Noninfectious Bud-Failure

Project No.: 99-DK-o0

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Abstract

The report is given in four sections, each corresponding to research papers being prepared. The first section describes the BF development pattern shown by the progeny of 11 commercial nurseries over the seven-year period. Higher increases in BF in individual years is shown to be correlated to higher than average temperatures during June and early July. Adverse effects on yield are associated with BF development within the first five years.

In the second section the statistical relationship between source and progeny shows that the greatest source of variation occurs among individual trees including individual branches. Evidence was found for a "genetic change" in BF potential during the annual growth cycle coinciding with the June-July temperature correlations.

The third section gives details about the characteristics of individual nursery sources. These were divided into four types. The dehorned original seedling tree showed the lowest BF-potential. Commercial orchards were shown to be the least useful kind of source because of the great tree-to-tree variability and the persistent increase with consecutive scion generations. Use of watersprouts on individual visually normal trees combined with progeny tests appeared to be a promising selection method. Various methods of managed source blocks by "hedge-rows" were used by some nurseries but did not overcome the difficulties of inadequate source selection procedures. The fourth section shows the results since 1988 of progeny testing 35 individual source trees. Five low BF-potential Foundation Clones are now maintained in the FPMS orchard at Davis. Successful commercial use of at least one of these has been ongoing since 1994.

Summary of Previous Reports

An Almond Board Project on Noninfectious BudFailure had been been in operation for many years first as a part of Almond Breeding project and then as a separate project. As a result of the earlier work, broad concepts of BF had been established (Kester and Gradziel, 1996). Low BF-potential single tree nursery sources of Nonpareil and a number of other varieties (Peerless, Ne Plus Ultra, Price, Sonora, Padre, Mission) had been identified and procedures were in place for their maintenance in the Foundation Plant Materials Service (FPMS) at UCDavis and distribution through the Registration and Certification program (voluntary) of the California Dept. of Food and Agriculture (CDFA).

This program was expanded to extend the same goals to other varieties not represented in the FPMS collection, including Carmel, Monterey, Ruby, Fritz and additional selections of Mission, Sonora, and Price. A joint meeting in April 1988 among representatives of the commercial nursery industry (AIB), Foundation Plant Materials Service (UCD) and UC pomologists identified new sources recommended from commercial nurseries. By 1994, new Foundation Clones of all of these varieties had been approved and were available to the industry through FPMS. Carmel proved to be a bigger problem. In 1990 BF was appearing in commercial orchards at high rates and in very young trees from essentially all nurseries. The concern was so high that many nurseries and individual growers were considering discontinuing its use.

Two programs specifically dealing with Carmel were instigated:

- Search for individual tree sources with low BF potential (BF_{pot}) to be Foundation Clones:
    A. 1988. Six single trees of Carmel from a commercially originated source were identified (see previous paragraph) as candidate Foundation Clones. Progeny trees were propagated from each source tree in 1988, planted in a test plot as part of a Paramount Orchard commercial trial (Kern County, near Wasco) in spring 1989. Yearly observations were begun in March 1990.
    B. 1989. Six individual source trees from various origins (Descriptions later) were part of this trial. Progeny trees were propagated in 1989 and planted in the Paramount Wasco Orchard in spring 1990. Yearly observations began in March 1991.
    C. 1993. A third group of candidate Foundation Clones had been selected from the Manteca RVT plot and from a commercial orchard near Ripon. Progeny trees were propagated in 1993 and planted in commercial orchard test plots in Fresno Co. Annual observations began in 1995 and continued each year, except 1996, through 1999.

- Analysis of BF variability in commercial nursery sources of Carmel:

    The idea for this study was developed in 1989-90; trees were propagated in 1990 and planted in February, 1991 in a commercial orchard of Paramount Farming Corporation in northwest Kern County. Observations were started in March 1992 and continued annually through March 1998.

    The experiment consisted of approximately 3000 Carmel trees, which were planted in a single 80-acre orchard in alternate rows with an equal number of Nonpareil trees to provide cross-pollination. The ‘Carmel' population trees consisted of (a) *progeny* trees representing eleven nurseries in which the pedigree of each tree was known for the *individual nursery source*, *individual tree, individual branch* of the tree and *individual position of the bud* on the budstick. (b) unpedigreed trees provided from specific commercial nurseries whose data have been used where appropriate and (c) trees omitted from consideration for various reasons, including tree loss and replacement, incorrect identity, or lack of records.

'Nonpareil' nursery trees sources were planted, which included two source identified Foundation Clones (FPMS 3-8-2-70; FPMS 3-8-5-70) and five nursery sources, were planted in replicated rows across the orchard.

All individual trees were rated for BF annually (mid-March) on a scale of 0 (none), 1 (slight), 2 (moderate), 3 (severe) and 4 (very severe) for seven years (1992 through 1998). Note that the actual BF symptoms had developed the previous summer.

Objectives:

1) To complete the analysis of the accumulated data from the Carmel nursery experiment, incorporate the significant findings into a comprehensive biological model on the nature of the BF phenomenon and prepare and publish the findings into scientific journals.
2) To prepare a final report concerning the horticultural application of the findings and for the education of almond producers and nursery persons to guide future management of the BF problem in the orchard and nursery.

Summary of Results

Results presented in the following four sections correspond to four scientific papers that are being written. Definitions of terms used continuously throughout this report

1. *Source* - the trees from which budsticks are collected to propagate nursery trees. In this study, sources are identified as to block used by a specific nursery, individual tree in that block, individual branch of the source tree (up to five branches), relative position of bud on each budstick.

2. Progeny - the nursery trees that had been propagated from specific source trees.

3. BF potential (BF_{pot}) - the inherent potential of the source to produce BF in its progeny trees.

NO SOURCE TREE SHOWED BF AT THE TIME OF COLLECTION.

4. BF expression (BF_{exp}) - The expressions of BF symptoms on progeny trees rated on a scale of 0 (none), 1 (slight), 2 (medium), 3 (severe) and 4 (very severe).

Section I. Variability of BF Expression in Progeny Trees

This section summarizes the observations and calculations pertaining to BF expression of the population of trees in the Paramount orchard. BF_{exp} is expressed either as (a) percentage of trees showing BF or (b) average rating (AvBF). Individual nursery sources are anonymous and are identified by code letter chosen by the alphabetical sequence of the relative severity of BF from low to high.

- The final results (as of 1998) of the source comparisons for the seven year test (Table 3) shows not only significant differences among all of the eleven sources but consistent patterns among individual sources over time. All nursery sources produced some BF trees but large differences existed in the number of BF trees, the severity of expression and the age at which these appeared.

- The accumulated numbers (percentage) of trees affected by BF increased regularly each year during the 7-year study but not at a constant rate as discussed further in this section. Furthermore there were differences in the average severity of BF expression (AvBF), which reflected the change in individual ratings over time (see next paragraph). These reflected an interaction between the change in tree morphology and the proportion of the tree affected at different ages. In general, the earlier in the life of the tree that BF occurred the more severely it was affected when the tree matured.

- At the end of the first year (ratings made in March of the next year), we found a complete range of severity and rated trees from 0 (none) to 4 (very severe) based upon the proportion of the annual growth sequence that was affected. In other words, rating of 4 meant that essentially all of buds on the total shoot were killed. Ratings of 3 meant that the buds on the upper 2/3 to 1/2 of the shoot were killed. A rating of 2 meant that perhaps only 25% of the buds on the upper end of the shoot were killed. A rating of 1 (slight) meant that only single side branch or perhaps 10% or less was affected.

In the second year, this pattern was repeated but since bud failure occurs only on new growth, a spatial pattern begins to develop. Trees with very severe BF (rating 4) produced a reduced number of shoots with high vigor that continued to show very severe BF. These maintained very severe BF in each of the subsequent years of the test. Those with less severe BF (rating of 3) during the first year followed the same pattern and became increasingly severe in each of the succeeding year. Those with only mild symptoms the first year followed a similar pattern but required several years to reach the severe stage. Similarly, those with only slight BF the first year continued to increase in severity each succeeding year.

Trees that began to show BF the first time in the second year were invariably rated as 1 (slight) or 2 (medium) with a small number rating 3. This meant that the symptoms were being produced higher and affecting a smaller proportion of the tree. However, these also increased in severity in succeeding years usually reaching the severe category by maturity.

This pattern was repeated in each succeeding year of the seven years in that "new" trees BF was produced on new shoots produced higher in the tree, affected less of the tree canopy and invariably rated 1 or 2. Once BF started to appear, each "new" tree tended to increase in severity of BF expression over the next few growing years. This trend tended to decrease at about five years as the number of shoots overall tended to decrease, individual shoots tended to grow less, and fruiting spurs and flowering began to appear. Thus after an unaffected tree had reached around five years or more in age, the production of "new" cases of BF tended to be restricted to the upper parts of the tree and affected a smaller portion of the canopy (ratings of 1 or 2).

A basic concept upon which this was based is that every individual in the almond tree population has a latent potential (BF_{pot}) to express BF (BF_{exp}) as it grows. In order to standardize comparisons among sources or compare environmental conditions in biological studies, we have adopted the "age when BF is first identified" in the tree as the criteria for BF. This definition differs from the %BF or AvBF, which measures the total impact of BF and is produced by the accumulation of BF ratings of different "ages"

- Yield.

Yield was reduced in direct proportion to the severity of BF that developed during the first five years. This occurred because the initiation of BF inhibited the formation of fruiting shoots and spurs during their initial appearance. The reduction in yield was in direct proportion to the extent of the canopy affected. Consequently there appeared to be an economic threshold at about five years beyond which new BF is not economically harmful.

- Temperature relationships to yearly increases in BF.

Significant differences were shown among years in the annual increase of numbers of trees first showing BF for that year (Table 1). The number of trees showing BF the first year (1991) is artifically high because some of trees had already passed the BF threshold. Highest increases occurred in 1994 and 1996, lowest increases occurred in 1995 and intermediate increases in 1993 and 1997.

These yearly increase tables were found to be correlated to total temperature accumulation during the previous growing season using total D(egree)D(days) >28^{o} C (80^{o}F) (a measure of heat) as well as DD15-32^{o}C (a measure of growth). This analysis was extended further and showed *that the most critical temperatures for BF increase appeared to be before about July 15.* The data was then subjected to more sophisticated correlation analysis and verified that the month of June and to a lesser extent July were indeed the most critical months for the induction of BF in any one year with the best fit to average (growing) temperatures without specific consideration of heat.

Significance of timing. Why should this precise timing *before* the onslaught of heat be important? Prior research (Kester, et al., 1996) has provided evidence that the almond bud development process goes through precise stages beginning with (Stage 1) active growth from March through April (Stage 2), decrease in growth and initiation of bud maturation in May, (Stage 3) development of budscales in June and (Stage 4) the induction of a *high temperature dormancy* period in July and August. Higher than average "growing" temperatures in June is believed to inhibit this dormancy induction process, initiate the symptoms and produce a genetic shift in the cells that increases BF_{pot}.

Section II. Variability of BF-potential in the Source Trees

All budwood collections were made from trees which did not have BF symptoms (i.e., BF_{exp}) but as shown in Table 2 have the potential to produce BF in their progeny (BF_{pot}). Differences in BF_{pot} were determined by the rate (age) at which BF appeared in the progeny. The graph compares the AvBF after four growing seasons (evaluations made at the beginning of the fifth year) in progeny from 70 individual source trees present in the commercial orchards used by five of the cooperating nurseries as bud-sources.

- First, this graph verifies the concept of continuous variation in source trees from very low to very high $BF_{pot.}$ and eventually BF_{exp}.

- Second, the array of results illustrates that there is no such thing as a BF-free almond tree. Instead we must distinguish among different levels of BF_{pot} and select specific sources for low potential.

- This graph is an attempt to establish criteria based upon the performance of progeny trees over a given time period. Our data suggests that this test requires at least four years (comparisons made in the fifth year) with followup examinations after 6 and 7 years. AvBF is combined with % BF.

- This section also describes the source: progeny relationship in another way and answers the question posed at the start of the experiment: what is the relative importance on the BF variation in BF of *source*, *trees*, *branch* and *bud location* on the budstick? This analysis utilizes the statistical procedure of calculating the percentage of the total variability of the BF data that can be attributed to each parameter in the total population. This procedure actually measures the correlation between progeny and source in a fashion analogous to that which plant breeders measure the *heritability* of individual traits in a parent - seedling progeny study. In this case the trait is the BF_{exp} and the variation is due to somatic variation within the clone. The kind of variability describe here has been previously defined in biological literature as somaclonal variation and we are examining the relevance of this concept to the bud-failure variability in almond.

Previous breeding studies showed that variation in BF_{exp} within a clone is heritable (Kester, 1968) in seedling populations. This means that the BF differences in consecutive yearly growth cycles (referred to here as "vertical" variation) and differences in different branch sequences of the same plant or in branch sequences of different plants ("horizontal" variation) shown in Section I are heritable and represent permanent changes in genotype. This has not only theoretical application to the bud-failure problem but practical application as well.

- These variability partitioning data (Table 3) shows that by far the most important selection parameter is the *individual tree,* which in combination with *individual branch* accounts for 70% of the total variability in BF. Thus at the time that the trees are planted, each has a genetically controlled inherent BF_{pot} that was established by the combination of source tree used and to some lesser degree the method of collecting the budsticks within the tree. The differences among nursery source become larger as more and more individual progeny trees began to express BF. This data also indicates that not only all trees but each part of the trees has its on inherent BF_{pot}

- Position of the bud on the budstick showed zero relationship to the relative variation of their respective progeny. This indicates that the time of genetic change (mutation?) occurs within annual cycles of growth specifally occurring in June (see Section I) after the individual buds have been formed as shown by the temperature correlations. The long continuous changes associated with BF distribution are apparently due to consecutive individual small mutations (?) in specific genes affecting BF that occur at a very specific time in the annual cycle. Vegetative tissue now becomes changed and the new buds at the end of cycle have an increased BF_{pot} either in next years cycle or in plants propagated from them.

Section III. Patterns of BF from Separate Commercial Nursery Sources

This section describes the results of source-progeny analysis where the heritability concept can be applied to the evaluation of nursery sources of Carmel. This analysis includes the origin of Carmel, its early propagation history from the time of its origin in 1966 as a seedling tree planted in a commercial Nonpareil orchard near LeGrand, and the subsequent pattern after introduction into the industry in 1972. The history includes the separation into five consecutive orchard generations designated as S_o (original seedling tree), S_1 (first scion generation), S_2 (second scion generation) and so on. Within this sequence we have defined six VegLines, which trace propagation sequences from the original seedling tree to each of the nursery source blocks used in this study.

The eleven nursery sources in this study are separated into four groups (Table 4):

Group I. Original Seedling Tree

This source tree originated in a commercial orchard near LeGrand, CA in 1949 apparently as a rootstock tree whose bud failed in the nursery. In recent years, the tree has been pruned back to main scaffolds and repruned annually to generate bud wood for nursery production. The tree has tested *ringspot virus positive* but this does not seem to adversely affect orchard production. The progeny showed lowest percentage of BF (1.8) of any source and "slight" symptoms appearing after the sixth year and only in upper parts of the tree.

Group II. Commercial Carmel Orchards

One of the long time concepts of BF selection is that the probability of BF tends to increase with each scion generation of propagation. Five of the nursery sources utilized orchards determined to be of the 3^{rd}, 4^{th} and 5^{th} generation. Plotting the AvBF against scion generation of progeny of these sources confirmed this relationship. This relationship cannot be attributed to a so-called "juvenility" effect and can now be explained as the progressive accumulation of individual "mutations" occurring during consecutive annual cycles. Scion generation was apparently the only factor in change because there is much variability among orchards that can be associated with location, growing conditions, vigor and even rootstock.

All of the commercial orchards used were found to show great variability in BF_{pot} not only among individual trees but also within trees, i.e., branch to branch. This problem underscores the point that using commercial orchards as budwood sources is hazardous in combatting BF and is probably the primary reason that BF has not only continued to be a problem in the industry over the past 75 years but has extended its occurrence.

Group III. Pre-selection

One nursery source (NS-C) utilized a unique procedure which turns out to have promise in identifying individual low BF_{pot} sources from commercial orchards. The orchard utilized was 18 years old, S_4 generation and a different VegLine from those described previously. BF was present in 20 percent of the trees in the orchard usually in the top but not in the ten trees selected. Budsticks were cut from watersprouts (suckers) emerging from the base of the trees. Originally, progeny from individual trees were propagated and progeny tested over several years to identify suitable individual tree sources. In our tests from 10 of these original trees, the average level of BF was significantly lower than other the other commercial orchards of comparable age, the main source of variability being among branches of the same tree.

This study emphasizes that there is significant variation in BF_{pot} in both horizontal (separate branches) and vertical (base vs. top) variation within individual trees which can be utilized in selection procedures for BF (see Section IV)

Group IV. Managed Budwood Sources

Five nursery sources were under unique management conditions in which the sources were maintained and pruned to produce budwood rather than nuts, as occurs with commercial orchards. Maintenance of these blocks utilized some variation of a "hedge-row" either in the nursery or in the orchard or utilized the concept of an "increase nursery block". Results were as follows:

- NS-B utilized unsold nursery trees to provide budwood for the next generation of nursery plants, which involved recycling the source every few years theoretically increasing the scion generations considerably more than the commercial orchards listed in Group II. The operation was located in a cool summer site and the source of the original budwood was unknown. However, under this combination of conditions BF_{pot} very low with very little BF_{exp} in the progeny (2.2 percent at seven years with very mild expression).

- NS-D included nursery trees growing in closly-planted hedge rows originally from a commercial orchard of uncertain scion generation but completely separate origin (VegLine 4). Percentage of BF progeny trees was significantly less (31.5 percent) than many of the other sources. The pattern of BF appeared to come from variability in BF_{pot} among individual trees and also from separate sides of the trees.

- NS-H (commercial) and NS-M (test) appear to have been propagated from the same source block which was maintained as hedge row of nursery trees maintained in consecutive years. The original source was not known for certain but apparently was a commercial orchard of perhaps an S_4 generation. This source was designated as VegLine 5. Many of the progeny trees of NS-M died the first year which we believe was related to their high BF_{pot}. However, the percent BF in this reduced population was very high. Furthermore, the BF production of NS-M (commercially supplied trees) was also high.

- NS-K was maintained as a typical orchard scion block and produced very vigorous budwood material. There was a wide range of BF_{pot} both among and within the individual trees of the source. The origin of the budwood to establish this scion block apparently came from VegLine 5, which had a high BF_{pot} comparable to that of NS-H and NS-M.

- NS-G(cl) is interesting in that it originated as a single tree selection of the same orchard as NS-G which was maintained as a scion tree row in the same orchard. The significance is the high degree of uniformity among the trees as compared to those of NS-G. Unfortunately, the overall level of BF_{pot} was somewhat higher than desired. This material is further discussed in Section IV.

Conclusions

Providing satisfactory nursery trees requires two basic ingredients a) Selection of source materials with low BF_{pot} at the outset and b) stabilization, maintenance and management of the source blocks to allow continued distribution of the same material without increasing the BF_{pot} of the source.

Of the sources used, apparently NS-A and (apparently) NS-C achieved both aims. NS-B also appeared to have achieved that aim but we cannot be sure why, whether this method is superior to other techniques if the same source was used or if the cooler summer location provided a favorable environment not present with the other nursery sites.

The primary conclusion from this section is that use of commercial orchards as budwood sources violates both principles and over time their use can be expected to increase the problem for a specific nursery.

Section IV. Selection of Low BF_{pot} Foundation Clones of Carmel

At the beginning of this report, three different tests of single tree sources were described. The results of the progeny tests of the three groups of candidate clones are given in Table 5. The first group came from a commercial nursery (NS-G) whose bud-source was a S_3 commercial orchard. Certain rows (e.g. R116) were planted with progeny from a single tree in the prior generation, designated as "clone source" and pruned back each year for budwood. Progeny from trees R114 -1 through 6 were utilized in the test. Three trees of the group were retested in the nursery trial (section III) as NS-G (cl), B114-3 was included in the Group 2 and others were in Group III. The average BF_{pot} of the "clone trees" was not significantly different but the range in BF_{pot} was much more restricted making for high uniformity among progeny trees. The pattern was slower to develop than most other sources (3rd to 5th year) and most of the trees were slight or moderately affected. Thus although these sources were an improvement over most of the other sources tested, in the long run somewhat more BF was produced than did other sources, particularly in Group II and III.

Group II (Established 1990) included three sources (D13-2, D13-13, and D13-7) from the Delta RVT plot, Manteca. Two selections (W1-4 and W-9) were from individual trees (S1) in a nursery test plot propagated from the original seedling tree and a few trees from the original seedling source (S0). BH is the source of the background orchard. D13-2 and D13-13 produced no BF until the 8th year and their expression was very slight. D13-7 produced some BF in the 7th year and the expression was also very slight but was found in a relatively high percentage. W1-4 had low BF_{pot} but W1-9 had very high BF_{pot} B114-3 duplicated that of Group I.

Group III selections were made utilizing the procedure followed by NS-C and described in Section III Of the seventeen selections tested in commercial orchard plots in Fresno County, eight had produced no BF expression by 1999 (5th year).

From these tests, low BF_{pot} sources have now been established as Foundation Clones in the FPMS Orchard at UCD. These are identified by specific FPMS numbers and are listed below. These source trees have been established under Registration and Certification Regulations and currently supervised the by FPMS staff and its Advisory Committee, including UC and USDA researchers, commercial nursery persons (AIB) and regulatory personnel from CDFA. All selections are maintained as free of known viruses.

FPMS 3-56-1-90. This selection originated as D13-2 from the Delta RVT plot and results of its progeny test is shown in Table 4, Group 2. Some very slight BF has appeared at the 8th and 9th year. Material was released to the nursery industry in 1994 and some commercial orchards were planted in winter spring 1995, the numbers increasing since that time. No BF has been reported to date in any commercial orchard. Neither has any BF appeared in the RVT plots where this source was planted in 1993.

FPMS 3-56-2-90. This selection originated as D13-7 from the Delta RVT plot (see Table 4, group 2). Although originally released with D13-2, its use has been discontinued because of its slightly earlier initiation of BF.

FPMS 3-56-6-93. This selection originated with NS-B (Table 3). Originally found to be PRSV positive, it was since heat-treated to eliminate the virus. No commercial information of subsequent performance is available.

FPMS 3-56-7-92. This selection has the same origin and history as 3-56-7-93.

FPMS 3-56-8-92. This selection is D4 from the Delta plot. No BF has appeared in the progeny test through 1999 (Table 4, Group III).

FPMS 3-56-9-92. This selection is from D8 from the Delta plot. No BF has appeared in the progeny through 1999 (Table 4, Group III).

Table 1. Relationship between *individual year of occurrence*, the *age of first BF appearance* and *BF severity rating*

Rating	Age = 1 1991[a]	Age - 2 1992	Age = 3 1993	Age = 4 1994	Age = 5 1995	Age =6 1996	Age = 7 1997
1	52	68	138	309	48	246	195
2	138	22	129	125	7	53	15
3	121	7	22	31	2	3	3
4	51	0	0	3	1	1	0
Total trees:	362	97	289	468	58	303	213
Total trees (1 and 2):	190	90	267	434	55	299	200

[a] data obtained the following spring

Table 2. Distribution of BF_{pot} among 70 single tree sources from six commercial orchard sources. None showed BF at the time the buds were collected. AvBF at the end of four years progeny testing (1995) is shown with a followup of performance at the end of the 6th (1997) and 7th (1998) year.

Sequence number of progeny tree	*No. of Progeny Trees*	*AvBF 95*	*AvBF 97*	*AvBF 98*	*% BF trees*	*BF_{pot} Rating of source Trees*
1-4	9	0.0	0.0	0.0	0	Very low
5-16	7-26	0.0	0.0-0.8	0.1-0.8	4--44	Low
17-42	7-35	0.1-0.8	0.1-1.4	0.9-2.5	21-100	Medium
43-48	7-31	1.3-1.6	2.0-2.5	2.3-3.0	79-100	High
49-70	7-34	2.0-4.2	2.3-4.7	2.3-4.7	67-100	Very high

Table 3. Distribution of the total variance in AvBF among selection parameters of Carmel nursery sources as established from 1991 propagations

Variance Parameter	1992 (%)	1993 (%)	1994 (%)	1995 (%)	1996 (%)	1997 (%)	
Nursery source	10**	14**	25**	32**	33**	37**	
Source tree	45**	47**	42**	41**	40**	36**	
Budstick within tree	24**	25**	17**	14**	12**	14**	
Position of bud	NS	NS	NS	NS	NS	NS	
Unaccounted	20	14	15	13	13	13	

** = statistically significant at 1% level
NS = not significant

Table 4. Characteristics of source and progeny trees of Individual Nursery Sources at the end of the 7 year trial at Paramount West orchard in Kern County.

Source ID	No. of Source trees	No. of Progeny trees	BF %	Significant differences among:			Remarks
				Sources	Trees in source	Within trees	
I. Original seedling tree							
NS-A	1	31	1.8	A	**	*	Severely pruned for budwood
II. Commercial Orchards							
NS-E	25	266	34.3	C	**	Ns	S_4 ; VegLine 1B
NS-F	8	79	42.5	CD	**	**	S_4 : VegLine 1B
NS-G	10	307	42.5	CD	**	**	S_3 ; VegLine 1B
NS-I	Unk	100	52.4	DE	unk	unk	Commercial nursery trees
NS-J	7	215	54.1	DE	**	**	S_5 ; VegLine 1B
NS-L	10	295	83.0	F	**	**	S_5 ; VegLine 1B
III. Pre-selection							
NS-C	10	234	19.3	B	**	**	S4 ; VegLine 2
IV. Managed Source blocks							
NS-B	25	210	2.2	A	ns	na	Nursery increase block; VegLine 3
NS-D	21	297	31.5	C	**	**	Nursery scion block; Vegline 4
NS-H	unk	315	50.1	DE	unk	unk	Nursery scion block; VegLine 5
NS-G (cl)	3	98	55.0	DE	ns	**	Orchard scion block; clonal selection of NS-G
NS-K	16	420	59.4	E	**	**	Orchard scion block; VegLine 5
NS-M	19	72	81.0	F	ns	ns	Nursery scion block; VegLine 5

** = statistically significant at 1% level; ns = non-significant; na = not applicable

Table 5. Progeny tests of single tree candidate selections for low BFpot Foundation Clones in Carmel

Group I. Original nursery Carmel selections

Source ID	No. trees	1990	1991	1992	1993	1994	1995	1996
A. BF percentage								
114-6	14	0	0	0	0	21	29	29
114-2	19	0	0	5	11	21	26	42
114-5	11	0	0	0	18	55	64	64
114-4	16	0	6	21	50	62.5	69	69
114-1	13	0	0	3	31	62	92	77
114-3	13	0	0	38	62	77	92	100
B. AvBF								
114-6	14	0	0	0	0	0.29	0.29	0.29
114-2	19	0	0	0.11	0.11	0.32	0.42	0.69
114-5	11	0	0	0	0.27	0.73	1.18	1.00
114-1	13	0	0	0.03	0.38	1.15	1.38	1.08
114-4	16	0	0.06	0.50	0.81	1.12	1.25	1.19
114-3	13	0	0	0.23	0.62	1.54	1.54	1.77

Group II. Miscellaneous Carmel selections made in 1989.

Source ID	No. trees	1991	1992	1993	1994	1995	1996	1997	1998	1999
A. Per cent BF										
S_o	8	0	0	0	0	0	0	0	0	0
D13-2	39	0	0	0	0	0	0	0	5	5
D13-13	39	0	0	0	0	0	0	0	11	14
W1-4	27	0	0	0	15	7	0	0	41	22
D13-7	39	0	0	0	0	0	0	51	74	41
B114-3	40	0	0	0	22	28	43	75	92.5	70
BH	57	0	10.5	12	35	39		68	81	70
W1-9	38	0	36	78	97	100	100	100	100	100
B. AvBF										
S_o	8	0	0	0	0	0	0	0	0	0
D13-2	39	0	0	0	0	0	0	0	0.03	0.08
D13-13	39	0	0	0	0	0	0	0	0.11	0.09
W1-4	27	0	0	0	0.15	0.1	0	0	0.4	0.5
D13-7	39	0	0	0	0	0	0	0.8	0.9	1.0
B114-3	40	0	0	0	0.3	0.4	0.5	1.3	1.4	3.9
BH	57	0	0.11	0.14	0.5	0.8	1.0	1.3	1.7	2.0
W1-9	38	0	0.5	0.6	2.1	2.8	3.6	4.4	4.4	2.9

Group III. Carmel source selections made from UC selections in 1992 and 1993 plus commercial selections. Trees planted in January 1994.

Source ID	Test plot	No. progeny trees	March 1998		March 1999	
			% BF trees	AvBF	% BF trees	AvBF
Sources from commercial orchard near Ripon						
VG 8-8	Fresno 1	2	0	0.0	0	0.0
	Fresno 2	10	0	0.0	0	0.0
VG 8-14	Fresno 1	2	0	0.0	0	0.0
	Fresno 2	10	0	0.0	1/10	0.1
VG 8-18	Fresno 1	2	0	0.0	0	0.0
	Fresno 1	10	0	0.0	0	0.0
VG 8-23	Fresno 1	2	0	0.0	0	0.0
	Fresno 2	10	0	0.0	0	0.0
VG 11-3	Fresno 1	2	0	0.0	0	0.0
	Fresno 2	10	0	0.0	0	0.0
VG 11-6	Fresno 1	2	0	0.0	0.0	0.0
	Fresno 3	10	0	0.0	0.0	0.0
VG 8-7	Fresno 1	2	100	3.0	100	3.0
	Fresno 2	10	60	1.2	100	3.0
VG 8-10	Fresno 1	2	0	0	0	0.0
	Fresno 2	10	10	0.1	20	2.0
VG 8-12	Fresno 1	2	50	1.0	50	3.0
	Fresno 3	10	70	2.1	80	1.7
VG 8-13	Fresno 1	2	0	0.0	0	0.0
	Fresno 2	10	10	0.1	-	-
VG 8- 15	Fresno 2	10	30	0.5	40	0.5
VG 11-1	Fresno 1	1	50	-	100	1.5
	Fresno 2	9	67	50	50	0.4
VG 11-5	Fresno 1	2	0	0.0	0	0
	Fresno 2	10	20	0.3	70	1.3
Sources trees tested from Delta RVT plot, Manteca						
D2	Fresno 1	2	0	0.0	0	0.0
	Fresno 3	10	0	0.0	0	0.0
D4	Fresno 1	2	0	0.0	0	0.0
	Fresno 2	10	0	0.0	0	0.0
D8	Fresno 1	2	0	0.0	0	0.0
	Fresno 3	10	0	0.0	0	0.0
D20	Fresno 1	2	0	0.0	0	0.0
	Fresno 2	10	20	0.2	60	0.9
Trees from commercial selections						
Mach	Fresno 1	4	0	0.0	25	0.25
	Fresno 2	7	30	0.3	14	0.14
	Fresno 3	8	37.5	0.5	60	0.9
72-2E	Fresno 1	3	0	0.0	67	1.3
112-40	Fresno 1	3	0	0	67	1.0
	Fresno 3	4	25	0.5	67	1.0
112W-4	Fresno2	7	40	0.9	41	0.9
27-448	Fresno 1	16	75	2.1	95	2.1
Background commercial source within test orchard						
Unknown	Fresno 1	59	44	0.7	70	0.8
	Fresno 2	66	61	1.5	64	1.2
		68	54	1.1	-	-
	Fresno 3	73	55	1.1	57	1.0