1989 ANNUAL RESEARCH REPORT TO ALMOND BOARD OF CALIFORNIA

Project No. 89-F14 - Tree Research: Pollination

Project Leader: Dr. Robbin W. Thorp
Department of Entomology
University of California
Davis, CA 95616
(916) 752-0482, 752-2802 or 752-0475

Cooperating Personnel:
Dennis Briggs, Medhat Nasr, Ernesto Guzman, Joan Leong, Tim Tyler, Karen White, Kim Yashuda, Dr. Eric Mussen; Dr. Gloria DeGrandi-Hoffman (USDA/ARS, Tucson)

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

Interpretive Summary

Menthol treatments--Menthol is used to treat honey bees for tracheal mites in spring and fall. Our data show statistically significant reductions in pollen foragers and in colony strength in colonies treated during almond bloom, especially in colonies with four frames of bees. No significant effects were found in a late spring treatment. No detrimental effects were found in a fall treatment on colonies to be overwintered for almond pollination in 1990.

Colony strength--There were no significant differences in entrance flight activities among colony strength groups (4, 6 and 8 FOB) this season. While our colonies started with significantly different strengths, they were not different at the end of the season. Smallest colonies had the greatest increase in population, while strongest colonies lost some population.

ALMOPOL model--Data were gathered to validate each component of the ALMOPOL cross-pollination and nut set prediction model in an orchard near Davis, CA containing five cultivars: NePlus, Nonpareil, Peerless, Price, and Mission.

Nectar & pollen production--The amount of nectar per blossom was significantly greater for Mission than for NePlus, Nonpareil, and Peerless. We could not obtain sufficient nectar to include Price. The amount of nectar per meter of branch was significantly highest in NePlus, but not significantly different among the other cultivars. Pollen per meter of branch was significantly most in NePlus. Nonpareil and Peerless were intermediate while Price and Mission had the least pollen per meter of branch.

Bees per blossom--There was no significant difference among the five cultivars in numbers of honey bees foraging per blossom. NePlus attracted most bees per tree, followed by Mission. Nonpareil and Peerless attracted fewer bees per tree, but significantly more than Price, the least attractive cultivar.

Hand pollinations--Peerless and Price had highest sets on their day of anthesis (81% and 70% respectively), but these decreased to 40% and 54% as blossoms aged. NePlus and Mission had intermediate sets on their day of anthesis (66.7% and 50%), but these decreased to 33.3% and 42% as blossoms aged. Nonpareil had the lowest set of newly opened blossoms (46.7%) and this dropped to 25% as blossoms aged. Price X Price pollinations confirmed that this cultivar is self-incompatible.

Nut set--The equation used to estimate final nut set from initial set predicted average final set in all five cultivars within the 95% confidence interval. ALMOPOL nut set predictions were within the 95% confidence interval of average actual nut set for all cultivars except Mission, where ALMOPOL predictions underestimated actual nut set.

Introduction

Our studies in the 1989 season were conducted in the same 30 acre orchard located near Davis, CA as our studies of the past several years. The orchard contained five cultivars: NePlus, Nonpareil, Peerless, Price, and Mission. The average strength of 60 colonies based on cluster counts (NOF) was 4.65 $\pm$ 2.47 (S.D.). A weather station provided readings on temperature, solar radiation, relative humidity, wind speed, wind direction and precipitation from 4 February through 25 March. In contrast to the ideal weather for pollination throughout the season in both 1987 and 1988, the weather conditions in 1989 during peak bloom for all cultivars except Mission were less than ideal including considerable rain and low temperatures.

Menthol Treatments

Menthol is used to treat honey bees for tracheal mites in spring and fall. Growers questioned whether menthol treatments during almond bloom might have any detrimental effect on bee foraging and thereby on almond pollination. We designed a test to answer this question. We repeated the experiment in late spring to determine when might be the best time for beekeepers to treat for acarine mites. We also conducted a fall treatment to determine effects on colonies to be overwintered for almond pollination in 1990.

Methods: Menthol crystals were applied in 50 gram bags, as recommended, in three separate trials: early spring, during almond bloom (1 March); late spring, after almond bloom (27 April); and autumn, before overwintering bees (11 September). A large number of colonies were surveyed for strength using the cluster (NOF) estimation method (Nasr, et al. 1990). From these a smaller group was examined by the intensive frames of bees (FOB) method used in our previous studies to estimate worker bee populations on each frame until we arrived at adequate numbers of colonies in three strength groups for our trials. Data were analyzed using T-tests and 2-way analysis of variance.

Numbers of colonies examined for strength, numbers used in experiments and strength categories by treatment period.

Colonies examined		Colonies	Strength Groups (FOB)	
Cluster (NOF)	Intensive(FOB)	Used		
60	60	24	Early Spring	4, 6, 8
60	34	30	Late Spring	6, 8, 10
68	56	29	Fall	5, 7, 9

Colonies tested in early spring were in a 30 acre almond orchard near Davis, CA; those tested in late spring and autumn were at Lagoon Valley, near Vacaville, CA. Half of the colonies in each category received bags of menthol placed as recommended: in early spring between the hive body and super in 4 FOB colonies and under the top cover for 6 and 8 FOB; on the bottom board of hives used in late spring and fall. Strength estimates of all test colonies were made by the intensive method: a. prior to the experiment, b. 3 weeks after treatment, and c. 6 weeks after the treatment. In the autumn test, all colonies were also evaluated for the amount of stored honey and brood nest area. Samples of bees were taken from each colony to determine levels of mite infestation before the treatment in all three trials and at the end of the fall trial. Bees with and without pollen loads were counted as they returned to their colonies during a 30 second period while the hive entrance was blocked with a screen. Counts started 3 days before treatment and continued for 2 weeks after treatment.

Results: **A. Early spring during almond bloom:** most of the colonies increased in worker bee population during almond bloom. Treated colonies had 22% fewer bees by three weeks after treatment. However, statistically significant differences ($P < 0.0138$) were found between treated and untreated colonies only after 6 weeks, when the treated colonies had 33% fewer bees (Fig. 1) (Table 1). There was a significant reduction ($P < 0.0001$) in foragers returning to treated colonies, which were reduced by 56% (Fig. 2) (Table 2). **B. Late spring:** most colonies continued to increase in worker bee population (Fig. 3), but not as much as during almond bloom. At the end of three weeks, treated colonies were 11% lower in bee population than control colonies, but the difference was not significant and by the end of the test there was only a 1% difference in bee population (Table 3). Differences in foraging activities between treated and untreated colonies were not significant (Fig. 4) (Table 4). **C. Fall:** most colonies lost some population by the end of the experiment (Fig. 5). At the end of 3 weeks there were significant differences ($P< 0.002$) between menthol treated and untreated control colonies, at which point menthol treated colonies had 25% fewer bees. However, there was no significant difference between treated and control colonies by the end of the test, when there was only a 2% difference in bee population (Table 5). Foraging activities were significantly higher ($P< 0.0001$) for the treated colonies than for the controls, but pre-treatment counts showed the same differences. Honey stores decreased in all colonies by the end of three weeks, but increased nearly to starting levels by the end of six weeks (Fig. 7). Brood area decreased considerably in all colonies throughout the fall (Fig. 8).

In all treated colonies bees avoided the areas where the bags were placed and brood nearest the bags showed effects of abandonment. Menthol bags were heavily sealed with a coating of propolis shortly after introduction (4-7 days) so that evaporation of menthol was reduced.

Discussion: Both foraging activities and population increase were significantly lower in treated colonies in the early spring treatment during almond bloom. This argues for withholding spring treatments for mites until after almond pollination season and after major brood production. Application in late spring in California, when bee colonies have completed their spring growth, caused no significant reduction in bee population growth or in foraging activities. Likewise, there were no significant reductions in bee population growth, or in honey stores or brood area due to the treatment in autumn. In the fall trials, the pre-treatment flight activities of the colonies to be treated were significantly greater than those of the control colonies, so it is unlikely that the greater post-treatment flight activities noted for treated was due to the treatment. Since bees rapidly seal off the menthol bags with propolis, a more effective way of releasing menthol vapors in the hive will be needed.

Colony Strength

This year we initially surveyed colonies to estimate strength during almond bloom using our cluster method based on numbers of frames covered with bees (NOF) (Nasr et al. 1990). Flight activities, counts of bees returning to these hives with and without pollen, were made on a small number of colonies in three strength groups determined by our intensive counts (FOB). These were added to our database on foraging activity in relation to colony strength and air temperature that may provide a simplified method allowing growers to assess colony strength without opening hives.

Methods: NOF measures were made on 60 colonies on 15 February. From these, 15 were selected on the basis of FOB counts on 15 and 16 February with 5 colonies in each of three strength groups (4, 6, 8 FOB). Numbers of pollen and non-pollen foragers were measured by placing a screen over the hive entrance for 30 seconds and counting bees with and without pollen returning to the colony during that time. At the end of the brief 3 week season, a final FOB strength count was made.

Results: There were no significant differences in entrance flight activities between colony strength groups (4, 6 and 8 FOB) this season (Fig. 9). Flight activity at temperatures less than 60^{O}F was lower and more variable than at higher temperatures, but there were still no significant differences among strength groups this year (Fig 10). While our colonies started with significantly different strengths, they were not different at the end of the season. Smallest colonies had the greatest increase in population, while the strongest colonies lost some population (Table 7).

Discussion: Flight data were based on incoming activity throughout the season and on a very small number of colonies this year. The bloom season for 1989 was very late and very short. The dynamics of the colonies were such that they rapidly equalized thus obscuring any potential strength related activity. This resulted in flight activity being most highly correlated with colony strength at the end of the season as we have found in previous years.

ALMOPOL Model

Data were gathered to validate each component of the ALMOPOL cross-pollination and nut set prediction model in an orchard near Davis, CA containing five cultivars: NePlus, Nonpareil, Peerless, Price, and Mission.

Nectar and Pollen Production

Nectar and pollen production by the 5 cultivars were measured to determine the amounts of resources available to bees and to see if this could be related to attractiveness.

Methods: Nectar and pollen were measured from blossoms of each cultivar throughout bloom. The amount of nectar per blossom was estimated by collecting the nectar in micropipettes, measuring the length of the pipette that was filled with nectar, and converting the proportion of the pipette tube's length into microliters of nectar. The amount of soluble solids was measured with a hand refractometer to estimate sugar content of the nectar. Pollen per blossom was estimated by removing all anthers from samples of blossoms of each cultivar throughout bloom. The pollen was removed from the anthers by sonication. Each sample was then weighed. An analysis of variance followed by a Duncan's Multiple Range comparison test when appropriate were conducted to determine if the average amount of nectar and weight of pollen per blossom differed among the cultivars. The number of blossoms per cluster (BL) and number of clusters per meter of branch (CL) were measured for each cultivar. The counts were made by choosing blossom clusters and limbs randomly from the four sides of trees selected on a diagonal transect across the orchard. The number of blossoms per meter of branch (BR) was estimated using the equation:

$$BL \; X \; CL = BR$$

The average amount of nectar per blossom and pollen per blossom were then multiplied by BR to estimate the amount of nectar and pollen per meter of branch.

Results: Mission contained significantly more nectar per blossom (Table 8) and had a higher percentage of sugar in the nectar (Table 9) than the other cultivars, which did not differ significantly from each other. We could not obtain measurable amounts of nectar from Price blossoms. Nectar per blossom ranged between 2.54 µl (Mission) and 0.84 µl (Nonpareil). The percentage of sugar in the nectar ranged from 4.18% (Nonpareil) to 10.7% (Mission). There were no significant differences among the five cultivars in terms of the weight of pollen per blossom (Table 8). Weights of pollen per blossom ranged between 0.00094 µg (Nonpareil) and 0.00123 µg (Mission).

NePlus had the greatest number of blossoms per cluster and blossoms per meter, while Mission and Price had the least (Table 10). NePlus had the greatest amount of nectar and pollen per meter of branch. The other cultivars did not differ significantly with respect to the amount of nectar per meter of branch, but Nonpareil and Peerless had significantly more pollen per meter of branch than did Price or Mission (Table 10).

Discussion: The early flowering time and high amount of resources (nectar and pollen) available per meter of branch correspond closely to the high attractiveness of NePlus to bees (Table 11) (Fig. 11A).

Bees per Blossom

Counts of bee activity in trees of the five cultivars were made to determine differences in attractiveness and in relation to weather parameters.

Methods: Bees were counted on 5 trees of each of the 5 cultivars twice daily (weather permitting); once in the morning and again in the afternoon. The observer counted all bees seen during a 60 second period while moving completely around each tree. Separate observations were made following individual bees to determine the time in seconds they spent visiting individual flowers for pollen or nectar on each of the 5 cultivars.

Results: There were no significant differences among the five cultivars in numbers of honey bees foraging per blossom (Table 11) (Fig. 11A) . NePlus attracted the most bees per tree, followed by Mission. Nonpareil and Peerless attracted fewer bees per tree, but significantly more than Price, the least attractive cultivar (Table 11). Pollen foraging bees spent the most time at flowers of NePlus (Table 12) and the most time foraging for nectar at flowers of Nonpareil (Table 12). The least amount of time was spent by all foragers at flowers of Price (Table 12).

Discussion: Bee activity per tree was highly related to the blossom density. NePlus had the most blossoms and was the most attractive, while Price had the least blossoms and was the least attractive. However, final percent nut sets were highest in Mission and Price and lowest in NePlus. Perhaps this reflected weather patterns with rains and low temperatures resulting in poor bee activity during mid bloom and improvements toward the end of the season (Figs. 11 & 12). The differences in nut set may also have been due to availability of compatible pollen and bloom overlap among the cultivars. Also, calculating nut set by percent blossoms setting nuts always favors cultivars with the least blossoms in terms of having higher percentages of set. NePlus had the most blossoms per tree and Price and Mission the least.

Estimating the Size of the Cross-Pollinating Population of Honey Bees on Almonds

Many honey bees often are seen foraging on almond blossoms, but only those carrying pollen from different cultivars (cross pollen) are able to cross-pollinate blossoms and initiate nut set. The proportion of honey bees capable of cross-pollinating almond blossoms was determined by collecting foragers from each cultivar, and identifying the types of pollen carried on their bodies.

Methods: Honey bees foraging almond trees were collected from each cultivar and frozen. Pollen was removed from the bodies of foragers by rolling them over a scanning electron microscope (SEM) stub pre-treated with adhesive. The sample was then examined under SEM and the pollen types were identified by comparing their exine patterns to known standards. Pollen was identified as "self" if it was identical to the cultivar the bee was foraging on at the time of collection, "cross" if the pollen was from a different cultivar, and "other" if the pollen was from a species other than almond.

Results: Every honey bee we examined to this point had some "cross" pollen on its body along with "self" and "other" species pollen (Table 13). Statistics have not been run on the data at this point because we are still analyzing the samples.

Discussion: Our preliminary data indicate that the size of the honey bee population capable of cross-pollinating blossoms is large, and under some conditions may be equal to the honey bee foraging population. The means by which honey bees obtain compatible pollen may be from contact with nestmates in the hive. Data from almond orchards in Israel and California indicate that honey bees rarely move between cultivars while foraging on almond trees. However, additional data and analysis of pollen types of the bodies of foragers are needed.

Hand Pollinations

Flowers of each of the cultivars were hand pollinated at different stages of development to determine when they were most receptive and the effects that the time within the bloom period when the flowers were produced had on subsequent nut set.

Methods: One limb on each of ten trees per cultivar was enclosed in either a plastic bag with about 50-3/16" holes punched or a plastic window screen bag before bloom. Flowers of Nonpareil were hand pollinated with NePlus pollen, all other cultivars were hand pollinated with Nonpareil pollen. Some Price X Price pollinations were tried to confirm self-incompatibility in light of the high percent set obtained from this cultivar in 1988.

Results: Peerless and Price had highest sets on their day of anthesis (81% and 70% respectively), but these decreased to 40% and 54% as blossoms aged. NePlus and Mission had intermediate sets on their day of anthesis (66.7% and 50%), but these decreased to 33.3% and 42% as blossoms aged. Nonpareil had the lowest set of newly opened blossoms (46.7%) and this dropped to 25% as blossoms aged. Price *X* Price pollinations confirmed that this cultivar is self-incompatible.

Discussion: The best set for most cultivars was obtained by hand pollinations made shortly after the flowers opened. We confirmed that Price is self-incompatible. Thus, the high percent nut set noted in 1988 and again in 1989 for Price may be a function of low blossom production.

Nut Set

Nut set predictions were generated by a thinning equation which accounts for the higher nut drop in cultivars that have the highest initial nut set and by the ALMOPOL model based on weather parameters, curves of cumulative bloom production, tree size, flower production, and bee activity in trees.

Methods: Data on orchard parameters including tree height and width, trunk height, average number of blossom clusters per meter of branch, blossom viability, and number of trees of each cultivar per acre were collected at a 30 acre commercial orchard located near Davis, CA, and were entered into the ALMOPOL model. Weather data (temperature, wind velocity, solar radiation and rainfall) were collected hourly throughout bloom. These weather data were also entered into the ALMOPOL program. Initial nut set was determined by counting blossoms during bloom, and then counting the number setting nuts 6-8 weeks after petal fall to estimate the percentage of blossoms setting nuts.

Results: The equation used to estimate final nut set from initial set predicted average final set in all five cultivars within the 95% confidence interval (Table 14). ALMOPOL nut set predictions were within the 95% confidence interval of average actual nut set for all cultivars except Mission, where ALMOPOL predictions underestimated actual nut set (Table 15).

Discussion: The thinning equation worked extremely well in predicting final set from initial set. It accounts for the fact that cultivars with highest percent set have the greatest nut drop. High variation in actual nut set of Mission may have contributed to the significant underestimate of mean by ALMOPOL model. ALMOPOL continues to underestimate Price, but not as greatly as in previous years nor as greatly as Mission this year. We plan to validate the ALMOPOL model based on data gathered during the bloom season in spring of 1990.

PUBLICATIONS

DeGrandi-Hoffman, G., S. A. Roth and G. M. Loper. 1989. ALMOPOL: A cross-pollination and nut set simulation model for almond. J. Amer. Soc. Hort. Sci. 114: 170-176.

Nasr, M. E., R. W. Thorp, T. L. Tyler and D. L. Briggs. 1990. Estimating honey bee (Hymenoptera: Apidae) colony strength by a simple method; measuring cluster size. J. Econ. Entomol. 20 pp. [In press].

Table 1.
Effects of menthol treatment for mite control on colony strength.
I. during the almond bloom (early spring)

Date Examined	Strength Group [1]	# Colonies Counted	Colony Strength in FOB[2] ± Standard Error: Menthol Treated	Colony Strength in FOB[2] ± Standard Error: Untreated Control
Beginning	4	4	4.13±0.13	4.25±0.15
	6	4	6.25±0.15	6.38±0.13
	8	4	8.75±0.15	8.50±0.00
3 Weeks	4	4	4.06±0.70	7.06±1.33
	6	4	5.25±1.25	8.38±2.06
	8	4	8.06±1.73	6.69±0.63
	Combined	12	5.79 ±2.05	7.38 ±0.88
6 Weeks	4	4	8.50±2.51[3]	13.63±0.78
	6	4	7.63±3.04	10.75±2.17
	8	4	6.88±1.39	10.13±1.92
	Combined	12	7.67 ±0.81[4]	11.50 ±1.87

1. Based on colony strength at beginning of experiment.
2. # frames of bees (FOB) assessed by intensive count method.
3. For 4 FOB, there was a significant difference between menthol treated & untreated colonies as determined by T-test ($P<0.0138$).
4. For all strength groups combined, there was a significant difference between menthol treated & untreated colonies as determined by F-test ($P<0.09$)

Table 2.
Effects of menthol treatment for mite control on flight activity at hives.
I. during the almond bloom (early spring)

Forager Type	Strength Group [1]	n	Number of Returning Bees ± Std Error: Menthol Treated	Number of Returning Bees ± Std Error: Untreated Control	% Difference
With Pollen	4	92	3.14 ±0.38	5.13 ±0.43	39
	6	92	2.79 ±0.34	5.43 ±0.43	49
	8	92	3.44 ±0.39	5.84 ±0.51	41
Without Pollen	4	92	12.55 ±1.25	31.53 ±1.70	60
	6	92	12.98 ±1.32	30.94 ±1.55	58
	8	92	14.88 ±1.54	29.90 ±1.58	50
Total # Bees[2]	4	92	15.70 ±1.56	36.66 ±1.86	57
	6	92	15.77 ±1.57	36.36 ±1.64	57
	8	92	18.32 ±1.84	35.79 ±1.76	49

1. Based on colony strength at beginning of experiment: # frames of bees (FOB) assessed by intensive count method
2. For all strength groups combined, there was a significant difference between menthol treated & untreated colonies as determi by F-test ($P<0.001$), but there were no significant differences within treated strength groups nor within untreated stren groups as determined by Tukey's Mean Separation Test.

Table 3.
Effects of menthol treatment for mite control on colony strength.
II. Late Spring

Date Examined	Strength Group [1]	# Colonies Counted	Colony Strength in FOB[2] ± Std Error: Menthol Treated		Untreated Control	
Beginning	6	5	6.54	±0.17	6.06	±0.25
	8	5	7.86	±0.17	7.85	±0.25
	10	5	9.81	±0.27	9.31	±0.18
3 Weeks	6	5	8.28	±0.70	9.73	±1.67
	8	5	10.93	±0.91	11.98	±0.80
	10	5	12.05	±0.37	13.28	±0.59
	Combined	15	10.42	±1.94	11.66	±1.80
6 Weeks	6	5	8.60	±2.51	9.03	±1.40
	8	5	10.05	±1.14	9.71	±0.62
	10	5	10.58	±1.29	10.25	±0.88
	Combined	15	9.81	±2.86	9.73	±2.27

1. Based on colony strength at beginning of experiment.
2. # frames of bees (FOB) assessed by intensive count method.

Table 4.
Effects of menthol treatment for mite control on flight activity at hives.
II. Late Spring

Forager Type	Strength Group [1]	n	Number of Returning Bees ± Std Error: Menthol Treated		Untreated Control		% Difference
With Pollen	6	175	4.38	±0.20	5.63	±0.24	22
	8	175	4.82	±0.22	5.00	±0.19	4
	10	175	4.63	±0.20	6.71	±0.23	31
Without Pollen	6	175	29.10	±0.67	31.88	±0.68	9
	8	175	30.63	±1.32	29.84	±0.61	- 6
	10	175	31.08	±0.66	37.61	±0.55	17
Total # Bees	6	175	33.49	±0.80	37.50	±0.50	11
	8	175	35.45	±0.81	34.84	±0.74	- 2
	10	175	35.70	±0.81	44.32	±0.71	20

1. Based on colony strength at beginning of experiment: # frames of bees (FOB) assessed by intensive count method

Table 5.
Effects of menthol treatment for mite control on colony strength.
III. Fall

Date Examined	Strength Group [1]	# Colonies Counted	Colony Strength in FOB[2] ± Std Error: Menthol Treated			Untreated Control		
Beginning	5	5	5.50	±0.10		5.60	±0.01	
	7	5	6.800	±0.22		6.80	±0.22	
	9	5[3]	8.4	±0.16		8.50	±0.21	
3 Weeks	5	5	5.28	±0.43	a[4]	7.28	±0.43	a[4]
	7	5	5.21	±0.96	a	6.93	±0.77	a
	9	5[3]	7.13	±0.57	b	9.63	±1.01	a
	Combined[5]	29	5.78	±1.70		7.79	±1.82	
6 Weeks	5	5	5.13	±0.45		4.85	±0.52	
	7	5	4.85	±0.69		5.80	±0.52	
	9	5[3]	6.13	±0.70		6.47	±0.49	
	Combined	29	5.38	±1.40		5.57	±0.72	

1. Based on colony strength at beginning of experiment.
2. # frames of bees assessed (FOB) by intensive count method.
3. Four colonies were counted in the control group.
4. There were significant differences within treated strength groups and within untreated strength groups as determined by Tukey's Mean Separtation Test (P<0.05). Within the same column, means followed by the same letter are not significantly different.
5. For all strength groups combined, there was a significant difference between menthol treated & untreated colonies as determined by F-test (P<0.002),

Table 6.
Effects of menthol treatment for mite control on flight activity at hives.
III. Fall

Forager Type	Strength Group [1]	n	Number of Returning Bees ± Std Error: Menthol Treated			Untreated Control			% Difference
With Pollen	5	135	2.16	±0.28		1.58	±0.16		**- 29**
	7	135	0.99	±0.12		1.11	±0.15		11
	9	108	3.11	±0.25		1.38	±0.14		**- 125**
Without Pollen	5	135	8.16	±0.42		6.62	0.38		**- 23**
	7	135	5.62	±0.31		6.29	±0.39		11
	9	108	8.82	±0.47		6.31	±0.41		**- 40**
Total # Bees[2]	5	135	10.33	±0.51	a[3]	8.20	±0.40	a[3]	**- 40**
	7	135	6.60	±0.35	b	7.40	±0.43	a	11
	9	108	11.93	±0.56	a	7.69	±0.45	a	**- 40**

1. Based on colony strength at beginning of experiment: # frames of bees (FOB) assessed by intensive count method
2. For all strength groups combined, there was a significant difference between menthol treated & untreated colonies as determined by F-test (P<0.0001),
3. There were significant differences within treated strength groups but not within untreated strength groups as determined by Tukey's Mean Separtation Test (P<0.05). Within the same column, means followed by the same letter are not significantly different.

Table 7
Changes in colony strength during the 1989 almond bloom period in an orchard near Davis, CA.

Strength	Number	Colony Strength (Mean & Standard Error)					
Group [1]	Colonies	Begin [2]		End [3]		% Change	
4	5	4.2	±0.12	7.25	±1.05	70.97	±0.21
6	5	6.3	±0.12	8.25	±1.60	29.68	±0.24
8	5	8.4	±0.10	6.75	±0.49	-19.56 [4]	±0.06
Combined	15	6.3	±0.80	7.42	±1.09	27.03	±0.24

1 Numbers of frames of bees (FOB) determined by intensive count technique.
2 Significant differences at 95% probability level existed between strength groups at the beginning of the season.
3 There were no significant differences in strength between colonies at the end of the season.
4 Colonies which began the season in the 8 frames-of-bees strength group lost strength by the end of the season.

Table 8
Nectar and pollen produced per blossom by five almond cultivars in an orchard near Davis, CA.

Cultivar	Blossoms Sampled	Average Nectar per Blossom (μl)	Blossoms Sampled	Ave. Pollen per Blossom (μg)
NePlus	11	1.17 a[1]	33	0.00120 a
Nonpareil	12	0.84 a	28	0.00094 a
Peerless	10	1.23 a	42	0.00117 a
Price	0	*	15	0.00120 a
Mission	21	2.54 b	39	0.00123 a

1. Means followed by the same letter are not significantly different at the 0.05 probability level as determined by Duncan's Multiple Range Test.

* Price did not produce enough nectar to measure

Table 9
The percentages of sugars in the nectar of blossoms of four almond cultivars[1] from samples taken in an orchard near Davis, CA in 1989.

Cultivar	Blossoms Sampled	% Sugars in the Nectar
NePlus	26	6.38 ab[2]
Nonpareil	22	4.18 a
Peerless	12	4.33 a
Mission	12	10.70 b

1 Price did not produce enough nectar to measure
2. Means followed by the same letter are not significantly different at the 0.05 probability level as determined by Duncan's Multiple Range Test.

Table 10
The average number[1] of blossoms per cluster and blossoms, nectar, and pollen available per meter of branch on five almond cultivars in an orchard near Davis, CA in 1989.

	Blossoms per		Nectar	Pollen
Cultivar	Cluster	Meter	per Meter	per Meter
NePlus	6.1 a	59.6 a	426.9 a	0.44 a
Nonpareil	4.2 b	35.3 b	123.8 b	0.14 b
Peerless	4.4 b	28.8 bc	155.7 b	0.15 b
Price	3.0 bc	17.1 c	*	0.06 c
Mission	2.8 c	17.4 c	121.4 b	0.06 c

1. Means followed by the same letter are not significantly different at the 0.05 probability level as determined by Duncan's Multiple Range Test.

* Price did not produce enough nectar to measure.

Table 11
Relationship between number of bees per tree and blossoms per tree.

Cultivar	Bees per Tree[1]		Blossoms per Tree	Bees per Blossom
NePlus	10.90	c	7272.7	0.0195
Nonpareil	5.08	a	4160.4	0.0028
Peerless	4.47	a	3370.3	0.0096
Price	2.02	d	1971.4	0.0009
Mission	8.10	b	2086.3	0.0040

1. Means followed by the same letter are not significantly different at the 0.05 probability level as determined by Duncan's Multiple Range Test.

Table 12
Time spent (in seconds) per blossom by honey bees foraging for pollen or nectar on 5 almond cultivars.

	Honey Bees Foraging for	
Cultivar	Pollen	Nectar
NePlus	9.2 (sec.)	11.75 (sec.)
Nonpareil	8.0	15.0
Peerless	7.8	9.3
Price	5.6	6.5
Mission	8.4	11.75

Table 13
The percentages of different pollen types on the bodies of honey bees foraging in almond trees in an orchard near Davis, CA. in 1989.

Cultivar	Sample Size	% of pollen type on Forager's Body: Self	Cross	Other Species
NePlus	10	71.4	23.3	5.2
Nonpareil	10	43.6	47.5	8.8
Peerless	10	67.5	23.2	8.9
Price	10	64.6	26.7	8.5
Mission	10	53.2	39.2	7.5

Table 14
Predicted final nut set from thinning equations based on actual set and compared with final set in an almond orchard near Davis, CA in 1989.

	Initial Set		Final Set	
Cultivar	Actual	Predicted	Actual	Predicted
Ne Plus	10.80 ± 2.98	13.48	8.94 ± 2.74	10.8
Nonpareil	16.54 ± 5.18	10.65	16.19 ± 5.06	15.8
Peerless	15.64 ± 4.50	17.24	13.53 ± 4.26	15.3
Price	31.23 ± 6.51	23.70	30.31 ± 5.97	28.5
Mission	39.71 ± 10.43	19.22	34.85 ± 9.33	34.8

Table 15
ALMOPOL predictions of initial and final nut set compared to actual sets in an almond orchard near Davis, CA in 1989.

	Initial Set		Final Set	
Cultivar	Actual	Predicted	Actual	Predicted
Ne Plus	10.80 ± 2.98	13.48	8.94 ± 2.74	13.40
Nonpareil	16.54 ± 5.18	10.65	16.19 ± 5.06	10.65
Peerless	15.64 ± 4.50	17.24	13.53 ± 4.26	16.80
Price	31.23 ± 6.51	23.70	30.31 ± 5.97	22.40
Mission	39.71 ± 10.43	19.22	34.85 ± 9.33	18.50

Figure 1.

Changes in colony strength in menthol treated colonies.

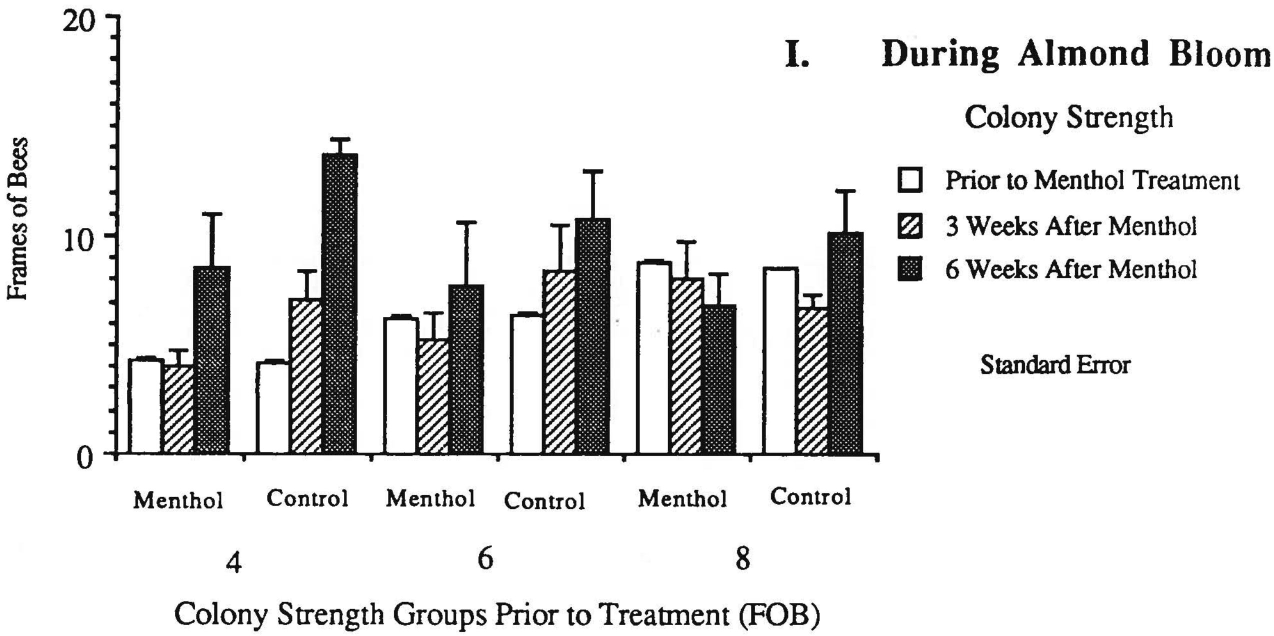


Figure 2.

Differences in total number of bees returning to hives between untreated and menthol treated colonies.

(Average number of bees from counts made beginning on date of treatment and ending 15 days after treatment)

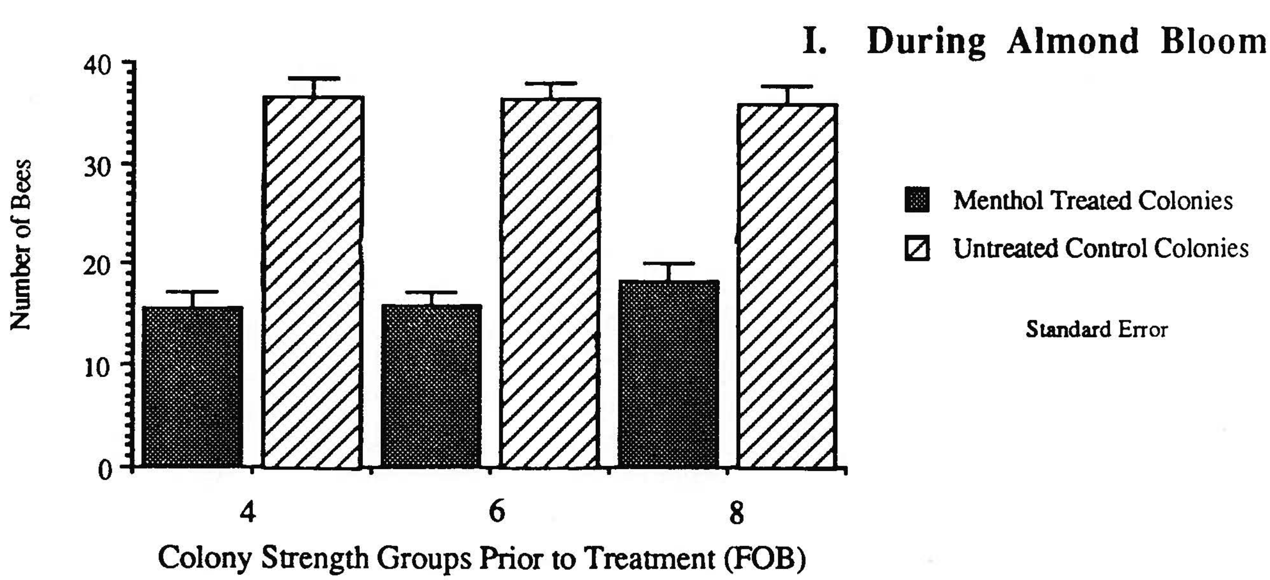


Figure 3

Changes in colony strength in menthol treated colonies.

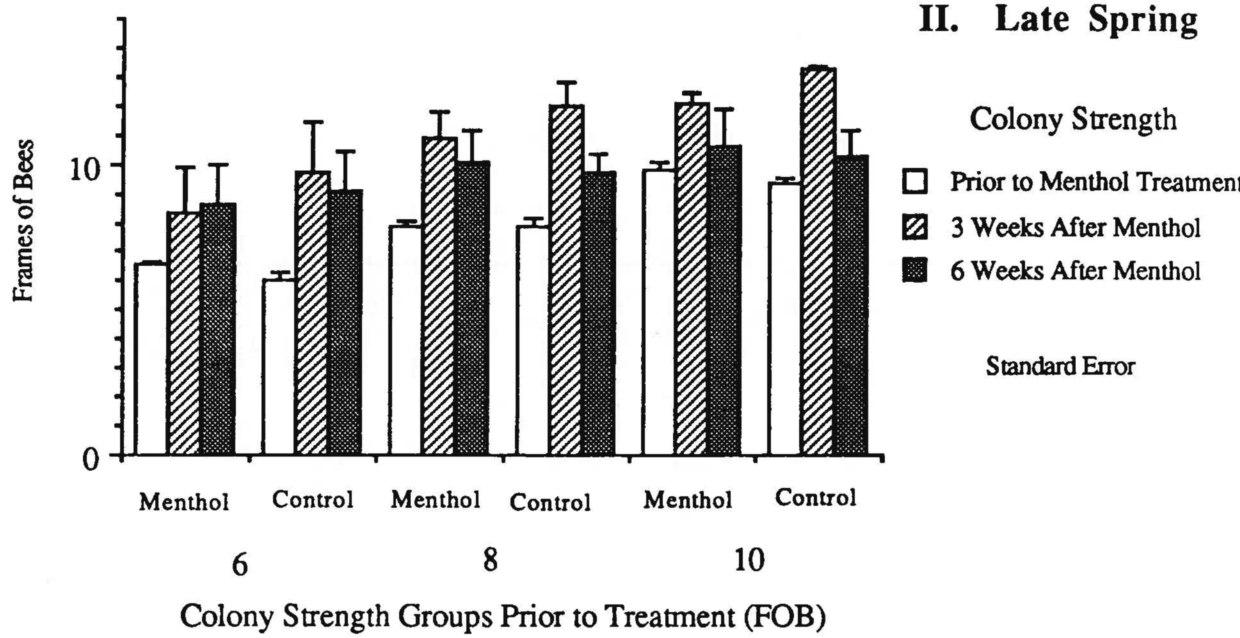


Figure 4

Differences in total number of bees returning to hives between untreated and menthol treated colonies.

(Average number of bees from counts made beginning on date of treatment and ending 15 days after treatment)

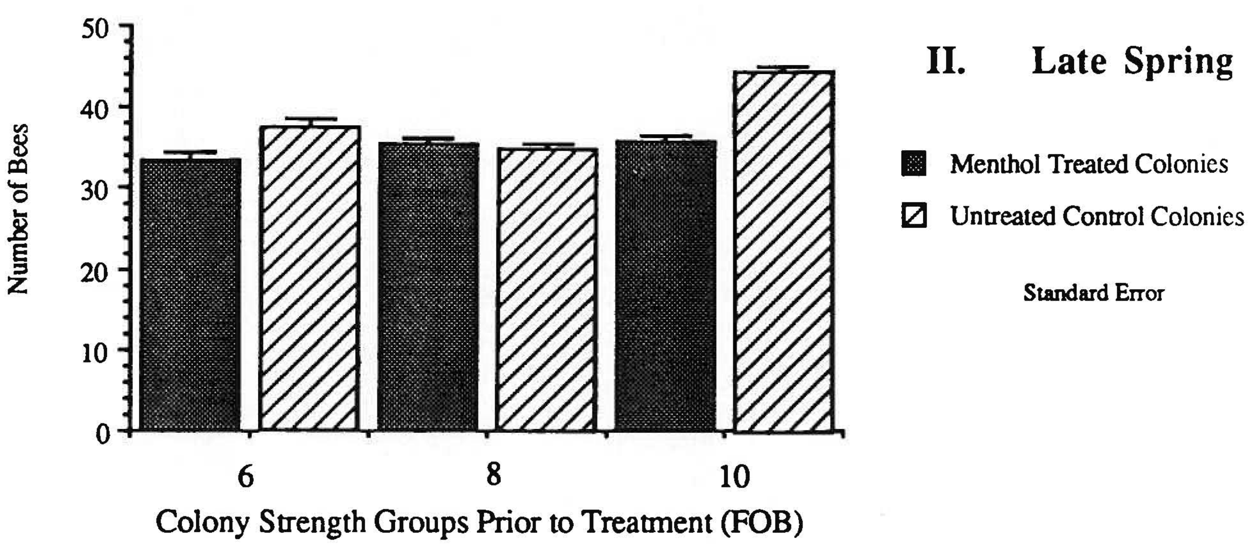


Figure 5

Changes in colony strength in menthol treated colonies.

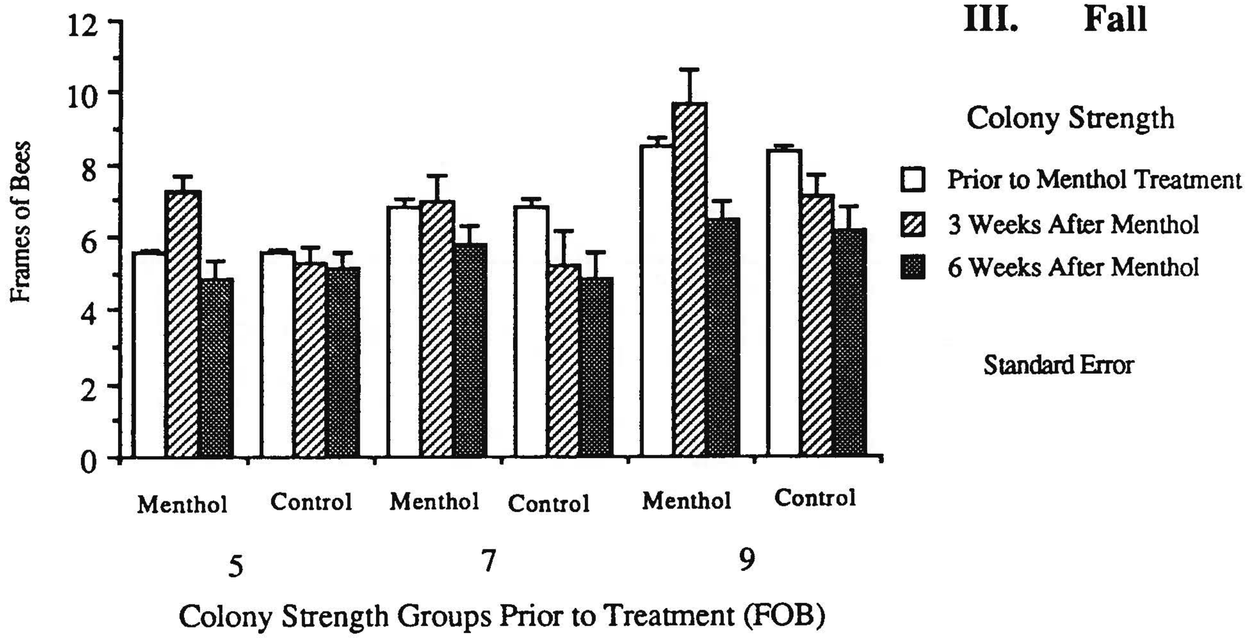


Figure 6

Differences in total number of bees returning to hives between untreated and menthol treated colonies.

(Average number of bees from counts made beginning on date of treatment and ending 15 days after treatment.)

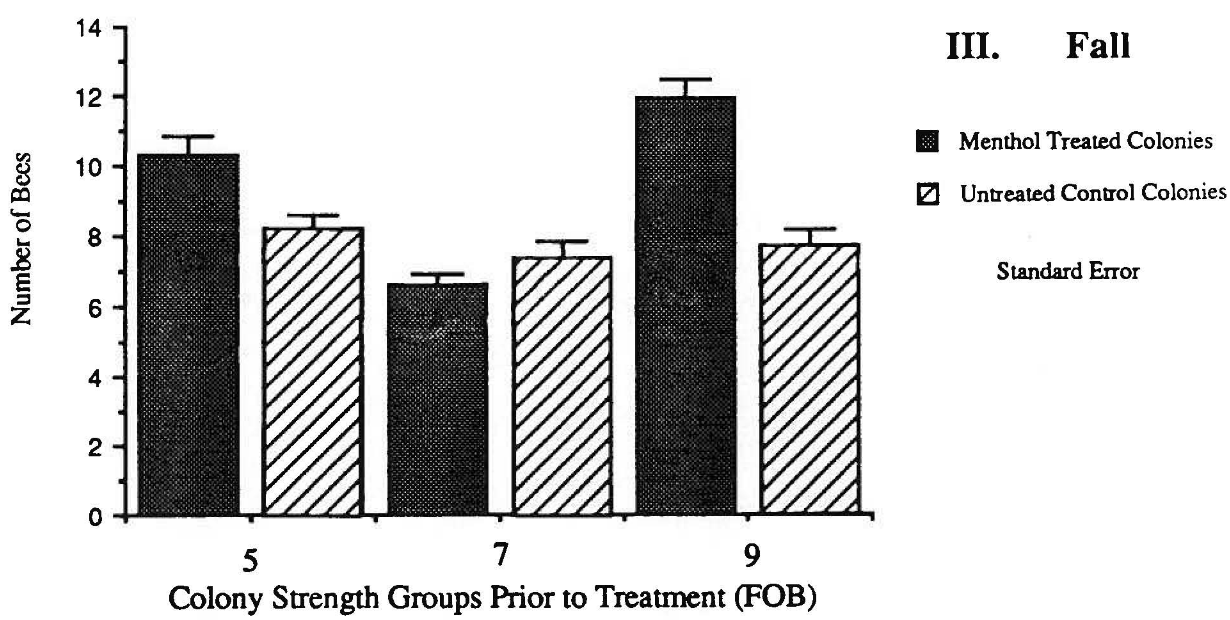


Figure 7

Changes in stored honey in untreated and menthol treated colonies.

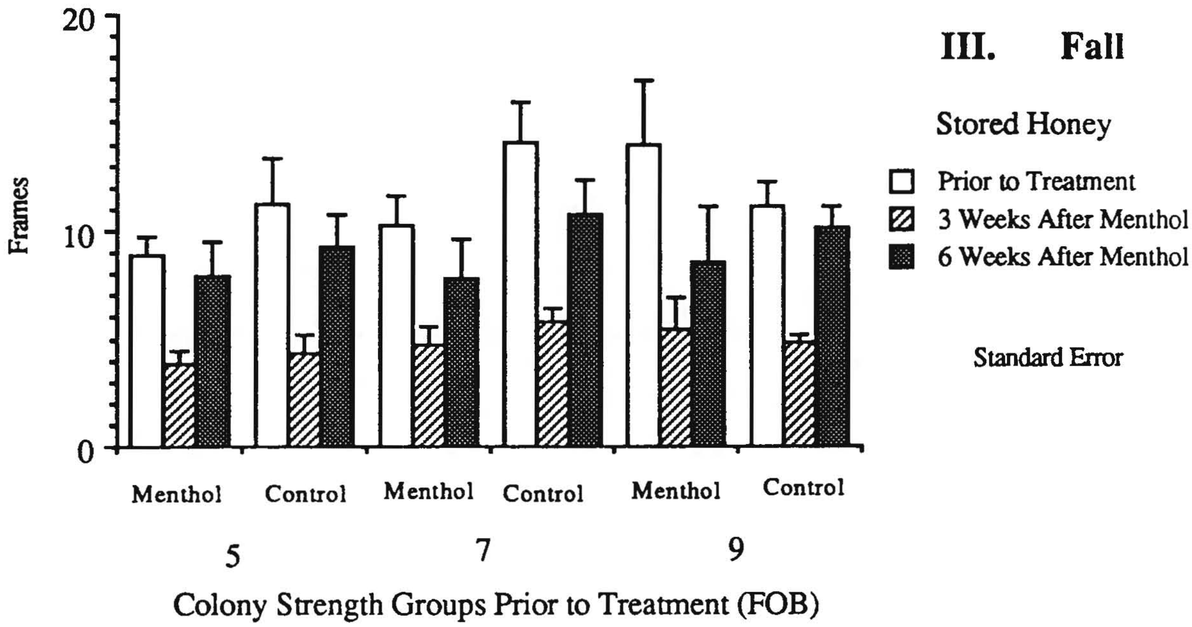


Figure 8

Changes in brood nest area in menthol treated and untreated colonies.

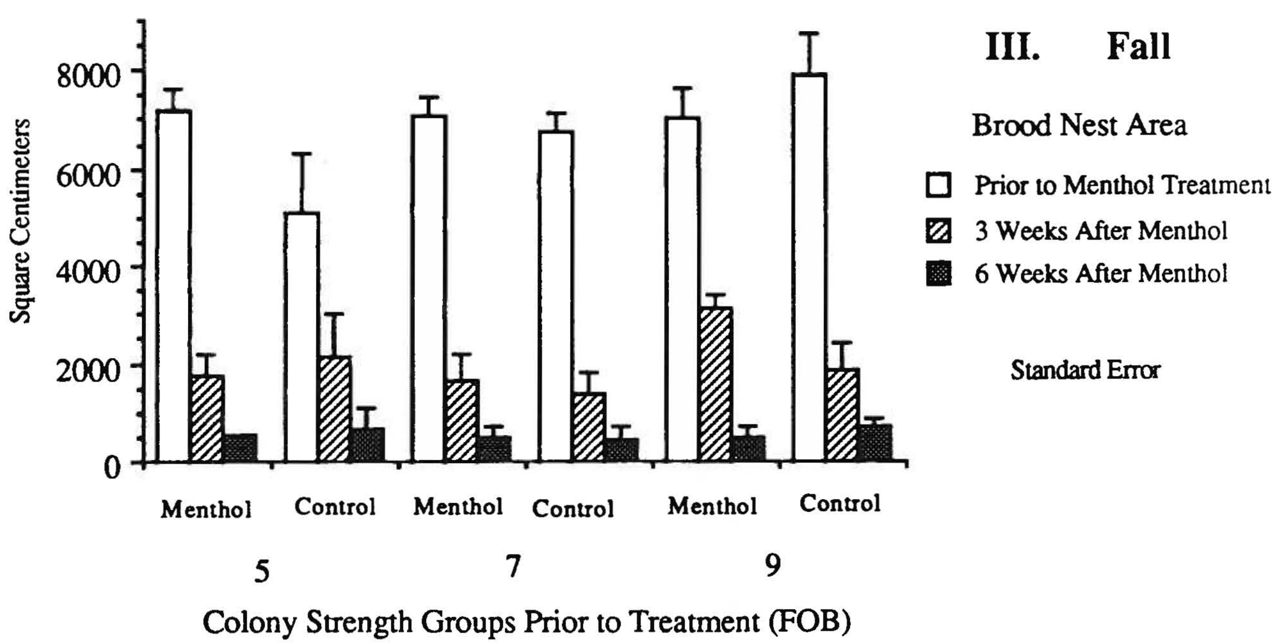


Figure 9

Comparison of returning flight to hives, based on colony strength at beginning of 1989 almond bloom season

(Average numbers of bees returning during 30 seconds, after covering the hive entrance with a screen.

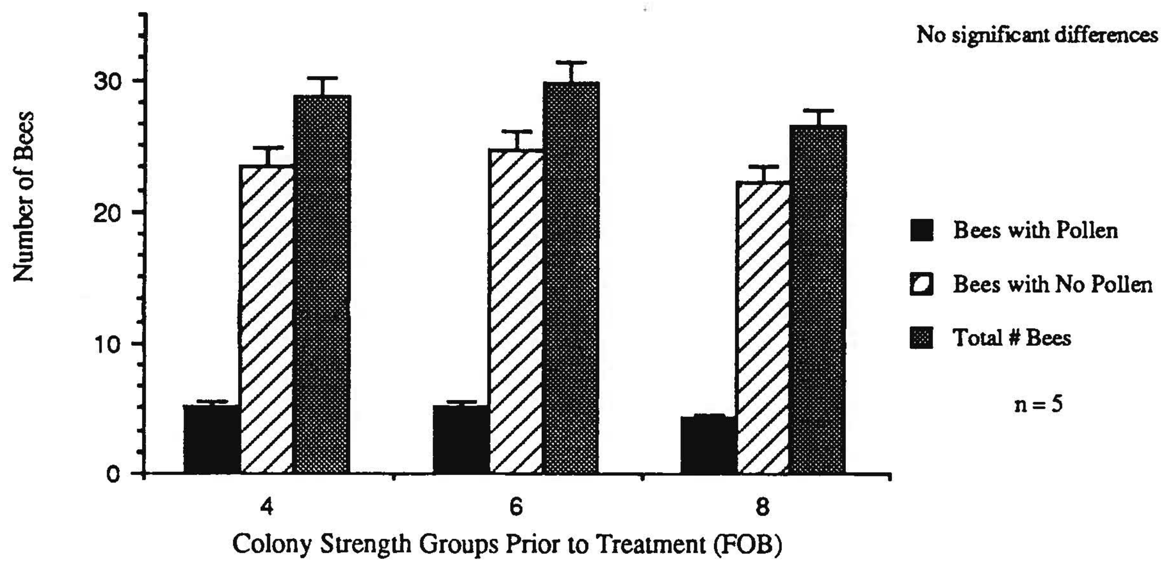
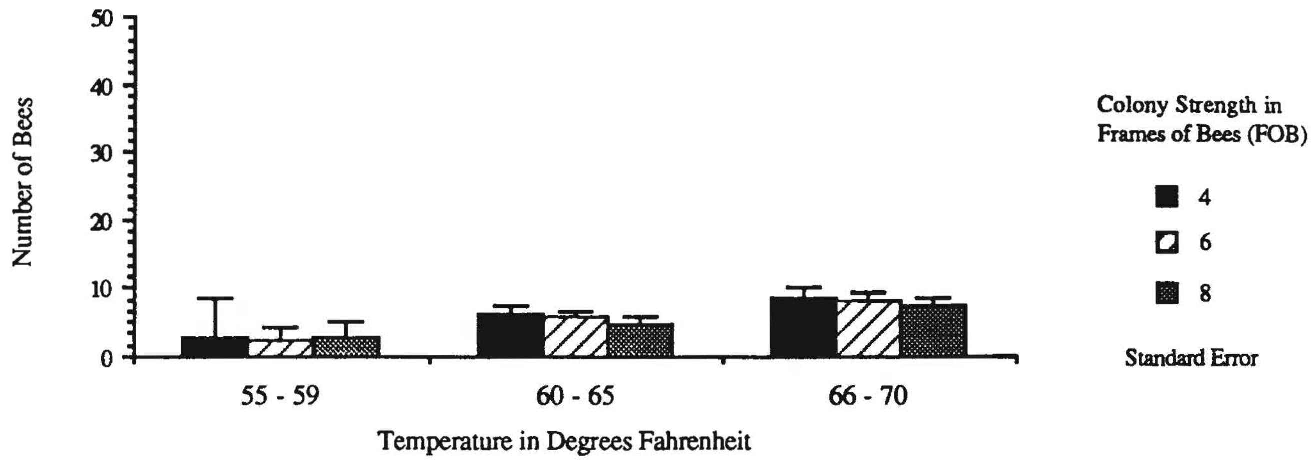


Figure 10

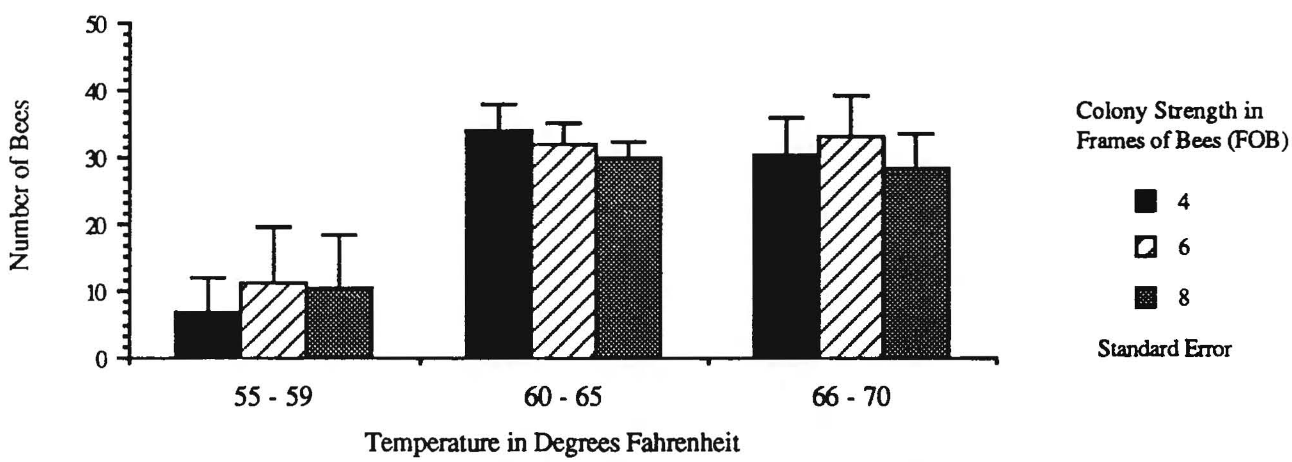
Relationship between bee flight at hive, ambient temperature, and colony strength (assessed at the beginning of the bloom) for the 1989 almond season.

(Average numbers of bees returning during 30 seconds, after covering the hive entrance with a screen.)

A. Bees with Pollen



B. Bees Without Pollen



C. Total Number of Bees

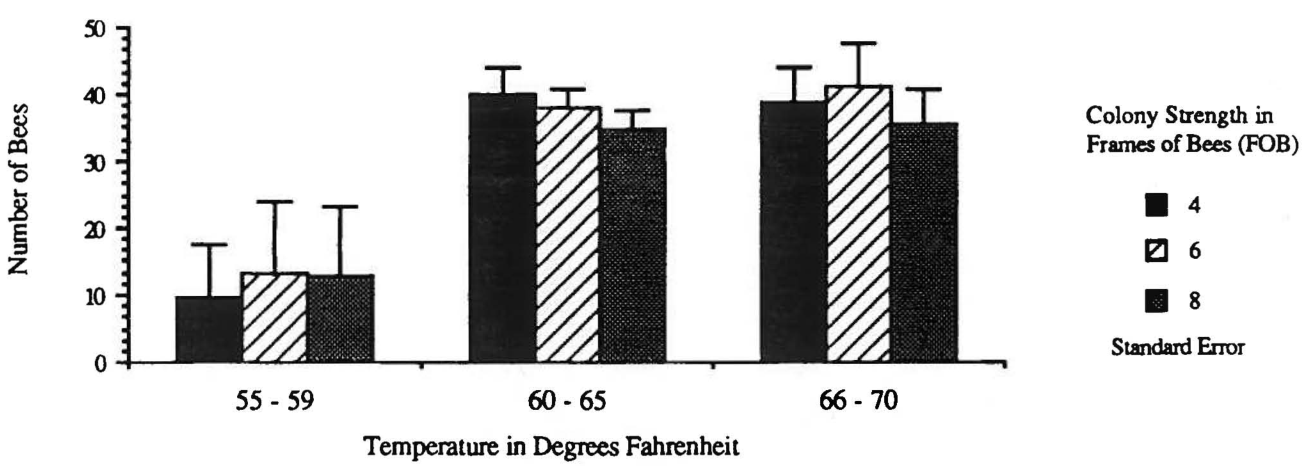
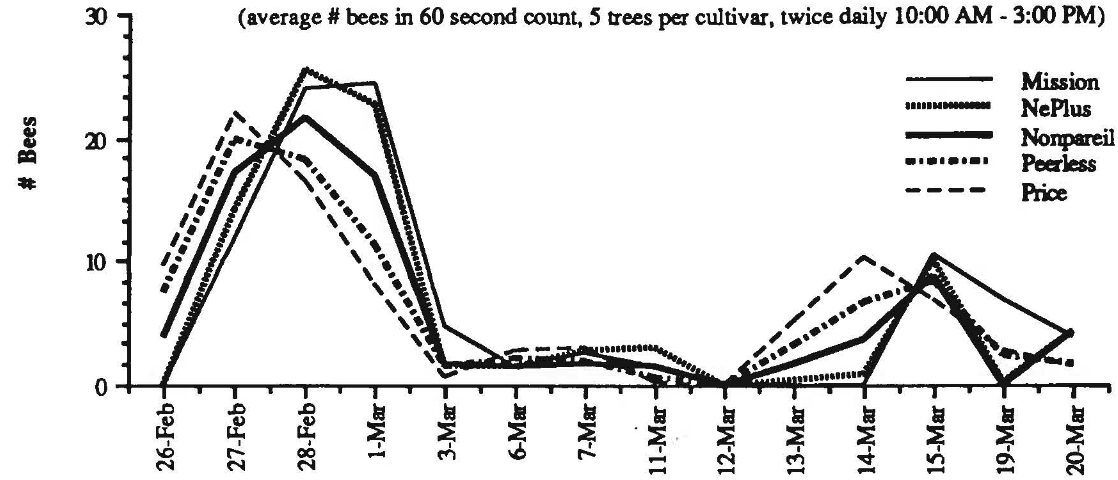
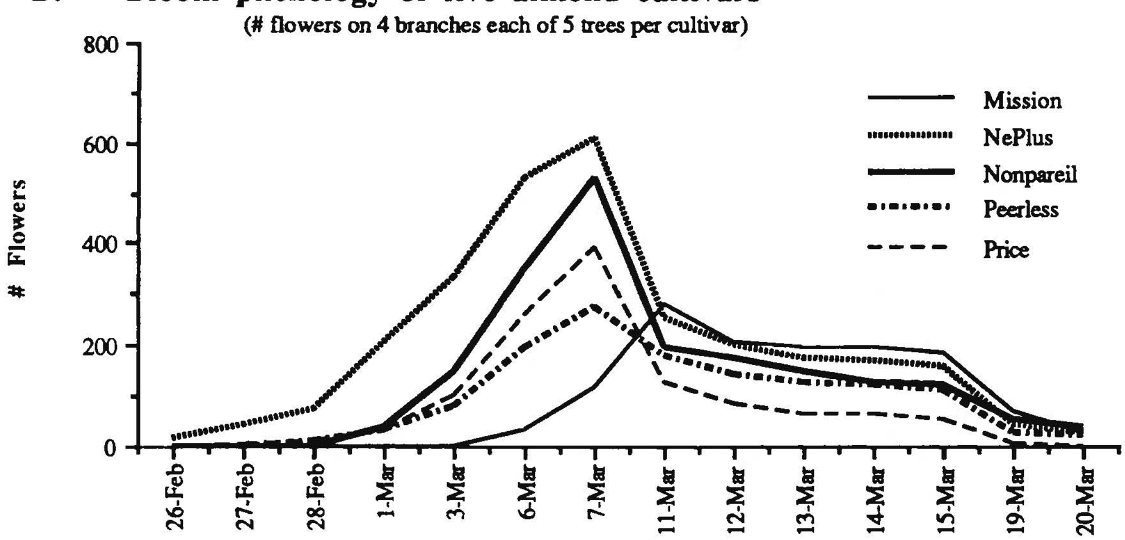


Figure 11
Relationship of bee flight and bloom phenology in an almond orchard near Davis, CA in 1989.

A. Bees Foraging in Almond Cultivars



B. Bloom phenology of five almond cultivars



C. Bees returning to hives during honey bee flight hours

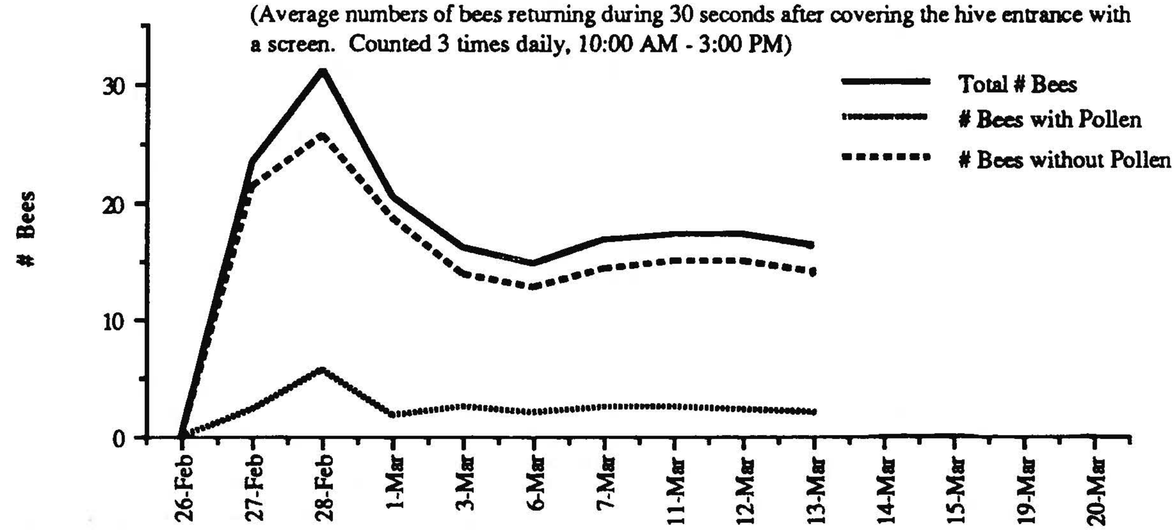
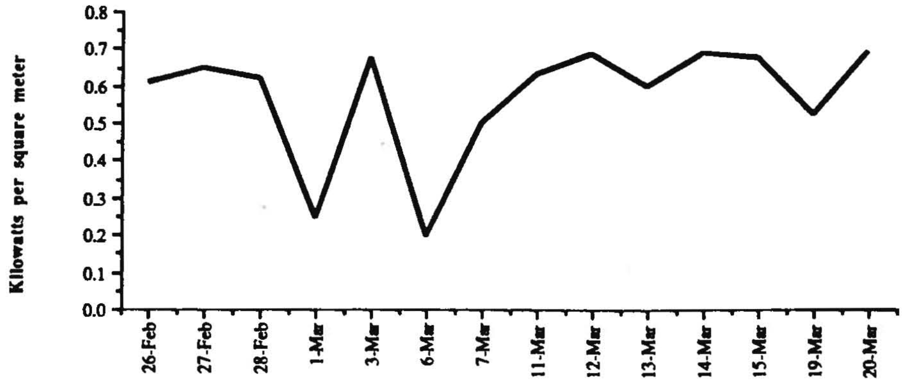
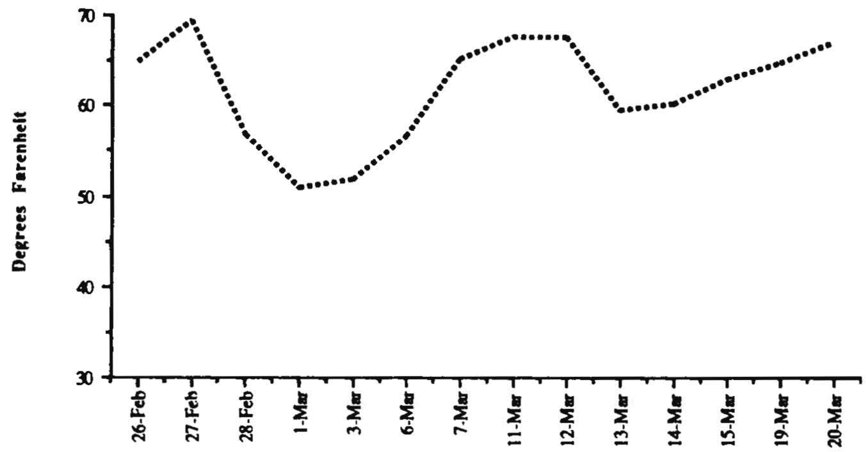


Figure 12.
Weather parameters in an almond orchard near Davis, CA in 1989.
(During honey bee flight hours: 10:00 AM - 3:00 PM)

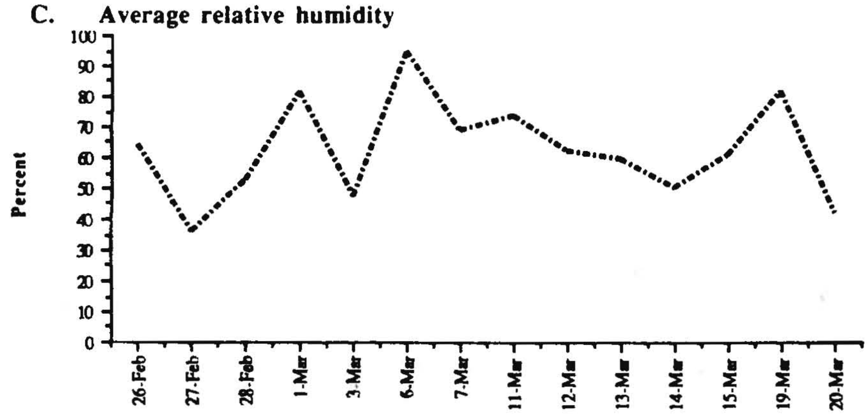
A. Average solar energy



B. Average temperature



C. Average relative humidity



D. Average wind speed