Lindcove Navel Strain Trials after Nine Years

This article is one of a series of continuing reports on University of California crop improvement studies. Authors are E.M. Nauer, specialist; W.P. Bitters, professor emeritus; D. Cole, D.R. Atkin and T.L. Carson, staff research associates, all of the department of botany and plant sciences at UC Riverside. Atkin is stationed at the Lindcove Station.

TREES of 12 strains of navel oranges, all on Troyer citrange rootstock, were planted in a randomized block at the U.C. Lindcove Field Station in Tulare County in the spring of 1976. The planting consists of 24 trees of each strain in 12 plots of two trees each. A preliminary report on this experiment was published in *Citrograph* in December of 1982 (2). This report summarizes production and fruit quality data collected from 1978/79 through the 1984/85 harvest season.

Strains included in the trial are:

1. *Apopka* nucellar — A seedling budline grown at the Citrus Research Center (CRC), U.C., Riverside from seed received from Florida.

2. *Atwood* (Atwood Early) — An old budline sport of parent Washington. Originated as a limb sport in the orchard of Frank Atwood near Lemon Cove about 1935.

3. *Bonanza* (Skagg's Bonanza) — Found as a limb sport by John Walker in the orchard of Mr. Skaggs of Lindsay, California. This is a patented cultivar placed in the navel strain trial through the courtesy of Walker.

4. *Dream* nucellar — A seedling budline grown at CRC from seed received from Florida. Dream originated as a budded tree in an old orchard of mixed varieties in Florida in 1939.

5. *Fischer* (Fisher) — An old budline sport of parent Washington. Fischer came to CRC from Armstrong Nurseries which had earlier received it from Mrs. Fisher.

6. *Frost* nucellar — A nucellar seedling budline from parent Washington which was developed at CRC, Riverside.

7. *Lane Late* — A budwood introduction from Australia. Lane Late is presumed to be a limb sport, but no detailed information was received when it arrived at CRC in 1973.

8. *Leng* — A budwood introduction from Australia. Originated as a limb sport in the orchard of A. D. Leng in New South Wales about 1935.

9. *Newhall* nucellar — A seedling budline derived at CRC from the old budline Newhall which originated as a limb sport near Duarte and was propagated by the Newhall Land and Water Company.

10. *Parent Washington* — The original old budline Washington navel brought to California in 1873.

11. *Rio Grande* nucellar — A seedling budline grown at CRC from seed received from Texas.

12. *Workman* (Summernavel) nucellar — A seedling budline developed at CRC from the late maturing budsport which originated in

TABLE 1. Total yield (pounds per tree) for 10 navel strains, 1978/79 through 1984/85 seasons.

	1978/79	1979/80	1980/81	1981/82	1982/83*	1983/84	1984/85	Total*
Apopka nuc.	8	33	250	167	(392)	161	223	842a**
Rio Grande nuc.	8	50	156	122	-	72	226	634b
Dream nuc.	10	32	212	76	(315)	38	261	629b
Newhall nuc.	1	23	136	63	(256)	19	348	590b
Frost nuc.	5	28	164	140	(290)	65	180	582b
Fischer	12	29	196	78	(303)	33	229	577b
Lane Late	4	21	145	149	-	91	167	577b
Atwood	6	28	120	131	-	71	73	429c
Parent	8	30	127	134	-	43	85	427c
Leng	4	27	84	68	(128)	32	103	318d
Average all strains	7	30	159	113	-	63	190	561

*Total excludes 1982/83 season.
**Mean separation within columns by Duncan's multiple range test, significance at the 5 percent level. Possible strain-year interactions were not taken into consideration.

TABLE 2. Yield of Bonanza (pounds per tree) compared with Atwood, Fischer, Frost, and Parent in seasons of early Bonanza harvest.

	1978/79	1979/80	1983/84	1984/85	Total*
Bonanza	22	43	97	146	308a*
Fischer	12	29	33	228	302a
Frost nuc.	5	29	65	180	279a
Atwood	6	28	71	73	178b
Parent	8	30	43	85	166b
Five strain average	11	32	62	142	247

*Mean separation within columns by Duncan's multiple range test, significance at the 5 percent level. Possible strain-year interactions were not taken into consideration.

the J. A. Workman orchard in Riverside in 1934. Although Workman produces fruit of acceptable quality in southern California, it has been totally unsatisfactory at Lindcove, producing low yields of poor quality fruit. It has, therefore, been dropped from the navel strain trial and results with Workman are not included in this report.

Individual tree yield records were begun in the 1978/79 season. Numbers of fruit were counted in 1978/79 and 1979/80, field box counts were taken in 1980/81 and 1981/82, and fruit weight was taken in 1982/83, 1983/84, and 1984/85. In 1982/83, no yield record was obtained on several strains. Harvest records of most strains (Bonanza excepted) were taken in December of 1978/79 and 1979/80, March of 1980/81, April of 1981/82, 1982/83, and 1983/84, and in March and April of 1984/85.

Fruit weight, fruit shape, rind color and texture, rind thickness, juice content, total soluble solids, and percent titratable acid were determined by appropriate laboratory tests. Beginning in 1979/80, a total of 32 fruit samplings were brought to Riverside for analysis. Of these, 19 were complete samplings of all strains, and 13 were partial samplings of early or late season strains.

Yield

Yields of ten strains are summarized in Table 1. Fruit and field box counts obtained in the early years were converted to pounds per tree, and weights of samples taken for laboratory analysis are included for all years. Figures for 1982/83 are included where available but are omitted from the total.

The significantly low yield totals for Atwood and Parent Washington cannot be fully explained. These two strains, along with Apopka and Lane Late, were harvested almost six weeks later than the others in April of 1985, so there was considerable fruit drop that would not have occurred with an earlier harvest. Also, the Atwood and Parent navel budlines in this trial are infected with a mild strain of exocortis viroid, which may have contributed to lower production. However, it does not seem that these factors should lower yield as much as is shown for Atwood and Parent when compared with Fischer and Frost. Exocortis-free budlines of both Atwood and Parent are now available but were not available when this trial was initiated.

Bonanza was omitted from Table 1 yield results because it was not harvested until March in 1980/81 and April in 1981/82, when a considerable volume of the crop had dropped on the ground. Comparison of Bonanza yield with Atwood, Fischer, Frost, and Parent is shown in Table 2 for 1978/79, 1979/80, 1983/84, and 1984/85. In these seasons, Bonanza was harvested earlier than the others, in December of the first three seasons listed, and in January of 1985. Bonanza has a good yield record when harvested relatively early in the season.

All strains in this trial had some tendency toward alternate bearing with the possible exception of Atwood (Tables 1 and 2). In view of the incomplete harvest record of 1982/83, these alternate bearing tendencies need to be watched and evaluated several more years before firm conclusions can be drawn.

TABLE 3. Approximate date of color break of 11 navel strains in five harvest seasons.

	1980/81	1981/82	1982/83	1983/84	1984/85	Five Yr Average
Bonanza	Oct. 20	Oct. 20	Oct. 18	Oct. 20	Oct. 13	Oct. 18
Leng	Nov. 3	Oct. 22	Oct. 22	Oct. 18	Oct. 14	Oct. 22
Newhall nuc.	Oct. 31	Oct. 24	Oct. 31	Oct. 26	Oct. 14	Oct. 25
Dream nuc.	Nov. 7	Oct. 27	Nov. 5	Oct. 31	Oct. 15	Oct. 29
Apopka nuc.	Nov. 13	Oct. 27	Nov. 2	Oct. 29	Oct. 18	Oct. 30
Atwood	Nov. 11	Nov. 1	Nov. 3	Oct. 28	Oct. 23	Nov. 1
Fischer	Nov. 13	Oct. 28	Nov. 10	Oct. 29	Oct. 17	Nov. 1
Rio Grande nuc.	Nov. 13	Nov. 1	Nov. 5	Oct. 30	Oct. 19	Nov. 1
Parent	Nov. 13	Oct. 31	Nov. 10	Oct. 30	Oct. 18	Nov. 2
Frost nuc.	Nov. 15	Nov. 2	Nov. 11	Oct. 29	Oct. 19	Nov. 3
Lane Late	Nov. 25	Nov. 20	Nov. 19	Nov. 4	Nov. 14	Nov. 16

Earliness of Maturity

Two criteria were used to measure earliness of maturity, both based on laboratory analysis of fruit samples. In each season, beginning with 1980/81, fruit samplings were begun early enough in the season to detect rind color break and when juice reached the 8 to 1 soluble solids to acid ratio needed to meet legal maturity standards. These samplings were made at approximately 2-week intervals.

A total of 60 fruits (10 fruits from each of six 2-tree replications) were collected from each strain at each sampling. Fruit were rated individually for color against a color chart, and the samples of 10 fruits representing two trees each were juiced for determination of sugar-acid ratio.

Data on color break and solids to acid ratio obtained at each sampling date were plotted on graph paper. The points where the curves for each strain crossed the 8 to 1 ratio and the predetermined color break level were used to estimate the dates shown in Tables 3 and 4. These dates are approximate because fruit development does not occur at a constant rate, and differences can be due to sampling errors. Color break, as shown here, was determined by rating one side of each fruit, at random, for loss of green color. Our definition of color break should not be used to imply that the fruit was colored sufficiently to harvest. Attainment of color for legal harvesting probably followed our color break date by a week or more.

Other Fruit Quality Evaluations

Fruit size, fruit shape, rind thickness, and percent juice are shown in Table 5. These figures are an average of all 19 complete fruit quality samplings taken in five harvest seasons beginning in 1980/81. These samples consisted of a total of 1140 individual fruit of each navel strain.

Fruit size did not differ significantly among strains except for Leng and Apopka, which were both considerably smaller on average than the other strains.

Fruit shape differed little among strains. Only Newhall produced undesirably elongate-shaped fruit. All other strains produced nearly spherical fruit ranging from 0.99 to 1.03 average width-length ratio.

Rind thickness was generally correlated with fruit size but with several exceptions. Bonanza had very thin rind in relation to fruit size. Rind

TABLE 4. Approximate date of attainment of 8 to 1 soluble solids to acid ratio of juice of 11 navel strains in five harvest seasons.

	1980/81	1981/82	1982/83	1983/84	1984/85	Five Yr Average
Fischer	Oct. 29	Sep. 27	Oct. 28	Oct. 14	Sep. 22	Oct. 12
Newhall nuc.	Oct. 8	Oct. 10	Oct. 16	Oct. 26	Oct. 11	Oct. 14
Dream nuc.	Nov. 4	Sep. 29	Nov. 4	Oct. 25	Oct. 13	Oct. 21
Bonanza	Nov. 2	Oct. 19	Oct. 28	Nov. 2	Oct. 10	Oct. 25
Leng	Nov. 3	Oct. 22	Nov. 6	Nov. 5	Oct. 3	Oct. 26
Atwood	Nov. 5	Oct. 23	Nov. 1	Nov. 9	Oct. 13	Oct. 29
Frost nuc.	Nov. 6	Oct. 23	Nov. 4	Nov. 4	Oct. 13	Oct. 29
Parent	Nov. 10	Oct. 20	Nov. 9	Nov. 7	Oct. 17	Oct. 31
Rio Grande nuc.	Nov. 11	Oct. 28	Nov. 15	Nov. 11	Oct. 21	Nov. 5
Lane Late	Dec. 17	Nov. 8	Nov. 23	Nov. 16	Oct. 22	Nov. 17
Apopka nuc.	Jan. 18	Dec. 1	Dec. 8	Dec. 14	Dec. 20	Dec. 18

TABLE 5. Fruit quality characteristics of 11 navel strains.

	Fruit size oz/fruit	Fruit shape	Rind thickness (mm)	Juice %age
Newhall nuc.	9.20a*	.94d	8.0a	39.1h
Atwood	9.09a	1.02ab	5.9de	45.4cd
Rio Grande nuc.	9.01a	1.01b	6.6bc	43.7efg
Parent	8.98ab	1.02ab	5.9de	46.3c
Fischer	8.96ab	1.02ab	6.4c	43.3fg
Bonanza	8.84ab	.99c	4.7f	47.9ab
Frost nuc.	8.43bc	1.02ab	6.5c	44.5de
Lane Late	8.10cd	1.02ab	5.8e	44.1ef
Dream nuc.	8.04cd	1.03a	6.7b	42.9g
Leng	7.69d	1.01b	4.6f	48.7a
Apopka nuc.	6.72e	1.02ab	6.0d	47.4b
Average all strains	8.46	1.01	6.1	44.8

*Mean separation within columns by Duncan's multiple range test, significance at the 5 percent level. Possible strain-year interactions were not taken into consideration.

of Dream was somewhat thickner in relation to fruit size; while Newhall rind was exceptionally thick even considering the large fruit produced by this strain.

Juice percentage by weight was satisfactory and differed little among strains except for Newhall which was lowest in juice content. In general, fruit with the thinnest rind had the highest juice percentage.

Rind texture was rated on fruit samples in the laboratory at two sampling times during the 1984/85 season. Bonanza and Leng were noted to have the smoothest rind, while Newhall's rind was the roughest. The other eight strains were all very similar in rind texture.

Evaluation of Strains

The evaluations that follow are based on performance of young trees at Lindcove. Performance may differ in locations with different environments or as the trees age. Several strains appear to have little or no commercial potential for the San Joaquin Valley.

Apopka nucellar — Although this strain had the largest total yield, its small fruit size effectively rules it out as a commercially useful strain for California. It is similar to the high-acid navel variant which was a considerable problem in California in the 1960's (3).

Atwood — In 1967 (1) Atwood navel was described by R. W. Hodgson as being "virtually indistinguishable" from the parent variety, Washington. Our results certainly seem to confirm this earlier observation. Although sometimes called "Atwood Early," this strain was only a day or two earlier than Parent Washington in both color break and sugar-acid ratio on average at Lindcove. The ability of Atwood to store fruit on the tree without loss of quality was not directly investigated, but a count of dropped fruit of Atwood and Parent in late April of 1985, indicated no difference between these two strains in holding fruit on the tree late in the season; Atwood dropped 24.4 percent of its crop compared with 25.4 percent of the crop of Parent Washington.

Atwood is an excellent quality navel orange. Fruit size is good, rind is of medium thickness, and juice percentage is good. It is slightly early in some years, but is basically a mid-season budline. Yields have been somewhat low in the Lindcove navel strain trial to date.

Bonanza — This patented budline is useful in the early season market. Bonanza breaks color two to three weeks earlier than Parent Washington, and reaches 8 to 1 sugar to acid ratio about a week earlier on average. While well ahead of Fischer navel in color break, Bonanza is behind Fischer in reaching 8 to 1 ratio in most seasons. Bonanza fruit is of good size, has a very thin rind compared to the other strains in this trial, and is high in juice content. Yields of Bonanza have been good at Lindcove. Fruit of Bonanza tends to drop on the ground earlier in the harvest season than the other strains in this trial, and, therefore, should always be harvested early in the season.

Dream nucellar — This budline appears to be a borderline commercially acceptable navel with possible early season advantages in some years. It reaches sugar to acid maturity about ten days earlier and breaks color a few days earlier than Parent Washington. Yields have been good to date. However, fruit size of

laboratory samples has been somewhat smaller than Parent although this difference is not statistically significant. The rind of Dream is slightly thick and juice percentage is somewhat low. Based on our results to date, we would not recommend planting Dream on a large scale; trials on a limited acreage basis might be worthwhile.

Fischer — The primary favorable attribute of Fischer is early juice maturity. In most seasons, Fischer reached 8 to 1 ratio well ahead of all other strains in this trial. However, Fischer does not break color earlier than mid-season strains such as Atwood and Parent. Fruit of Fischer holds well on the tree for mid-season harvest, and sugar-acid ratio continues to remain higher than sugar-acid ratios of other strains throughout the season, making Fischer sweeter to the taste whenever it is harvested.

Yields and fruit size have been good at Lindcove. The rind has been slightly thick and juice percentage a little low, but not enough to affect commercial acceptability. Fischer is a good quality navel, well suited for both early and mid-season marketing. However, very early season harvesting is limited by relatively late coloring of the fruit.

Frost nucellar — This seedling budline, derived from old budline Washington by Dr. H. B. Frost in 1916, was widely planted in California and elsewhere at one time. Currently, very little Frost is being propagated commercially.

At Lindcove, Frost has been virtually identical to Parent Washington in fruit quality characteristics. Fruit collected for laboratory analysis has been slightly, but not significantly, smaller than fruit of Parent; the rind has been slightly thicker. Yield of Frost nucellar has been good, in the same range as Fischer, and higher than Atwood and Parent.

Lane Late — This import from Australia looks like a very good late season navel. Fruit holds well and remains firm on the tree well into May and June without application of gibberellin or 2,4-D. Fruit color is not as deep orange as other strains late in the season, and there appears to be some re-greening during the spring as with Valencias; but this lighter color does not seem to adversely affect marketability. A comment from the packinghouse people was that they liked the appearance of the fruit, and were surprised to hear that no Gibb or 2,4-D had been applied.

Yields of Lane Late have been about the same as Fischer, medium among the strains in this trial. Fruit size appears small in Table 5, but this reflects all 19 complete fruit quality samplings, of which 14 were taken in October or November, three in December, two in January, and none later. Fruit held on the tree for late harvesting attains good size. Four samples of Lane Late collected 3/85, 4/85, 5/83, and 6/83 averaged 10.2 oz per fruit. Rind thickness and juice percentage are in the medium range. At harvest in late April of 1985, Lane Late had dropped only three percent of its crop on the ground, compared with an average of 25 percent for Atwood and Parent Washington.

In April of 1985, Lane Late was run as a separate lot through the packinghouse. The other lot at this harvest date consisted of a mixture of Apopka, Atwood, and Parent. Unfortunately, this mixture contained almost 60 percent Apopka by weight, so it was not a very good comparison with Lane Late. In these packinghouse runs, four bins (16 field box equivalent) of Lane Late packed 76 cartons Sunkist and five cartons choice for a total of 81 packed cartons; peak size was 72. The Apopka, Atwood, Parent mix was nine bins and packed 153 Sunkist and 12 choice for a total of 165 packed cartons, which peaked on size 88. Percentage packout for Lane Late was 82.6 Sunkist, 5.4 choice, 9.8 juice, and 2.2 cull cartons. The mixed lot packed 73.2 Sunkist, 5.7 choice, 19.2 juice, and 1.9 culls.

Leng — This budline has been grown for many years in Australia but was only recently imported into California. Leng is an early to mid-season navel of excellent quality. Timing of color break and 8 to 1 sugar to acid ratio are similar to but slightly behind Bonanza. Leng has very smooth, thin rind and the highest juice content of all strains in this test.

Unfortunately, Leng has exhibited two flaws, which probably rule it out for commercial use. It has the poorest yield record of all 11 strains, and fruit size tends to be small (Tables 1 and 5).

Newhall nucellar — This relatively young seedling budline of Newhall does not look promising. It produces many very large, elongate fruits with extremely rough, thick rind and low juice content. For these reasons, this Newhall seedling budline has been removed from the Lindcove foundation budwood block, and will not be available for distribution.

However, Newhall has some very favorable traits, such as moderately early color break, early 8 to 1 ratio, large fruit size, and a deeper orange color, similar to Minneola tangelo, when fully colored. Therefore, the old budline Newhall, which was not available when this navel strain trial was initiated, has been cleansed of several viruses and is established in the Lindcove foundation block. Following fruit quality evaluation, budwood of old budline Newhall will be available for distribution to California citrus nurserymen about 1988, provided fruit quality is acceptable.

Parent Washington — This old budline is the standard with which all other navel strains are compared. In the Lindcove navel strain trial, Parent has been somewhat low in total yield to date. Some possible reasons for this low yield were discussed earlier in this report.

Other than yield potential, Parent has lived up to its reputation for quality fruit. It has produced good-sized fruit of average rind thickness and slightly higher than average juice content. Parent is a typical mid-season navel.

Rio Grande nucellar — This budline has performed well in the navel strain trial. Production has been second to Apopka, and fruit size has been good. The rind has been slightly thick and juice content slightly low, but both well within the range of acceptability.

Rio Grande is a late mid-season navel, reaching color break at about the same time as Parent and 8 to 1 ratio about a week later than Parent. No particular late-holding advantages were noted for this strain.

Small scale commercial trials of Rio Grande might be worthwhile on the basis of relatively high yields at Lindcove to date. Rio Grande has not yet been processed for planting in the Lindcove foundation block, so no budwood is available at this time. If budwood demand develops, one or two navel strain trial trees of Rio Grande will be registered for interim use while a foundation block source is being developed.

Foundation budwood, tested for trueness to type and freedom from virus diseases, is available from Lindcove to California citrus nurserymen and growers. All strains listed above, except Apopka, Bonanza, Newhall nucellar, and Rio Grande, are currently available. Many of these budlines are also available through commercial sources as both budwood and trees. The budline of Parent Washington now available from Lindcove is infected with a very mild form of exocortis viroid. Exocortis-free Parent budwood will be ready for distribution in the fall of 1986.

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