1997 Final Report, Project No. 97-KS-o1: Noninfectious bud-failure

Project Leader Ken Shackel
University of California
Dept. of Pomology
Davis, CA 95616

Cooperating Personnel
Tom Gradziel, Dale Kester, Mario Viveros, Warren Micke, Mike Cunningham.

Summary

The primary goal of this project has been to determine whether any nursery sources of the 'Carmel' variety have a low bud-failure (BF) potential when tested in a common environment conducive to BF expression. In addition to identifying sources with low BF potential, the project has been part of an effort to identify nursery sources which meet the requirements of the California Dept. of Food and Agriculture (CDFA) Registration and Certification program, which includes freedom from known viruses, trueness-to-cultivar and trueness-to-type. The yield effects of BF were also evaluated. Budwood was collected from the original 'Carmel' seedling tree, in addition to over 160 trees used as sources by 12 California nurseries. Each source tree was replicate propagated for a total of over 2,700 test trees, and these trees were rated for BF expression from 1992 - 1997. The overall percentage of trees showing BF has increased progressively from 13% in 1992 to 65% in 1997. The overall increase in BF was greater following years of particularly hot summer temperatures than following years of cooler summer temperatures. More importantly for the almond industry however, is the fact that significant differences in BF potential did occur for different sources of 'Carmel', with some sources still free from BF expression as of 1997. The commercial nursery industry has been kept informed of our findings since the beginning of the study, and most nurseries started the process of converting to low BF potential sources as soon as those sources had been identified. Yield was measured on a group of trees representing a range of BF expression, and severe BF expression was associated with a 50% reduction in yield. Based on the relation of BF to yield, and the fact that BF expression generally increases over time for any particular tree, we recommend early diagnosis and replanting, even for trees expressing mild BF symptoms. A preliminary "break-even" yield analysis indicates that lost yield will be recovered within 8-9 years if a tree with moderate to severe BF expression is replanted even in the 4th or 5th leaf of the orchard.

Specific objectives:

a. Compare commercial propagation sources within the Carmel variety for BF potential when tested in a common environment conducive to BF expression.

b. Identify relative importance of variation in BF potential among nursery sources, individual trees, separate budsticks and bud position on budstick.

d. Characterize the Carmel variety for its overall BF

e. Identify specific Foundation Clones with low Bf potential which also meet the requirements of the California Registration and Certification program, including freedom from known viruses, trueness- to cultivar and trueness-to-type.

f. Establish methods of stabilization during budsource management

Procedures and Results

I. Assessment of BF potential and BF expression within commercial nursery sources of Carmel

Note: BF potential is defined as the years (age) until BF is expressed in the progeny. BF expression is the severity of symptoms, rated on a scale of 0 (none) to 4(very severe).

A sample of budsticks (one to 5) was collected from about the periphery of individual trees of separate nursery sources and individual buds propagated in sequence such that the identity and origin of each tree produced could be maintained from source to progeny. Ten nurseries cooperated in this test. Two additional nurseries provided material but without this pedigree information. Trees were planted in an orchard of the Paramount Farming Corporation in northwest Kern Co., an area of hot summer temperatures. BF expression was rated each March beginning in 1992. Approximately 2700 trees were evaluated representing progeny from approximately 150 individual source trees. The relative BF potential of separate source trees from individual nurseries was designated by (a) the percentage of progeny trees which produced BF symptoms over five years and (b) the average BF rating of progeny trees during the last observation year. A third method based on the age of first BF expression is planned for a later analysis to predict future development of BF.

BF expression among progeny trees.

The pattern of BF expression among the approximately 2700 trees of the Paramount test plot as reported in 1996 after five years of observations appeared to have established the primary response pattern of trees planted with a range of BF potential. Total numbers of trees expressing BF had progressively increased each year, leveling off at approximately 50% during the 4th and 5th years. A shift in the severity of expression and the location of the symptoms accompanies this pattern, interpreted to mean that BF is expressed later in tree development, occurs farther up in the tree and affects a smaller part or the total canopy.

This pattern is consistent with that found in other BF susceptible cultivars, such as Nonpareil, with large increases in BF trees following particularly hot summers. Greater expression was observed in the first three years (primarily moderate to severe) which developed as the framework was established and growth was rapid, whereas in later years, growth was less and symptoms were not as severe.

1997 results. Nineteen ninety-seven brought an apparently new situation in that the BF expression in both Carmel and Nonpareil appeared to be in epidemic proportions throughout the entire State of California. However, analysis of the 1997 data did not produce any major surprises but it did make possible a better interpretation of the overall project. Progeny of

sources which had previously shown BF continued to show BF but usually at a slightly higher rate and individual trees were rated somewhat more severe. This pattern is shown clearly in Figure 1 (percentage of BF trees per year) and Figure 2 (BF severity relationships of individuals trees over time). New cases of BF within progeny of each source tended to be relatively mild in expression and produced higher in the tree).

Analysis of temperature patterns. The increase in BF in spring 1997 was widely associated with the high temperatures in 1996 throughout California. This led us to an extensive analysis of temperature patterns. The effect of 1996 temperature was not only confirmed but we found that the summer temperature patterns throughout the entire study had not been sufficiently appreciated.

Data on accumulated degree days greater that 80°F. was obtained for a number of weather sites in California through the UC IPM facility at UCDavis. 1996 had the highest temperatures but 1991 and 1992 were also very high. BF production was started and trees starting with BF showed very severe expression which might be associate with the high temperatures during 1991 and 1992. The percentage increased in 1994 but the level of BF expression was low. Similarly the percentage of BF trees doubled in 1995 but the level of expression of new cases was low. However, this increase was associated with very high summer temperatures. To the contrary the percentage actually decreased in 1996 which can be associated with the very low heat accumulation. The 1996 heat was the highest on record and resulted in a sharp increase in BF in 1997. The accumulated temperature for 1997 was the lowest of the entire seven year period throughout California. It may be safe to predict that 1998 will have a low overall expression of BF throughout the almond growing areas of the state.

Yield Effects

In the Paramount test orchard, the first three years were the most important in establishing the presence and the significance of BF affected trees in the orchard. During this period the tree is growing rapidly and most extensively to establish the primary framework of the tree and to initiate the bearing surface. Carmel is precocious in bearing and begins to develop spurs and flower buds at an early age, often by the third growing season. BF kills lateral shoot buds, stimulates vigor on the new shoots, inhibits spur formation and essentially prevents the normal beginning of the fruiting period. Figure 2 shows that the severity of BF symptoms generally increased with time. For this analysis, trees were grouped together if they first developed symptoms in the same year, or if they showed the same level of symptoms in 1992.

Figure 3 shows that severe BF symptoms were associated with substantial reductions in yield (about 50%), and that moderate symptoms had lesser effects. Based on the assumption that this pattern of yield reduction with increasing BF severity will continue as the trees reach full bearing, it is possible to estimate how yield will be effected over the life of the orchard, and a "break even" yield estimate can be made for different scenarios of tree replanting. These estimates must be considered **preliminary** however, because they do not account for economic factors such as the increased costs associated with replanting, or the potentially slower establishment of replants in a mature orchard. Both of these factors would increase the time to an economic break even point. The results of this analysis are presented in Table 2, and clearly indicate the importance of early diagnosis in reducing the time to a break even yield. Since the first opportunity to observe BF in the field is Spring of the second leaf, removal of BF expressing

trees, even those with mild symptoms, should have beneficial yield effects in 4 - 5 years. It appears that mild symptom expression may not warrant replanting after about the fourth leaf, although more severe symptoms may continue to be important after that.

II. Analysis of source selection

Clear differences found among individual source trees, and statistical analysis of the effects of source tree, budstick within source tree, and nursery (Table 1), continued to show that the major source of variation in BF is attributable to the individual source tree (overall 46%), with a significant but lesser role played by nursery (32%) and even individual bud stick within the source tree (14%).

THESE RESULTS CONFIRM THAT THE KEY TO CONTROL OF BF IS THE SELECTION OF INDIVIDUAL SOURCE TREES WITH LOW BF POTENTIAL.

Our results also indicate that sampling multiple budsticks per tree, rather than multiple buds per stick, may be a more efficient method of progeny testing candidate material in the future.

How long to continue progeny testing? A key question is: how long must observations continue to indicate low BF potential? High BF potential can be expressed within one year after planting but initial expression in the progeny has continued in the progeny from some sources but the level of BF expression tended to be low and not likely to be significant in later orchard performance as predicted from yield analysis. We had concluded in 1996 that observations should continue for 5 years. The 1997 season produced doubts because progeny from specific sources began to express BF at six and seven years. Analysis of the temperature patterns (see earlier in report) showed that conditions of the test and individual season must be taken into account in evaluating the material.

A. Analysis of single tree progeny from commercial orchard sources of individual nurseries.

To get a comparative picture of the total pattern within Carmel, we plotted the 1997 BF potential ratings from progeny of 73 single source trees of six commercial orchards used as sources by individual nurseries, including the original seedling Carmel tree. These made a continuous plot from *very low* (no BF expression), *low* (4 to 60% at 6 years but average BF severity ratings of 0.03 to 0.20), *medium* (65 to 95%, average BF severity of 0.20 to 1.00), *high* (95 to 100 %, average BF severity of 1 to 2), *very high* (100 %, average BF severity of 2 to 4).

The numbers in each class were very low = 7, low = 25, medium = 16, high and very high 25. This analysis shows that the comparison among sources is one of degree and that no source exists which can be rated as no BF potential. This data is based upon 1997 results with the strong influence of the 1996 high summer temperatures. We need to have the 1998 data to determine if this pattern will change. Although BF potential rating of very low is preferred, it is likely that sources rated at low could also be acceptable in commercial practice. This is because although symptoms might appear late, their severity is less and they are located higher in the tree on fewer branches.

B. Identification of FOUNDATION CLONES of Carmel eligible for inclusion in Registration and Certification program.

Procedure: Progeny tests of specific individual source trees have been carried out separately from the comprehensive nursery progeny tests. Individuals have been selected or recommended from various sources. Trees were propagated by a commercial nursery and progeny trees planted in the Paramount orchard near Wasco for progeny testing. At the same time, a tree from each source was propagated at the Foundation Plant Materials Service at UC Davis, submitted to virus indexing and when shown to be free of virus placed into the Foundation Orchard for maintenance with a scion orchard type of management. When verified as free of serious virus and genetically true to cultivar, the individual trees are Registered with the California Dept of Food and Agriculture (CDFA). These are now available for commercial nursery use.

I. The first group of FOUNDATION CLONE candidates of Carmel planted in 1989 began to produce BF on individual progeny trees within three years. Several had been planted at FPMS but have not been registered and distributed. At five years progeny trees had produced significant BF.

2. A second group of six candidates established in 1990 at the Paramount Orchard test plot near Wasco , have produced a range of responses from zero BF to literally 100 percent in the seven subsequent years through 1997.

A. FPMS 3-56-1-90 (originated from Manteca RVT test plot tree 13-2). This source is the only one of the test that produced no BF in the 41 progeny test trees planted in 1990). Material was made available to propagate all of the Carmel trees in the three UC Regional Variety Plots planted in 1993 in Kern, San Joaquin and Butte Cos. No BF trees were observed in any of these plots in 1997. Material from this source was registered and released to nurseries in 1994 to enable the establishment of commercial sources. Some commercial orchards were planted in 1995 with no reported BF trees produced in 1997. There is now apparently significant amounts of source material at nurseries.

B. FPMS 3-56-2-90 (originated from Manteca RVT plot tree 13-7). This source has the same history as above but originated from a different Manteca source tree. No BF trees were produced during first five years (up to 1995). In 1996 one progeny test tree out of 40 produced mild symptoms in one branch in the top of the tree. In 1997 50% of the progeny trees were rated as slight (r = 1), located in the tops of the trees and represent an expression considered not likely to be of economic importance (see discussion of yield).

This material was registered and released for commercial use in 1994 along with FPMS 3-56-1-90 and some planting has occurred with no BF been established as Foundation Clones and were released to commercial nurseries in 1994. Scion blocks by many nurseries have been established in preparation for commercial distribution.

C. A third group of Foundation Clone candidates of Carmel were selected and propagated in 1993, and planted in 1994 in test orchards in Fresno Co. No BF was observed in progeny trees

in 1995 but trees were not observed in 1996. Eight of these Foundation clones have been placed in FPMS but progeny tests are not sufficiently advanced to allow distribution. Five of these came from a commercial orchard near Manteca and three were additional trees from the Manteca RVT

plot.

D. FPMS 3-56-7-93 and FPMS 3-56-8-92. These two Foundation clones were placed in FPMS by a commercial nursery whose material had a low pattern of BF production. These sources however were RS positive initially. These sources were submitted to IR-2 Repository, Prosser WS for heat treatment. These were returned and planted at FPMS where they are registered and available for distribution.

E. (Original Source Carmel tree) This tree is not eligible for Registration but is maintained by the Bright Nursery, LeGrand. The 31 progeny trees from this source had remained free of BF through 1995. In 1996 two trees produced some mild symptom on two trees in 1996 and again in 1997. Symptoms are very mild and located high in the tree. This pattern falls within the range previously described as probably not having an economic effect.

Conclusions.

1. The strong seasonal effect on 1997 bud-failure results throughout California was also clearly expressed in the 1997 data obtained in the various plots in this project. This effect can be shown to be due to the strong influence of the high temperatures in summer 1996 which had a more or less constant effect across the board of all sources in these studies. The low 1997 heat pattern indicates low BF expression in 1998. We need to verify this next year.

2. The temperature effect of the different years has had a larger impact on the pattern of BF development in the test plots and needs to be taken into account in evaluating different sources.

3. A major question needing further evaluation is the appearance of mild symptoms on progeny trees after reaching 5 years into the test. Presence of such trees may show relative difference among sources but are not necessarily indicative of a "bad" source. Further observations are needed.

4. A second question is once a very low or low BF potential source is identified, what is best methods for stabilizing and maintaining this material during propagation. The study shows that commercial orchard management leads to increasing levels and variation in BF_{pot} and historically is the source of BF in orchards. Procedures based on hedge-row type management, such as scion orchards and nursery increase blocks, are apparently needed to stabilize BF_{pot} at a more or less constant level.

Further evaluation and perhaps research may be required to answer all of these questions.

Table 1. Statistical analysis describing the per cent of the variation attributable to the effects of source tree, budstick within source tree, and nursery.

Factor	1992	1993	1994	1995	1996	1997	Overall
Source Tree	**45%**	**47%**	**42%**	**41%**	**40%**	**36%**	**46%**
Nursery	**10%**	**14%**	**25%**	**32%**	**33%**	**37%**	**32%**
Stick	**24%**	**25%**	**17%**	**14%**	**12%**	**14%**	**14%**
Unaccounted	**20%**	**14%**	**15%**	**13%**	**13%**	**13%**	**7%**

Table 2. Estimated years to a "break even" yield, for replanting BF affected trees of different severity at various times in the early life of the orchard. These estimates must be considered **preliminary** because they do not account for economic factors, which would most likely increase the time to an economic break even point.

Orchard year (leaf)	BF symptom severity			
	1	2	3	4
2	5 yrs.	5 yrs.	4 yrs.	4 yrs.
3	7 yrs.	6 yrs.	6 yrs.	6 yrs.
4	16 yrs.	8 yrs.	6 yrs.	6 yrs.
5	over 30 yrs.	19 yrs.	9 yrs.	7 yrs.
6	over 30 yrs.	19 yrs.	10 yrs.	9 yrs.

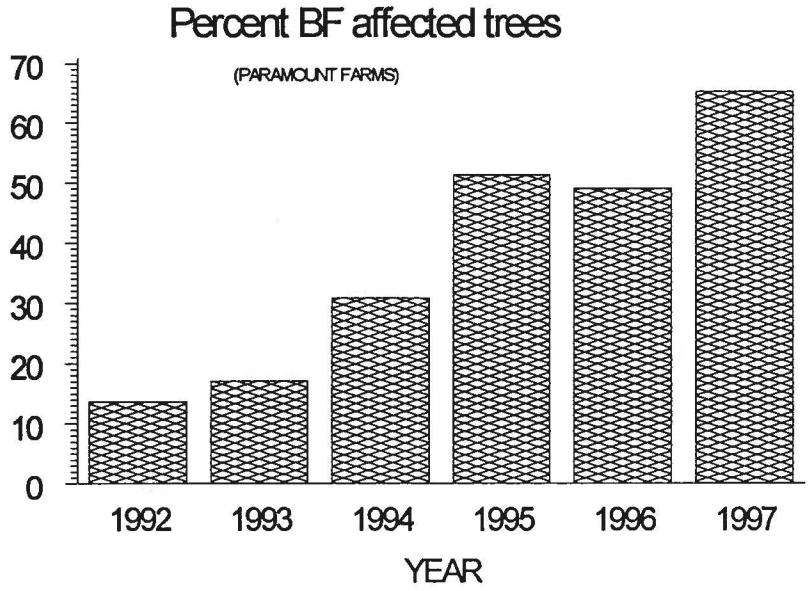

Figure 1 Percentage of trees expressing any level of BF symptoms for the 1992 - 1997 period.

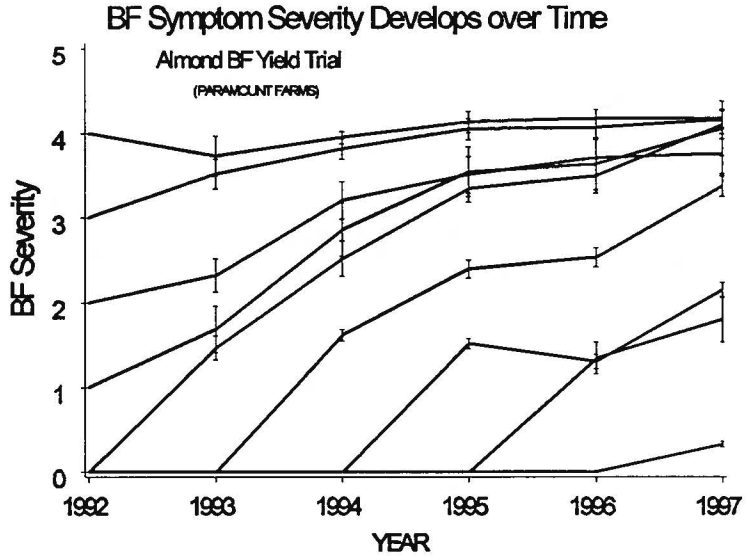

Figure 2 Increase in BF severity over time for trees grouped by the level of BF (1 - 4) they expressed in 1992, or by the year in which their first BF symptoms were expressed.

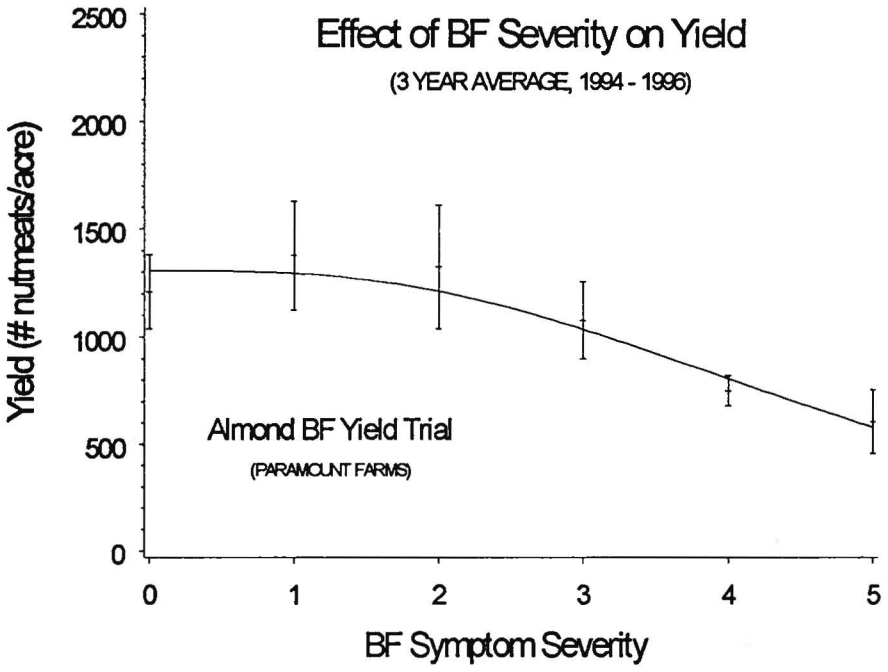

Figure 3 Relation of 3 year average yield (based on individual trees, but expressed as pounds nutmeats per acre), and 3 year average BF symptom severity.