time the seedling plant is grown and when BF appears within the clone.

Concept of BF

The picture emerging from these studies is of a cellularly based, unstable condition, probably chromosomal in nature. Changes occur as cells divide and as the plant grows; consequently, variation in BF potential can develop in various parts of the plant and the clone. Some part of the cells' basic metabolic machinery appears to be altered and when the alteration becomes sufficient, symptoms of the disorder appear. Buds used to propagate a new plant carry the BF potential of the cells of the growing point of that bud. Buds from one part of the plant can have a BF potential different from other parts. If the bud carries low BF potential, then the new plant may never produce the BF phenotype. If it carries a high potential, or if change in BF potential is rapid, then the new tree may produce the BF phenotype at an early age. If enough buds of a BF potential clone are propagated, and if trees are grown long enough, it is likely that some trees with BF will eventually appear.

Many unanswered questions, both theoretical and practical, remain. Perhaps the most pressing is how to identify BF potential prior to the time actual symptoms appear. Such information would be applicable both to almond breeding programs and to the development of propagating sources in the case of such varieties as Nonpareil.

Another question to be investigated is what controls levels of BF potential? Can it be altered or reduced? Conditions producing BF symptoms actually appear to develop in summer rather than late winter or spring when symptoms develop. Some evidence now at hand suggests that the BF level is associated with extensive shoot elongation and high temperature during summer. Work directed toward clarifying these and other questions is underway.

One line of investigation concerns interspecific hybridization between BF varieties and peaches in which a different pattern of inheritance than that shown in the graph exists. This breeding procedure is being investigated as a progeny test for BF potential. A second line involves the study of normal and BF tissue as masses of callus in sterile culture. A third series of investigations involves the relationship among growth, temperature, and BF development.

Significance to industry

The BF phenomenon can continue to produce serious problems to the commercial almond industry, and particularly to individual growers. We are unable at present to identify BF potential before it occurs. Consequently, it is not possible to predict how extensive BF will eventually become. Two dangers present themselves. One is that BF may develop in the many new almond varieties that have been introduced from various sources since 1956. Essentially all are, either directly or indirectly, offspring of Nonpareil and there is a probability that at least some have inherited a BF potential. In the varieties already affected, about 10 years have elapsed between the time of their introduction and the time when enough trees had been grown long enough to produce BF.

New acres

Many new acres of almond have recently been planted. Much of this has taken place in southern San Joaquin Valley, predominantly with varieties known to have BF potential. If the pattern of greater incidence of BF in this area continues, the problem may become more acute.

(2) *Identification and control of bud failure in almond varieties*

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THIS ARTICLE describes the current status, identification, and control, of noninfectious bud failure (BF) as it affects particular almond varieties in California. Characteristics of the disorder were described in the accompanying article. A recent survey taken to estimate the prevalence of BF in affected varieties in the almond districts of California is summarized in tables 1, 2, and 3, and is discussed here.

Varieties affected

JORDANOLO. This variety resulted from a cross, Nonpareil × Harriott made in 1923 and introduced in 1937 by the USDA and University of California. It was planted extensively and reached a maximum of 6,000 acres. About ten years after introduction, BF was discovered in the variety and the percentage of affected trees rapidly increased. It has been the most seriously affected variety. In the state as a whole practically all orchards with Jordanolo have affected trees. The percentage of seriously affected trees per orchard ranges from less than 25 to 100 per cent. The incidence of affected trees is somewhat less in the central part of the state as compared with the northern Sacramento and southern San Joaquin valleys. Few orchards with Jordanolo have been planted within the past 10 years and the current (1968) acreage is down to 2,800. The variety is gradually being eliminated.

PEERLESS. This was one of the six major varieties which originated in California prior to 1900 and became the basis of the commercial industry. It comprises 7,000 acres most of which are in the Sacramento Valley. Although BF-affected Peerless trees can be found in most districts, the incidence is relatively low. However, in the Arbuckle district of Colusa County, about 50 per cent of the orchards were reported to have some affected Peerless trees although the percentage per orchard was small.

NONPAREIL. This variety also is one of the six major varieties which originated in California prior to 1900 and is the most important variety in the industry. Currently (1968), it makes up 111,000 acres, somewhat more than one half of the total almond acreage. Nonpareil has been used

DISTRIBUTION AND BUD FAILURE (BF) STATUS OF BUDLINES OF NONPAREIL ALMOND TREES ORIGINATING FROM FOUNDATION PLANT MATERIALS SERVICE (FPMS) BLOCK, U.C. DAVIS

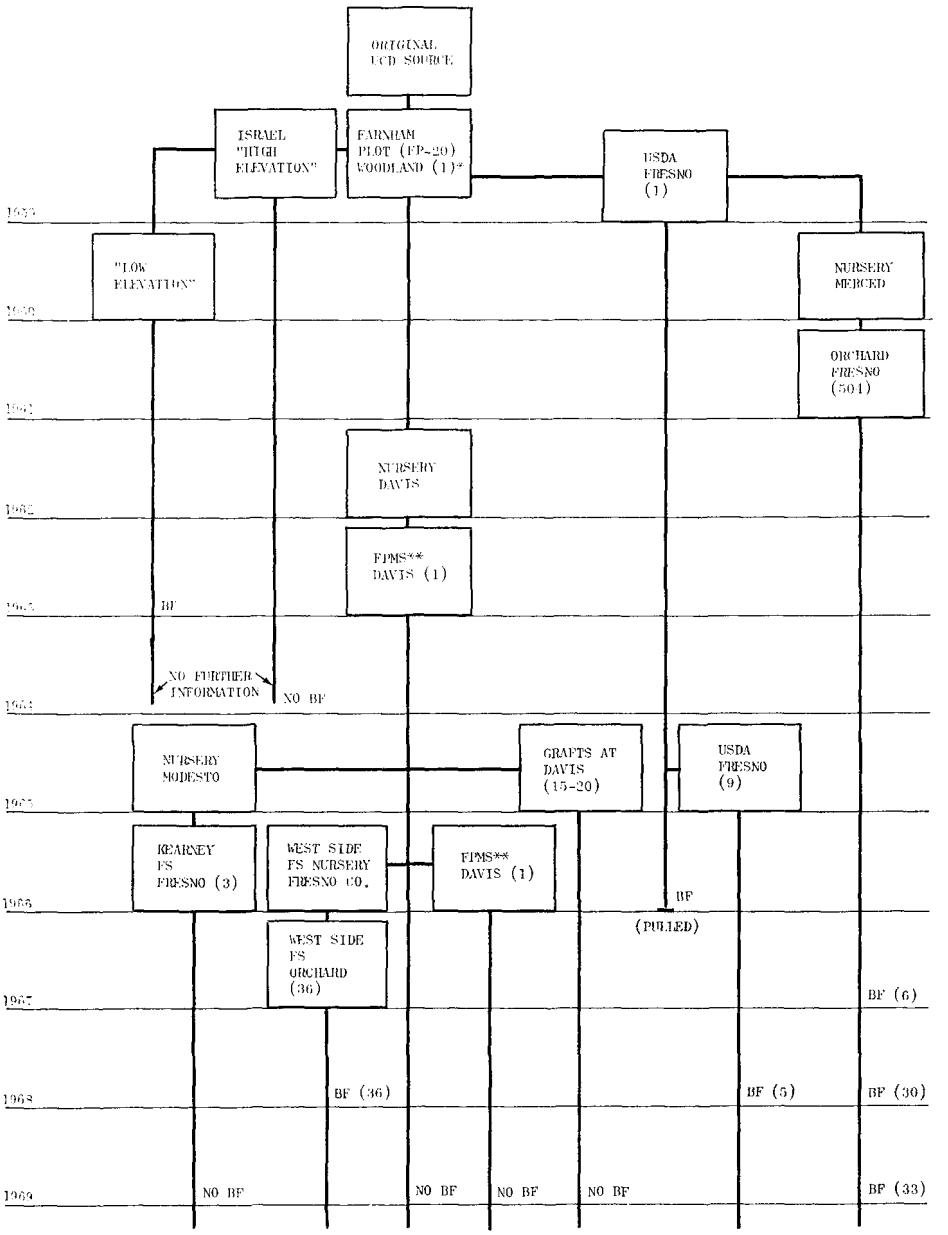

TABLE 1. DISTRIBUTION OF BF AFFECTED TREES OF 'JORDANOLO' IN COMMERCIAL ALMOND ORCHARDS IN CALIFORNIA, BASED ON ESTIMATES FURNISHED BY FARM ADVISORS IN VARIOUS COUNTIES. ONLY TREES 10 YEARS OLD OR MORE GROWING.

County	Proportion of orchards affected	Proportion of trees within orchards seriously affected
Butte	++++	++++
Yuba	++++	+++
Colusa	++++	++
Yolo	++++	+++
Contra Costa	++++	+
San Joaquin	++++	++
Stanislaus	++++	++
Merced	++++	+++
Fresno	++++	++++
Kern	++++	++++

Key to symbols: – no data reported; 0 none affected; + few; 5% or less; ++ some; more tran 5%; +++ about half; ++++ many; more than half.

TABLE 2. DISTRIBUTION OF BF AFFECTED TREES OF "NONPAREIL" IN COMMERCIAL ALMOND ORCHARDS IN CALIFORNIA, BASED ON ESTIMATES FURNISHED BY FARM ADVISORS IN VARIOUS COUNTIES. ONLY TREES 10 YEARS OLD OR MORE GROWING.

County	Proportion of orchards affected			Proportion of trees in orchards affected		
	1–6 yrs	7–14 yrs	15 or more yrs	1–6 yrs	7–14 yrs	15 or more yrs
Butte	++	+	+	++	++	++
Yuba	–	+	0	–	++	0
Colusa	+	++	+++	+	+	+
Yolo	+	+	+++	+	+	++
Contra Costa	0	0	0	0	0	0
San Joaquin	+	++	+	+	++	+
Stanislaus	+	++	+	+	++	++
Merced	+	+++	+	+	++	++
Madera	–	++++	–	–	++	–
Fresno	++	++++	++++	+	++	++
Kern	++	++++	++++	+	++	+++

TABLE 3. DISTRIBUTION OF BF AFFECTED TREES OF 'PEERLESS' IN COMMERCIAL ALMOND ORCHARDS IN CALIFORNIA, BASED ON ESTIMATES FURNISHED BY FARM ADVISORS IN VARIOUS COUNTIES

County	Proportion of orchards affected			Proportion of trees in orchards affected		
	1–6 yrs	7–14 yrs	15 or more yrs	1–6 yrs	7–14 yrs	15 or more yrs
Butte	+	+	+	+	+	+
Colusa	–	–	+++	–	–	+
Yolo	0	0	+	–	–	+
San Joaquin	0	+	+	0	+	+
Stanislaus	–	–	+	–	–	+

predominantly in breeding programs and it is one of the parents of most of the varieties introduced in recent years.

BF exists in Nonpareil in all districts of the state except Contra Costa county, but it is more serious in some than others. In Colusa (Arbuckle) and Yolo (Winters, Capay) Counties the amounts tended to be in proportion to age, so that 50 per cent or more of the orchards which were 10 years or older had some affected trees. Butte County (Chico, Durham) reported slightly more in recent plantings. Yuba County, on the other hand, reported the problem to be negligible.

In the upper San Joaquin Valley (San Joaquin, Merced and Stanislaus Counties), a greater prevalence of affected trees in the seven- to 15-year-old age bracket was reported. This reflects the widespread observation that during the planting period of 1958, when considerable expansion in acreage occurred, a high incidence of affected trees appeared. Improved propagation practices have apparently reduced the problem but have not completely eliminated it. Significant numbers of affected trees occur in the younger and older plantings in all districts.

The most serious outbreaks of BF have occurred in the southern San Joaquin Valley from Merced County south. Here rapid and extensive expansion in almond acreage has taken place during the past 10 years. For example, Fresno County increased from 1,800 acres in 1957 to 12,270 acres in 1968 and Kern County from 100 acres in 1957 to 11,090 in 1968. Although younger plantings have fewer affected trees than do those five years or older, more than half of the orchards have affected trees with the percentages per orchard usually amounting to about 25 per cent. Symptoms of BF in trees of this area are often very severe and develop at a young age.

According to one observer, a planting

boom of almonds in the Fresno area about 25 years or more ago was curtailed because of excessive production of BF Nonpareil trees.

OTHER VARIETIES. Jubilee originated as a chance seedling in Paso Robles district and was introduced about 1929. BF was discovered in 1953 and since then the variety has become severely affected. It is no longer planted. Harpareil, a sister seedling of Jordanolo, was tested and introduced at the same time as Jordanolo. Since then, few trees have been grown; there are no significant commercial plantings. It was tested side by side with Jordanolo, but BF was not discovered on any tree until 1968. Merced, which originated as a chance seedling, probably of Nonpareil and Texas origin, was introduced in 1958. BF was discoverd in 1968 in this variety in orchards in Merced, Kern, Colusa and Butte Counties.

Improved Nonpareil sources

The great significance of Nonpareil to the industry necessitates efforts to develop propagation sources that are free of both harmful viruses and BF potential. Commercial nurserymen have made particular efforts, with varying degrees of success, to select their propagation material for freedom from BF. The University of California and the State Department of Agriculture, Sacramento, have also had a program to develop true-to-type, propagating sources free of serious viruses.

A successful virus control program, however, will not necessarily solve the BF problem since no comparable indexing method for determining BF potential exists. The chart gives the history of the budlines of Nonpareil that have developed in this program. The initial Nonpareil budwood source was selected at the University of California, Davis from among trees that have been grown there and repeatedly propagated for many years with no evidence of BF. Plant pathologists at the State Department of Agriculture maintained this source near Woodland (Farnham plot) and carried out two series of eight-host indexing—testing negative to known viruses.

Experience with three separate budlines from this Farnham plot source tree are now available. One budline consisted of a single FPMS (Foundation Plant Materials Service, UCD) source tree that was established in 1963 and again in 1966, neither of which have shown any BF symptoms. Since 1965, buds from this budline have been used to propagate trees for various uses at Davis. None have produced BF trees. In 1965 (and again in 1966) trees were propagated by a Modesto nursery for an experimental planting established the following year at the Kearney Field Station, Reedley (Fresno County). None of these trees have produced BF. In 1966, trees were also propagated in a nursery at the West Side Field Station, Five Points (Fresno County) and transplanted to an orchard on the Station the following year. In spring 1968, all 36 Nonpareil trees in the planting showed BF in varying degrees of severity.

A second budline was established in 1959 in a necrotic ring-spot-free S-37 seedling peach tree at the USDA Horticultural Field Station, Fresno (Fresno State College orchard) with scions from the Farnham plot. This tree at Fresno produced BF symptoms in 1966 and was subsequently removed. Prior to its removal, buds were taken from this tree to propagate trees by a Merced nursery to establish a planting in 1961 at Fresno. BF trees began to appear in this planting by the sixth year. Again in 1965 buds of this budline were used from the tree at Fresno to grow trees for a planting in the Fresno State College orchard. BF appeared after three years.

A third budline was established in Israel about 1959. Israeli horticulturists report that trees propagated and maintained at the original introduction site at high elevations did not produce BF. On the other hand, buds from this source used to propagate trees at a low elevation desert area produced severe BF trees within two or three years.

Differences in the incidence of BF in the Nonpareil budlines originating from a single initial source suggest that BF development is affected by the location where the trees are propagated and by the location where they are subsequently grown. Two points are at issue. One is: how much and by what mechanism does location affect BF development? A second is: does the pattern shown here represent the pattern of any Nonpareil budwood source or is it unique to the FPMS virus-tested source? Experiments are underway to obtain answers to both questions. Likewise, plant pathologists at the State Department of Agriculture and cooperating nurserymen are seeking additional selections of Nonpareil with a long history of freedom from BF.

Three of the factors that affect the distribution of trees with BF-potential in commercial orchards can now be identified as variety, propagation source and location.

VARIETY. Varieties with BF potential differ in the level of potential they characteristically exhibit. The variety with the greatest BF potential has been Jordanolo, where the chance of developing the disorder is so high and the severity, when it does occur, is so great that this variety is unprofitable in many orchards. Jubilee appears to be similar. Nonpareil is less prone to BF and its recent increased incidence may have resulted from effects of other factors described below. Peerless appears to have a somewhat lower BF potential than Nonpareil. Harpareil appears also to have a relatively low BF potential, at least as compared to Jordanolo. How Merced should be rated in BF potential at this time is uncertain.

PROPAGATION SOURCE. Experimental and practical experience over a long period has implicated the source of budwood as an important determining factor in many situations. Differences in BF potential undoubtedly exist, not only among trees, but also among propagation lines within specific varieties. Propagation histories are useful to help distinguish among sources as to their level of BF potential but diagnostic methods for precise identification are needed. The question basic to this problem is: why do sources differ in their BF potential?

LOCATION. Evidence has been cited which indicates that the incidence and severity of BF in orchards is greater in certain areas than in others. Nurserymen report that nursery trees planted in the southern San Joaquin Valley will develop BF symptoms earlier and at higher percentages than will comparable trees of the same origin and produced under the same conditions when planted in the northern San Joaquin Valley. The experiences with the FPMS budline described previously shows a similar pattern. The survey reported in this article (tables 1, 2, and 3) tends to confirm this relationship, although it is difficult to separate out the effects of location and budwood source. The relationship between the two factors may explain in part why certain propagation sources produce more BF than others.

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