J. Amer. Soc. Hort. Sci. 103(3):377–382. 1978.

Variability in Noninfectious Bud-failure of 'Nonpareil' Almond. I. Location and Environment[1]

Dale E. Kester and R. N. Asay[2]
Department of Pomology, University of California, Davis, CA 95616

Additional key words. temperature sensitivity, genetic disorder, *Prunus amygdalus*

Abstract. **The incidence of noninfectious bud-failure (BF) in 'Nonpareil' almond (*Prunus amygdalus* Batsch) trees propagated from a single source tree increased continuously with time at different rates in different orchards. Development was fastest and symptom expression was most severe in areas with the highest summer temperatures. BF-potential (susceptibility) could be modified by nursery conditions, although only to a minor degree compared with the effect of orchard location. Symptomless can be converted to BF by shifting from a low to a high-temperature regime. A reverse shift gave no reversion in BF-potential, but symptoms may not be expressed at a low-temperature location.**

Almond cultivars are clones, propagated vegetatively with the expectation of genetic constancy. Nevertheless, an abnormality known as *noninfectious bud-failure* (BF) occurs in significant numbers of trees in commercial orchards in California. The disorder has been classified as "a noninfectious disorder that resembles virus diseases" (28) since current knowledge shows that it is inherited (11, 12), is perpetuated by vegetative propagation, and has not been linked to a virus or other pathogen (29). The problem has been associated with certain cultivars, including 'Nonpareil', 'Peerless', and 'Jordanolo' (17). Also it is associated with particular propagation sources within those cultivars (18). In 'Jordanolo', the incidence of BF trees has been described as increasing with the number of "scion generations" away from the original seedling tree (29). At the same time, the problem has been more severe in certain locations in California, which suggests an environmental effect (15, 19).

The principal manifestation of the disorder is a failure of or delay in shoot bud emergence in the spring. It thus has some resemblance to inadequate winter chilling. However, the buds lose viability in the summer preceding emergence rather than in winter (9, 10). The impaired viability of buds has been associated with high temp in controlled-temp tests (16), with location (19), and with seasonal timing (9). Yields can be reduced by reduction in bearing area (7).

The experiments described here were given impetus by the discovery of BF among trees propagated from the 'Nonpareil' clone originally selected for the California Registration and Certification Program (1, 19, 28) and grown and distributed by the Foundation Plant Materials Service (FPMS), Davis, California[3]. Only trees growing in certain locations were affected initially so it was not certain whether the source material or the location was the cause of BF in those orchards.

This study was done to separate the factors of propagation source within 'Nonpareil' and environment in the locations of the nursery and the orchard. In the study of location effects, described in this paper, plants from a single source tree were propagated and grown in a range of nursery locations and later grown in orchard plots in various locations in California. The nursery and orchard test sites were selected to provide a range of summer temp from cool to hot and a range in the amount of winter chilling, environmental factors hypothesized to be associated with the problem. A second paper describes results of the studies of propagation sources (14).

Materials and Methods

The principal budwood sources were 2 'Nonpareil' trees in the FPMS orchard at Davis. This clone was identified as Farnham 'Nonpareil' and later as FPMS 3-8-1-63. The original plant material had been indexed on 8 indicator hosts to qualify it for the California Registration and Certification Program (1). The source trees at Davis have shown no visual symptoms of BF.

Distribution experiments. Budwood was collected randomly from the source trees and supplied to 4 commercial nurseries for propagation onto Nemaguard seedling rootstocks. Two lots of trees were produced from fall budding by 2 nurseries located at Modesto and Wasco, and 3 from June budding from nurseries located at Stockton, Merced and Wasco (Fig. 1).

Trees grew in the nurseries for one season and then were transplanted in winter 1968-69 to 8 orchard sites in California. At each site, 50 trees were planted from each separate nursery collection, distributed as 5 replications of 10 trees within each plot. The intended numbers were 250 trees (both fall and June buds) in 4 plots (Lost Hills, Five Points, Winters, Davis) and 150 (only June buds) in 4 other plots (San Luis Obispo, San Jose, Escalon, Chico). The final numbers were somewhat less because of tree losses. At transplanting, the tops of all trees were pruned to about 75 cm in accordance with standard commercial practices. The Chico, Lost Hills, and Escalon plots were in commercial orchards with spacing of 7.5 × 7.5 m, whereas, the others were in experimental orchards with spacing at 1.8 × 4m.

Trees were examined for BF symptoms each spring (mid to late March) after the new shoots had grown enough for living and failing buds to be differentiated. Trees were rated visually for severity of symptoms: 1 = no symptoms, 2 = very slight, 3 = distinct but moderate, 4 = severe, and 5 = very severe. Rating was primarily on % of dead buds on the one-year-old shoots of the tree. An overall grade was calculated as Σ (grade × no.) /Total no. Trees in the first experiment (BF-100) provided budwood for other experiments.

Induction and recovery experiments. Several experiments were done to determine whether the potential for BF changed with time in either the nursery or the orchard. Expt. BF-102A compared BF production in the orchard as a function of the location of bud source block and the location of nursery. To study the first variable, budsticks were collected from BF-100 orchard trees at Davis, San Jose, San Luis Obispo, Five Points, and Lost Hills. At the time of collection (May 1971), the

[1]Received for publication September 10, 1977.

[2]Professor of Pomology and Staff Research Associate, respectively. The authors are indebted to various individuals and organizations for providing trees, growing areas and much assistance: Stuart Nursery, French Camp, CA; Burchell Nursery, Modesto, CA; Stribling Nursery, Merced, CA; Armstrong Nursery, Wasco, CA; Bellridge Farms, Lost Hills, CA; Mr. Ray Betcher, Escalon, CA; Paul Fountain, California State Polytechnic College, San Luis Obispo, CA; personnel at the West Side Field Station, Five Points, CA; and Deciduous Field Station, San Jose, CA; various members of Cooperative Extension Service, particularly Warren Micke, Marvin Gerdts, Clem Meith, Don Rough, Ken Hench and Foundation Plant Materials Service (FPMS), Davis, CA.

[3]FPMS is now known as Foundation Seed and Plant Materials Service (FSPMS).

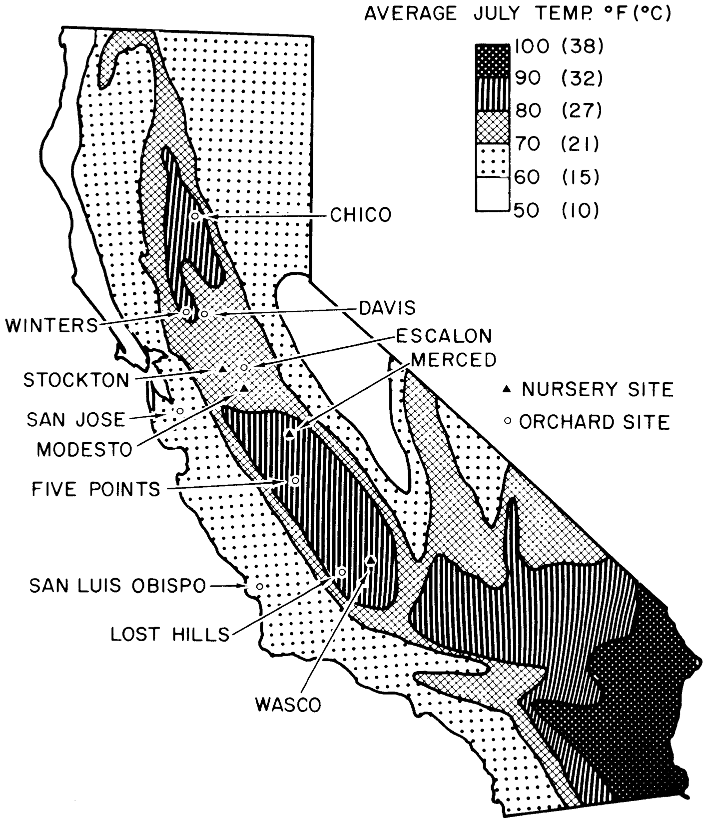

Fig. 1. Location of nursery and orchard sites in California of Expt. BF-100 plots with associated temp patterns.

trees had grown 1½ years at these sites. From each plot, budsticks were taken from symptomless trees produced by June-budding at the Stockton, Merced, and Wasco nurseries.

To study the second variable, each budstick was cut in half with apical and basal portions placed alternately into 2 lots. One lot was supplied to the Modesto nursery, the other supplied to the Wasco nursery. Each nursery budded one tree from each budstick; these trees grew 2½ years in the nursery and were examined for BF symptoms in April of the 2nd and 3rd season. During the 2nd season a sub-propagation was made in May from each nursery tree. These new nursery trees grew the remainder of that year, were dug in the winter, transplanted to a single orchard plot near Lost Hills and subsequently examined for symptoms in April 1974, 1975, and 1976.

Comparisons between treatments were made to account for rate of change in BF-expression during the 3 orchard years. Data of % BF for each test lot for each year was combined as replications within subgroups comparing cool vs. hot exposure for both bud source plot and nursery. These data were transformed to an arc sine value and compared by Students t-test.

Two parallel tests were started in 1973 to study the sequence of temp exposure on subsequent BF symptom development. In Experiment BF-105A, budsticks were collected at the end of May from symptomless trees of the BF-100 plots at Davis and Five Points, inserted into nursery trees in a commercial nursery at Wasco, and grown with usual nursery practices. At least 10 buds were removed from each stick and inserted individually into separate nursery trees. The rootstocks were cut back within 1 to 2 weeks to grow new budded shoots from July through Oct. The nursery trees were examined for BF symptoms in the nursery row in the following spring and again a year later.

In Expt. BF-105B, bud source trees were also at Davis and Five Points, The 2 Five Points trees used, which originated

Table 1. Accumulated high and low effective summer temp as degree-hours and estimated chilling hours at different test sites of BF-100 experiments (1970-75).

Location	Accumulated effective max temp over 28°C (80°F) (degree-days)	Accumulated effective min temp over 16°C (60°F) (degree-days)	Estimated chilling hours below 7°C (45°F)[z] (hr)
Orchard sites			
San Luis Obispo	0	3	390
San Jose	0	181	466
Davis	199	355	984
Escalon[y]	330	678	1061
Chico	472	830	1147
Winters	502	858	1044
Five Points	544	989	1199
Lost Hills[x]	642	1222	–
Nursery sites			
Stockton[w]	–	–	1061
Modesto	338	764	1035
Merced	612	903	1130
Wasco	954	1424	1154

[z]From Aron (3)
[y]Manteca Station
[x]Blackwells Corner Station
[w]Similar to Escalon

from the FPMS trees, had developed BF symptoms at an early age. The 9 Davis trees had been propagated from scions taken from these Five Points trees in 1968. From 1969 to 1973, the BF symptoms on the Davis trees had decreased noticeably in severity, although the original scion source trees at Five Points continued to be severely affected. The propagation test was carried out at the same time and in the same manner as Experiment BF-105A, described above.

Field tests of greenhouse-grown material. This experiment compared BF development in the orchard as a function of previous temp exposure in a greenhouse. Trees were from greenhouse tests where propagation "lines" of plants had been grown through 5 consecutive annual cycles of repropagation and growth at low (24°/18°C) or high (38°/26°) temp (16). The plants had originated from 'Nonpareil' 3-8-1-63 trees, both symptomless and BF phases. 'Jordanolo' plants had originated from trees in the UCD orchards, one symptomless, the other with BF symptoms. The plants had been grown in 4-liter con-

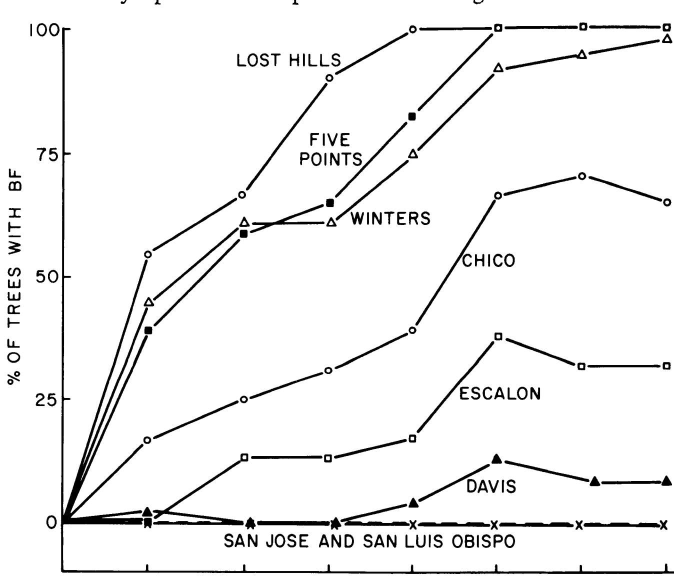

Fig. 2. Changes in % BF trees with time in BF–100 test plots.

Table 2. Severity of BF symptoms in different plots in 2 consecutive years.

Location	Year data taken	Total no. of trees	% of trees in following grade categories[z] 1	2	3	4	5	Overall grade
San Luis Obispo	1973	150	100	0	0	0	0	1.0
	1974	150	100	0	0	0	0	1.0
San Jose	1973	150	100	0	0	0	0	1.0
	1974	150	100	0	0	0	0	1.0
Davis	1973	135	100	0	0	0	0	1.0
	1974	135	98	>1	<1	0	0	1.0
Escalon	1973	147	89	6	5	0	0	1.2
	1974	147	84	9	6	<1	0	1.5
Chico	1973	143	72	9	14	5	0	1.5
	1974	143	52	8	13	20	7	2.2
Winters	1973	214	69	<1	19	11	<1	1.7
	1974	214	26	7	22	23	22	3.1
Five Points	1973	243	35	14	25	19	7	2.5
	1974	24[y]	8	8	25	21	38	3.7
Lost Hills	1973	227	6	7	36	28	23	3.6
	1974	54[y]	0	0	9	22	69	4.6

[z]1 = no symptoms; 5 = very severe symptoms.

[y]Parts of block removed by 1974.

tainers in the greenhouse. The trees were subsequently planted at close spacing in an orchard at Winters in spring, 1975. Data were obtained in spring, 1977.

Temperature summations. Accumulated *effective summer temp* were calculated by the method of Kimball (20). Effective max and min temp were determined by subtracting the following adjustment max - min/4 from the max and adding to the min. To determine the seasonal accumulations of day temp, the mean max temp for the month was converted to an effective max temp and the degrees over 28°C were multiplied by the number of days. For night temp the same procedure was applied for min over 16°. The temp records were published in U.S. Weather Bureau Reports from stations nearest the orchard sites.

Estimates of chilling hours were based on a procedure of Aron (3) who developed and used the following equation:

$$\text{chilling hours} = 801 + 0.2523B + 7.574B^2 \times 10^{-4} - 6.51B^4 \times 10^{-10} - 11.44T_1 - 3.32T_2$$

where $B = (45 - T_1/T_2 - T_1)\ HD$
and T_1 = average min temp
T_2 = average max temp
H = 24 (hr in a day)
D = period of days

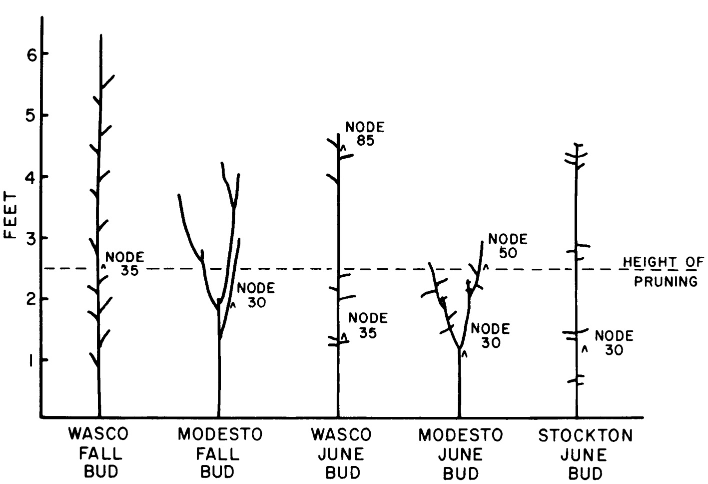

Fig. 3 Characteristic growth patterns shown in nursery trees at the time of transplanting to the orchard for the BF-100 experiment.

Table 3. Percentages of BF trees developing by 1974 in 4 BF-100 plots (Davis, Lost Hills, Winters, Five Points) from 'Nonpareil' almond trees as a function of their previous nursery locations. Budwood was collected in 1969 from a single FPMS orchard tree at Davis.

Nursery location	Type of propagation	No. of orchard trees	% with BF[z]	Remarks
Modesto	Fall bud	190	61c	Pinched in May to force branching
Wasco	Fall bud	192	31a	Continuous growth
Stockton	June bud[y]	193	64c	Large, vigorous continuous growth
Merced	June bud[y]	154	59c	Small; erratic growth
Wasco	June bud[x]	201	45b	Vigorous; continuous growth

[z]Mean of 4 plots; mean separation by Duncan's multiple range test, 5% level.

[y]Budded about June 1

[x]Budded about June 15

Results

Locations. Nursery locations and orchard sites are shown in Fig. 1, and the corresponding summer and winter temp regimes in Table 1. Summer and winter temp differed significantly among the orchard and nursery locations. The summers were coolest along the coast (San Luis Obispo, San Jose), somewhat warmer in central California (Davis, Escalon, Stockton, Modesto), still warmer in the west and northern parts of the Sacramento valley (Winters, Chico), and highest in the western and southern part of the San Joaquin valley (Merced, Wasco, Five Points, Lost Hills). Winter chilling was less in the coastal areas than in the central valley.

Orchard location. Fig. 2 shows the percentage of BF trees in Expt. BF-100 that developed with time at each of the test sites shown in Fig. 1.

By 1977, no BF trees had appeared at San Luis Obispo or San Jose. At Davis, mild symptoms appeared on 2 trees in 1971, disappeared in later years, reappeared significantly in 1974 and 1975 on several trees and became less pronounced again in 1976 and 1977. At Escalon some trees began to show symptoms

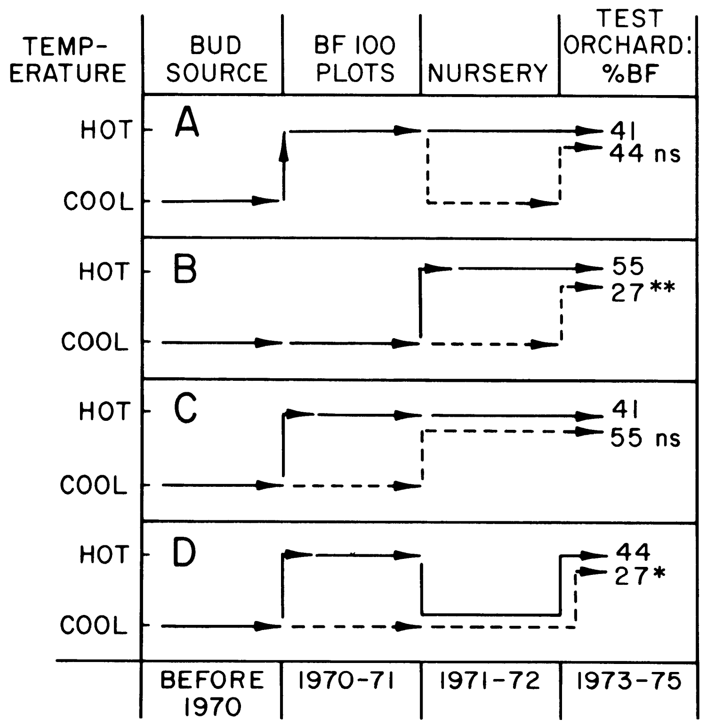

Fig. 4. Flow chart for Expt. BF-102A showing % BF trees appearing after 2 years in a test orchard at Lost Hills (hot area) as a function of previous exposure of propagules to high or low temp in the BF-100 plot and the nursery. All trees originated from FPMS at Davis.

Table 4. Incidence of BF trees previously maintained in containers in consecutive annual propagation cycles at high (H) and low (L) temp for 5 years. Data obtained after 2 subsequent growing years in a high temp location (Winters).

Cultivar	Status of original tree	Temp regime	Total	No. of trees with BF None	Slight	Moderate	Severe
Nonpareil	BF	HLLLF[z]	7	0		1	6
Nonpareil	BF	HH[y]					
Nonpareil	Normal	LHHHF	6	0		3	3
Nonpareil	Normal	LLLLF	7	7			
Jordanolo	Normal	LHHHF	7	3	2	2	
Jordanolo	Normal	LLLLF	8	8			

[z]L = low temp; H = high temp; F = field.

[y]died within 2 years.

by 1972, although the percentage was low and the symptoms mild, restricted primarily to south limbs. Percentages were higher in 1975, but the amount and severity were less in 1976 and 1977. At Chico, higher percentages of BF trees appeared in the earlier years, mostly on the south limbs. By 1975, 1976, and 1977, the percentages had increased significantly and symptoms were pronounced. High percentages of severely affected BF trees developed at Winters beginning in the first year, finally increasing to essentially 100%. High percentages developed at Five Points also increasing to 100% with very severe symptoms. The highest percentages, most pronounced symptoms, and earliest appearance were at Lost Hills, being 50% the first year and 100% by 1974.

Trees varied in severity of symptoms within each plot (Table 2) and increased in average level of severity in the 2 representative seasons. There was a general association among percentage of BF trees, severity of symptoms, and earliness of symptom development.

Nursery effects. The average percentages of BF trees produced in Expt. BF-100 plots as a function of the previous nursery location where propagated differed significantly (Table 3), indicating the potential for BF developed at different rates at the separate nursery locations. Such differences persisted in the orchard. These differences due to nursery location, however, were not the same as the differences due to orchard location. Instead, variability in BF-potential appeared to be affected by tree size and shape which are associated with handling practices of individual nurseries that modify growth-rate and patterns of tree development (Fig. 3). Thus, each nursery appeared to have a unique influence. For example, the Wasco fall-budded trees grew continuously throughout the season, whereas the Modesto fall-budded trees were pinched in May to produce new flushes of growth and more branching. June-budding was done later at Wasco than at Stockton or at Merced (Table 3). Trees produced at Stockton and Wasco grew continuously throughout the growing season, whereas those at Merced grew in a series of flushes resulting in trees that were small and branched.

At transplanting, the removal of tree tops further modified any gradients or patterns that would have developed in the nursery tree since one-half or more of the nursery top was removed.

Changes in BF-potential at nursery and orchard sites. In Expt. BF-102A, nursery trees propagated at Modesto (cool) grew well during the first year and showed no visually identifiable BF symptoms in the nursery in the spring of either the second or the third season. Nursery trees at Wasco (hot) were adversely affected by hot weather in the first season. Many buds failed to grow and the remaining budded trees grew poorly during the first season. However, no clearly identifiable visual BF symptoms were observed the following April. In this second nursery season, trees grew well, and 20% of 240 trees showed BF symptoms of varied severity the following spring. All of these trees at Wasco, with or without symptoms, had relatively sparse foliage, whereas trees of the same age from different 'Nonpareil' sources, but produced under the same conditions, showed vigorous growth and dense foliage throughout.

Fig. 4 compares BF percentages in the orchard at Lost Hills after 3 years as a function of previous temp exposure in the BF-100 plots and in the nursery. Trees originating from buds of the hot BF-100 plots (Five Points, Lost Hills) and propagated at hot (Wasco) and cool (Modesto) nurseries had the same BF development pattern in the orchard, 41 and 44%, respectively (Fig. 4A). In contrast, trees from cool BF-100 orchard plots (San Luis Obispo, San Jose, Davis) produced significantly less development of BF when propagated at the cool nursery (Modesto) than when propagated at the hot nursery (Wasco), 27 vs. 55% (Fig. 4B). Considering the data from the standpoint of those propagated at the cool nursery (Modesto) (Fig. 4D) trees whose origin traced to the hot sites (Lost Hills, Five Points) showed more BF than from those originating from the cool sites (San Luis Obispo, San Jose, Davis), 44 vs. 27%. On the other hand, there was no significant difference between plots when the trees were propagated at the hot (Wasco) nursery (Fig. 4C). It appears that a shift toward higher BF-potential results from high-temp exposure whether in the budwood source tree or in the nursery. Once the higher BF-potential is established growth or propagation under cooler temp does not reduce the BF-potential.

Further studies in changes in BF-potential, orchard tests. The flow chart and results from Expt. BF-105A and B are shown in Fig. 5. Percent bud survival was relatively low in all lots resulting from somewhat late budding just preceding a hot weather period. Thus, a survival range of 32-40% was reasonable for the conditions. On the other hand, the 22% survival of Five Points buds undoubtedly reflects the severe BF of the source trees. The results of the 2 tests were different, however, in the % of BF trees produced. In BF-105A trees produced from buds taken from the cool Davis BF-100 plot showed only 40% BF with relatively mild symptoms. Trees from buds collected from Five Points (hot) produced 8% BF with more severe symptoms. In contrast, in BF-102A trees propagated from buds collected from both Davis (cool) and Five Points (hot) were 100% affected, with severe symptoms. Those from the Davis source trees, which had relatively mild or no symptoms, produced the most severely affected trees in the test. These results are evidence that BF-potential can increase as one shifts from a low temp location to a high temp location. However, shifting from a high temp location to a low temp location did not decrease the BF-potential, but masked the symptoms.

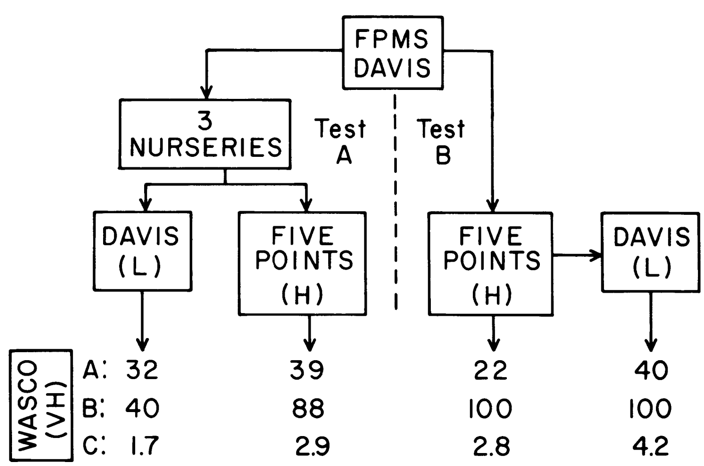

Fig. 5. Flow chart for Experiment BF-105A and B showing effect of previous exposure of propagules to hot (H) and cool (L) temp regimes. All originated at FPMS, Davis. Data obtained in a nursery (very hot) at Wasco, California. A = % bud survival; B = % of plants with BF; C = mean grade for severity.

Further studies in changes in BF-potential, greenhouse tests. Trees maintained in containers through 5 consecutive annual greenhouse cycles at either high or low temp and then grown for 2 years in the orchard at Winters (high summer temp) showed differences in BF production (Table 4). Plants propagated from 'Nonpareil' 3-8-1-63 trees with symptoms were killed at high temp, but produced no symptoms in the greenhouse during 5 consecutive low temp cycles. However, all of the latter group produced moderate or severe BF symptoms immediately when transplanted to high temp locations in the orchard. Plants propagated from 'Nonpareil' 3-8-1-63 trees which had no symptoms in the orchard also produced no symptoms in the greenhouse during 5 consecutive annual low-temp cycles. Furthermore, when transplanted to the orchard, no symptoms developed within the period of the test. On the other hand, all plants originally propagated from the same 'Nonpareil' 3-8-1-63 budstick and subsequently grown for 5 consecutive annual high temp cycles developed moderate to severe BF symptoms when transplanted to the orchard. Four of 7 'Jordanolo' plants propagated initially from symptomless trees and subsequently grown for 5 high temp cycles developed symptoms when transplanted to the orchard. On the other hand, plants maintained for 5 low temp cycles developed no BF symptoms during the 2 year period in the orchard.

These results provide further evidence that BF-potential does not decrease when shifts are made from high to low temp, but symptoms are masked. On the other hand, plants with low potential grown at high temp can increase in BF-potential to a threshold where symptoms are produced. If maintained at low temp, BF-potential does not increase or does so at a slower rate than at high temp.

Discussion

Two characteristics appear to be involved in the BF phenomenon. One is an inherent *BF-potentiality* that is present in somatic tissues, is perpetuated during vegetative propagation (13) and is transmitted during sexual reproduction (12). This BF-potentiality exists at various levels from low to high and may be defined by relative susceptibility to an environmental stress. The second is *BF-expression* which is manifested by specific symptoms, including bud-failure and necrosis of shoot buds (10, 25, 26), damage of cortex tissue, in some cases leading to rough-bark and lesions (26) and killing of shoot tips under appropriate conditions, leading to shoot dieback (16). Both BF-potentiality and BF-expression involve temp sensitivity, although perhaps with separate mechanisms. Hellali et al. (10) have characterized morphological aspects of BF-expression in buds.

Thus, BF-expression may result from exposure of susceptible tissue to high lethal temp. The pattern of symptoms expressed at any one time in a given tree may be the result of a complex interaction of sensitive tissues and environmental exposure, each of which may vary within a tree. This can account for the variability in symptoms within and among trees, orchards, and locations.

Changes in BF-susceptibility also appear to be temp related although the mechanism of change in somatic tissue from low BF-susceptibility (resistance ?) to high BF-susceptibility is obscure. Although the rate of change increases with an increase in high temp exposure, no change to a lower BF-susceptibility appears to result from exposure to lower temp. On the other hand, BF-expression can be reversed because of a masking effect of lower temp below the threshold that would produce damage.

The application of this concept to the present work is that the original source trees had BF-susceptibility at a relatively low level, at least below the threshold needed to produce symptoms at Davis (symptomless). Conversion to high levels of BF-susceptibility (BF) resulted from exposure to high temp of the plants propagated from them. Conversion could occur in the nursery with the rate and final amount depending on temp, various handling practices to modify growth patterns, and, particularly, removal of tops at transplanting. Thus, in this study, the nursery phase was less significant in BF induction then the environment in the orchard. Under some conditions, e.g., in nursery buds produced by consecutive recycling in the nursery row in an appropriate environment, however, one might have a rapid change in BF-susceptibility.

In this study orchard location was the most important factor in producing BF-expression. The ultimate numbers of trees affected and symptom severity were directly related to the summer-temp exposure. Thus, trees grown in the coastal areas of California were unaffected, trees grown in the central area were relatively unaffected, and trees grown in the western and northern parts of Sacramento Valley and the San Joaquin Valley, particularly from Merced south were severely affected. The location of bud-source trees was also significant. Maintaining trees at San Luis Obispo and San Jose, both cool summer areas, resulted in slower rates of BF induction. Growing trees at Davis appears to permit some increase in BF-susceptibility but evidently slowly. Returning plants with a high BF-susceptibility to a cooler area, as at Davis or in a cool greenhouse, did not cause a shift toward less BF-susceptibility, but did lower BF-expression.

Wilson (28) found that BF-susceptibility in 'Jordanolo' increased with time and clonal age beginning with the original seedling tree. The increase in age, however, was accompanied by shifts of propagation and orchard sites to high-temp areas, so that both time and temp must have been involved in this phenomenon. We have shown that seedling populations undergo the same shifts in BF-potentiality (11).

Earlier publications (11, 12) suggested a parallel between the BF phenomenon and some classes of somatically unstable genotypes. The present results are consistent with that view. With BF and other so-called genetic disorders, if the organism is a clone that is vegetatively propagated, the various phases of the genotype can be indefinitely perpetuated.

Temp-sensitive alleles are now known in plants (22, 23, 27), animals (2, 24), and microorganisms (21). In some cases the higher temp enhances expression of the allele; in others it depresses it. Somatically unstable genotypes (5) have also been investigated extensively and include such conceptual phenomena as paramutation (4) and controlling elements (6, 8). Characteristically, many unstable systems are also found to be temp-sensitive (5, 6). For example, Sheridan and Palmer (27) described an effect on a chlorophyll-controlling allele in soybean in which increasing temp increased the size of the mutant sector. The response was interpreted as an increase in the rate of mutation since the size was related to the time when the change occurred. This effect is analogous to the effect of increasing temp on BF in that the rate of BF induction increases.

Variation in original BF-susceptibility was not a factor in this study since all plants came from the same propagation source and had the same initial level. Thus, it is not certain that these results can be applied to all 'Nonpareil' trees. That variation in BF-susceptibility among source trees is a major factor in BF distribution is demonstrated in an accompanying paper (14).

Literature Cited

1. Anonymous. 1968. Regulations for Registration and Certification of Stone Fruits. Calif. State Dept. of Food and Agriculture, Sacramento.
2. Arking, R. 1975. Temperature-sensitive cell-lethal mutants of Drosophila: isolation and characterization. *Genetics* 80:519-537.
3. Aron, R. H. 1975. Chilling as a factor in crop location with particular reference to deciduous orchards in California. PhD thesis. Oregon State Univ., Corvallis.
4. Brink, R. A. 1974. Paramutation. *Annu. Rev. Genet.* 7:129-152.
5. Fincham, J. R. S. 1973. Localized instabilities in plants – A review

and some speculation. *Genetics* 73(Suppl.):195-205.
6. ________ and G. R. K. Sastry. 1974. Controlling elements in maize. *Annu. Rev. Genet.* 8:15-50.
7. Gerdts, M., W. C. Micke, D. Rough, K. W. Hench, L. T. Browne, and C. S. Sibbett. 1975. Almond yield reduction. *Calif. Agr.* 29(3):14.
8. Green, M. M. 1973. Some observations and comments on mutable and mutator genes in Drosophila. *Genetics* 73(Suppl.):187-194.
9. Hellali, R., D. E. Kester, and K. Ryugo. 1976. Seasonal development of symptoms of noninfectious bud-failure in almond (*Prunus amygdalus* Batsch). *J. Amer. Soc. Hort. Sci.* 101:494-497.
10. ________, J. Lin, and D. E. Kester, 1978. Morphology of noninfectious bud-failure (BF) symptoms in vegetative buds of almond (*Prunus amygdalus* Batsch). *J. Amer. Soc. Hort. Sci.* (in press).
11. Kester, D. E. 1968. Noninfectious bud-failure, a nontransmissible inherited disorder in almond. I. Pattern of phenotype inheritence. *Proc. Amer. Soc. Hort. Sci.* 92:7-15.
12. ________. 1968. Noninfectious bud-failure, a nontransmissible inherited disorder in almond. II. Progeny tests for bud-failure. *Proc. Amer. Soc. Hort. Sci.* 92:16-28.
13. ________. 1970. Noninfectious bud-failure in almond, a nontransmissible inherited disorder. III. Variability in BF potential within plants. *J. Amer. Soc. Hort. Sci.* 95:162-165.
14. ________ and R. N. Asay. 1978. Variability in noninfectious bud-failure of 'Nonpareil' almond. II. Propagation source. *J. Amer. Soc. Hort. Sci.* (In press).
15. ________, R. Hellali, and R. N. Asay. 1975. Variability of bud-failure in 'Nonpareil' almonds. *Calif. Agr.* 29(3):11-12.
16. ________, ________, and ________. 1976. Temperature sensitivity of a "genetic disorder" in clonally propagated cultivars of almond. *HortScience* 11:55-57.
17. ________ and R. W. Jones. 1970. Noninfectious bud-failure from breeding programs of almond (*Prunus amygdalus* Batsch). *J. Amer. Soc. Hort. Sci.* 95:492-496.
18. ________, and A. D. Rizzi, 1970. Noninfectious bud-failure in almond. Univ. of Calif. AXT-324, pp. 1-14.
19. ________, ________, H. Williams, and R. W. Jones. 1969. Noninfectious bud-failure in almonds in California. II. Distribution. *Calif. Agr.* 23(3):15-16.
20. Kimball, M. and F. A. Brooks. 1957. Plant climates in California. *Calif. Agr.* 13(5):7-12.
21. Rasse-Messenguy, F. and G. R. Fink. 1973. Temperature sensitive nonsense suppressors in yeast. *Genetics* 75:459-464.
22. Rhodes, M. M. 1971. The genetic control of mutability in maize. *Cold Spring Harbor Symp. Quant. Bot.* 9:138-144.
23. Robertson, D. S. and I. C. Anderson. 1961. Temperature-sensitive alleles of the Y locus in maize. *J. Hered.* 52:53-60.
24. Roufa, D. J. and S. J. Reed. 1975. Temperature-sensitive mutants of a Chinese hamster cell line. I. Selection of clones with defective macromolecular biosynthesis. *Genetics* 80:549-566.
25. Saikia, B. N., D. E. Kester, and M. V. Bradley. 1966. Dormant vegetative buds in normal and bud-failure forms of almond (*Prunus amygdalus* Batsch). *Proc. Amer. Soc. Hort. Sci.* 89:150-156.
26. Schein, R. D. 1952. Studies of bud-failure disorder in almonds. PhD thesis, Univ. of California, Davis.
27. Sheridan, M. A. and R. G. Palmer. 1977. The effect of temperature on an unstable gene in soybeans. *J. Hered.* 68:17-22.
28. U. S. Dept. of Agr. 1976. Virus diseases and noninfectious disorders of stone fruits in North America. U. S. Dept. Agr. Handb. 437.

J. Amer. Soc. Hort. Sci. 103(3):382–384. 1978.

Bud Opening of *Gypsophila paniculata* L. cv. Perfecta with Physan-20[1]

D. S. Farnham, A. M. Kofranek, and J. Kubota[2]
Department of Environmental Horticulture, University of California, Davis, CA 95616

Additional index words. postharvest, cut flowers, floral preservatives, quaternary ammonium compounds

Abstract. **A 200 ppm solution of Physan-20 [Active ingredients: n-alkyl (60% C_{14}, 30% C_{16}, 5% C_{12}, 5% C_{18}) dimethyl benzyl ammonium chlorides, 10%; n-alkyl (68% C_{12}, 32% C_{14}) dimethyl ethylbenzyl ammonium chlorides, 10%; inert ingredients, 80%.] was as effective in opening buds of 'Perfecta' gypsophila as was a 25 ppm silver nitrate solution when combined with sucrose. Sucrose (10%) was more effective in a short time period than 5% in combination with Physan-20. The minimum time in the solution for producing high quality blooms was 4 days. Physan-20, a quaternary ammonium compound, effectively opened gypsophila buds in tap water moderately high in salts, bicarbonates and nitrates. Physan-20 offers an effective alternate to silver nitrate for opening gypsophila without deionized water.**

Gypsophila flowers respond to floral preservatives when applied after distribution and storage of the blooms (3). Effective flower opening, improved longevity and increased turgidity occurred when 8-hydroxyquinoline citrate (8-HQC) + sucrose was used as a floral preservative during storage and shipment (4). Stems impregnated with silver or continuous exposure to 25 ppm of silver nitrate improved the quality of fresh and dried gypsophila 'Bristol Fairy' when combined with 5 or 10% sucrose in deionized water as a conditioning or bud opening solution (2). A recent report (1) indicates gypsophila treated with 10% sucrose solutions containing either thiobendazole glycolate (TBZ) 300 ppm or solutions containing 8 hydroxyquinoline glycolate (8 HQ) 300 ppm+TBZ 300 ppm, known as TOG preservative, gave consistently larger leaves and flowers than those treated similarly with 8-HQC or silver nitrate. Problems of spoilage of the TBZ solution were reported, and were overcome by adding 8-HQ in the TOG preservative.

A simplified method is described for short term conditioning or bud opening to improve the quality of gypsophila by immersing the cut flower stems in solutions containing Physan-20[3] plus sucrose.

Materials and Methods

'Perfecta' gypsophila was harvested from commercial plantings located at Watsonville, California. Uniform flowers were selected for a given term of development. Bud stage harvest with about 5% of the blooms open or with visible petals were utilized for most experiments (Fig. 1). The flowers were field bunched into 450g bunches and transferred dry by car to UC Davis. The flowers were held at 2°C overnight and the stems were recut prior to treatment the following day. Single bunches were used in expt. 1 and 2 for each test. Two bunches were

[1]Received for publication *December 27, 1977.*
[2]The authors wish to acknowledge the Fred C. Gloeckner Foundation for partial financial support of this project.
[3]Distributed by Consan Pacific Inc., P.O. Box 208, Whittier, CA 90608.