Project Number 78-K5

Project 78-K

Tree Research: Part 1. Noninfectious bud-failure
Part 2. Variety evaluation

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Objectives

Part 1.

The overall goals are:

a. to modify BF-expression in orchards,

b. to identify BF-resistant plants in BF susceptible varieties, and

c. to select BF-immune varieties.

Specifically the current objectives are:

1. to understand what happens when bud-failure symptoms develop and to establish the effects of heat and water stress on this process,

2. to develop methods to define differences in BF-susceptibility, to use these to compare clones of Nonpareil and other varieties for propagation purposes and to measure changes that occur in shifts from normal to BF, and

3. to determine the pattern of inheritance of BF in almond-peach hybrids and to use this progeny test to detect presence of a BF factor in specific varieties.

Interpretive Summary

The first phase of these investigations (objective 1) is being aided by two relatively simple procedures to measure effects of BF which have emerged from the recent studies. One is the forcing of shoot buds on single node cuttings under lights. The other is the examination, the growing point of shoot buds for internal necrosis which appears as a black spot in the center of the bud which can be detected by October and

November. In the trees studied, it appears that this symptom originated as heat damage in August. These two procedures can be combined or the latter can be used directly in the orchard. We have not yet tested how close we can predict the percentage of failing buds in the spring by the necrosis of individual buds in the fall.

These tests provided evidence this year that BF plants do not "harden-off" or go dormant in the same degree as normal plants in the summer or when exposed to high temperatures.

Abscisic acid, as previously reported, could play a significant role in this process. Limited sampling and analysis for this hormone is in progress, but results are inconclusive.

By these methods we also found that severely water stressed trees in our BF block at Winters produced more failing buds in 1977 then non-stressed trees and that a single irrigation in late July offset the stress. However, in 1978, the slightly or moderately stressed trees had less numbers of dead buds and somewhat more flower buds. Thus, the effect appears to be quite and may depend on the degree of stress and the associated physiological status in the plant.

However, these results and other observations raise the possibility that conditioning the tree to increase BF resistance is possible much the same way that one might condition a plant to withstand cold damage. The effect would be expected to vary with the magnitude of high temperature in the orchard and the degree of inherent BF susceptibility that was established when the tree was planted.

The second phase (objective 2) of the project deals with the measurement of BF susceptibility in different source trees and how the susceptibility changes from the level present in a "normal" tree to that of an affected tree. Earlier we have described how orchard performance tests in a high summer temperature environment has separated among different clones of Nonpareil in their BF susceptibility. We are currently using these plant materials to compare differences in budded container grown plants exposed to high temperature in a growth chamber, using the 2 test methods described earlier. Again, we find that buds on BF plants show less dormancy than buds from normal plants. Only limited work on test tube cultures was made this year because of emphasis on other activities. This in vitro activity will now be given high priority beginning in early 1979.

Inheritance studies (objective 3) likewise led to significant developments in 1978. We find that different Nonpareil source trees, whether normal or BF, produced up to 50% BF offspring after 2 years seedling growth in the field (3 years from time of cross). This finding shows that there is a heritable potential BF factor present in all the Nonpareil tested which is transmitted to half the offspring. Similar percentages have been produced with other almond varieties, but not with such varieties as Mission and certain others, that bloom late. Seedling progeny growing in the orchard to be evaluated next spring should provide more direct evidence that late bloom (or higher inherent dormancy) is associated with BF resistance.

On the basis of the interpretation of inheritance data produced to date, we began limited crossing in 1978 to obtain BF resistance utilizing the principles that we now believe govern their inheritance. Materials that we have been developing that appear to have BF-resistance have been used. Because of limitations of budget, personnel, and time this effort is small and essentially a pilot program.

Part 2.

Objectives:

1. to coordinate the establishment and management of Regional Variety Trial (RVT) orchards,

2. to continue to evaluate selection block and commercial variety material, and

3. to continue to investigate variety and environmental factors affecting variability in shell hardness and sealing properties as a basis for NOW resistance.

Interpretive Summary

Regional Variety Trials. The 2nd year of crop samples and yield data was obtained at Kern and Colusa plots. A first crop was obtained from the Butte County plot and one years growth was obtained at the San Joaquin County plot. Differences are occurring, but it is too early to make definitive conclusions. However, comparative data obtained to date is incorporated into this report.

Shell hardness and seal tightness. These characteristics have been recognized to be important factors in worm damage, whether due to twig borer or navel orange worm. Examination of shells of many varieties over a period of years shows that few varieties, current or experimental, consistently have such well sealed, hard shells, with the exception of Peerless and Mission, that they can be said to be truly immune. Some varieties do show some resistance, but even here environmental variation can occur.

Within our germplasm collection, we have various species and European varieties that have very hard "stone-shells" which would be immune to worms, but the shelling percentage would be much too low for our use. However, we also find among the species, and hybrids that we have made with them, certain individual plants which have not only very hard, but also thin shells. We believe this kind of shell would provide complete immunity and yet be sufficiently thin that the shelling percentage would be acceptable. Among these germplasm materials are also found precocious, late blooming, and self-fertile types. Limited crossing is being started with these materials to determine if such characteristics can be combined with the BF-resistance described earlier.

Progress Report - I. Noninfectious bud-failure

Subproject 1. Expt. 1 - Seasonal bud development in BF and normal buds.

Procedure. Shoots were collected at intervals beginning in late July. Lengths of buds were measured and fresh and dry weights obtained. Each shoot was cut into single node cuttings and insected upright through a sheet of pliofilm covering a petri dish filled with 2% sucrose. The unit was then placed under lights to force buds to initiate growth. Growing buds were counted each week. After 2 weeks the non-growing buds were removed and dissected to determine if the non-growing buds were dead or were flowers.

Results. The procedure was begun in late July, but all the details were not worked out until late August. It was found that the necrotic growing tip inside the bud as described by Hellali (Ph.D. thesis, 1978) began to become visible to the naked eye by late August and September and became quite noticeable by November and December. In July and August, external differences between shoot and flower buds could not be detected, but internal differences began to appear by September and differences in external growth and size also appeared.

Two shoots per treatment were used for each growth test on each date. Sampling was a problem since it became apparent that large differences occurred from shoot to shoot in bud behavior, particularly in the proportion of flower buds and failing buds from BF trees. Differences were also observed in the rate of shoot initiation such that in the future, records should be made at consecutive time periods as every 2 days.

Some shoots collected in July from normal trees showed 100% bud growth, but the percentage decreased in August possibly due to inability of flower buds to reverse their trend toward flowering. The percentage of growing buds gradually decreased through September and November and the rate of initiation also increased.

Buds from BF trees showed a different pattern. Many buds from trees at Winters under both wet and dry soil conditions collected in early September failed to grow. Thereafter, the percentage of failed buds was high (50-85%), but those not failing grew quickly with no apparent dormancy. BF trees at Davis showed considerably less failure (0-60%) and the remaining buds grew extensively in all samples taken during the fall. Buds from the wet plot at Davis did not show dormancy in August or September and maintained this same level of dormancy throughout the fall.

Trends in bud sizes with time were studied to determine whether a difference between normal and BF buds could be established and when this difference occurred. This process was complicated in that flower buds developed during this same period and could not readily be separated from shoot buds.

By plotting distribution of size classes with time one could separate two major groups which appeared to be flowers + shoot buds. In general it appears that no large difference in bud sizes occurred in normal and failing buds except that there appeared to be more slender shoots and consequently smaller buds overall in the BF plants.

Expt. 2 - Differences in BF as affected by bud source, location, and irrigation treatment.

Procedure. In 1977 and 1978 the two blocks of BF Nonpareil trees at Davis and WEO were given 3 irrigation treatments: a) frequent irrigation (wet); b) no irrigation (dry); and c) dry, but 1 irrigation at harvest (semi-dry). Moisture was measured at each foot of soil depth at 2 week intervals with a neutron probe. Fruit samples were collected at regular intervals.

In January 1978, shoots were collected and stored at 32°F until September when they were brought out for bud forcing. This procedure was done by placing entire shoots on 1% sucrose solution in cans covered with plastic bags. The shoots were placed in light and buds growing after 2 weeks were recorded.

In December 1978, shoots were collected from all treatments measured for various parameters and subject to a forcing treatment as described for Project 1. Bud necrosis was also recorded.

Results. Soil moisture stress varied considerably in different treatments because of soil variations. At Davis, summer temperatures are somewhat mild and the level of BF in the block was low. In the block at Winters different trees produced a range of BF severity from mild to severe. In 1977, trees in the dry plots were very stressed for moisture early - by June. Trees with the single irrigation on July 21 did get good moisture for a short period. Defoliation was quite marked on all of the dry plots.

In spring 1978, trees were examined for differences in visual symptoms. All of the irrigated trees had grown much more than the non-irrigated trees and the amount of bloom was more extensive. Stressed trees had bloom restricted mostly to the top of the trees with lower shoots and spurs either barren of bloom or dead. These differences are similar to what one could expect on a stressed normal tree. At Winters almost all of the trees showed symptoms whether stressed or non-stressed. Since pollination conditions were poor in 1978, very little crop was produced.

Trees on the outside of the block have grown better overall than those in the center 3 rows which show effects of competition and more overall stress (Table 1). The percentage of growing buds was higher in these outer trees with little difference among irrigation treatments. The trees in the inner part which received the most irrigation had lesser percentages of buds growing.

Shoots forced after 8 months storage did show significant differences among treatments in the percentage of buds failing to grow (Table 2). Well irrigated BF trees produced 20% growing buds as compared to 46.7% for normal plants. Severely stressed trees showed only 2.8% whereas the trees given a single irrigation on July 23 produced 20.6%, the same as the irrigated block. Since internal bud necrosis was not measured at that time, it cannot be certain whether the low percentage of growing buds from dry trees was due to more BF or to lack of survival during storage. Comparable dry trees from normal sources were not tested.

In 1978, the trees were subjected to the same irrigation regimes, but because of greater natural rainfall, the trees under dry conditions were not particularly stressed and had soil moisture through early August.

Comparison of shoots taken from trees of the various regimes and locations is given in Table 3. These data show that the shoots sampled in mid-December from BF trees as compared to shoots from normal trees were longer and had less flower buds. The BF trees at Winters (where symptoms have been very severe) showed high percentages of dead buds which could be detected by visual inspection. Less than 5% of the buds were non-growing buds without internal symptoms. At Davis (where symptoms have been milder) the percentage of dead buds was less and there were up to 10% dormant buds without internal symptoms similar to that of normal plants.

Most significantly the irrigated trees showed higher percentages of failed buds than did that of the nonirrigated trees.

Expt. 3 - Orchard modification. Cooperation with Dr. Robt. Brewer, KFS, and Lyndon Brown, Cooperative Extension, Kings County.

Procedure. A block of severe BF Nonpareil trees are growing at the West Side Field Station. Facilities to provide cooling by overhead sprinkling has been installed. In addition trees have been given differential pruning, including severe dehorning.

Results. Because of inadequate water quality during the past 2 years, no treatment has been applied because of danger to leaves. However, plans are well advanced to apply differential treatments in 1979 and to monitor temperature in orchards both in soil, air, and inside plant.

Preliminary comparisons of dehorned vs. non-dehorned shoots show much less bud necrosis in samples of shoots collected in fall 1978 from dehorned trees.

Subproject 2. Selection for freedom from BF within varieties.

It is well known that within BF-susceptible varieties, such as Nonpareil, differences in the inherent BF susceptibility can exist among trees at the time they are planted in the orchard. The object of this subproject is to establish methods by which the inherent BF susceptibility can be measured and to identify source materials with low BF susceptibility.

Procedure. Studies are involving 3 different levels of activity, orchard tests, greenhouse and growth chamber tests and test tube tests. In all cases the purpose is to compare performance of "progeny" trees or plants propagated from known source trees.

Orchard tests involve growing plants propagated from specific sources in a high temperature area. The initial test has been conducted at the West Side Field Station (Fresno County) beginning in 1971. These tests have been extended to testing various "clones" in the Regional Variety Test Orchards (see variety section).

For greenhouse tests, buds were taken in from normal and BF plants of Nonpareil and Harpareil and budded into almond and peach seedlings. Resulting plants are being subjected to $100^{o}/80^{o}$F temperatures for periods of 1 to 5 weeks to determine the time-temperature course of heat injury. Petri dish growing tests are being used for determining bud damage, as described previously.

Some tissue culture tests were started, but had been curtailed because of lack of time. However, tests will be started after the first of the year.

Results. Earlier work describing testing procedures at the orchard level has been published (see bibliography). At present, Nonpareil clones have been selected as free of known viruses and are established at the Foundation Plant and Seed Materials Service Orchard at Davis. These are undergoing tests for orchard performance at either the West Side Field Station (Fresno County) or in the Regional Variety Trials Orchards. A Jordanolo clone free of BF has also been included.

Growth chamber tests are in progress, but it is too soon to make a report.

Table. 1. Estimates of bud survival based on % growing buds/shoot visually observed in February 1978. Winters, Calif.

Source trees	Treatment	Trees inside block; shows competition		Trees on border; better trees	
		No. of trees	% buds growing	No. of trees	% buds growing
3-8-1-63 Winters	A. Irrigated	13	13	10	48
3-8-1-63 Winters	B. 1 Irrigation	10	38	8	48
3-8-1-63 Winters	C. Dry*	13	26	9	31

*Actually, had more water than B because of seepage from adjoining block.

Table 2. Incidence of growing buds in stored shoots from trees subjected to different irrigation regimes. Shoots were collected in January, stored at 32°F until October.

Source trees	Treatment	No. of shoots	No. of shoots/tree	Total buds	% growing
Normal trees (Davis)	Irrigated	7	5	872	46.7
3-8-1-63 Winters	Wet	7	5	875	21.0
3-8-1-63 Winters	1 Irrigation	7	5	875	20.6
3-8-1-63 Winters	July 23 - No Irrigation	6	5	750	2.8

Table 3. Comparison of shoots collected in December 1978 in BF and normal trees in relation to source, location, and treatment.

Source trees	Treatment	No. of trees	No. of shoots	Average no. of nodes	Average no. of flowers	Average shoot diam. (mm)	Average shoot length (cm)	Dead buds % (1)	Growing Test: Dead % (2)	Growing Test: Dormant % (3)
3-8-2-70 (normal)	Davis-none	4-5	9	20 ± 6	2	.45 ± .06	27 ± 3	0	0	11
	Winters-none	1	7	16 ± 6	8 ± 7	.40 ± .06	25 ± 8	0	0	8
Wells (normal)	None	2	8	16 ± 7	8 ± 7	.49 ± .15	23 ± 16	0	0	6
3-8-1-63	Winters-wet	5	22	23	4.2	.56	42	90	65	2
	Winters-dry	7	29	20	9.2	.52	38	57	55	4
3-8-1-63	Davis-wet	5	34	21	5.3	.43	34	33	40	6
	Davis-dry	4	39	22	9.5	.51	31	10	13	11

(1) Based on visual evidence of necrosis in buds examined at time of collection.

(2) Based on visual evidence of necrosis in buds examined after growing test.

(3) Buds not growing, but with no visible necrosis internally.

Subproject 3. Inheritance studies.

Procedure. The basic concept in this procedure is to transmit a BF factor from a BF susceptible almond tree to F_1 hybrid offspring when crossed to peach. Trees of these F_1 progeny families are uniform and vigorous. BF affected offspring occur as severe bud-failure or roughbark individuals, some appearing the first year after planting. A very early blooming peach, 40A-17, has been used as parent. Large amounts of pollen are collected, which is applied to flowers of almond varieties as they come into bloom. During the past couple of years a later blooming pollen sterile peach 'J.H. Hale' has also been used. In this case, almond pollen has been collected and applied all at one time to the peach without emasculation of the flowers. High set produced in 1977 showed the practical advantage of this approach.

General procedure is to make crosses in spring, germinate seeds in same summer, grow plants in containers in greenhouse during the same summer and fall, and transplant to orchard the next spring. Identification of BF individuals can begin 1 year later.

Results. 1) Comparisons for BF transmission from different Nonpareil clones have been studied in crosses made in 1973, 1974, 1975, and 1976. These studies are in close agreement and show that about 1/2 the offspring of the peach-almond hybrid population show BF. The percent increases from the first to the second year and then levels off. Representative data is shown in Table 4.

The same results were shown with all Nonpareil clones studied whether the tree showed BF symptoms or not. This finding demonstrates that the absence of a BF factor is not the requirement for BF-freedom. Instead, the BF factor appears to be universally present. The problem is to prevent the BF factor from being expressed.

Table 4. BF offspring in progenies of Nonpareil clones crossed with peach 40A-17. Cross was made in 1974. Trees were planted in Spring 1975.

Nonpareil Source	Phenotype of source tree	No. of trees	% BF in: 1976	1977	1978
F-B1 Davis	Normal	38	24	59	58
F-B2 Davis	"	22	9	23	27
F-B3 Davis	"	2	0	50	50
Wells Davis	"	40	30	60	62
3-8-1-73 Davis 1-1	"	17	22	41	44
" WEO 1-49	BF	35	20	34	34
" " 2-49	BF	16	31	68	69
" " 4-49	BF	10	20	40	40
	TOTAL	170	20	45	48

2) Progeny tests of about 25 almond varieties have been made since 1970 to determine the transmission of BF. Earlier tests have produced BF offspring from the following varieties (in addition to Nonpareil): Jordanolo, Harpareil, IXL, Ne Plus Ultra, Tardy Nonpareil, Titan, and three numbered selections of (Nonpareil x Jordanolo). In 1976, crosses were begun to systematically examine different varieties. In spring 1978, BF offspring appeared at the first year from Vesta, 5A-3 and Milow.

Other tests have involved too small numbers, but the following individuals have not produced BF offspring.

Mission. Standard variety.

CP 5-33. (Nonpareil x Mc Lish). Very late bloom.

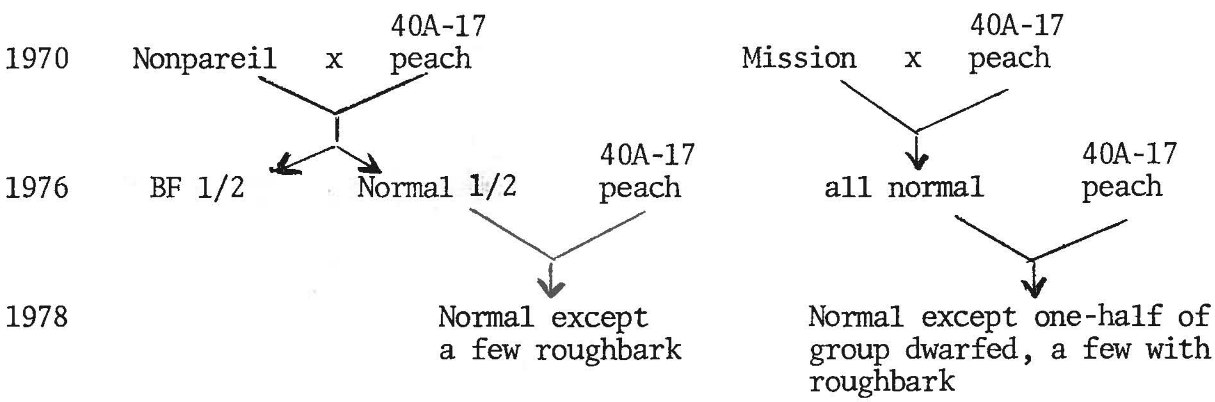
324E. A very late blooming almond.

1-31. (Almond x *Prunus mira*). Very late bloom.

5-58. Mission x Swanson. Numbers small. Blooms with Mission.

The pattern that is beginning to emerge is that the varieties not producing BF offspring bloom late, i.e., time of Mission and later. In addition, several previous tests have been made with late blooming peaches and no BF offspring have been found, but the populations were small. Thus, the tests with 'J.H. Hale' peach (a late blooming variety) which will start to produce results in spring 1979 (Table 5) will be particularly important for future directions. These results suggest that resistance to BF may be associated with late bloom.

3) Another test that has been made is as follows:



This experiment was done to determine if the normal F_1's were BF-free (normal) or if they were carrying a BF factor that could be detected by crossing back to peach. The results indicate that they are BF-free. This finding suggests a way to breed BF out of the almond, that is by crossing among the F_1 as follows:

Nonpareil x Peach → 1/2 BF → Discard; 1/2 normal; All peach-like

Any vareity x Peach → 1/2 BF → Discard; 1/2 normal; All peach-like

(1/2 normal; All peach-like) x (1/2 normal; All peach-like) → All BF free; expect range of types from almond to peach

4) Almond x BF-almond crosses have been studied previously and show that BF off-spring appear in offspring, but at a slower rate than with peach. A small group of offspring from open-pollinated Nonpareil BF has been growing at WEO, Winters since 1972. Three of eight have shown severe BF for several years. If one assumes the 50% transmission shown in peach crosses (and other studies), one can expect two applications. One is that the 5 trees nonaffected by this date in this population are free of BF and should be suitable material to use in breeding. The second is that one makes a cross with a severe BF almond, those offspring that are BF affected should appear at an early age and thus be eliminated.

(1) Any variety x Nonpareil →
1/2 BF - delayed in time; cannot separate from BF
1/2 normal

(2) Any variety x Nonpareil BF →
1/2 BF - early expression → discard
1/2 normal → use in breeding or for variety testing

Table 5. Crosses made in 1977. Results will begin to appear spring 1979.

Population no.	Seed parent		Pollen parent	No. of seeds planted	No. of plants
771	J.H. Hale	x	FPMS Jordanolo	124	103
772	J.H. Hale	x	BF Jordanolo	94	91
773	J.H. Hale	x	Wells Nonpareil	92	89
774	J.H. Hale	x	BF Nonpareil	78	76
775	J.H. Hale	x	Mission	81	80
776	Wells Nonpareil	x	40A-17 peach	41	38
777	BF Nonpareil	x	40A-17 peach	110	105
778	Mission	x	40A-17 peach	10	10
779	Merced-normal BF	x	40A-17 peach	100	86
7710	Merced-BF-Br	x	40A-17 peach	92	79
7711	CP 5-58	x	40A-17 peach	56	54
7712	CP 5-33	x	40A-17 peach	4	3
7713	2-62	x	40A-17 peach	20	13
7714	1-69	x	40A-17 peach	2	2
				TOTAL	829

5) Crosses made in 1978 involved experiments to test the validity of these ideas for obtaining BF free plants. See Table 6 and 7.

Discussion. The objectives of the 3 separate subprojects should be kept in mind. Progress is being made in all 3, but one must be careful on interpretation at this stage in applying them to orchard situations. The concept of heat injury to the growing point, which appears to be the most sensitive part of the plant, is being increasingly borne out. Thus the severity of BF is determined both by the temperature regime in the orchard and by the inherent resistance of the tree. We have earlier reported evidence for a hormonal response to heat stress by the normal plant which appears to be lacking or reduced in the BF plant. We are now getting evidence suggesting that this difference is translated into differences in the way the buds go dormant in summer. The final result is damage to the sensitive growing point which appears now to be detectable by visual observations of the bud later in the year. Although the inherent level of BF susceptibility of the tree at the time of planting is an important consideration, it now appears that the physiological state of the tree as affected by pruning, nutrition, and irrigation may also influence both the percent of BF and the percent of flower buds produced much the same as these factors can influence the development of maturity and resistance to freezing in other plants. The results of irrigation trials are not clear, but at present it appears that some moisture stress may actually be helpful in increasing resistance whereas a severe moisture stress may be harmful. The studies now in progress are designed to establish more specifically the physiological basis for resistance.

Subproject 2 deals with measuring the inherent BF susceptibility of particular trees which might be used for budwood. To do this, comparisons must be made among test plants that are in the same environment and at the same physiological state. Comparisons have been made in the orchard among populations of trees propagated from a specific source and clones and selections of differing BF potential have been identified. Using these materials as test objects, the goal now is to reduce the test material to small objects (shoots and tissue) which can be grown in test tubes under standard conditions where the physiology and the environment can be closely controlled. With this kind of technique it should be possible to follow changes in BF susceptibility that can occur with time.

Inheritance studies (subproject 3) are beginning to suggest ways to develop BF resistant varieties. The important step now is to test these hypothesis on a relatively reduced scale of breeding such that future breeding strategies can then be utilized where these procedures are applied on a large scale.

Table 6. Groups of crosses made in 1978.

Group 1. Crosses to 'J.H. Hale' and '40A-17' peach

Population no.	Seed parent	x	Pollen parent	No. of seeds	No. of plants
781	J.H. Hale	x	Nonpareil 3-8-2-70	2	2
782	J.H. Hale	x	Nonpareil 3-8-5-72	4	4
783	J.H. Hale	x	BF Nonpareil	7	7
784	J.H. Hale	x	Carmel	12	12
785	J.H. Hale	x	Butte	15	15
7816	45-13	x	40A-17	3	3
7827	28-21	x	40A-17	83	66
7832	3-24E	x	40A-17	12	11
7834	3-63E	x	40A-17	58	57
7836	19-18	x	40A-17	94	94
				TOTAL	271

Group 2. Crossed to Nonpareil BF.

Population no.	Seed parent	x	Pollen parent	No. of seeds	No. of plants
786	F5 4-4	x	BF Nonpareil	61	61
787	F5 4-5	x	BF Nonpareil	7	7
788	F5 4-13	x	BF Nonpareil	37	37
7815	45-13	x	BF Nonpareil	74	72
7821	1-98	x	BF Nonpareil	1	1
7825	2-1E	x	BF Nonpareil	57	56
7826	28-21	x	BF Nonpareil	100	96
7831	3-24E	x	BF Nonpareil	29	29
7835	19-18	x	BF Nonpareil	99	99
				TOTAL	458

Group 3. Interspecific

Population no.	Seed parent	x	Pollen parent	No. of seeds	No. of plants
789	F5 4-8	x	Self	2	1
7810	F5 4-10	x	Self	1	1
7811	F5 4-12	x	Self	6	6
7812	F5 4-16	x	Self	6	6
7813	F5 4-19	x	Self	5	5
7814	F5 3-57	x	Self	5	5
5817	45-13	x	F-5, 2-7,8	10	10
5818	45-13	x	F-5, 3-37	5	5
5819	45-13	x	F-5, 3-38	6	6
5820	45-13	x	F-5, 2-11,12	2	2
7828	28-21	x	F-5, 3-37	33	30
7829	28-21	x	F-5, 3-38	41	40
7830	28-21	x	F-5, 3-43	26	25
7836	19-18	x	OP	96	96
				TOTAL	238
				GRAND TOTAL	967

Table 8. Origin of numbered selections used in crosses made in 1978.

Selection	Origin	Characteristics
SB #2, 45-13	CP5-33 x 24-6	Late bloom, good quality, large
SB #13, 28-21	SB #2, 45-96 x SB #4 5-58E	Self-fertile, late bloom
SB #4, 3-24E	WSB 3C-29 x Arbuckle	Very late bloom, productive
SB #4, 3-63E	WSB 3C-29 x Arbuckle	Moderate, late bloom, productive
F8 19-18	Nonpareil BF (open pollinated)	No BF, productive
SB #4, 1-98W	WSB 3C-29 x CP 5-33	Late bloom, productive
SB #7, 2-1E	Mission x Kapareil	Moderate, late bloom, productive
F5, 4-4, 4-5, 4-8, 4-10, 4-12, 4-13, 4-16, 4-19	Prunus webbii x SB #6, 56-88	Small, bushy, stone-shell, late bloom, possible self-fertile
F5, 3-37, 3-57	SB #16, 2-7 x SB #6, 56-98	Very precocious, possible self-fertile, productive
F5, 3-57	Prunus webbii x SB #6, 56-98	Similar to above
CP 5-33	Reams x Mc Lish	Very late bloom, productive
24-6	Eureka x (Nonpareil x Eureka)	High quality
25-26	(Nonpareil x Eureka) x (Nonpareil x Harriott)	Flat, broad kernel
1-31	Prunus mira x Almond	Self-fertile, late bloom
3C-29	5-3 x 25-26	Good quality, paper
5-3	Nonpareil x Sans Faute	
Prunus webbii	From Yugoslavia	Late bloom, small, bushy, hard shell
Sel. 5-15	Nonpareil x (Mission x Lukens Honey pch.)	Self-fertile

Progress Report - II. Variety Evaluation

Subproject 1. Regional variety trials (RVT).

Procedure. Layout of plots and the varieties and selections included have been previously described. In 1978, samples were obtained from the Kern, Colusa, and Butte counties samples. Yield data was obtained from Kern County by harvesting 5 tree replications of each of the various varieties. In the Colusa plot, yield estimates were obtained by counting all of the nuts on a single major limb and multiplying by number of equally sized limbs on 3-5 trees of each variety. The number of lbs./tree was obtained by multiplying nut size with number.

Tom Aldrich, Cooperative Extension, obtained estimates of worm damage (essentially all twig borer) on representative nut samples.

Results.

(1) Regional Variety Trials.

a) Kern County (with Marvin Gerdts and Ken Hench). Observations have been made of yield and tree behavior. Yield data based on both nut number and kernel weight is shown in Table 9. Nut and kernel data is summarized in Table 10.

b) Colusa County (with Tom Aldrich, Cooperative Extension). Tree observations were made during pruning. Bloom and harvest dates have been obtained. Photographs of most of the trees in bloom were taken.

Table 11 shows estimates of yield for both 1977 and 1978 based on nut number and kernel weight. Data on worm count, principally twig borer, is shown in Table 12. Nut and kernel data is included in Table 13 to compare to similar data from Kern County.

c) Butte County (with Dr. Richard Baldie, California State University, Chico). Nut samples were collected for the first time although the crop overall was very light. Samples have not been evaluated as of this writing. New trees were planted to provide a second block at this location.

d) San Joaquin County (with Don Rough, Cooperative Extension and Gary Blomgren, Delta College). Trees were planted in spring 1978 and have made good growth during this first year.

(2) Samples were also collected of selections in the UC blocks at Kearney Field Station (Fresno County), WEO (Winters), and at Davis. In addition, samples from various commercial selections were obtained and evaluated. The samples and data were used in a variety workshop session in conjunction with the Research Conference.

Table 9. Tree data obtained at the Kern County Almond Variety Trial - 1978. Collected by Marvin Gerdts, Harry Andris, Don Luvisi, and Ken Hench.

Selection	Average kernel weight (gms.)	Nuts per tree	Yield per acre kernel (lbs.)
Nonpareil #7	1.18	3147	612.8
Nonpareil #8	1.21	2529	504.8
Nonpareil #9	1.23	2708	549.8
Nonpareil #10	1.15	3755	712.5
Nonpareil #11	1.17	3498	675.0
Nonpareil 2-70	1.16	2890	553.5
Nonpareil 6-70	1.16	2683	513.8
Nonpareil 4-72	1.19	2655	521.2
Nonpareil 5-72	1.13	2520	469.5
5A-20	1.42	2453	574.5
5A-3	1.04	3159	542.2
Vesta	1.27	1811	379.5
Norman	1.00	2085	344.2
Granada	1.04	1429	245.2
23-122	1.31	587	126.8
2-17	1.13	2564	478.5
K13N	1.21	1651	329.2
Moneytree	1.73	494	141.0
Jordanolo	1.79	1753	517.5
NePlus	1.58	2306	600.8
Price	1.07	2415	426.0
3-24E	.85	2299	322.5
Carmel	1.34	3573	789.8
Robson	1.22	2232	449.2
Ruby	1.25	3260	672.0
CP5-58	1.16	2898	555.0
Merced	1.28	2622	553.5
Harvey	1.11	1915	351.0
Ripon	1.11	827	151.5
Thompson	1.31	2690	581.2
Carrion	1.33	1723	378.0
Butte	1.00	2602	429.0
Fritz	1.10	3399	617.2
Mission/Lovell	1.26	1181	409.5
Mission/Nemaguard	1.28	1309	460.5
Mission/Bright Hybrid	1.26	1271	440.2

Table 10. Nut data of samples collected at Kern County Variety Trial - 1978. Crack-out data for Kern County plot.

	Nut		Kernel								
				Size		Shape		% Defects			
Varieties or Selections	Shell type	% sealed	% kernel	Avg. wt. gms.	No./oz.	Avg. thickness (cm)	W/L (1)	Doubles	Rejects (2)	Worms (3)	Notes
Butte	Soft	80	60	1.08	26	.92	62	0	0	0	
Carmel	Paper	52	63	1.32	21	.86	52	12	4	0	
Carrion	Soft	72	67	1.48	19	1.00	56	4	4	4	
Fritz	Soft	100	56	1.08	26	.92	58	4	24	0	Shrivel
Granada	Soft	36	62	1.15	25	.94	70	8	12	8	Blanks
Harvey	Paper	28	75	1.08	26	.88	55	0	4	12	
Jordanolo	Paper	80	65	1.70	17	.81	44	0	4	4	Creases
Merced	Paper	68	70	1.30	22	.91	61	0	8	8	Blanks
Mission/Alm.	Hard	100	48	1.14	25	.93	60	0	4	0	
Milow	Paper	100	72	.93	31	.71	62	4	0	0	
Money Tree	Paper	20	77	1.73	17	.85	47	0	24	8	Blanks, gum
Ne Plus	Paper	76	64	1.38	21	.81	51	8	0	0	Creases
Nonpareil	Paper	52	73	1.33	21	.83	58	3	8	3	Blanks, Shrivel
Norman	Paper	28	60	.94	30	.80	59	0	16	4	Blanks
Price	Paper	24	63	1.13	25	.85	51	4	4	4	
Profuse	Soft	60	67	1.56	18	.80	55	0	4	0	
Ripon	Soft	100	65	1.26	23	.82	58	0	16	0	Blanks
Robson	Soft	72	81	1.30	22	.96	56	0	4	8	
Ruby	Hard	100	52	1.39	20	.84	65	4	4	0	
Thompson	Paper	60	69	1.31	22	.86	57	0	0	0	

(Continued)

Table 10. Nut data of samples collected at Kern County Variety Trial - 1978. Crack-out data for Kern County plot.

	Nut		Kernel								
				Size		Shape		% Defects			
Varieties or Selections	Shell type	% sealed	% kernel	Avg. wt. gms.	No./oz.	Avg. thickness (cm)	W/L[1]	Doubles	Rejects[2]	Worms[3]	Notes
Vesta	Paper	64	59	1.25	23	.85	56	0	8	0	
5A-3	Paper	72	65	1.05	27	.81	50	0	0	0	
5A-20	Paper	52	73	1.49	19	.79	49	0	0	0	
2-17	Soft	100	55	1.13	25	.80	61	0	0	0	
3-24E	Paper	60	59	.86	33	.84	58	0	0	0	
K-13N	Paper	76	56	1.29	22	.65	61	0	4	4	
23-122	Paper	96	64	1.25	23	.80	56	0	0	0	
CP 5-58	Hard	100	60	1.15	25	.91	63	12	4	0	

(1) W/L = Width/Length x 100

(2) Rejects includes shriveled, gummy, blanks, based on number in 25 nut sample

(3) Worms includes both TB and NOW

Table 11. Tree data obtained at the Nickles Research Farm - Arbuckle, Calif. Planted 1975.

Standard varieties		Bud density	1st bloom Febr.	Nuts per tree	Kernel size no./oz	Yield per acre (lbs)	Harvest data A=Aug.	Rank in no. of nuts
Nonpareil								
3-8-2-70	1977	4/0		138	24	27	A3	
	1978	7/2	F21	840	24	164	A25	8
3-8-4-72	1977	NC		-	-	-	-	-
	1978	-		738	21	165	A25	11
3-8-5-72	1977	NC		-	-	-	-	
	1978	NC		660	22	141	A25	16
3-8-7-72	1977	NC		-	-	-	-	
	1978	NC		856	22	182	A25	7
Mission								
3-6-1-65	1977	1/0	F27	74	21	16	S20	
	1978	3/5		868	21	194	01	5
3-6-2-72	1977			68	-	-	-	
	1978			700	20	164	01	13
3-6-3-67	1977	-		62	-	-	-	
	1978	-		706	21	158	01	12
Ne Plus Ultra								
3-7-1-63	1977	4/0		40	21	9	S1	
	1978	8/4	F12	603	21	135	S7	18
Peerless								
3-10-1-63	1977	3/0		100	18	26	A24	
	1978	4/4	F18	858	18	223	S1	6
Test Varieties								
Butte								
	1977	5-6/0		135	24	26	S7	
	1978	8/6	F24	940	24	184	S15	3
Carmel								
	1977	3/0		75	19	18	S7	
	1978	7/4	F22	968	19	239	S20	1
Carrion								
	1977	5/0		95	18	25	S7	
	1978	8/4	F23	524	18	136	S20	21
Fritz								
	1977	3/0		31	22	7	S20	
	1978	7/5	F21	729	22	155	01	10
Granada								
	1977	3/0		48	25	9	A11	
	1978	6/6	F22	532	25	100	A16	20
Harvey								
	1977	5/0		125	22	27	S7	
	1978	8/6	F21	640	22	136	S15	17

(Continued)

Table 11. Tree data obtained at the Nickles Research Farm - Arbuckle, Calif. Planted 1975.

Test Varieties		Bud density	1st bloom Febr.	Nuts per tree	Kernel size no./oz	Yield per acre (lbs)	Harvest data A=Aug.	Rank in no. of nuts
Jordanolo								
3-3-1-70	1977	3/0		frozen	22	-	S1	
	1978	7/5	F6	662	22	141	S7	15
Milow								
	1977	5/0		100	27	17	A3	
	1978	6/7	F20	378	27	66	A15	25
Money Tree								
	1977	4/0		40	17	11	S1	
	1978	7/4	F12	296	17	82	S7	28
Norman								
	1977	3/0		58	27	10	S1	
	1978	7/5	F24	926	27	161	S7	4
Price								
	1977	2/0		41	23	8	S1	
	1978	4/2	F22	514	23	105	S7	22
Robson								
	1977	3/0		NC	22	-	S1	
	1978	6/4	F22	570	22	121	S7	19
Thompson								
	1977	3/0		140	19	35	S1	
	1978	4/4	F25	700	19	173	S7	14
Vesta								
	1977	4/0		160	20	38	A24	
	1978	6/2	F21	374	20	88	S1	26
5A-3								
	1977	3/0		150	24	29	A24	
	1978	7/4	F21	492	24	96	S1	23
5A-20								
	1977	2/0		142	19	35	A24	
	1978	7/2	F16	963	19	238	S1	2
69-60								
	1977	1/0		34	22	7	A16	
	1978	3/2	F22	338	22	72	A25	27
K13N								
	1977	2/0		56	23	11	S1	
	1978	7/5	F18	426	23	87	S7	24
23-122								
	1977	2/0		NC	21	-	A11	
	1978	-	F21	740	21	165	A16	9

Explanation

Bud density: on shoots/on spurs; visual rating: 1 - very few -- 9 very heavy

Yield calculated at 75 trees per acre. Based on counts of nuts on 1 representative limb on each of 3 trees per variety.

Table 12. Worm damage (Twig borer) in nut samples collected by Tom Aldrich at the Nickels Research Farm, Arbuckle - Colusa County, 1978.

Variety	Worm damage (percent)	Crackout (percent)	Harvest date
Jordanolo	23	70	Sept. 6
12-38 Milow	15	71	Aug. 30
Thompson	11	71	Sept. 7
Nonpareil	10	70	Aug. 30
Money Tree	9	72	Sept. 7
Robson	5	67	Sept. 12
Price	5	65	Sept. 7
23-122	5	77	Aug. 30
5 A-20	4	76	Sept. 11
Granada	4	63	Sept. 7
K 13 N	3	64	Sept. 7
Harvey	3	74	Sept. 12
Vesta	3	57	Sept. 12
Ne Plus	1	67	Sept. 11
5 A-3	1	68	Sept. 6
Fritz	.6	59	Sept. 18
Norman	.6	70	Sept. 7
Carrion	.6	65	Sept. 11
Carmel	.6	67	Sept. 12
Butte	.6	59	Sept. 13
Peerless	0	41	Sept. 6
69-60	0	52	Aug. 30
Mission	0	46	Sept. 18

Table 13. Nut data of samples collected at the Nickles Research Farm, Colusa County - 1978.

	Nut		Kernel							
				Size		Shape		% Defects		
Varieties or Selections	Shell type	% sealed	% kernel	Avg. wt. gms.	No./oz.	Avg. thickness (cm)	W/L (1)	Doubles	Rejects (2)	Worms (3)
Butte	Paper shell	52	58	1.20	24	.95	59	0	0	0
Carmel	Soft	72	62	1.48	19	.90	46	0	4	4
Carrion	Soft	56	65	1.55	18	1.01	52	8	0	0
Fritz	Soft	36	57	1.27	22	.86	53	12	0	0
Granada	Soft	60	61	1.13	25	.88	68	8	4	0
Harvey	Paper	0	71	1.29	22	.88	52	0	0	0
Jordanolo	Paper	56	74	1.31	22	.80	48	4	12	16
Mission	Hard	100	42	1.34	21	1.05	64	14	0	0
Milow	Paper	92	68	1.06	27	.76	55	0	4	0
Money Tree	Paper	4	72	1.65	17	.86	47	4	4	8
Ne Plus Ultra	Paper	44	65	1.33	21	.88	48	8	0	0
Nonpareil	Paper	40	68	1.19	24	.79	50	0	13	4
Norman	Paper	0	68	1.05	27	.84	58	0	8	0
Peerless	Hard	100	40	1.54	18	.89	57	8	4	0
Price	Paper	32	65	1.24	23	.85	52	8	8	0
Robson	Paper	28	66	1.28	22	.93	54	0	0	8
Thompson	Paper	16	67	1.47	19	.86	55	0	0	8
Vesta	Paper	88	53	1.40	20	.84	51	0	0	0
5 A-3	Paper	88	63	1.19	24	.78	48	0	0	0
5 A-20	Paper	56	75	1.48	19	.79	45	0	4	12

(Continued)

Table 13. Nut data of samples collected at the Nickles Research Farm, Colusa County - 1978.

	Nut		Kernel							
				Size		Shape		% Defects		
Varieties or Selections	Shell type	% sealed	% kernel	Avg. wt. gms.	No./oz.	Avg. thickness (cm)	W/L(1)	Doubles	Rejects(2)	Worms(3)
69-60	Soft	96	49	1.30	22	.73	56	0	0	4
K-13N	Paper	32	59	1.25	23	.60	61	0	12	20
23-122	Soft	96	63	1.37	21	.72	59	4	0	8

(1) W/L = width/length x 100

(2) Rejects includes shriveled, gummy, blanks, based on number in 25 nut sample.

(3) Worms includes both TB and NOW.

Subproject 2. Shell resistance to worm damage.

Procedure. Information to be presented involves growing seedling progeny which has been described. Shell characters have been identified visually and through calculations of shelling percentages.

Measurements with shell seal meter were not made this year, because of lack of time and because estimates could be made from shelling percentage and shell seal data.

Results.

(1) Comparisons of shelling percentage and percent sealed are shown in Tables 10 and 13 for a range of varieties at the Kern County and Arbuckle plots. In the Kern plot, varieties with 100% sealed shells included Fritz, Milow, Mission, Ruby, Ripon, Sel. 2-17, and 5-58. These also showed no worm count. In Arbuckle, only Mission and Peerless showed 100% sealed. Fritz had only 36% sealed, but showed few worms. Milow had 92% sealed, but had 15% worm damage. Outstanding kernel characteristics based on lack of doubles, rejects or worms at Kern included Butte, Thompson, 5A-3, 5A20, 2-17, 3-24E and 23-122. Similarly, outstanding varieties in the Colusa plot were Butte, Harvey and 5A-3.

(2) Samples have been obtained this year from certain hybrid selections with nuts that are very hard, but thin which should combine high resistance to worm damage with a relatively high shelling percentage. These selections originated from crosses made previously. The most promising selections had been replanted into a block for further study and trees of them have come into bearing this year.

The original source of these hybrids were certain wild species in the UCD germplasm collection including *Prunus webbii*, *Prunus argentea*, *Prunus tangutica*, *Prunus bucharica* and others. The shell of these are similar to many European varieties in which the shell is thick and must be described as stone-shelled. Their shelling percentage runs 20-30. These differ genetically from the soft and paper shelled varieties in that the stone-shelled character is completely dominant. For instance, a cross of Nonpareil x *Prunus webbii* produced individuals whose shelling percentage ranged from 28 to 34. A cross of Mission and Merced produced offspring with shelling percentages ranging from 43 to 65. However, within the hybrid progeny of various crosses of Nonpareil or Mission with these species, individuals appeared whose shelling percentage were as high as 50 to 60 percent and other progeny showed individuals of the 40-50% range. The almond shell consists of an outer and inner layer which in stone shelled varieties is fused together. In those with high shelling percentages, the inner shell is hard, but the outer tends to be missing or has such large grooves that the weight is less. In addition, its hull was observed to be thin.

Progress Report I. Noninfectious bud-failure
Report II. Variety Evaluation

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