Correct Project Number: 96-K22

1996 Report, Project No. 96-K23: Noninfectious bud-failure

MAY 20 1997
ALMOND BOARD OF CALIFORNIA

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.

The Almond Board has supported research on noninfectious bud-failure (BF) and other disorders since the beginning of the sponsored research program, initially as part of the varietal improvement project and eventually separately. By 1988, research had established the basic nature of BF, determined distribution patterns within commercial varieties and germplasm and identified propagation sources of major varieties that had low potential for BF. The kind of source selection utilized was based upon single tree selection accompanied by vegetative progeny testing in orchards utilizing in part the five Regional Variety Trial (RVT) plots.

This 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. During the past eight years we have worked closely with the deciduous tree fruit and nut nurseries, most recently with the California Fruit Tree, Nut Tree and Grapevine Improvement Advisory Board (IAB) to expand the list of almond varieties eligible in the program, adding the characteristic for almond of having low BF potential. This source selection process is based upon selection and testing of single tree sources (known variously as "nuclear sources", "clones", "source-clones", "foundation clones") within a variety. Source trees are maintained in isolated foundation blocks (Foundation Plant Materials Service [FPMS], UC Davis and some private nurseries) and in nursery scion orchards or nursery increase blocks. Multiplication and distribution takes place only with limited numbers of generations of vegetative increase from the original foundation tree. This procedure is a major change in commercial nursery practices and is unique for almonds when the requirement of controlled "progeny testing"is added. The adoption of this program represents a revolutionary change in nursery practice which has been underway during the past five or more years and is still being implemented. Information about the Foundation Source accessions available in this program can be obtained from Foundation Plant Materials Service, University of California, Davis CA 95616.

In 1988, the Almond Board project started a new phase by extending the Foundation Clone search to commercial varieties not represented at that time in the program and also concentrating efforts to understand better the serious problem of noninfectious bud-failure in Carmel. Results obtained annually up to 1996 from plots established in 1989, 1990 and 1991 have now provided the data to fulfill the original objectives of these studies. Several more years will be required to implement all of the applications, to provide enough new tested Carmel propagation material to meet requirements and to obtain commercial experience. This report summarizes what has been learned to date. Specific details will be provided in subsequent summaries and publications.

Results

The 1996 ratings were essentially identical or slightly less on a tree by tree basis to 1995 such that the conclusions reached are largely the same as in the 1995 report.

II. Assessment of BF potential in commercial nursery sources of Carmel

Procedure: 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 evaluations on a rating scale of 0 (none) to 1 (slight) to 4 (severe) were made each March from 1992 through 1996. Approximately 2700 progeny trees were evaluated representing approximately 150 individual source trees. Relative BF potential of individual source trees was designated by (a) the percentage of progeny trees which produced BF symptoms over the five year period and by (b) the average BF rating of these progeny trees, the latter procedure taking into account the difference in severity among trees. A third method using the age at which BF first appears will be utilized later in a model which predicts future development of BF potential within those trees not showing BF at the present time.

The total number of trees expressing BF symptoms has progressively increased, reaching about 65% as of 1997 (Figure 1). This pattern is quite consistent with the patterns found in other BF susceptible cultivars, such as Non Pareil, with large increases following particularly hot summers (eg., the summer of 1996). There were also shifts in symptom expression between the first three years (primarily moderate to severe) which developed as the framework was established and growth was rapid, and the fourth and fifth year. The percentage of trees affected in 1995 was about double that of 1994 but the amount in 1996 was about the same as

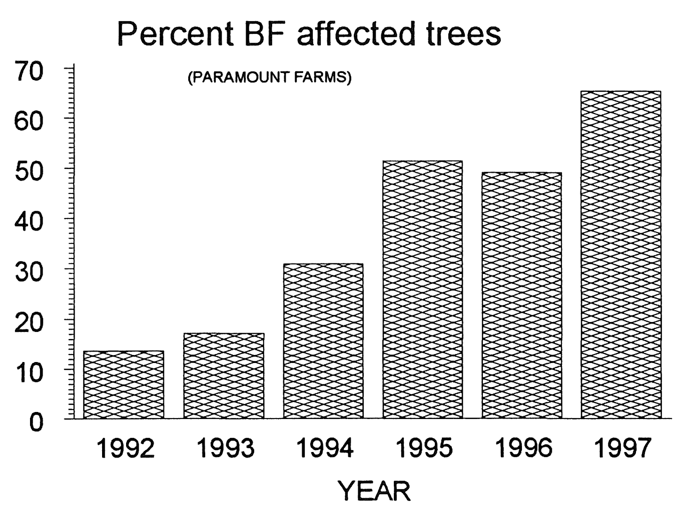

Figure 1 Percentage of trees expressing any level of BF symptoms for the 1992 - 1997 period.

1994. Essentially all of the new symptoms in 1995 and 1996 had ratings from 1 to 2, located in the top of the tree and probably of lesser overall effect to tree health and production.

Clear differences were found among individual source trees, and a statistical analysis of the effects of source tree, budstick within source tree, and nursery (Table 1), has consistently shown 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%).

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%

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. One can obtain indication of high BF potential within one year after planting although it appears that observations should continue for at least 5 years. Although BF symptoms can appear later than that, the rate at which new symptoms appear for the first time tends to level off, and their severity is less because of the higher location of BF affected branches.

Each year (until 1996) the BF data in the progeny trees of each source block has been supplied to the cooperating nursery to enable individual nurseries to make adjustments in the sources used. A wide range of response was shown among the progeny sources even though in each case the original source trees at the time of collection in 1990 had no recognizable symptoms. Progeny from the original source tree remained free of BF until this year when two trees showed mild symptoms (rating = 1) on two trees. Another source has produced trees with mild symptoms off and on in different trees at various times during the five years of the test with none expressed in 1996. A single Foundation Clone has been selected from this source and is present in FPMS. A number of the nursery sources showed a rather low overall rating with BF coming primarily from specific trees in the planting. In this case, removal of the offending source trees should improve their BF level and in some cases have been the origin of new source clones.

Other nursery sources have had such a high level of BF potential that new sources have had to be sought. Consequently, most sources used in 1990 have undergone changes such that information about individual nurseries does not necessarily directly apply to individual sources used at the present time.

II. Management of BF affected trees in orchards.

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.

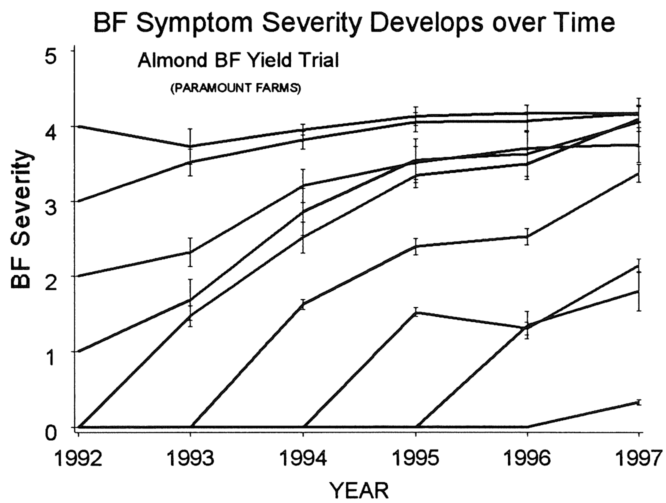

Figure 2 Increase in BF severity over time for trees grouped by the level of BF (1 - 4) they expressed in 1992, or by the year in which their first BF symptoms were expressed.

Procedure: The relationship of symptoms to yield is the major application towards control of BF in orchards. Individual tree yields were obtained for individuals with various degrees of BF expression, i.e., ratings of 0 to 4 (or 5).

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

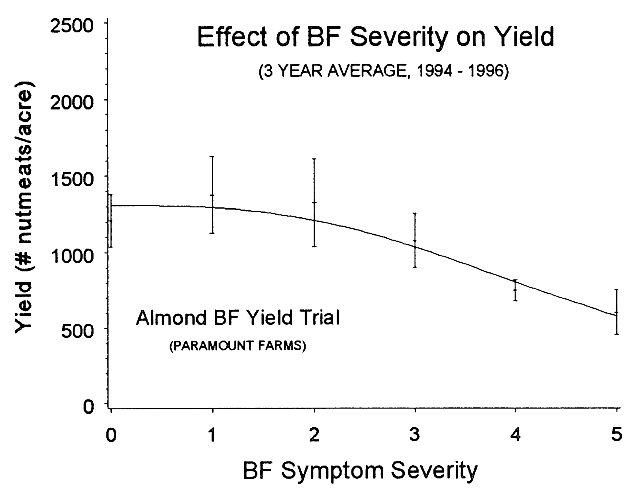

Figure 3 Relation of 3 year average yield (based on individual trees, but expressed as pounds nutmeats per acre), and 3 year average BF symptom severity.

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.

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.

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

Foundation clones of Nonpareil, Mission, Peerless, NePlusUltra, Thompson, Padre, Sonora and Titan had been previously selected, placed into the FPMS Foundation orchard and have been available to commercial nurseries prior to 1988. New candidate selections of Fritz, Ruby and Monterey were virus positive and submitted to USDA IR-II Station, Prosser, Washington for thermotherapy, subsequently being established at FPMS. Trees of Butte, Price, Fritz, and Mission were virus negative, visually judged to be “true to-type”, showed no BF in the progeny tests, and have been propagated at FPMS, UCDavis. All of these are now released for commercial distribution as FOUNDATION CLONES.

Procedures: Candidates for individual source trees of varieties not represented in the list of eligible materials in the Registration and Certification program were solicited in a 1988 meeting of the FPMS tree fruit and nut advisory committee, made up of personnel from commercial nurseries, UC research and extension workers, and FPMS. A list of candidates from various sources, mostly commercial nurseries, was compiled for Butte, Price, Carmel, Fritz, Ruby, and Monterey. Twenty to twenty five trees of each candidate tree were propagated by a commercial nursery in 1988 and progeny trees were planted in two orchard locations in the San Joaquin Valley in 1989. One was at the Paramount Farms, Wasco, Ca. The other was at Diener orchard, FresnoCo.Each tree source was virus indexed by FPMS, UC Davis and candidate trees maintained in a greenhouse in isolation until tests were completed before placing in the Foundation Orchard.. Progeny trees at the Paramount test block in central Kern Co. were visually inspected for BF and other varietal characteristics each spring during 1991, 1992, 1993 and 1994. Production and nut characteristics were observed in summer 1994.

The first group of FOUNDATION CLONE candidates of Carmel were planted in 1989 but began to produce BF on individual trees within three years. Several had been planted at FPMS but have not been registered and distributed. A second group of candidates established in 1990 at the Paramount Orchard test plot, have produced a range from zero BF to literally 100 percent in the seven subsequent years through 1996. Two selections (Manteca 13-2 and 13-7) had produced no BF in the progeny trees through 1995 but Manteca 13-7 produced very slight symptoms on one branch of one tree in 1996. Both of these have 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.

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.

IV. Establish the pattern of BF development within the Carmel variety

Procedures: Pedigree history of budwood sources of Carmel have been provided by commercial nurseries from propagation records. Some original Carmel orchards were examined in 1995 for BF distribution. A comprehensive survey was made of each of the nursery source blocks in 1995. The genealogy pattern of most of the Carmel propagation lines have now been constructed and correlated to the patterns of BF showing among the progeny of the various nursery source block. A system of designating individual orchards by pedigree history is used in this discussion. The propagation generation is designated by S_0 (original seedling), S_1 (first generation), etc. Individual orchards are designated by lower case letters, as S_{2a}, S_{2b}, etc.

The original Carmel arose as a seedling plant (S_0) in a Nonpareil row in the Arakaki orchard near

LeGrand originally planted in 1947. Although originally claimed to be a budsport because the trees were believed to on peach rootstock, the rootstock was later found to be almond. Fingerprint data indicates that it's origin is as a hybrid of Nonpareil and Mission, similar to most other California varieties of local origin. A commercial orchard was established in 1964 (S_1) which appeared so promising that two orchards were established in 1966 by two local growers (S_{2a}; S_{2b}), one near LeGrand and the other near Merced. Another orchard established near Durham is believed to have been planted in 1968 (S_{1c}). Commercial nursery production was started in 1971 by the primary nursery propagator with commercial orchards first being planted in Kern and Fresno beginning in 1972, with either the S_{2a} and S_{2b} orchards as budwood source used from 1971 through 1973.

Most of the budwood source pattern for Carmel has been reconstructed but is not complete. Consequently, a detailed account of Carmel distribution will be presented when the analysis is complete.

OVERALL CONCLUSIONS

I. Low BF potential sources of Carmel are appearing from this project but are likely to be in short supply for the immediate future.

. At present the following are possible sources.

A. Original seedling tree of Carmel. The amount of budwood is limited and may not be sufficient to provide all that might be desired.

B. Modified budwood orchards of individual nurseries from results of Paramount progeny tests. Information must be obtained from individual nursery but in many cases may not provide a sufficient supply.

C. New FOUNDATION CLONES in FPMS, UCDavis. This includes Accession nos. 3-56-1-90 (Manteca 13-2), 3-56-2-90 (Manteca 13-7). These may be present in some nursery scion orchards but is likely to be in short supply.

D. Other sources of individual nurseries may be present but no information is available from this project.

II. Orchard management.

Closely inspect Carmel trees in the first three years and replace those which show BF symptoms.