and those on C35 had the highest yield per unit of canopy volume.

Table 3. Average performance of 6 satsuma selections by rootstock, ranked by canopy volume.

Rootstock	2011 Height (m)	2011 Canopy Vol. (m^3)	2011 Tree Health Rating (0-5)	2011 Budunion Rating (0-7)	2011 Sucker Count	2010 Yield (lb/tree)	Yield/ Canopy Vol. (lb/m^3)
Carrizo	1.78	5.45	3.84	3.38	0.27	104	21.54
C35	1.68	4.59	3.92	3.18	0.28	108	25.81
Rubidoux trif.	1.67	4.11	3.52	3.10	0.31	88	22.50
Rich 16-6	1.61	3.69	3.46	3.09	0.38	83	23.42
LSD(0.05)	0.72	0.49	0.21	0.34	0.33	9	3.15
F-test	***	***	***	ns	ns	***	*

S2 and Iveriya produced larger trees than the other four selections, with trees of Aguzdera being quite small. Tree health ratings were highest for S2 and Iveriya, lowest for Aguzdera, and intermediate for the other selections. Aguzdera produced the most rootstock suckers and was the only selection to produce scion suckers from near the budunion. This selection may have a compatibility problem with these rootstocks. The S9 selection had moderate yield and tree size.

Table 4. Average performance by scion, ranked by canopy volume.

Scion	2011 Height (m)	2011 Canopy Vol. (m^3)	2011 Tree Health Rating (0-5)	2011 Budunion Rating (0-7)	2011 Sucker Count	2010 Yield (lb/tree)	Yield/ Canopy Vol. (lb/m^3)
S2 Satsuma	1.87	6.32	4.09	3.23	0.19	102	16.50
Iveriya Satsuma	1.90	6.09	4.16	3.22	0.16	130	23.27
S6 Satsuma	1.72	4.74	3.77	3.17	0.00	104	22.43
S7 Satsuma	1.77	4.68	3.53	3.02	0.13	100	21.82
S9 Satsuma	1.53	2.99	3.59	3.58	0.28	76	26.47
Aguzdera Satsuma	1.31	1.95	2.97	2.91	1.09	58	30.01
LSD(0.05)	0.89	0.65	0.28	0.43	0.30	14	3.40
F-test	***	***	***	ns	***	***	***

Satsuma mandarin rootstock – scion trial at Lindcove. Generally there were few statistically significant scion x rootstock interactions, indicating that the main effects discussed above generally hold across all scions and rootstocks. The strongest interaction was for tree health where the tree health rating of Aguzdera on Rich16-6 was considerably below that on the other rootstocks.

Table 5. Performance of scion x rootstock combinations.

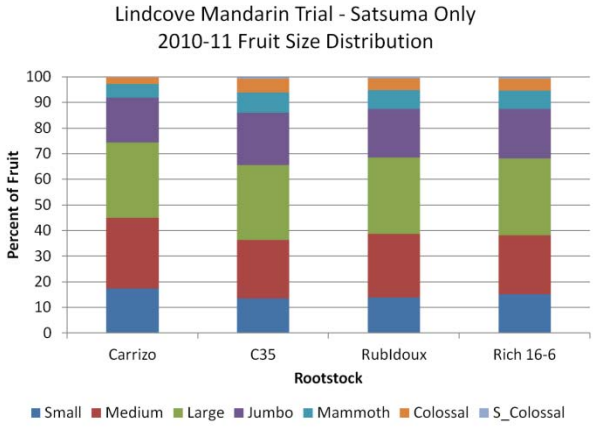
Scion	Rootstock	2011 Height (m)	2011 Canopy Vol. (m^3)	2011 Tree Health Rating (0-5)	2011 Budunion Rating (0-7 scale)	2011 Sucker Count	2010 Yield (lb/tree)	Yield/ Canopy Volume (lb/m^3)
S9 Satsuma	C35	1.51	3.18	3.88	3.75	0.88	84	27.40
	Carrizo	1.64	3.72	3.75	3.94	0.00	90	24.26
	Rich 16-6	1.48	2.36	3.44	3.31	0.00	62	26.49
	Rubidoux trif.	1.50	2.70	3.31	3.31	0.25	72	27.19
S7 Satsuma	C35	1.73	4.55	3.25	2.86	0.29	108	24.66
	Carrizo	1.89	5.94	3.63	3.00	0.00	116	19.32
	Rich 16-6	1.76	4.38	3.75	2.88	0.00	95	21.70
	Rubidoux trif.	1.69	3.82	3.50	3.31	0.25	82	21.95
S6 Satsuma	C35	1.64	4.64	4.00	3.06	0.00	125	28.13
	Carrizo	1.90	6.27	4.06	3.56	0.00	119	19.06
	Rich 16-6	1.61	3.76	3.56	3.25	0.00	80	21.03
	Rubidoux trif.	1.74	4.29	3.44	2.81	0.00	92	21.51
S2 Satsuma	C35	1.88	6.43	4.31	3.50	0.00	112	17.66
	Carrizo	1.95	8.05	4.19	3.44	0.13	111	13.96
	Rich 16-6	1.79	4.99	4.06	3.13	0.00	88	18.00
	Rubidoux trif.	1.88	5.80	3.81	2.88	0.63	96	16.56
Iveriya Sats.	C35	1.81	5.87	4.44	3.19	0.00	134	27.50
	Carrizo	2.03	7.09	4.25	3.38	0.13	137	21.14
	Rich 16-6	1.88	5.41	3.81	3.06	0.50	112	20.86
	Rubidoux trif.	1.89	5.99	4.13	3.25	0.00	135	23.58
Aguzdera Sats.	C35	1.50	2.85	3.63	2.69	0.50	82	29.35
	Carrizo	1.25	1.65	3.19	2.94	1.38	46	32.15
	Rich 16-6	1.16	1.24	2.13	2.94	1.75	53	34.49
	Rubidoux trif.	1.33	2.06	2.94	3.06	0.75	47	24.45
F-test (scion x stock interaction)		*	*	**	ns	ns	ns	ns

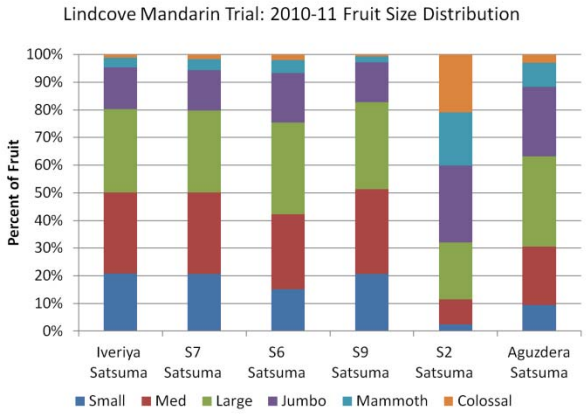
Satsuma mandarin rootstock – scion trial at Lindcove - packline results for scion x rootstock combinations. Fruit were harvested Oct. 27, 2010 (S9 satsuma) or Nov. 29, 2010 (all other satsumas). The packline recorded grade but it is not clear that this is meaningful because settings appropriate for satsumas could not be obtained. For all scions and rootstocks, more than 75% of fruit were classified as yellow-green in color, and less than 10% classed as orange. S2 produced the largest average fruit size, followed by Aguzdera and then the other four selections which were similar to each other. Trees on Carrizo had somewhat smaller size fruit than those on the other three rootstocks. This data should be interpreted cautiously since it is based on only a single year of harvest.

Table 6. Lindcove mandarin scion-rootstock trial, packline data for satsumas in 2010-11 harvest season. Fruit size in grams per fruit for all rootstock and scion combinations. S9 harvested Oct. 27, others Nov. 29, 2010.

Scion	C35	Carrizo	Rich 16-6	Rubidoux	All
S9 satsuma	217	202	186	178	193 c
S7 satsuma	186	162	179	206	183 c
S6 satsuma	206	191	195	190	196 c
S2 satsuma	291	245	304	289	283 a
Iveriya Satsuma	185	172	193	220	192 c
Aguzdera satsuma	206	220	252	222	223 b
All	214 a	198 b	215 a	217 a	211

Differences between scion or rootstock means followed by the same letter are not statistically significant.





Satsuma mandarin rootstock – scion trial at Lindcove. S-9 satsuma fruit quality. Fruit quality studies were conducted on 10-fruit samples of S-9 satsuma from all trees (8 single-tree replications) in October 7, 2010 and Nov. 18, 2011. Means are shown below for each rootstock. Higher values of rind color are more deeply orange, rind texture rating scale ranges from 1.0 (smooth) to 8.0 (very rough). In 2010, fruit from trees on the trifoliate orange rootstocks were smaller than those on citranges, but this was not observed in 2011. At the early harvest data used in 2010, fruit were more greenish in color than at the later date sampled in 2011. In both years, differences between rootstocks in rind color were small. Differences in rind texture were small. Soluble solids content was slightly higher for fruit from trees on trifoliate selections in both years. Acid was higher for the trifoliate orange selections in 2010, but not in 2011. The average number of seeds/fruit was low for all selections in both years. Among tree differences were relatively large for internal quality values. For example, among the 8 trees on C35, one tree had soluble solids of 12.7% and acid of 1.28%, while another had 8.6% solids and 0.85% acid. Individual tree values for acids and solids were highly correlated (r^2=0.8), suggesting that this variation reflects characteristics of the tree or individual fruit sample. Additional years of data are needed to clarify rootstock effects.

Table 7. S-9 satsuma fruit quality by rootstock. Oct. 7, 2010 and Nov. 18, 2011 data.

Trait	Year	Rich 16-6	Rubidoux	Carrizo	C35
Fruit wt (g)	2010	84.0	82.6	92.8	93.2
	2011	106.0	109.0	104.9	106.0
Rind Color	2010	5.00	5.06	4.92	5.19
	2011	6.75	6.50	7.13	7.00
Rind Texture	2010	2.00	1.88	2.17	1.94
	2011	3.00	2.88	3.00	2.88
Rind Thickness (mm)	2010	2.19	2.20	2.45	2.47
	2011	2.23	2.26	2.35	2.38
Juice %	2010	40.0	40.3	38.2	38.6
	2011	38.1	35.3	36.8	37.7
Solids (%)	2010	11.8	11.6	11.0	10.8
	2011	12.0	12.2	11.7	11.9
Acid (%)	2010	1.16	1.12	1.09	1.06
	2011	0.80	0.82	0.81	0.92
Solids/Acid	2010	10.7	10.9	10.6	10.7
	2011	14.9	15.3	14.6	13.7
Seeds/Fruit	2010	0.14	0.10	0.12	0.06
	2011	0.11	0.04	0.04	0.00

2005 Fukumoto navel orange bud source x rootstock trial at Lindcove. The objective of this trial is to determine whether decline of Fukumoto on C35 and Carrizo rootstocks, as observed in some commercial groves, is bud transmissible, that is, due to genetic or pathogen factors present in some bud sources. Buds were collected from 3 source trees in each of 8 Fukumoto groves in Tulare and Kern Co. In each county, two healthy groves and two groves affected by decline were sampled. In decline-affected sites, buds were collected from declining trees. Budwood tested negative for CTV and citrus leaf blotch and, with control buds from the CCPP Foundation Block tree (LCFB), was used to propagate trees at Lindcove. Trees were propagated on C35, Carrizo, and Volk rootstocks. The experiment has 4 replicate blocks. The tables below summarize results through January 2011. Gumming was noted on some 1-2 year-old trees, but affected a relatively small percentage overall and was not associated with bud source. In 2010, nearly all trees had good or excellent tree health ratings and these did not differ significantly among rootstocks or bud sources. Trees on Carrizo were larger than those on C35 or Volk. Trees on C35 had significantly more stock overgrowth (benching) than trees on Carrizo or Volk. In fall 2009 and 2010, the highest yields, as measured by a fruit count, were for trees on Volk. Trees propagated from different bud sources did not differ in total yield, and differences in yield among rootstocks were consistent across bud sources. Trees on Volk and C35 had significantly more rootstock suckers than those on Carrizo. Trees on C35 and Carrizo had significantly more scion sprouts growing from the bud union area than those on Volk. Trees propagated from some bud sources had more scion sprouts than others, but this was not related to whether the bud source grove was healthy or declining. Overall, there is little evidence so far that declines are bud transmitted, but decline is not always observed until trees are somewhat older than those in this trial.

Table 8. Effects of rootstock on tree performance, averaged over all bud sources. Differences among rootstocks were consistent across all bud sources.

Stock	No. Trees N	2007 Health Rating	2008 Health Rating	2010 Health Rating	Canopy Volume m^3	Tree Height m	Union Rating (0-7)	2009 Fruit Count	2010 Fruit Count
Carrizo	108	3.82	4.71	4.19	5.51	2.59	4.13	87.3	199.4
C35	107	3.80	4.56	4.03	4.86	2.44	3.32	85.0	163.0
Volk	101	3.95	4.33	3.97	4.83	2.44	4.82	129.1	225.8
LSD(0.05)	-	0.22ns	0.31	0.29ns	0.48	0.11	0.25	12.2	17.9

Tree health rating on 0-5 scale where 0 is dead and 5 is excellent. Bud union ratings of 1-5 reflect degree of stock overgrowth with 5 being smooth. Ratings of 6 and 7 indicate scion overgrowth and a bulge at the union, respectively.

Table 9. Effects of bud source on tree performance, averaged over rootstocks. Sources coded G were healthy groves, and those coded P were declining.

Bud Source	No. Trees N	2007 Health Rating	2008 Health Rating	2010 Health Rating	Canopy Volume m^3	Tree Height m	Union Rating (0-7)	2009 Fruit Count	2010 Fruit Count
KernG1	36	3.97	4.76	4.15	5.47	2.58	4.24	118.9	209.6
KernP1	33	3.98	4.33	3.93	5.45	2.54	4.12	94.7	202.8
TulrP1	35	3.97	4.61	4.03	5.41	2.58	4.28	114.1	209.8
TulrG1	36	3.76	4.69	4.29	5.32	2.48	4.00	103.8	193.8
TulrG2	35	3.91	4.60	4.28	5.09	2.44	4.20	95.1	189.4
KernG2	35	3.84	4.38	3.99	5.04	2.58	3.86	101.3	203.8
KernP2	36	3.90	4.69	4.14	4.85	2.45	4.03	97.3	191.0
LCFB	34	3.86	4.38	3.97	4.72	2.45	4.08	89.9	189.8
TulrP2	36	3.51	4.36	3.81	4.32	2.34	3.86	90.1	171.9
LSD(0.05)	-	0.37ns	0.54ns	0.50ns	0.83ns	0.20ns	0.44ns	21.2ns	30.9ns

The number of dead trees ranged from 1-3 among the 9 bud sources, and was 1, 6, and 11 for Carrizo, C35 and Volk respectively. Nearly all tree death occurred within the first 2-3 years after planting.

Table 10. Lindcove Fukumoto navel orange budsource-rootstock trial, planted in 2005. Fruit quality data collected in Nov. 2010. Mean effects of rootstock on fruit quality averaged across 3 budsources. There were no significant interactions between budsource and rootstock.

Stock	Fruit Weight (g)	Rind Color Rating	Rind Texture Rating	Length: Width	Rind Thickness	Juice (%)	Brix	Acid	Solids: Acids
C35	272.72	5.500	2.850	1.018	5.749	35.869	10.090	0.979	10.312
Volk	253.70	5.227	2.500	1.019	5.923	36.663	8.773	0.864	10.167
Carrizo	245.51	5.875	2.583	0.996	5.307	36.339	10.042	0.977	10.289
LSD(0.05)	24.56	0.501	0.467	0.012	0.517	2.167	0.660	0.052	0.554
F-test	0.05	0.030	ns	<0.001	0.045	ns	<0.001	<0.001	ns

Table 11. Lindcove Fukumoto navel orange budsource-rootstock trial, planted in 2005. Fruit quality data collected in Nov. 2010. Mean effects of bud source on fruit quality characteristics.

Budsource	Fruit Weight (g)	Rind Color Rating	Rind Texture Rating	Length: Width	Rind Thickness	Juice (%)	Brix	Acid	Solids: Acids
9 (CCPP)	269.79	5.409	2.727	1.011	5.691	35.81	9.491	0.941	10.107
1A (good)	254.39	5.773	2.591	1.001	5.642	36.98	9.882	0.951	10.399
7A (poor)	245.28	5.455	2.591	1.019	5.605	36.11	9.527	0.927	10.260
F-test	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 12. 2008 Tango rootstock trial near Porterville. Tree size and health data collected in July 2010. Trees ranked by canopy volume.

Rootstock	2010 Canopy Volume (m^3)	2009 Tree Health Rating	2010 Tree Health Rating	2010 Chlorosis Rating	2010 Chlorosis (% of canopy)	2010 Union Rating	2010 Sucker Count
Yuma Ponderosa	1.29	4.32	4.36	0.18	0.9	3.82	0.45
Volk	1.23	4.23	4.27	0.36	3.6	5.00	0.09
Schaub rough lemon	1.13	4.05	4.05	0.00	0.0	4.32	0.00
Sunki x F.D. trif	1.02	3.77	3.91	0.55	2.3	3.82	0.00
Brazil Sour	0.99	3.86	4.00	0.00	0.0	4.55	0.00
Macrophylla	0.89	4.05	4.00	0.00	0.0	4.50	0.09
Santa Barbara Red Lime	0.88	3.41	4.05	0.55	2.5	4.77	0.91
Carpenter (C54)	0.86	3.71	4.00	1.00	2.7	3.86	0.00
Bitters (C22)	0.86	3.72	3.78	0.00	0.0	3.88	0.33
Tosu	0.84	3.60	3.70	0.20	1.0	3.90	0.30
Cleopatra	0.83	3.45	3.59	0.18	1.8	6.36	0.18
C35	0.80	3.68	4.00	0.82	5.9	3.50	0.09
ASRT	0.74	3.28	3.67	0.22	1.1	3.44	0.00
Swingle citrumelo	0.72	3.27	3.32	1.95	21.8	1.95	0.40
Rangpur x Shekwasha	0.72	3.23	2.91	2.14	32.2	3.86	0.36
Obovoidea	0.69	3.77	3.77	0.00	0.0	4.14	0.00
Carrizo	0.67	3.18	3.64	0.27	0.1	3.59	0.00
Koethen Sweet	0.65	3.20	3.75	0.00	0.0	4.40	0.00
Rangpur x Marks trif	0.64	3.45	3.32	0.00	0.0	3.14	0.09
Sun Chu Sha	0.62	2.89	3.00	1.33	17.8	5.25	0.33
Rangpur x Swingle trif	0.59	2.95	2.82	2.05	35.4	4.05	2.09
Rich 16-6 trif	0.41	2.23	2.18	1.90	49.0	2.40	1.10
Pomeroy trif.	0.25	2.23	1.55	3.36	72.7	2.36	2.55
LSD(0.05)	0.27	0.54	0.54	0.73	13.1	0.61	1.17

The largest trees were on Yuma Ponderosa, Volk and Schaub rough lemon. Trees on trifoliate orange selections were very chlorotic and grew poorly. Trees on Bitters and Carpenter were among those with low chlorosis and good tree health. Trees on Swingle already show substantial rootstock overgrowth at the bud union.

Table 13. 2011 iron chlorosis greenhouse screening trial. For each rootstock 5 large seedlings were grown for 87 days in soil amended with 0, 5, or 15% calcium carbonate. Ratings scale as follows: 0 = no chlorosis, 1 = pale green leaves, 2 = pale green interveinal chlorosis with green veins, 3=yellow or white interveinal, 4=shoot tips or leaves chlorotic and dying, and 5= plant dying or dead.

	0%	5%	15%	All
Rootstock				
ASRT	0.00	0.00	1.00	0.33
Australian trifoliate	1.80	3.60	4.00	3.13
Brazil sour orange	0.00	0.00	0.40	0.13
C35 citrange	1.00	3.00	3.00	2.33
C146	0.00	1.20	2.60	1.27
Bitters (C22)	0.00	0.00	0.40	0.13
Carpenter (C54)	0.00	1.60	2.60	1.40
Furr (C57)	0.00	1.00	2.00	1.00
Carrizo citrange	0.00	1.00	2.40	1.13
Cleopatra mandarin	0.00	0.80	1.60	0.86
Macrophylla	0.00	0.00	0.00	0.00
P. trifoliata #22	1.40	4.00	4.00	3.13
Pomeroy trifoliate	2.40	3.60	4.00	3.33
Rangpur x Marks trifoliate	0.00	1.80	2.60	1.47
Rangpur x Shekwasha	0.00	1.60	2.80	1.47
Rangpur x Swingle trifoliate	0.40	2.40	3.00	1.93
Rich 16-6 trifoliate	2.00	3.60	3.80	3.13
Rubidoux trifoliate	1.20	3.80	4.00	3.00
Schaub Rough Lemon	0.00	0.00	0.40	0.13
Shekwasha x English trif	0.00	1.60	2.80	1.47
Sun Chu Sha	0.00	1.20	2.00	1.00
Sunki x F.D.	0.00	1.00	2.40	1.13
Swingle citrumelo	1.80	3.20	4.20	3.07
Tosu	0.40	0.80	2.40	1.20
Volkameriana	0.00	0.60	1.40	0.67
X639	2.80	3.75	3.80	3.43
ALL	0.59	1.72	2.45	1.59
LSD (0.05)	1.06	1.15	0.91	0.60

The most susceptible rootstocks were trifoliate orange selections, which were slightly chlorotic even in normal greenhouse soil. X639 showed as much chlorosis as the trifoliates. C35 and Swingle were also quite susceptible. The most tolerant rootstocks based on chlorosis ratings were Macrophylla, Brazil sour orange, Bitters trifoliate hybrid (C22), ASRT, Volk, and Cleopatra. For growth, measured as change in total shoot length (including branches), there were significant differences among rootstocks but the interaction between calcium carbonate level and rootstock was not significant (all rootstocks responded similarly). Possibly a more sophisticated analysis of growth will show significant interaction.