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ANNUAL REPORT FOR 1991

Project No. 91-K18 - Selection, Maintenance and Monitoring for Low BF-Potential and Genetically true-to-type propagation sources for almond

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Objectives:

1. to maintain annual field observations of (a) clonal source selections of different varieties in test plantings in Fresno and Kern Cos. started in 1989 and 1990 and (b) progeny tests of Carmel, started in 1990,
2. to determine the effect of management parameters on the expression and rate of development of BF, specifically on (a) vigor and growth on young orchard trees (MANAGEMENT EXPERIMENT) and (b) pruning management of bud-wood source trees (STABILIZATION EXPERIMENT),
3. to evaluate BF symptom expression in seedling populations of almond x peach and almond x Nonpareil BF
4. to verify the high temperature dormancy phenomenon observed in previous years tests
5. to publish accumulated manuscripts from current and past research arising from this project.

INTERPRETIVE SUMMARY

Previous work in the noninfectious bud-failure project has defined the biological concepts of the disorder, determined patterns of development both in seedling breeding populations and in populations of trees within specific varieties. A feature of this work was to develop a series of theoretical "models" which predict distribution patterns within varieties and orchards. A further feature was the selection of specific sources in Nonpareil which had low potential for BF which could be incorporated along with Mission, Ne Plus Ultra and various other varieties in Registration and Certification programs to control virus and trueness-to-type problems in nursery selection.

In 1988, the program took a new turn in beginning a program

which extended the source selection program to newer varieties in particular to confront the growing problem with Carmel. A feature of this program was the close working relationship with the commercial nursery industry who have been cooperating in a joint program not only to select and test new selections with low BF potential but to assist in the establishment of a series of comprehensive orchard experiments to verify the concepts of the BF model and accompanying selection procedures. These separate experiments are identified as:

1. Selection of low BF-potential propagation sources

2. Carmel variability experiment
    a. Propagation
    b. Pedigree analysis

2. Management experiment
    vigor
    irrigation scheduling

3. Stabilization experiment

These programs are well underway with nursery trees propagated and established in orchards either in commercial areas or in experimental orchards at Winters and Davis. All parts of this program are in place with earliest comprehensive data to begin to appear in the spring of 1992. Although a number of years of observations will be required to provide the complete picture from these experiments, it is expected that trends will be quickly established to which the BF model can be applied to forcast the major outcomes of the research.

The unusual temperature pattern of the 1991 season as well as the continuing drought effects may modify the expression of BF in orchards next spring in a way that it is not possible to predict. 1991 was the coolest spring and summer on record and that September and October were the hottest in the past 8 years. The uncertainty about the timing of the heat exposure in relation to the annual cycle of growth and development emphasizes the need to understand better the underlying physiological nature of the BF-susceptible plants.

PART 1. CLONAL SELECTION

Specific clonal sources of Nonpareil, Mission and certain other varieties were previously identified which were not only free of specific viruses, true-to-type and performed well horticultually in RVT plots, but also have had low potential to produce BF in progeny orchards. Beginning in 1988, the project was extended to clonal selection of additional commercial varieties (Carmel, Monterey, Fritz, Price, Butte and Ruby) which had not been previously included in the program.

The primary test for BF-potential is to plant clonally propagated progeny trees from individual selected tree sources in test orchards located in a high temperature site. The rate and pattern of BF development within the progeny trees is a measure of both the kind of source used and its level of BF-potential. For example, the pattern from orchard sources, where a combination of many individual trees are used, tends to show gradual development of BF among individual trees within the progeny orchard population over time. The pattern from single tree (clonal) sources shows a high percentage of trees within the progeny population performing the same way at any one time with BF appearing at different ages from separate sources, depending on the BF potential of the individual source. If the BF-potential is sufficiently low, no BF will appear in any tree of the progeny population within the effective life of the orchard.

Procedure.

Initial steps for selection were described in the 1990 annual report. During 1991, all progeny trees in the test plots growing in Kern and Fresno Cos. were observed for BF symptoms in mid-March. Observations for virus indexing, as described in the 1990 report, is continuing.

Results.

Table 1 compares the BF incidence among trees of the test sources observed in spring 1991. Selections were planted in 1989 in blocks where they can be compared to trees from other commercial sources growing in the same orchard. Of the 85 Carmel test trees (5 sources) planted, one tree had suspicious symptoms but this observation needs to be confirmed next year (1992). In contrast, commercial source trees of both Carmel and Nonpareil showed an increasing trend in numbers of BF trees in the two years observed.

Table 1. Percentages of BF affected plants in 2-year old Carmel and Nonpareil trees.

	No. of trees	Per cent BF	
		1990	1991
Carmel 3*	87	10.3	10.3
Carmel 2	52	6.5	9.6
Carmel 4	87	4.6	8.0
Carmel 1	93	2.1	1.1
Average	319	5.9	7.2
Carmel sources	85(5)**	0.0	1(?)
Nonpareil	696	1.9	4.3

* number represents separate sources of trees

** 5 clones represented. 1 tree had suspicious symptoms in 1991

In addition, no tree of five new Carmel sources planted in 1990 showed BF as did trees propagated from the original source tree of Carmel.

Seven of the eleven clonal sources of Carmel were negative in the initial virus indexing tests. The complete range of tests for these seven will be completed in spring 1992. Greenhouse grown trees of this material should then be eligible to be planted into the Foundation Orchard for variety verification. Virus tested source trees of Price, Butte, and Mission (new), are now in the Foundation Orchard pending variety verification in 1992.

None of the trees of the other varieties in the Kern and Fresno plots produced any evidence of BF. All showed characteristics typical of the variety. Sonora and Butte were precocious with good flower production, Sonora on long shoots and Butte on "annual spurs". Mission and Padre were very vigorous with "bare-node" growth characteristics typical of vigorous young trees of these varieties.

Discussion.

The tests are proceeding on schedule. In varieties as Butte, Mission, Price, Sonora and Padre, the tests probably need to continue through two bearing years and could be completed by the end of 1992. None of these varieties have shown any significant predisposition towards bud-failure. Varieties as Fritz, Ruby and Monterey also do not appear to have much predisposition to bud-failure but the current sources are infected with Prunus RingSpot Virus and current efforts to remove viruses by thermotherapy must be completed before new sources can be entered into the Registration and Certification programs.

Successful selection of specific Carmel sources which have a low potential for bud-failure is problematic at this time and may depend upon interpretation of results from the companion experiments in this project.

PART II. VARIABILITY OF BF WITHIN CARMEL

This investigation grew out of commercial experience of the past three years in which BF trees have been appearing in significant numbers in 2 year old trees after one year in the orchard. Affected trees appear to be coming from all commercial sources of Carmel but the incidence also varies greatly in different orchard locations and sites.

This phase of the investigation, which seeks to determine the pattern of BF-potential throughout the entire Carmel variety, consists of two parts. One involves a propagation test in which progeny trees from current commercial sources of Carmel are produced where the source identity of each individual tree is maintained from source to orchard. The second part establishes the pedigree history of all these sources with their geneological history to the individual source tree. This data will provide an analysis of the variation in BF-potential within the Carmel variety to identify the biological origin of variability in BF-potential within the clone.

Procedure.

Propagation details were described in the 1990 report. Trees were budded, processed and distributed to the planting site in the 1990-91 winter season using standard commercial procedures. In addition, Nonpareil nursery trees roughly equivalent to the numbers of Carmel trees propagated were provided by most of the nurseries. These trees were planted in separate rows in the plot adjoining the Carmel rows and represent another opportunity to determine the range of variability of BF-potential within Nonpareil.

The pedigree of the entire Carmel variety was developed from information supplied by nurseries, beginning with the selection of the original tree in the Iwakaki orchard, LeGrand, CA.

Results.

Planting took place in mid-February in an approximately 80 acre orchard of the Paramount Farming Corporation, Western Division, located just south of the northern boundary of Kern Co. and several miles west of I-5. Carmel trees were delivered to the orchard bundled in lots of ten, some of which were graded by size. All propagated trees were planted regardless of size. Each tree had been given a unique number in the nursery that remained with the tree through the entire process of digging, grading and planting. These unique numbers identified the source block, the individual tree where collected, the location of the budstick on the tree, and the position of the bud on the budstick.

Trees from each nursery source were combined into bundles of 10 each. Size grades were determined in some cases but not all. Each lot of 10 trees was considered as a unit and individual trees of a unit were planted together in a random sequence. Tree size for each lot was recorded if known. Ten-tree units (representing each of the eleven nurseries) were then planted together as a block in a random sequence of different nursery sources. Blocks made up of trees from all nurseries were then planted in a random sequence to provide approximately 25 ten tree replications for each nursery depending upon the number of trees. Because differences in total numbers existed, some adjustment in sequence had to be made towards the end of the planting.

An identifying tag with a unique number remained with the tree while digging, sorting and planting. Immediately after planting, Paramount personnel made a complete inventory, recording row and tree location by numbers attached to trees. Tree locations, tree numbers and prior recorded pedigree information were entered into a computer file using a SAS program. A search was then made for missing or duplicate numbers. Two verification surveys were made to double check the recorded data against the location and numbered tags on the tree.

When we were satisfied that all of the recorded information was correct, tree tags were removed from the trees to prevent identification of the individual sources by casual observers in the orchard. Future observations and analyses of data will be identified by code number in order to respect the confidentiality of the individual sources. Results of the analysis will be reported in this project on a generalized basis as they develop. However, results that relate to a specific nursery source will be immediately relayed to that nursery. Since we cannot now predict how the variability pattern will develop, one cannot be certain what immediate impact such information will have. However, it is expected that modification of some source blocks could result and provide an immediate benefit to the industry.

Carmel trees from a twelfth nursery were also provided and planted. These represented standard nursery trees as sold and individual trees had not been pedigreed for specific source trees. A group of Carmel/Hybrid rootstock were also provided. Trees of both of these lots were planted at the end of the orchard and were not included in the randomization process.

Nonpareil trees from separate nurseries were planted in single separate rows. Enough trees were provided in most cases to plant four replicated rows from each source. Their sequence was randomized by row. Nonpareil trees were standard nursery trees, all from any one nursery being of the same size.

Tree losses of Carmel were very low. Some losses occurred in some lots where very small trees, below the acceptable marketable size, were included in order to account for all trees propagated from each source.

Pedigree information will be combined with the results of the progeny test information to establish patterns of BF-variability in Carmel.

PART III. MANAGEMENT EXPERIMENT

The purpose of this experiment is to establish the effects of (a) vigor (amount of growth) controlled by water and nitrogen and (b) moisture stress, controlled by irrigation regimes, on trees of Carmel and Nonpareil propagated from three different levels of BF-potential (low, medium and high).

Procedure.

In 1991, the three irrigation treatments (WET, MEDIUM and DRY) were monitored by periodic measurement of applied water and tree stem water potential. In 1992, the same measurements will be used, and, in addition, some soil based moisture measurements will be made for reference. Monitoring for BF will begin spring 1992, and depending on these results, additional physiological measurements related to BF expression will be made during the summer, especially if water stress is found to increase the rate of BF expression.

Results.

The three irrigation regimes were very successful in causing striking differences in overall growth and vigor in 1991. DRY treatment trees reached 1.7m in height, MEDIUM treatment trees 2.2m and WET treatment trees 2.5m. One surprising result scheduling was that the MEDIUM trees were actually irrigated at slightly over calculated ET. Since the WET trees showed growth response to the increased water supply over this level, this may indicate that the currently accepted ET requirements of young almond trees may be underestimated.

Examination of the vegetative buds on shoots in both Carmel and Nonpareil from plants of both normal and BF sources in October, showed evidence of severe BF necrosis in the shoots from the BF sources. Higher percentages of the total buds produced were severely BF-affected in the DRY treatment trees as compared to the WET treatment trees.

However, these differences were related to the pattern of growth that occurred during the season. In the DRY treatment trees, vegetative growth was restricted from mid summer on. All buds on this material appeared damaged. In the WET treatment, shoot growth continued through the summer and fall. Buds on the basal parts of these shoots, corresponding to a comparable growth sequence of the DRY treatment trees, were severely damaged, whereas newer growth which had continued through summer and fall and where buds had not reached the brown budscale stage, buds were undamaged. Confirmation of these observations need to be made in spring 1992.

PART IV. STABILIZATION EXPERIMENT

The purpose in this experiment is to stabilize the BF-potential at a given level within a tree by annually pruning new shoots back to a specific height. We expect to compare the initial level established at the time of planting with changes in BF-potential change with time in comparable shoots produced after annual consecutive grafting.

Procedure.

Carmel and Nonpareil trees from the same sources as the management experiment were planted February 1991. Each tree will be pruned back to the main scaffold late this winter (1991-92) after any BF symptoms have been identified. Apical buds from the same plant will have been previously collected and stored during winter and scions grafted back to the same plant at the same scaffold level as the pruning. Both parts of the tree will be allowed to grow next summer and observations will again be made in spring 1993 to compare BF development in the two parts of the tree. This treatment will continue annually over a period of several years.

Results.

Trees were planted at WEO, Winters, which is a hot summer area, and at UC Davis, which is a moderately mild summer climate area. No results will be possible to evaluate until next spring.

PART V. SEASONAL CHANGES IN BUD FORCING

One of the concepts previously developed was that BF symptoms developed in vegetative buds in mid to late summer because BF-affected buds failed to develop heat dormancy. This concept was based upon results of forcing tests with excised single node cuttings in petri dishes (Kester, et al., Intern. Hort. Cong. 1990). Evidence for a bud-failure and dormancy correlation pattern was deduced from data on the loss of bud viability (% sprouting) and the rate of bud sprouting (days to produce 50% sprouting). During the past two summers additional tests at a controlled 70° F temperature were conducted to follow these trends. The time course of failure in buds began to develop by midsummer (August) but did not provide evidence of "heat dormancy". It was believed that the cool temperature environment might have prevented the expression of the hypothesized dormancy. Consequently, one of the objectives of this year's test was to compare bud forcing at both high (95°F) and low (70°F temperatures.

Procedure.

Forcing tests have been previously described. Temperature chambers in which the tests were conducted included the same constant 70° chamber as used previously and a growth chamber where the temperature was held constantly at 95°. Both chambers had 16 hours light and 8 hours dark.

The sources of buds for the tests were the same nonaffected and BF-affected Nonpareil trees used in the past two years.
Tests were started on June 19 and repeated at 2 week intervals through the summer until October. Each test ran for at least three weeks. Observation intervals of single tests varied from 3 days to 1 week to sometimes 3 weeks or more. Thus some of the data had to be extrapolated between observations.

Data utilized was total sprouting (<u>final percentage at 3 weeks</u>) and rate of sprouting <u>(percentage at 10 days</u>). Percentages were based upon sprouting buds/node rather than number sprouting/total buds. It is believed that using number of nodes as the base makes an important correction to account for variation in flower and vegetative bud distributions in different shoots. The basis for this reasoning is described in the results.

Results

<u>Morphology</u>: Almond shoots develop during the early part of the growing season (March through May) laying down a sequence of nodes and internodes. Samples of shoots collected ranged from 20 to 40 nodes long. One, two or three buds are produced at each node. One (usually the center bud) is vegetative and others are destined to become flower buds. Initially all buds are vegetative and can be forced into sprouting. By mid August and early September, flower buds have become sufficiently committed to become flowers that they cannot be forced.

The value of buds/node shows the relative numbers of vegetative:flower buds of a given shoot where values higher than 100% per cent represent multiple flower buds at nodes (table 2). The distribution pattern of buds/node for shoots taken from the normal show that 65% of the shoots from normal sources had a bud/node ratio of 150% or more (average = 173%) whereas shoots from BF sources had only 33%. Characteristically many of the shoots on BF-affected plants are long, slender and have only a single bud per node, which are vegetative and which often represent failing buds. This difference appears to reflect different physiological backgrounds of "normal" and "BF' shoots indicating that two populations of shoots are produced on BF plants. Since flower buds are essentially resistant to BF, using total buds as a base would bias the results.

Table 2. Distribution of buds/node ratios of shoots from normal and BF plants

Range of % buds/node	Normal source number	 per cent	BF source number	 per cent
100-119	2	5	17	39
120-139	8	14	6	14
140-159	6	4	6	14
160-179	8	19	7	16
180-199	11	26	5	11
200-219	7	16	2	5
220-239	3	7	1	2
Total shoots	45	100	44	101
Mean % buds/node	173		144	

Sprouting patterns: The pattern of bud forcing beginning in June showed that literally all of the buds could sprout on shoots from both normal and BF sources (Table 3). When presented as a

Table 3. Final sprouting percentages of buds on shoots from normal and BF trees in forcing tests at 70° and 95° C. Based on sprouting shoots per node.

Date of Collection	Non-BF source 70	 95	BF source 70	 95
June 19	127	127	114	129
July 5	105	85	87	63
July 16	104	39	109	83
July 31	100	*	100	*
August 12	100	*	100	*
August 21	95	*	95	*
September 3	87	35	81+	42
September 13	82	36	57	20
October 2	63	11	66	27

* shoots and buds deteriored during test.

percentage of buds\node, the values were more than 100%. As the season progressed, the sprouting percentage from the shoots from the non-BF source gradually decreased through the summer and fall when placed at the cool temperature. This decrease may reflect both a gradual induction of flowering in some buds as well as the induction of the rest period by late September and October. At the high temperature the percentage was sharply reduced suggesting that there may have been an induction of high temperature dormancy. However, a problem of fungal contamination and damage to the shoots was so severe in the July 31, August 12 and 21 that no results were achieved.

The shoots from the BF sources showed a similar pattern to that of the shoots from the normal source and do not provide evidence of differences between the normal and BF sources.

The pattern for rate of sprouting, as shown by the percentage at 10 days (Table 4), was similar to that of the percentage sprouting. The shoots from the normal source showed a high rate in the June collection which then decreased throughout the season particularly during September. At the high temperature the decrease was even more drastically evident. Shoots from the BF source showed a similar pattern to that of shoots from the normal. However, the rate did not decrease as much during the late August and September collections and might suggest a delay in developing the rest period. High temperature drastically reduced the rate of sprouting.

Table 4. Rate of sprouting. Given as percent sprouting at 10 days. Percentages given on per node basis.

Date of	Non-BF source		BF source	
collection	70	95	70	95
June 19	100	100	100	100
July 5	78	47	98	64
July 16	80	48	64	20
July 31	-	-	-	-
August 12	74	16	74	7
August 21	high	7	55	-
September 3	45	35	70	30
September 13	22	6	48	24
October 2	66	27	63	14

Bud necrosis. In previous years, evidence of necrosis within the bud could eventually be observed both in the buds in culture and buds collected from the orchard. These necrotic spots usually began to appear in September and continued to appear in samples collected from then on. No such necrosis was observed in the collected shoots in any of the tests made in 1991.

Buds at the high temperatures of both normal and BF sources showed deterioration but this condition was judged to be due to contamination and other problems associated with the test rather than to BF.

In early October, shoots were collected from the BF plants in the orchard and examined directly for bud necrosis. None could be observed and it appears likely that these BF plants will not show significant bud-failure in spring 1992. This finding not only contrasts with observations in previous years (see 1990 report) but also contrasts with orchard observations made at the same time (October) in the Management Experiment (see this report). In that block, vegetative buds in trees propagated from the "high" BF-potential sources of both Nonpareil and Carmel showed severe bud necrosis. It appears that there is a significant difference in the level of background BF-potential of the two sources used, a view consistent with concepts of BF-potential.

Discussion

In general the tests conducted this summer were not completely satisfactory. First of all, the high temperature treatment itself appears to have adverse effects on the buds of both normal and BF sources such that some details of the test need to be reexamined. Secondly, the recording of the sprouting data in some of the tests was not sufficiently frequent to provide precise results. Thirdly, it appears that the environmental pattern in the orchard this summer was unique and the level of BF symptoms that we expected from previous years did not materialize. The temperature pattern is described in a later section of this report.

Nevertheless, examination of the results of the separate tests shows a pattern that is in line with previous results. In June, all buds sprouted quickly and completely at both high and low temperatures, an observation previously noted. In July, the buds from BF plants sprouted at a higher level than did the normal and both sprouted better at cool than at high temperatures. Tests in early August were similar despite the inadequacy described above. From early September on, the pattern follows a trend in reduction of final percentages in the buds from the normal plant. Although, these data might suggest the inposition of winter dormancy, this period is also the time when flower bud differentiation begins. Differences might result from shifts in the population of the buds rather than an increase in dormancy, a difference which using the base of buds/node should minimize.

High temperature tests resulted in damage unrelated to BF and did not provide convincing evidence of a specific high temperature dormancy phenomenon. Further use of this test requires examination of the test itself. Cool temperature tests did not demonstrate bud failure in the material apparently because of the unique pattern of cool summer temperatures and seasonal delay in hot temperature. This view follows from the fact that no bud necrosis was found on the orchard trees from which the samples were collected.

PART VI. SEEDLING PROGENY TESTS

Past studies have shown that the BF character is inherited differently in almond x peach and almond x almond crosses. Certain almond x peach crosses tend to segregate for a severe BF phenotype up to 50% with early (first one or two years) expression of symptoms. This cross is thought to indicate the general sensitivity of a particular variety to BF.

In contrast, the almond x almond crosses produced progeny in which the percentage of BF progeny increased gradually over time with the rate of appearance proportional to the severity of BF in the parents. Using one parent with obvious BF symptoms increases the rate at which BF develops in the progeny and creates a potential test to test BF-potential of individual source selections used as a second parent.

Procedure.

Crosses were made in 1989 between 40A-17 peach x various almond varieties. Seeds were collected that fall, germinated, and seedlings were planted into the orchard in the late winter-spring 1990. Plants grew during 1990 and records of BF trees were made in spring 1991. Symptoms were listed as "bud-failure" and "roughbark", the latter being the most characteristic of these progeny.

Crosses of Nonpareil BF x various almond clonal selections were also made in 1989 but high losses of the seeds occurred due to crow predation. The small number of seeds germinated were planted along with the almond x 40A-17 peach progeny described in the earlier paragraph. More crosses were made in 1990, seeds were collected and germinated and plants transplanted to the orchard in spring 1991.

Results:

F1 almond x peach hybrids. Seedlings for this test grew very vigorously and uniformly with some exceptions. Certain trees were stunted with a yellowish color, apparently due to a site effect associated with replanting in particular locations where peach trees had been removed immediately prior to the planting. This condition tended to correct itself as the season progressed.

All of the source trees upon which crosses were made (seed parent) had normal phenotypes and had originated from sources which have not produced BF vegetative progeny. Nevetheless, symptoms of both roughbark and bud-failure characters appeared in individual progeny and could be graded for their severity. These results, produced after the first seasons growth, follows the pattern previously observed from comparable crosses (see earlier annual reports). Table 5 is arranged to show the order of decreasing percentages of BF,RB offspring produced.

Among the varieties previously tested, the range of apparent susceptibility follows the same pattern which also is correlated to the relative chilling requirement (bloom date) of the almond parent. This range is Jordanolo > Carmel > Nonpareil > Merced with none appearing in Price and Butte progeny.

Among these previously tested varieties, Jordanolo has the highest percentage (27%) and the severity of expression of

Table 5. Numbers of BF and RB seedlings in progeny of different almond varieties x 40A-17 peach.

Almond parent	No. of plants	RB,BF	BF-	BF+	almond	out	%
		No.	No.	No.	No.	No.	BF or RB
Sonora	10	6	4	2	0	1	60
Jordanolo	11	3		3	0	1	27
Carmel	12	1	1		1	2	17
	83	17	2	15	1	11	20
Monterey	22	4		4	2	13	14
Nonpareil	22	3	2	1	3	1	13
Merced	50	2	2		4	9	4
	98	3		3	3	11	3
	39	0			2	6	0
Price	31	0			39	12	0
1-69	14	0				1	0
	26	0			4	1	0
Butte	5	0			5	3	0

individual plants was relatively high. Carmel produced a relatively high percentage (20%) with most of the individual affected plants with severe symptoms. Nonpareil had only 13% and most of these had less pronounced expression of symptoms. Prior studies with Merced had produced no BF progeny and these results tended to confirm that the probability of BF transmission in seedling progeny is low.

Among the previously untested varieties, Sonora showed a high percentage of BF offspring (60%) although it should be noted that the severity of the symptoms tended to be lesser than that of the comparable progeny of Jordanolo. Also it should be noted that the population was small. Monterey followed the pattern of Nonpareil. Sel 1-69 produced no BF progeny out of 40 seedlings.

Some crosses produced a significant number of almond seedlings apparently as a result of open pollinations. The number is surprisingly high in some cases, as with Price. This result has occurred previously when the same crosses were made and may result from some peculiarity of the pollination process.

Observations need to be continued for additional years.

Nonpareil BF x almond sources. The limited results produced so far from the 1989 crosses are consistent with expected except that the first year populations were very small, ranging from 6 to 26. Seedlings grew much less than the hybrid plants and tended to be more severely affected by the yellowing syndrome observed in this field. One distinct BF affected plant appeared in the Nonpareil BF x Carmel population.

A large number of seeds of these crosses were produced in 1990 and included a number of individual sources, as described in Table 6, as pollen parents. The seed parents were individual BF-affected Nonpareil 3-8-1-63 trees growing in the UCD orchards. Seeds were collected and planted in two different operations. The first

Table 6. Crosses of Nonpareil BF x almond progeny
A. 1989 crosses

Pollen parent		No. planted	No.with BF	No. died
Butte		6		1
Carmel		11	1	2
Jordanolo	FPMS	26		2
Jordanolo	BF	18		13
Price	SG	9		0
Price	F	15		0

B. 1990 crosses

Variety	Sources tested
Butte	F 1-5
	F 1-9
	F 1-15
	F 2-4
Carmel	Wells Ave. 1-4
	Wells Ave. 1-9
	Delta RVT 13-2
	Delta Rvt 13-7
	GR 114-2
	GR 114-1
	GR 114-3
	Nickels (BF)
Fritz	VR 15-9
	VR 17-8
	Wells 1-23
Jordanolo	Delta RVT
	WEO (BF)
Merced	Delta RVT
Mission 3-6-5-67	Delta RVT
Monterey	GR 55N-4W
	GR 55N-2W
	GR 55N-1W
Padre	Delta RVT
Price	Fowler
	SG 5,6
Sonora	Delta RVT
Sel. 1-69	Delta RVT

planting was made on November 7 and 11, 1990. Many of these were lost in the subsequent freeze. Seeds of the second operation were planted on May 22, 1991. Some of these were used to replant spaces left by seedlings which were dead from freeze damage.

The number of seedlings planted (second planting and survivals of first planting) is 2450. First observations of this material will be made in spring 1992.

PART VII. SUMMER TEMPERATURE PATTERNS (Karen Pelletreau and Dale E. Kester)

The BF model (Fenton, et al. 1988) showed that the rate of BF development in orchards is directly proportional to the accumulated temperatures above 80 ° F at that site. We have likewise shown that the level of BF symptoms produced in the spring is positively correlated to the quantity of heat in any one year at that site. However the temperature pattern during a particular season at a site also may have an important bearing on the expression of BF symptoms during the following season.

An update of the temperature patterns in different years and locations was conducted as a background for the unusual pattern present in 1991.

Procedure.

The CIMIS temperature network was the source of temperature data which provided information on DEGREE-DAYS OVER 80° F. for six stations, 3 in the Sacramento Valley (Davis, Durham and Zamora) and 3 in the San Joaquin Valley (McFarland, Fresno and Five Points). Tabulations include the 1991 data for each month of 1991 of each of these stations compared to the mean of 1983-1990.

Results

1991 Season. The 1991 season stands out as having a much cooler pattern as compared to the 1983-1990 mean (Table 7). During an average year, high temperatures begin to appear in April,ncrease in May and June to a peak in July. There is then a small decrease in August, a further decrease in September and reduction to a low amount from October and later.

The 1991 season was characterized by much lower temperatures during April, May and June than the 1983-90 mean in all six stations examined. July temperatures were somewhat higher than the mean particularly in the Sacramento valley. August, however, was a very cool month. September and the early part of October were very hot months in all six locations.

Table 7. Accumulated degree days, temps> 80°F. for selected sites in California.

A. 1991 season

Month	Sacramento Valley			San Joaquin Valley			
	Davis	Zamora	Durham	McFarland	Fresno	5 Points	Mean
April	0	0	0	1	0	2	1
May	11	14	11	16	11	24	15
June	42	48	51	68	48	71	55
July	121	135	140	160	156	156	145
August	60	82	72	91	85	92	80

Sept	100	106	105	118	107	117	109
Oct	71	73	83	69	58	60	69
Total	405	458	462	523	465	522	473

Mean: Sacramento valley = 442 San Joaquin valley = 503

B. Mean 1983-1990

April	8	9	15	17	14	16	13
May	35	42	37	47	52	47	43
June	79	87	77	101	109	95	91
July	117	127	112	156	174	146	139
August	91	116	99	135	152	131	121
Sept	62	67	61	75	85	79	72
Oct	18	20	21	20	22	26	21
Total	410	468	422	551	608	540	500

Mean: Sacramento valley = 433 San Joaquin valley = 566

Table 8 compares the 1991 season with the 1983 to 1990 mean on the basis of accumulation of °days > 80°F. with time. By the first of July the accumulated heat was only about 50% or less of the 8 year mean. For the Sacramento valley this contrasted 59 by 130. For the San Joaquin valley the contrast was 80 vs. 145. July was nearly normal, so the difference was somewhat less. However, the very cool August reduced the accumulation vis-a-vis normal to 73% of the mean. However, with the very hot September and October, the accumulation of heat units for the year essentially reached the 8 year mean. We cannot be certain how the unique pattern will affect the expression of symptoms next spring. We have contrasting results from two collections made at Winters (WEO) in fall of this year, one of which produced no symptoms while the other had very severe symptoms.

Table 8. Accumulation of degree days >80 ° F. during the 1991 season in contrast to the mean of 1983-1990.

Month	Sacramento Valley						San Joaquin Valley							
	Davis		Zamora		Durham		McFarland		Fresno		5 Points		Mean	
	'91	M	'91	M	'91	M	'91	M	'91	M	'91	M	'91	M
April	0	8	0	9	0	15	1	17	0	14	2	13	1	13
May	11	43	14	51	11	52	17	64	11	66	26	56	16	56
June	53	122	62	138	62	129	85	165	59	175	97	147	71	147
July	174	239	197	265	212	241	245	321	215	349	253	286	216	286
August	234	330	279	381	274	340	336	456	300	501	345	407	296	407
Sept	334	392	385	448	379	401	454	531	407	586	462	479	405	479
Oct	435	410	458	468	462	422	523	551	465	608	522	500	473	500

<u>Year effects in seasonal timing</u>. A series of analyses have

been made to compare heat accumulation by year and by location as a basis for contrasting the heat interactions with bud-failure expression.

The overall seasonal mean (Table 9) shows the hottest year to be 1984, 1983 and 1988. These years were characterized by as high or higher than mean temperatures from May through September. 1987 was an intermediate year with the major summer months July, August and September as mean or below.

1990 was also an intermediate year with mean temperatures throughout the summer. 1985 was a cool year but had a hot June and 1986 was exceptionally cool but with a hot August. 1989 was average or below throughout the summer.

1991 was in the middle of the range but had a different pattern than all others with average or below mean temperature throughout the summer but with September and October as hot or hotter than any year of the series examined.

Table 9. Mean heat accumulation in California in relation to year and location.

Year	No.of reps.	Mean °days > 80	Duncans grouping
1984	6	568	A
1983	6	556	A
1988	6	535	AB
1987	6	512	ABC
1991	6	472	BCD
1990	6	467	BCD
1985	6	463	CD
1986	6	454	CD
1989	6	432	D

A. April

Year	No.of reps.	Mean °days > 80	Duncans grouping
1989	9	31	A
1987	9	26	A
1985	9	17	B
1990	9	11	BC
1988	9	8	CD
1984	9	6	CDE
1986	9	5	CDE
1983	9	1	DE
1991	9	0.5	E
Mean		12	

B. May

Year	No.of reps.	Mean °days > 80	Duncans grouping
1984	6	68	A
1983	6	67	A
1987	6	64	A
1986	6	45	B
1988	6	32	C
1989	6	28	CD
1990	6	21	DE

1985	6	18	E
1991	6	14	E
Mean		40	

C. June

1985	6	132	A
1983	6	104	B
1987	6	100	B
1986	6	92	BC
1984	6	81	CD
1988	6	79	CDE
1990	6	73	DE
1989	6	67	EF
1991	6	55	F
Mean		87	

D. July

1988	6	177	A
1984	6	172	A
1985	6	158	AB
1990	6	148	BC
1991	6	145	BC
1989	6	130	CD
1983	6	129	CD
1986	6	116	D
1987	6	80	E
Mean		139	

E. August

1986	6	140	A
1983	6	136	A
1987	6	125	AB
1990	6	124	AB
1984	6	123	AB
1988	6	123	AB
1989	6	103	BC
1985	6	92	CD
1991	6	80	D
Mean		116	

F. September

1984	6	113	A
1991	6	109	A
1983	6	102	A
1988	6	85	B
1987	6	77	BC
1990	6	68	CD
1989	6	58	D
1986	6	42	E
1985	6	27	F
Mean		76	

		G. October	
1991	6	69	A
1987	6	40	B
1988	6	32	B
1990	6	23	C
1983	6	19	C
1985	6	18	C
1989	6	15	C
1986	6	15	C
1984	6	5	D
Mean		26	

Location effects in seasonal timing. The Sacramento valley is shown to be significantly cooler throughout the spring and summer than the San Joaquin valley, the overall difference being as much as 100 ° Days or more. In amount of heat accumulation the rating is Zamora > Durham > Davis. In the San Joaquin valley the rating was Fresno> McFarland > 5 Points (Table 10).

The San Joaquin locations had higher than mean heat in all months of the year. Zamora tended to be consistently intermediate but cool in April. Durham was warmer in April and May but intermediate or cool during the rest of the summer. Davis was cool on the average in all months of the year.

Table 10. Heat accumulation in California during different months in relation to location

Location	No.	Mean °days > 80	Duncan's range
		A. Yearly mean	
Fresno	9	592	A
McFarland	9	547	AB
5-points	9	536	B
Zamora	9	464	C
Durham	9	426	CD
Davis	9	409	D
		B. April	
McFarland	9	15	A
5-Points	9	14	A
Durham	9	13	AB
Fresno	9	13	AB
Zamora	9	8	B
Davis	9	7	B
		C. May	
Fresno	9	47	A
5-Points	9	45	A
McFarland	9	44	A
Zamora	9	36	B

Durham	9	34	B
Davis	9	31	B

C. June

Fresno	9	102	A
McFarland	9	97	A
5-Points	9	92	AB
Zamora	9	82	BC
Davis	9	74	C
Durham	9	74	C

D. July

Fresno	9	172	A
McFarland	9	156	B
5-Points	9	147	B
Zamora	9	128	C
Davis	9	118	C
Durham	9	115	C

E. August

Fresno	9	144	A
McFarland	9	130	AB
5-Points	9	127	AB
Zamora	9	113	BC
Durham	9	96	CD
Davis	9	88	D

F. September

Fresno	9	87	A
5-Points	9	83	AB
McFarland	9	80	AB
Zamora	9	71	BC
Durham	9	66	C
Davis	9	66	C

G. October

5-Points	9	29	A
Durham	9	28	A
Fresno	9	26	A
McFarland	9	26	A
Zamora	9	25	A
Davis	9	24	A