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Project No. 84-M9 - Tree and Crop Research
Pollination

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Objectives: To develop information on pollination by bees which will result in increased production and greater grower returns.

Interpretive Summary:

Colony management: Weather during 1984 almond bloom was ideal for bee flight and pollination. Our experiments to determine ways of managing honey bee colonies to enhance their pollinating efficiency under adverse conditions therefore often lacked statistical significance this year. However, these data provide a base for comparison with future trials under adverse conditions.

A large factorial experiment tested simultaneously the effects of colony strengths in relation to: pollen traps, sugar syrup feeding, solar heating with black plastic covers, and extra space in strongest colonies on pollination efficiency. Solar heating did not affect bee cluster temperatures, but did elevate peripheral hive temperatures, especially on the south side. It had a depressing effect on bee activity and pollen income during the good weather of 1984. Feeding syrup did not increase activity or pollen income as in 1983. Extra space in colonies with > 12 frames of bees provided no effect on bee activity. Pollen traps provided increases in bee activity and pollen income, but the two traps tested differed in the amount of this positive affect.

Colony strength: Worker bee populations in 190 colonies were measured by cluster size and frames of bees counts. A table relating these counts appears similar to the one from 1983 with cluster size slightly underestimating strength based on frame counts in colonies of 3 to 6 frames of bees while increasingly overestimating stronger colonies. Variances also increased with increasing strength.

Hive distribution: In some large, uniform, young orchards near Arbuckle, we examined the impact on yield of spacing hives at 1/8 versus 1/4 mile intervals while keeping the number of hives per acre the same. Our fruit set counts show no significant difference between plots with single- versus double-spaced hive distribution in this year of good flight weather.

Amount of pollen on stigma: Preliminary hand pollination tests showed a direct correlation between average numbers of pollen grains per stigma and percent fruit set. This relationship should be more carefully defined and attention should be given to amounts of pollen deposited in each bee visit.

Stigma-anther positions: Stigmas of Peerless, Merced and Mission are well beyond the anthers at dehiscence and should receive little self deposited pollen; stigmas of NePlus should receive much self pollen; and stigmas of Nonpareil, Price and Thompson are somewhat intermediate.

Osmia (blue orchard bee): A small population of *Osmia* had poor emergence, but nested successfully, especially in wood shelter painted black. Summer and winter management need further study in order to increase populations of these bees.

SURVEY OF FACTORS AFFECTING POLLINATION AND YIELD IN ALMONDS

The almond growers of California were surveyed in order to define pollination problems and conditions that affect yield, and thus to be better able to seek solutions. We also hoped to gain information that might be useful in developing a computer model a grower could use to determine the number and strength of hives needed for his individual orchard.

Methods: In August of 1983, survey forms covering the 1982 crop were sent to 694 growers. A second mailing was made in September to 20% of those growers who did not respond to the first mailing. Responses were received from 200 growers (about 25%) covering 217 orchards. Of these, data for only 139 orchards were complete enough to be usable for analyses.

Results: The results are given in Tables 1-3. Table 1 shows the answers to questions that required filling a blank with a number. Table 2 lists the responses to questions requiring the grower to select a category. Table 3 gives grower answers to two questions concerning what orchard or bee conditions may have affected pollination and yield, and what were their most important pollination problems.

Table 1 shows responses by three major almond producing areas. The average orchard age decreases going south from the Sacramento Valley to the southern San Joaquin Valley. The average number of hives per acre and frames per acre is highest in the northern San Joaquin Valley, followed by the southern San Joaquin Valley, and the Sacramento Valley, respectively. Yield was also higher in the northern San Joaquin Valley followed closely by the Sacramento Valley, and more distantly by the southern San Joaquin Valley. (Statewide average reject fraction was .036, range 0.0 - .188.) This lack of correspondence in the regions between hives per acre and frames per acre and yield may be due to the fact that the plantings in the southern San Joaquin Valley are newer and may not be in as full production as the northern areas. The tree spacing in the 3 areas was very nearly the same. The overall statewide average tree spacing between and within rows was 23.4 (range 12-30) ft. and 23.3 (range 14-30) ft., respectively.

Table 2 reveals that about 3/4 of the growers surveyed felt that their hives were good to excellent in strength. About 60% orchards had competing bloom on at least two sides, and about 15% of orchards had at least moderate ground cover. Over 80% of orchards had hives spaced at less than 1/4 mile apart. Over 50% of orchards contained more than 1% missing, abnormal, and diseased trees. Over 60% of orchards had over 1% shothole, brown rot and fruit diseases. About 40% of orchards had over 3 applications of fungicides. Almost 60% of fungicide applications were by ground rig and another 25% were by combinations of ground rigs and aerial. Over 90% of orchards were owned by the respondants, and over 90% had at least 5 years of almond orchard management experience.

Table 3 reveals that bad weather was listed by over 2/3 of the growers as the most important factor other than those mentioned above affecting yield, and as the overall most important pollination problem. Most other factors and problems were mentioned by 15% or less of the growers.

Regression analyses were performed to determine which of the pollination factors surveyed most influenced yield. Frames of bees per acre gave the highest value ($r^2 = 30.2$). Hives per acre and orchard age gave much lower values ($r^2 = 8.0$; 2.5, respectively). Multiple regression of yield (for 8-20 yr. orchards) versus regional location, frames per acre, square feet per tree, orchard age and size gave $r^2 = 33.7$ with frames per acre being the only significant factor in yield. The average net yield is directly correlated with hives per acre groupings (correlation = 0.94) (Fig. 1).

Discussion: Frames of bees per acre is the most significant variable in explaining yield. The relationship between hives per acre and yield is linear except in the region between 1 1/2 to 2 hives per acre. Although the correlation between hives per acre and yield is high, there was much variation. However, these findings do confirm the importance of having enough strong colonies for maximum pollination and yield, especially under adverse weather conditions often present during almond bloom. Other generalizations from the survey are:

1. The northern San Joaquin Valley orchards followed by the younger plantings in the southern San Joaquin used more hives and frames per acre than the Sacramento Valley.

2. Most growers were satisfied with colony strength.

3. The majority of growers have competing bloom around their orchards, but few listed blooming ground cover within the orchard as being significant.

4. Most orchards had very good hive distribution (i.e. less than 1/4 mile apart).

5. The majority of orchards had over 1% missing, abnormal, and diseased trees. The same was true for shothole, brown rot, and fruit diseases.

6. Fungicide usage was heavy in 1982 (possibly in response to inclement weather), and most applications were by ground rig.

7. Weather was considered to be the biggest pollination problem by respondants.

8. Most growers had had a number of years of almond orchard management experience and owned the orchards surveyed.

The survey was probably biased towards the better growers, because they would presumably be more likely to respond. There is also a possibility for error in some of the more subjective questions of the survey.

A computer model to predict the number and strength of hives needed by each individual orchard may take several more years of data to develop, but may be as feasible in pollination as it has been in such areas as irrigation and pest management. As a result of the survey, we have slanted our research more towards determining how weather affects bee flight and colony vigor during almond bloom. We cannot control the weather, but we can help shield bees from its negative effects.

Table 1. Answers to Numerical Questions by Region.

		Sacramento Valley*	Northern San Joaquin Valley	Southern San Joaquin Valley	Over-all
Orchard Age (years)	n	27	59	51	139
	Mean	17.4	14.1	13.6	14.8
	Standard Deviation	(13.7)	(7.9)	(5.1)	(8.9)
	Range	7-70	3-40	4-25	3-70
Orchard Size (Acres)	n	26	59	51	138
	Mean	111	52	96	79
	Standard Deviation	(133)	(93)	(117)	(112)
	Range	8-450	3-665	1-622	1-665
Hives Per Acre	n	27	59	51	139
	Mean	1.8	2.5	2.3	2.3
	Standard Deviation	(.56)	(.77)	(.78)	(.81)
	Range	0-3	0-4	0-5	0-5
Frames Per Acre	n	16	45	35	97
	Mean	15.2	20.1	17.1	18.0
	Standard Deviation	(5.7)	(8.3)	(6.3)	(7.6)
	Range	0-27	0-42	0-34	0-42
Net Yield (lbs.)	n	23	44	39	108
	Mean	1132	1178	1004	1058
	Standard Deviation	(525)	(482)	(488)	(538)
	Range	171-2559	262-2159	84-1990	84-2559
Square Feet per Tree	n	27	59	51	139
	Mean	542	562	530	546
	Standard Deviation	(138)	(99)	(83)	(103)
	Range	222-900	308-784	336-625	222-900

*Sacramento Valley - Tehama, Glenn, Butte, Colusa, Sutter and Yolo Counties

Northern San Joaquin Valley - San Joaquin and Stanislaus Counties

Southern San Joaquin Valley - Fresno, Merced, Kern, Tulare, Madera, Kings Counties

Table 2. Answers to Categorical Questions (Growers n = 135, Orchard n = 163)

Question	Answer	Number	%
Colony strength (qualitative)	Poor	1	0.7
	Fair	29	21.6
	Good	76	56.7
	Excellent	28	20.9
Number of sides with competing bloom	0	7	5.9
	1	41	34.5
	2	34	28.6
	3	23	19.3
	4	14	11.8
Blooming ground cover during almond pollination season	None	34	23.3
	Little	90	61.6
	Moderate	19	13.0
	Much	3	2.1
Distance between groups of hives	D < 1/4 mile	120	82.8
	1/4 < D < 1/2 mile	19	13.1
	D > 1/2 mile	6	4.1
Diseased/Abnormal/Missing Trees	D.A.M. < 1%	68	46.3
	1% < D.A.M. < 10%	66	44.9
	D.A.M. > 10%	13	8.8
Shothole/brown rot/fruit diseases	< 1%	54	37.2
	1% < < 10%	62	42.8
	> 10%	29	20.0
Number of fungicide applications	0	18	12.3
	1	26	17.8
	2	44	30.1
	3	42	28.8
	4	12	8.2
	5	4	2.7
Method of fungicide application	Ground rig	75	58.1
	Copter	10	7.8
	Plane	11	8.6
	Combination	33	25.6
Orchard owned?	Yes	137	93.2
	No	10	6.8
Years of management experience	< 5 yrs.	13	9.8
	5-10 yrs.	36	27.3
	> 10 yrs.	83	62.9

Table 3. Responses concerning conditions that may have affected pollination and yield, and important pollination problems.

Conditions	Listed as affecting pollination and yield		Listed as pollination problem	
	%	n	%	n
Bad Weather (rain, hail, cold, wind, frost, etc. during bloom)	64.1	66	65.0	78
Cultivar Planting Problems (insufficient or pollinizer cultivars)	3.9	4	15.0	18
Split Bloom (lack of bloom overlap)	1.9	2	4.2	5
Too Few Bees Rented (insufficient bees to effect pollination)	1.9	2	4.2	5
Poor Beekeeper Management (weak or diseased colonies; bees brought in too late; unreliable beekeeper)	2.9	3	11.7	14
Tree Diseases (mostly shothole)	8.7	9	3.3	4
Bloom from Competing Orchard (neighboring orchards either without or with insufficient bees)	3.9	4	5.0	6
Bloom from Ground Cover (ground cover blooming during almond bloom)	3.9	4	2.5	3
No Problems (grower indicated no major difficulties)	12.6	13	3.3	4
Other (vandalism of bees, insect and other pest damage, poor nursery stock, cost of bees, soil type, irrigation problems, pruning, etc.)	15.5	16	8.3	10
		123*		147*

* There were 103 and 120 respondants, respectively, but some listed more than one condition resulting in these higher totals.

HIVE DISTRIBUTION

Current recommendations state that hives should be no more than 1/4 mile apart in orchards over 40 acres. This experiment was performed to determine whether production can be increased by spacing the hives closer together than 1/4 mile.

Experimental Procedure: In an 80-acre plot within a young uniform 930 acre orchard with a good planting pattern, bee drops were spaced at 1/4 mile intervals instead of 1/8 mile intervals in the remainder of the orchard. The total hives per acre was kept the same by doubling the number of hives per drop. Fruit set was counted in 3-4 areas on each of the 4 cultivars in the test plot and two adjacent control plots. Yield data were also taken for the 3 plots.

Results: There were no significant differences in fruit set between the 3 plots with Nonpareil, Peerless, and Price cultivars. However, there was significantly higher fruit set in the test plot for Mission cultivar ($P = .005$).

Discussion: Possibly the reason so little difference was observed between the plots may be due to the ideal flight conditions in 1984. In a year with more adverse weather conditions, hive distribution might be more of a critical factor.

COLONY MANAGEMENT

Our previous studies have shown that various management practices may effect flight activities and pollination efficiency of honey bee hives rented for almond pollination, especially during adverse weather conditions. A large factorial experiment was conducted to test simultaneously the effects of various management practices in relation to colony strength and flight activities in 1984.

Experimental Procedure: Eighty-five colonies were selected from a total of 190 colonies in overwintering yards by cluster size and frames of bees estimates as described in previous reports. The selected colonies were moved into the test orchard on 7 February. Twenty bottom type pollen traps with a double 5-mesh screen (OAC) and 5 front type traps with a vertical perforated plate were placed on hives containing eight frames of bees (FOB) on 11 February and the trap screens were activated on 16 February. A super (extra hive box) with empty comb was placed on 5 of 10 hives with 12 FOB on 10 February. "Solar" covers were placed on 20 hives with 8 FOB and 5 of 11 hives with 6 FOB on 17 February. These covers consisted of black plastic sheeting fitted directly over the hives and covered with clear plastic sheets. An air space was formed by placing two black bricks between the tops of the two layers of plastic. Twine was wrapped around the lower portion of the clear plastic to hold it in place. Thermocouples were placed in 6 positions in each of 5 hives with solar covers and another 5 without. Colonies were fed with approximately one gallon of sugar syrup on 17 and 23 February except for the following:

a. 5 with solar covers and OAC traps;
b. 5 without covers, but with OAC traps;
c. 5 with covers, but without traps;

d. 5 without covers or traps;
e. 6 of 12 colonies with 4 FOB

Foragers returning with and without pollen were counted as they landed on hardware cloth screens placed over the entrance of a hive for 30 seconds at all hives on 17 days between 21 February and 10 March. Temperatures were recorded for hives with thermocouples as frequently as possible on days when flight was observed. Pollen was removed from trapped hives on 17, 23, 28 February and 3, 13 March. Trap screens were removed from hives for about one day each week.

Effects of treatments on flight activites

Results: Tables 4 & 5 summarize flight data for hives with 8 FOB. Pollen traps produced a 53% increase in overall flight (121% more pollen collectors and 28% more foragers without pollen). Feeding and solar covers caused 11% and 18% decreases in flight respectively over all treatment groups.

Discussion: Pollen traps nearly always increased pollen flight and usually flight of foragers without pollen. This confirms our results in 1982. Feeding and solar covers may not have shown a positive effect because of the warmer than normal weather during almond bloom in 1984. Feeding showed a positive effect on flight in 1983 when weather conditions were worse than normal.

Feeding may give colonies the extra energy they need to maintain strength and foraging during adverse weather conditions. Feeding may also be predicated by the strength of the colony. Weaker colonies may respond better to feeding than stronger colonies do. If colonies have come into almonds weak due to lack of pollen in the autumn or pesticide damage the previous year, they may benefit from feeding. Our strong test colonies did not show benefits from feeding during the good flight weather of 1984 and some robbing was noted after the second syrup feeding. More research is needed to determine under which conditions feeding may be most beneficial. Solar covers might have some beneficial effects on colonies under cold, damp conditions, but did not show any benefits during the fine weather of 1984. Feeding and covering may both produce heat, beneficial during adverse weather conditions, but causing the bees to expend energy to compensate for unnecessary extra heat during periods of warm weather.

Effects of pollen trap type on amount of pollen trapped

Results: For each of four observation periods ending 23, 28 February and 3, 13 March the larger and more efficient OAC pollen traps accumulated more pollen than the front type traps ($p < 0.10$ for 23 February; $p < 0.02$ for all other dates) (Table 6). The mean weight of pollen from the front type traps was only 26.1% of that from the OAC traps. This agrees with our flight data which show pollen foraging was highest in 13 of 14 observation periods from hives with OAC traps ($P < 0.05$). The effect was most pronounced for later observation periods ($p < 0.01$ for the last 9 periods). Numbers of bees returning without pollen was increased at hives with OAC traps only for some of the latter periods (4 of 5 periods, $p < 0.05$).

The effects of feeding and solar covers on amount of pollen trapped (OAC traps only) are ambiguous. The combinations producing the greatest accumulated pollen for all 4 time periods were feeding without covers and not fed with covers respectively. Least effective was the combination of feeding and covers (lowest in 3 of 4 periods).

Discussion: The fact that the more efficient OAC traps had both more pollen foragers and pollen collected than the front trap hives supports the hypothesis that pollen traps increase the amount of pollen foraging by reducing the amount of pollen income.

Effects of extra space for strongest colonies

Results: Addition of an extra super with empty combs for stronger colonies (12 FOB) had virtually no effect on flight activities as measured by numbers of returning bees with or without pollen loads. In only 1 of 14 observation periods was the number of pollen foragers greater ($p < 0.05$) in colonies with extra space.

Discussion: Our previous research has shown less than expected flight activity for colonies in the highest strength categories (< 10 FOB). We hypothesized this might be due to a lack of space for colony growth which might in turn reduce queen egg laying, brood size, and foraging activities, especially pollen foraging. Our 1984 data do not support this hypothesis. The good flight weather of 1984 should have accentuated this problem. More research is needed to determine what limits flight and pollen collecting activites in larger colonies.

Effects of treatments on Colonies with 6 FOB

Results: Solar covers were not detrimental to flight in colonies with 6 FOB. Covered hives averaged 2.4 bees returning with pollen per 30 seconds versus 2.2 for those without covers. Corresponding flight for bees without pollen was 6.7 and 6.0 respectively. None of these differences were statistically significant.

Discussion: Solar covers did not reduce flight activity in colonies with 6 FOB as they did in colonies with 8 FOB. The extra heat provided by the solar covers may have been counter balanced by the smaller less efficient heating populations in colonies with 6 FOB so that they did not have to expend extra energy to compensate for higher hive temperatures. We still need to analyze our data further to determine whether solar covers had any effect on increasing flights at cooler temperatures at the beginning and/or end of each daily flight period. Further testing with these covers relative to different colony strengths, especially on weaker colonies, seems justified.

Effects of Frames of Bees on Flight Activities

Results: Numbers of bees returning with and without pollen during 30 second periods were compared for colonies with 4, 6, 8, and 12 FOB which were fed twice during the pollination season (Table 7). Colonies with 8 and 12 FOB consistently had more returning bees with and without pollen than did colonies with 4 and 6 FOB for all 14 observation periods. However, colonies with 12 FOB had more flight activity than those with 8 FOB in only 8 periods for bees with pollen and 9 periods for bees without pollen. Colonies with 6 FOB had more flight activity than those with 4 FOB in only 4 periods for bees with pollen and 2 periods for bees without pollen.

Discussion: Although stronger colonies generally had greater flight activity than weaker colonies, this was not always consistently so. Colonies with 6 FOB were added after the main experiment was designed and thus were concentrated at one site in the test orchard while most of the other treatments were randomized among six other sites. Therefore, position effects may account for some of the anomalous data from the 6 FOB colonies. Similar anomolies were noted in 1983 suggesting that relationships between colony strength measures and flight activities are not linear over the entire spectrum. An attempt to illucidate these relationships using data accumulated over the past 20 years is presented in another section of this report (see "multiyear analysis").

Temperatures in Hives with and without Solar Covers

Results: Central hive temperatures were often unaffected by covers (only 1 out of 18 periods for the upper hive body and 7 out of 18 for the lower). The one period that was significant ($P < .05$) in the upper central position was cooler in the covered hives. The lower central position was affected by covers mostly during the latter 2/3 of the observed periods (February 28 - March 10). Peripheral temperatures were often increased on the southeast side near the hive entrance (entrance facing south) i.e. 7 of 18 observations periods for the upper position and 17 of 18 times for the lower hive box, peripheral temperatures on the northwest corner were increased by covers 6 of 18 periods for the upper body and 1 of 18 for the lower. No correlation was observed between covers and outside temperatures.

Discussion: Plastic covers do affect hive temperatures significantly, especially in those areas away from the brood nest and apparently on the side near the entrance or more likely the south side which gets the most exposure to the sun. Apparently, the ability of the colony to regulate brood temperature overrides the effects of covers near the brood nest. The fact that upper central position was affected by covers more during the latter periods may be due to the colony's tendency to expand brood upward within the hive.

Humidity Measurements

We were concerned that solar covers might cause humidity inside the hives to increase creating disease problems. We noticed no moisture condensed on the insides of the hive lids when we opened the hives. Also, we noted no increase in disease.

Experimental Procedure: A small number of humidity readings were taken from hives with and without solar covers by inserting a probe inside the hive through a hole drilled in the hive cover.

Results and Discussion: No significant differences were found in humidity readings between covered and uncovered hives. Possibly in a damper year the covers might cause a problem.

Wear on Bees at Hives with Pollen Traps

We noticed that a large percentage of bees at pollen trap hives had more than what we considered to be a normal amount of wear on their bodies (i.e. missing hairs, especially on the top of the thorax and abdomen).

Experimental Procedure: Observations were made of about 50 bees entering hives with OAC and front type pollen traps and hives without traps. The numbers with shining ("bald") thoraces were noted.

Results: The ratios of bald to non-bald bees at OAC and front traps are .83 (± 0.55) and .08 (± .05), respectively (P = .000, N = 40; 10). The ratios of bald to non-bald bees from trapped (both OAC and front types) and non-trapped hives taken on another day are .89 (± .90) and .04 (± .03), respectively (P = .000, N = 24 each treatment).

Discussion: The double layer of hardware cloth used in OAC traps apparently causes a significant amount of wear on bees whereas the perforated metal causes much less wear. The extra wear caused by the OAC traps probably decreases the value of the worn bees as pollinators since the hairs tend to collect pollen grains for transfer to other flowers. These worn bees may only be a problem in the late bloom period of years with an abundance of good flight weather as in 1984. Other types of trap screen could probably be substituted in the OAC traps to alleviate the problem.

OSMIA

In line with our efforts to provide a better microclimate for honey bees using solar covers, we decided to test different types of domiciles with varying amounts of exposure to solar energy for *Osmia lignaria* nests.

Experimental Procedure: Equal numbers of cells (about 500 each) were placed in four different domiciles with varying amounts of exposure to sunlight. Counts were made of the numbers of cells provisioned at the end of the foraging season for each of the domiciles.

Results: The numbers of cells provisioned in each domicile is as follows:

1) domicile painted black - 190 cells
2) unpainted domicile - 108 cells
3) domicile painted black with transparent plastic top - 70 cells
4) domicile painted black with transparent plastic top and sides - 59 cells

Discussion: The *Osmia* females seem to prefer nesting in the darker (warmer?) domiciles. Renesting in all of the domiciles was low partially due to poor emergence (55%), and possibly also due to dispersal of bees away from the domiciles.

Table 4. Numbers of periods in which pollen traps, fed, and solar covers treatments and their interactions increased or decreased flight of bees returning during 30 second periods with or without pollen.

	Single Effects			Interactive Effects			
				Two-Way			Three-Way
	Trap	Fed	Cover	Trap + Fed	Trap + Cover	Fed + Cover	Trap + Fed + Cover
With Pollen							
Increase	14	0	7	1	5	0	0
Decrease	0	0	-2	0	0	-7	-1
Without Pollen							
Increase	9	5	4	0	3	0	0
Decrease	0	-2	-6	0	0	-8	0
Cumulative	23	3	3	1	8	-15	-1

Table 5. Mean numbers of bees and ratio of pollen foragers returning to hives with pollen traps, fed, solar covers treatments, their interactions or no treatment.

	Single Effects			Interactive Effects				
				Two-Way			Three-Way	Controls
	Trap	Fed	Cover	Trap + Fed	Trap + Cover	Fed + Cover	Trap + Fed + Cover	No Treatments
bees/30 sec.	21.6	14.3	13.6	22.0	19.9	10.4	13.3	12.2
bees with/ without pollen	0.54	0.34	0.37	0.68	0.58	0.39	0.69	0.33

Table 6. Effects of pollen trap type, sugar syrup feeding and solar cover on weight(g) of pollen collected.

Trap Type:	Front		Bottom (OAC)							
Treatment:	Fed		Fed		Cover		None		Fed + Cover	
1984	$\bar{x}$	(SD)	$\bar{x}$	(SD)	$\bar{x}$	(SD)	$\bar{x}$	(SD)	$\bar{x}$	(SD)
Feb. 23	158	(100)	455	(297)	433	(244)	367	(268)	115	(27)
Feb. 28	157	(94)	596	(242)	562	(192)	454	(201)	286	(203)
Mar. 3	247	(116)	1182	(306)	1015	(439)	776	(283)	712	(297)
Mar. 13	166	(78)	718	(226)	568	(260)	448	(99)	531	(304)
ALL DATES	182	(98)	738	(374)	645	(355)	511	(258)	411	(319)

*t tests: letters represent significant differences between pairs of comparisons between trap types and treatments for OAC traps for each date and all dates.

$P < .05$ A,B,C, F thru J - O and Q
$P < .01$ D
$P < .005$ N and P
$P < .001$ K,L, and M

Table 7. Mean numbers of bees returning during 30 second periods to colonies of different strengths based on frames of bees (FOB), and ratios of pollen foragers.

FOB	Bees with Pollen $\bar{x}$	(SD)	Bees without Pollen $\bar{x}$	(SD)	All Bees $\bar{x}$	(SD)	Bees with/ without Pollen
4	2.6	(1.0)	7.0	(2.1)	9.5	(3.2)	0.37
6	2.2	(1.4)	6.0	(2.1)	8.2	(3.5)	0.37
8	3.6	(1.7)	10.7	(3.7)	14.3	(16.0)	0.34
12	4.1	(1.8)	13.7	(3.9)	17.8	(5.7)	0.30

t tests:

1/ $P < 0.01$ when compared to a/ 4 FOB, b/ 12 FOB

2/ $P < 0.005$ when compared to a/ 4 FOB b/ 6 FOB c/ 8 FOB d/ 12 FOB

FLORAL BIOLOGY

In our attempts to gain a fuller understanding of the proceses involved in effective pollination of almonds, it has become apparent that we need to know more about the basics of its floral biology. Theoretically, only one pollen grain should be needed to fertilize the single ovule of each flower providing it is viable and from a cross compatible cultivar. However, data obtained in 1983 indicated that there is a direct relation between number of pollen grains and probability of fruit set in almond. Although most of the current almond cultivars are self-sterile, it should be possible to produce self-fertile cultivars. However, self-fertile does not necessarily mean that they will be self-pollinating. A number of other factors determine the ability of a flower to deposit pollen on its own stigma. Among these factors are the spatial and temporal relationships between the anthers at dehiscence and the receptive stigma. Preliminary hand pollination experiments and observations on the spatial relationships between anthers and stigmas at dehiscence for several cultivars were conducted to gain insights into these areas.

Effect of Amount of Pollen/Stigma on Fruit Set

Experimental Procedure: Pollen from NePlus Ultra was diluted with *Lycopodium* spores to 1%, 2%, 5%, 10%, and 25% pollen by weight by Dr. Steve Weinbaum (Pomology, UCD). Fine mesh screen cages were placed over one limb on each of 8 Mission trees before bloom. On 5 and 6 March all except 20 young receptive flowers were removed from each branch. The remaining 20 flowers were emasculated, tagged, hand pollinated and rebagged. All the flowers on one limb received one of the 5 dilutions with the 25% dilution applied to two limbs, or *Lycopodium* only, or no pollen. Stigmas of all test flowers were collected on 14 March by clipping the style 2-4 mm below the stigma and transferring them to spot plates covered with transparent tape. These were later transferred to microscope slides, stained with basic fuchsin and the number of grains per stigma were counted.

Results: Although the correlation between prepared dilutions used in hand pollinations and subsequent percent fruit set was not clear cut (Table 8), a better correlation was found when average numbers of pollen grains per stigma were taken into account (Table 9). Examination of pollen per stigma irrespective of treatment shows that those that set fruit had a mean of 30.7 pollen grains (range: 1-65; SD = 19.5). Best fruit set was obtained with means of 49 to 64 pollen grains.

Discussion: Many of the flowers on branch 12-9 were eaten or damaged by caterpillars from an unnoticed egg mass on the limb before it was caged, and not discovered until the stigmas were collected. Although this is only a preliminary test and there was the potential for bias since treatments were not randomized across all limbs, the results are suggestive that the amount of pollen which reaches a compatible stigma is important in determining the potential for fruit set. This makes it important to determine how much pollen can be deposited per bee visit, how much of this is likely to be compatible pollen, and how many times an individual flower may be visited while it is receptive.

Relative Positions of Stigmas and Anthers in Almonds

Experimental Procedure: The spatial relationship of the stigma to the anthers at the time the first anthers began to dehisce was observed on 27 and 28 February in 100 flowers, 10 per 10 trees of each of the following cultivars: Merced, Mission, NePlus Ultra, Nonpareil, Peerless, Price, and Thompson in an orchard near Dixon, CA. Each flower was viewed from the side so that the tallest anthers were in a single plane. Each stigma was recorded as being: above, below, or at the level of the anthers.

Results: Stigmas of Merced, Mission and Peerless were usually well above, those of Thompson were slightly above, those of NePlus Ultra were usually below, and those of Nonpareil and Price were about at the level of or slightly below the anthers at initial dehiscence (Table 10).

Discussion: Stigmas which are usually well above the anthers at the time of dehiscence should normally receive very little automatically self deposited pollen. This should be taken into account if self-fertility genes are ever transferred into commercial almond cultivars. These observations further stress the need to know how much pollen is deposited during bee visitations. They also raise the question as to the potential synergistic or inhibitory interactions of self versus cross compatible pollen on a stigma. These may be expected to be greatest in flowers with the stigma most frequently at or below the level of the anthers.

Table 8. Relationship between percent fruit set and dilutions of NePlus pollen by *Lycopodium* spores (weight by weight) for hand pollinated Mission flowers.

% Pollen:	25*	25	10	5	2	1	0	Untreated
% Fruit Set:	5*	45	5	10	5	15	20	10

* Caterpillars ate or damaged many flowers.

Table 9. Relationship between mean numbers of pollen grains per stigma and fruit set in Mission flowers hand pollinated with NePlus pollen diluted with *Lycopodium* spores.

$\bar{x}$ No. Pollen Grains:	96*	64	49	42	34	29	13	2
% Fruit Set:	5*	20	45	10	15	10	5	15

Table 10. Position of stigmas in relation to anthers at early dehisence for 7 almond cultivars.

	Above	Same Level	Below
Merced	91	9	0
Mission	90	10	0
Peerless 1/	95	5	0
Thompson 2/	62	33	5
Nonpareil	5	42	53
Price	11	65	24
NePlus 3/	0	3	97

1/ Stigmas usually 1 to 4 anther lengths above.

2/ stigmas above only slightly so in most cases.

3/ Stigmas level with or slightly above when all anthers have dehisced.

SUPPLEMENTAL POLLINATION VIA POLLEN TRAPS

As bees enter their hives through pollen traps, pollen is not only scraped from their hind legs, but some grains are inevitably deposited on the trap screen and therefore available to be picked up and redistributed by outgoing foragers. We designed an experiment to test whether this might aid pollination efficiency of these units.

Experimental Procedure: Cages were placed on two limbs each of four trees of NePlus Ultra and Nonpareil, and of 8 trees of Mission in an orchard near Dixon, California on 6 February. Flower buds were counted on NePlus and Nonpareil on 7 February and on Mission on 29 February. Four hives, 3 with pollen traps and one without were set up on 14 February. Pollen traps included the bottom (OAC) and front types used in other experiments and a top type for comparison. Outgoing flight was partitioned by placing a screen cone over each hive entrance. Ten to 20 bees exiting from the apex of the cone were collected in small screen cylinders, placed in a small dark ice chest and transferred into one of the cages as determined by a random number table. Bees were transferred on 21 February (NePlus), 29 February (Nonpareil) and 7 March (Mission). Fruit set counts were made on 25 April.

Results: There was considerable variation in fruit set (Table 11). Most fruit sets for limbs pollinated by bees from hives with pollen traps were higher than those by control bees. However, none of the t-test p-values comparing each pair of treatments were significant.

Discussion: It is apparent from this preliminary test that a larger number of replicates will be needed to determine whether contamination of outgoing bees by residual pollen from pollen trap screens ca increase fruit set. Highest fruit sets were obtained with bees from the hive with the bottom (OAC) trap. However, it was noted that many of the first bees exiting from the screen cone had pollen loads. For this reason many bees were allowed to exit after the last one with pollen on the hind legs was noted before the sample for transfer was taken. Even with this precaution some returning bees may have been included in some samples, especially with the OAC trap which has the largest chamber where returning bees may pause before entering the hive through the trap screen. Some of these bees may then be disturbed by the activities of bees in the cone. They may then become mixed in with the outgoing bees in their attempts to escape.

Table 11. Percent fruit set on caged limbs of three cultivars to which outgoing bees from hives with or without pollen traps were added.

	Trap type				
	Bottom (OAC)	Front	Top	None	$\bar{x}$/Cultivar
NePlus	5.2	7.7	4.8	2.2	
	4.9	3.0	4.8	--1/	4.7
Nonpareil	14.5	6.2	9.8	5.8	
	29.5	6.6	6.6	7.0	10.7
Mission 1	22.7	17.1	10.9	10.5	
	20.7	17.8	14.5	17.5	16.4
Mission 2	5.5	7.9	3.1	12.6	
	3.9	5.4	15.4	1.5	6.9
$\bar{x}$ % set	13.4	9.0	8.7	8.2	

1/ No data, bag accidentally removed while flowers in bloom.

Evaluations of Colony Strength

For the fourth year in a row, we compared the quicker cluster evaluation (CE) with intensive counts of frames of bees (FOB) to see whether the CE is reliable enough to estimate colony strength and potential for pollination. These counts were made in conjunction with selecting 85 colonies used in the multifactorial experiment mentioned elsewhere in this report.

Experimental Procedure: The procedures for evaluating colony strength are in the 1981-83 reports. In review with the CE, the hive lid is removed and the number of tops of frames covered with bees is estimated. The front of the top box is lifted, and the numbers of the bottoms of the frames covered with bees is estimated. If there is a difference, an average is recorded. Sometimes the total cluster can be observed by tilting the box up and observing the silhouette against the sky. If the bottom box is nailed to the bottom board, only observations of the tops of the frames can be made. In intensive FOB counts, each frame is removed from the hive, and the number of frames covered with bees is counted. Counts were also made of the number of frames of honey, and square inches of capped and uncapped brood and pollen. Initial strength evaluations were made 26 January to 3 February and final assessments were made 12-16 March.

Cluster Evaluations

Results: Table 12 shows the results of cluster evaluations in 1984 and the combined evaluations for 1981-84. Regression of analyses of CE vs. FOB revealed r^2 values of 48.3 and 46.5 for the two observers for the beginning counts and 80.3 and 54.7 for ending counts. Over all, observers and beginning an ending counts $r^2 = 61.5$.

Discussion: Cluster estimates appear to be an effective means of evaluating colonies if some variance is allowed by the grower. In colonies with less than 8 FOB, the CE gave counts corresponding to the FOB count. Above 8 FOB, nonlinearity is apparent. Some variation can be eliminated by more closely restricting environmental conditions (counts should be made before the cluster breaks up i.e., about 50°F). Also, observers need to be oriented properly with the technique. Hopefully, with use and feedback from the industry this technique can be perfected.

Changes in Colony Strength

Results: Table 13 lists the results of changes in hive strength between beginning and ending counts analyzed by ranking of % increase and by t-tests. All treatments increased under the parameters measured except FOB in 12 frame hives without extra space, and honey in unfed 8 frame colonies with no covers or traps.

Discussion: Four frame colonies overall had the highest percent increase in FOB and Brood (B). Covers, feeding, traps, and extra space did not have any significant effect on growth. The only significant differences observed in t-tests performed were between the colony strength groups. The 12 frame colonies had significantly less increase in strength than the 3 lower size categories. The six frame category had significantly less increase than the four frame category (possibly due to ants). One of two identical treatments with 8 FOB and feeding, increased more than the other treatments with 8 FOB, but not significantly so (an extra treatment group had been set up that was not used). The fact that two identical treatments had such varying increase may indicate a high degree of difference in potential growth in colonies possibly due to the quality of the queen, pesticides in food stores, diseases, and/or predators such as ants.

The fact that trapping did not decrease build up as noted in previous years may be due to our removal of the trap screens one day each week and the excellent weather conditions for foraging in 1984.

Table 12. Relationship between number of frames of bees determined by counting the cluster versus counting each frame separately.

Cluster Size (FOB) Category	1984 Intensive Counts $\bar{x}$	SD	n	1981-1984 Mean Count $\bar{x}$	n
0-2	3.0	(0)	1	1.8	96
3-4	4.7	(1.5)	7	3.4	148
5-6	6.2	(1.3)	23	5.3	138
7-8	7.0	(1.7)	35	7.1	146
9-10	8.3	(1.9)	43	7.7	119
11-12	9.9	(1.5)	43	9.6	96
13-14	11.2	(1.7)	28	11.3	53
15-16	10.9	(2.0)	5	11.4	17
17-18	12.3	(0.5)	3	12.3	3
19-20	16.9	(2.5)	2	14.5	3
			190		819

Table 13. Comparisons of changes in colony strength in hives used in the factorial experiment in 1984. Analyzed by t-test.

	Frames of Bees				
Treatment	Initial	Final	t-test	$\bar{x}$ Increase	t-test
--	4.8	8.1		3.3	
Fed	4.8	7.0	A,B[1/]	2.2	C
Fed, Cover	5.7	7.5		1.9	
Fed	5.9	7.3	F,H	1.5	D
Fed, Trap	7.8	9.4		1.6	
Fed, Trap	7.2	9.9		2.7	
Trap	7.5	9.8		2.3	
Cover, Trap	7.4	11.6		4.2	
Fed, Cover, Trap	7.6	9.6		2.0	
Cover	7.5	9.6		2.0	
Fed, Cover	7.5	9.1		1.6	
--	7.5	9.0		1.4	
Fed	7.5	11.2	B,H	3.7	E
Fed	7.6	9.8		2.2	
Fed	12.3	10.9	A,F	1.4	C,D,E
Fed, Space	12.3	13.1		0.8	

1/ A - E = $P < 0.05$; F = $P < 0.01$, G & H = $P < 0.005$ only for comparisons between the same pair of letters.

RELATIONS BETWEEN COLONY STRENGTH AND FLIGHT: MULTIYEAR ANALYSIS

Over the past twenty years we have made numerous comparisons between various measures of colony strength and correlated flight activities of bees in colonies used for almond pollination. We have begun to reanalyze these multiyear data in light of our findings in more recent years to see what broader patterns may exist.

Experimental Procedure: Our initial data sets compared square inches of brood with outgoing flight measured by placing a large screen cone over the entrance of a hive for 30 seconds and counting all exiting bees during that period. Subsequent data compared FOB with outgoing and later with returning flight partitioned by whether or not the bees had pollen loads on their hind legs. Return flight was measured by covering the hive entrance with a screen and counting the numbers of bees with and without pollen alighting on the screen in 30 seconds.

Results: Preliminary comparisons of 4 verus 8 FOB colonies show stronger colonies initiate flight earlier and differences in outgoing flight are greatest at the lowest temperatures, especially late in the afternoon. Differences in flight activities were often not as great as expected based on differences in strength, especially for colonies with > 11 FOB. Regression analyses indicate that frames of bees (FOB) is more highly correlated with flight than cluster or brood estimates, and that final strength evaluations, especially FOB, are more highly correlated with flight activities than are initial evaluations.

Discussion: Our multiyear data are not fully analyzed, but some preliminary conclusions can be drawn. It is clear that the stronger the colony the better the flight activity and pollination potential, at least up to a point (i.e., about 10 to 12 FOB). However, it is not clear whether these increases are linear, directly proportional to strength, or otherwise. Part of this is due to the different techniques we have used to measure strength and flight, but most of it is due to variation between colonies. This is particularly evident from the fact that final strength estimates are most highly correlated with flight which means that colonies within each strength category grew at different rates. Thus, our best efforts to select for "uniform" strength categories for comparisons are often overcome by differences in colony growth dynamics which are not predictable by our measures. The measures themselves are only estimates which vary according to observer experience and the quality of colonies available during any given year. Thus, our seemingly rigid categories (e.g. 4 vs. 8 FOB) may differ by a frame or more when averaged over a number of colonies and over several years. This necessitates large samples to detect statistical significance.