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1983 Annual Report on Almond Pollination Research

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Title: Tree Research: Pollination (Project No. 83-M8

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

Interpretive summary: Our previous studies have shown that pollen foraging honey bees are more efficient than nectar foragers for pollination of almonds, and that pollen traps increase pollen foraging. Our 1983 research continued to emphasize management techniques (pollen traps, sugar feeding, two queen colonies) to improve pollination efficiency of rented honey bee colonies. We also continued to search for methods to simplify colony strength measurements. Our grower survey garnered more responses than in previous years due to an extensive mailing effort. We initiated studies on temperatures in the hive to determine their effects on colony growth and foraging activity relative to our various colony management techniques.

Since pollen traps increase pollen foraging, but may decrease colony growth, we compared effects of traps on colonies of different strengths in 1983. We found colonies with less than 8 frames of bees showed significant increases in brood and pollen stores, but larger colonies did not. The latter may be due to space limitations. The larger entrance size of the traps we used caused

temperature reductions within the lower box in the early morning during the cold wet weather of 1983. Effects of trap entrance size and efficiency of traps in removing pollen on pollen foraging and colony growth need further testing. Feeding colonies with sugar syrup during bloom was found to be another means of increasing pollen foraging from colonies, especially those with less than 10 frames of bees. Sugar syrup feeding also increased population size of colonies with 6 to 10 frames of bees. Preliminary investigations of two queen colony management showed some increase in worker bee and brood populations where screens prohibited direct interchange of workers between top and bottom colonies. In these studies of colony management to increase pollination efficiency we compared colonies of different strengths and found that colonies of less than 10 frames of bees responded differently from those with more bees. These effects merit further study to improve our understanding of how colony strength relates to pollination efficiency. Effects of temperature within the colony, especially outside the cluster of bees on foraging activities seems important from our preliminary examinations and merits further study. We found our cluster count method closely correlated with colony strength based on intensive counts of frames of bees and a conversion table has been constructed. The cluster counts have the advantages of being quicker, less hazzard to the queen and less exposure to ambient temperatures. The main disadvantage is that cluster counts provide no information on the status of the queen or brood (important stimuli for pollen foraging). Our mail survey of growers was expanded, but is only partly analyzed. We find a direct correlation of yield with number of hives per acre, but the best correlation was with total strength (frames of bees) per acre. It is important to further refine this to determine whether frames of bees per colony is simply directly proportional to pollination efficiency or does it increase more geometrically and then taper off above some level? Our data suggest the latter in that colonies with 8 frames of bees seem more than twice as efficient as two 4 frame units, but that colonies with over 10 frames of bees seem not to show the same rate of improvement, but we need more data on this question. Preliminary tests indicate that the amount of pollen applied to the stigma may be an important determinant of pollination success. Such a dose response merits further study.

Cluster versus Intensive Colony Counts for Colony Strength Evaluation

For the third year in a row we compared the quick cluster count method with intensive counts of frames of bees to see whether the cluster count method can be used as a reliable estimate of the worker population size.

Experimental Procedure: The procedures used to assess colonies are described in the 1981 and 1982 reports. Briefly, in the "cluster" technique 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 so the bottoms of the frames covered with bees can also be counted. If there is a difference, an average is taken. Also, sometimes the total cluster can be observed by tilting the top box so that the cluster can be observed from below highlighted against the sky. If the bottom box of the hive is nailed on, only observations of the top of the bottom box can be made. In the "intensive" counts, each frame is removed from the hive, and the number of frames covered with bees and the amount of brood is counted. A total of 200 colonies were counted during almond bloom between February 14 and March 3. Seventy-five of these colonies, that were used in the other tests mentioned in this report, were assessed on April 7 and 8.

Results: The cluster counts done in almonds were regressed against intensive counts of frames according to the observer who did the counts. The three different observers had correlations of $r^2 = 0.64$, 0.70, and 0.85. Cluster counts, regressed against intensive counts gave a high correlation of r^2 = 0.875 (Fig. 1). A table of comparisons of counts done by the cluster versus intensive method has been developed (Table 1).

Discussion: The cluster estimates in assessing adult bee strength seem to be effective if some variance can be tolerated by the grower. For colonies of less than 8 frames, the number of frames estimated by the cluster is close to that of the intensive method. For colonies above eight frames, non-linearity is apparent. Some of this variance might be eliminated by more closely restricting the environmental conditions under which counts are done. The variations noted between observers could possibly be decreased by more thorough training and better coordination between observers. Cluster counts have the advantage that they are faster and thus less expensive if the grower is paying an outside observer to do them. Also, as described in another section of this report, the intensive count may be more harmful to the bees and more disruptive to foraging due to the amount of time the colony is open and the bees and brood are exposed to outside temperatures. In order to minimize chilling, intensive counts should be done only when temperatures are high enough that bees are foraging whereas cluster counts have to be done in the cool of the morning prior to foraging. With the extra handling of frames involved in the intensive count there is more danger of damaging or killing the queen which could be extremely detrimental to the colony. One possible reason for the intensive counts being lower in some cases than the cluster counts might be due to the number of bees out foraging or just flying around the disturbed colony. A disadvantage of the cluster estimates is that they tell us nothing about the brood which is an important stimulus for pollen foraging.

Pollen Traps and Foraging in Almonds

During the 1982 almond pollination season pollen traps appeared to be effective in stimulating more pollen and overall foraging, but at the expense of slowing colony growth rate. During 1983, we set up an experiment to try to determine what effect pollen traps might have on foraging and growth rate in different colony strength categories.

Experimental Procedure: Hives for the pollen trap study were moved into an almond orchard near Dixon, CA February 14-21. On February 17 colony strengths were assessed by intensive counts and non-activated (i.e. without trap screens) pollen traps were placed on them. At least four of the colonies were found not to be adequate for the experiment, and were removed February 18. These were replaced February 21. On February 23-24 the 22 colonies selected for the experiment were reassessed for strength, and pollen traps were activated. Pollen was emptied from the traps every 3-5 days while the hives were in almonds and every 4-7 days after they were moved from almonds March 14 to the time of the final strength assessment April 7-8. Counts of returning foragers were made in the same manner and on the same dates as mentioned in the section on feeding sugar syrup.

Results: Strength assessments that were done on February 17 and repeated on February 23-24 prior to trap activation showed increases of 9 to 25% in frames of bees, 23 to 45% in square inches of total brood and 115 to 403% in square inches of pollen stores (Table 2). These increases were statistically significant for total and capped brood in colonies with less than 8 frames of bees and for pollen stores of the 4-6 frame group (Table 2). Adult bee populations showed the greatest increase between trap activation on February 24 and final counts on April 7-8 in colonies with less than 8 frames of bees initially (Table 3). Those colonies with significant stored pollen (6 of 22 had greater than 20 in.^{2}) at final assessment tended to grow relatively more for both adults and brood. Amount of initially stored pollen was not correlated to colony growth. These 6 brought in much higher amounts of pollen than average 381 g. vs. 254 g. during the period in almonds. They brought in even more pollen than the higher colony strength categories of 8-12 frames (Table 4).

Colony flight was compared between ten trapped colonies and ten unfed colonies of similar strengths for the period March 30, April 4, and April 6. In only one of the eleven time periods analyzed (9:45-11:30 on March 30) were the trapped colonies shown to increase significantly pollen foragers ($p < .03$). There were no significant differences in the other time periods.

Discussion: In terms of short range growth in colonies without traps in early almond bloom, it appears that the 0-4 frame category has the highest percent increase in adult bees and total brood. However, the 4-6 frame category has the highest percent increase in capped brood and square inches of pollen. Over the long range, adult bees have a much higher rate of increase in the categories with less than 8 frames (Table 3). This could mean that the hives with more than 8 frames were cramped for space for bees and pollen storage, and therefore they could not increase as much. Colonies with less than 8 frames initially not only had greater increases in pollen stored in the comb, but also greater increases in pollen in traps (Table 4). Future studies should include evaluations of efficiencies of pollen traps to find those which will remove enough incoming pollen to stimulate more foraging, but not reduce colony strength. Also provision of more space for pollen storage and bees should be explored as a means of increasing colony strength and foraging especially of stronger colonies.

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The comparison of returning foragers at pollen trap hives with those at untrapped hives did not reveal the increased ratio of pollen foragers that we observed last year. The untrapped hives used for comparison were from the unfed hives mentioned in the experiment on sugar syrup feeding while the controls last year actually had non-activated traps on them. As observed in another section of this report, temperature losses through the larger pollen trap entrances can be significant. Under the extremely poor weather conditions during most of the period studied, there may already have been a pollen stress on all or most of the colonies. Thus the role of pollen traps in inducing pollen stress and thus creating more pollen foraging could have been thwarted.

Effects of Sugar Syrup Feeding on Pollen Foraging

Beekeepers commonly feed their bees sugar (sucrose) syrups in the winter and spring to supplement growing colonies during periods of inclement weather. Sometimes the syrup contains antibiotics to help prevent disease. We decided to feed colonies to see what effect this might have on colony strength and pollen foraging. This test and the other bee colony tests mentioned in this report were conducted in a commercial orchard near Dixon, CA, and continued near pear and plum orchards in Lagoon Valley to make up for observation days lost to inclement weather during almond bloom.

Experimental procedure: The colonies used in these experiments were supplied by a commercial beekeeper, and were moved into an almond orchard near Dixon, CA between Feb. 14 and Feb. 22. The colonies were assessed for strength (cluster size; frames of bees and brood) between Feb. 17 and Feb. 23. Thirty-eight colonies were paired by strength, and one of each pair was fed with 50% (by volume) sugar syrup in a half-gallon frame feeder on Feb. 25, Mar. 1-3, Mar. 14, Mar. 24, and April 4. On Mar. 3, 4, 7-11, 15, 18, 21, 23, 25, 28, 30, and April 4-6, screens were placed over the hive entrance for 30 second periods. Counts were made of the number of bees with and without pollen on their hind legs landing on the screens during the 30 seconds. The colonies were moved from almonds to an area within flight range of prunes and pears on March 14.

Results: The fed group had a highly signficantly ($p<.01$) greater average of pollen collectors than did the unfed group for 5 of 8 days during almond bloom (Fig. 2). For the other three days there was no significant difference ($p>.05$), but for all eight days the averages for the fed colonies were numerically higher. During the post-almond period the fed group had a highly significantly ($p<.01$) greater average of foragers than the unfed group for 6 of 10 days (Fig. 3). Of the remaining four days, one showed a significant difference ($p<.05$) while the other three showed no significant differences. For all 10 days, the averages for the fed group were numerically higher. With the exception of the 5 P.M. values, the fed group had consistantly higher amounts of pollen foraging during the day than the unfed group in almonds (Fig. 4). The fed groups also had higher pollen foraging during the post-almond period, except at 9 A.M. (Fig. 5). Colonies with 0-6 and 6.1 to 10 frames of bees initially showed highly significant differences in numbers of pollen foragers while the 10.1-15 frame colonies did not (Table 5).

We were also interested in what effect sugar feeding might have on colony growth. We found a highly significant ($p<.01$) difference in the net increase in frames of bees between the fed (3.8 ± 2.7) and unfed (0.76 ± 3.63) groups. The 0-6.0 and 10.1-15 frame categories showed no significant differences in colony growth, but the 6.1-10.0 group showed a highly significant ($p<.01$) difference between the two treatments.

These data were also analyzed to determine whether the beginning counts of frames of bees could be reliably used to predict pollen foraging activity. In both the fed and unfed groups, the intensive count was found to be a non-significant factor ($p>.05$), with r^2 terms of 0.8% and 11.1% respectively. The final strength counts were also compared with the corresponding values for pollen foragers. In both the fed and unfed groups, the intensive count was a highly significant factor ($p<.01$) with r^2 values of 44.1% and 72.0% respectively (Figs. 6 and 7).

Discussion: Our data indicate that sugar syrup feeding produces an increase in pollen foraging rather consistently throughout the day. It appears more advantageous to feed colonies with less than 10 frames of bees than larger colonies to stimulate increased pollen foraging. Sugar syrup feeding also had the greatest benefit to colony growth in those starting with 6 to 10 frames of bees. The final intensive count gave the highest correlation with pollen foraging activity because it may be the dependent variable with the number of pollen forgers in the previous two months being the independent variable. Therefore, caution is necessary in interpreting these results.

At least under the extremely unfavorable weather encountered during and after almond bloom in 1983, sugar syrup feeding looked very beneficial in increasing pollen foraging and colony strength.

Two Queen Colonies in Almond Pollination

Two queen colonies are those that have two queens and their brood nests in the same hive, but separated by a barrier to prevent the queens from fighting. There are reports in the literature that two queen colonies are superior under certain situations to single queen colonies. This study was initiated to determine whether two queen colonies might be useful in almond pollination, and to study how temperature relationships in two queen colonies might affect colony strength and foraging.

Experimental procedure: Two queen colonies were made up on February 26 by joining two smaller colonies together into one colony. One queen was placed in the top box and one in the bottom box. In four of the colonies (Group A), the top and bottom boxes were separated by a double queen excluder (a device with spaces just large enough for workers, but not queens, to pass through). Six colonies (Group B) had a board, with a 6 in^2 hole covered with 8 mesh hardware cloth over it, between the two hive bodies. Six colonies (Group C) had the same type of board in which a large hole (180 in^2) had been cut and covered with 8 mesh hardware cloth. In Group A the worker bees could pass back and forth between colonies whereas in Groups B and C they could not. Group A allowed the most heat exchange between boxes, and B the least. In Group A bees entered the colony through the normal entrance. In Groups B and C, bees in the bottom box entered the colony through the normal entrance while those in the top box entered through a standard size entrance at the bottom of the top box. Intensive strength counts were made on March 3 and April 7. Counts of incoming bees were taken in the same manner and on the same days as those described in the section on feeding. Holes were drilled in the top and back sides of the colonies so that a temperature probe could be inserted for readings inside and outside of the cluster.

Results: During the period between assessments, the upper colonies increased significantly more in strength than the bottom colonies ($p < .007$, adult bees). In colonies which were separated by 8 mesh wire, the significance was $p < .05$ for adults, $p < .01$ for uncapped brood, and no significant difference for capped brood. In contrast, two queen colonies separated by a queen excluder showed increases, but not significantly so, in the lower colony, and decreases in the upper colony. When both halves of the two-queen colony are taken as a unit, the colonies with the least interchange of heat and worker bees had the greatest growth (Table 6).

For the 19 periods tested, differences between the counts of returning foragers to upper or lower colonies of Groups B and C were never statistically significant for any one period. However, the flight was greater from the lower colonies in 15 of the 19 periods. When the periods are combined, the lower boxes show significantly more flight ($p < .02$).

Temperatures inside the hive, but outside of the clusters, were generally higher for the upper colonies. Temperatures inside the clusters were quite uniform for both the upper and lower colonies. When temperatures in the hive were regressed against total colony strength, temperatures within or outside the cluster, temperatures in the top or bottom box, and ambient temperatures the correlation was high ($r^2 = 76.7$). With temperatures outside the clusters in the top or bottom box as the dependent variable and regressed against independent variables of strength and ambient temperature the highest correlation was temperature in the bottom box versus total strength and ambient air (Table 7) with ambient air alone giving a correlation of $r^2 = 44.7$.

Discussion: The increases in adult population noted in the top boxes of hives with wire mesh separators may be due to bees deserting the lower boxes for the warmer boxes above. The fact that the opposite was true for the colonies with double queen excluders might be due to returning workers tending to stay with the first brood nest they contact when returning to the hive.

There appeared to be no correlation between temperatures and the population strength in one-half of the colony and strength in the other half of the colony suggesting that one-half of the colony is not helping to warm the other. The most important factor governing the outside of cluster temperatures, other than whether the top or bottom of the colony was being measured, was the temperature outside the colony. This agrees with the data showing the influence of outside temperatures on pollen trap colonies in another section of this report.

Apparently, the higher temperatures in the tops of two-queen colonies did not encourage greater flight from the upper halves. These results are not conclusive, however, because foraging counts were low due to bad weather, and because the beginning hive strengths were more variable than we hoped. Also, there may have been bees "drifting" from their own hives to new homes in other hives.

The Influence of Weather on Pollination

Because of the concerns that growers have expressed in pollination surveys concerning the negative influence of weather on pollination, a number of pilot studies were initiated to find what effects temperature and wind have on temperatures within the hive which may influence bee foraging activities.

A. The relationship of colony strength and cluster location to hive temperature.

An experiment was set up to determine whether the size of the colony or the location of the cluster (in the top or bottom hive box) has any effect on maintenance of hive temperature outside the colony cluster.

Experimental procedure: Seven of the colonies used in the syrup feeding experiment were monitored for temperatures in the top and bottom hive boxes 4-5 times per hour from 9 A.M. to 4 P.M. for 7 days between March 25 and April 6. Temperatures were taken outside of the cluster using mercury thermometers inserted in small holes drilled in the hive bodies. The hives were divided into 3 groups as follows: Group A - three hives with an average of 11.8 ± 0.4 frames of bees evenly distributed in top and bottom boxes; Group B - two hives with an average of 6.2 ± 0.7 frames of bees predominantly in the top box; Group C - two hives with an average of 6.7 ± 0.8 frames of bees predominantly in the bottom box.

Results: We found significant difference ($p > .05$) between the hive temperature of Group A and those of either B or C, but no significant difference between

B and C (Table 7). The only time period that was not significantly different between A, and B and C was 2 P.M. The only period that was significantly different between B and C was 4 P.M. Possibly, this latter may be explained by lower outside temperatures at 4 P.M. making it more difficult for colonies of group C to maintain their temperature. T-tests were performed within each of the three groups to compare the hive temperature from one hour to the previous hour. In Group A there were no significant differences from 10 A.M. to 4 P.M. In groups B and C the hive temperatures did not change significantly until 12 P.M. Correlation analysis showed a positive correlation between colony strength and temperature ($r^2 = 0.47$). The correlations between inside hive temperature and outside temperatures, and between inside hive temperatures and average wind velocities were much lower, r^2 equals 12.6 and 0.7 respectively.

Discussion: Under the weather conditions of this study, colonies with more than 10 frames can build up and maintain their temperatures better than 6-7 frame colonies. These data also suggest that keeping the main cluster of a 6-7 frame colony in the top box away from the entrance help it to maintain its temperature.

B. Effects of pollen traps on hive temperature.

A pilot experiment was set up to determine whether the OAC pollen traps used in our studies which have larger entrances than normal colonies (1.5:0.38 inches respectively), might have adverse effects on the temperature within test hives and thus reduce foraging, especially during cooler weather.

Experimental procedure: On April 7 and 8, eight of the colonies mentioned in the section on pollen traps were paired by initial strength counts. Temperatures outside of the bee clusters were monitored in the top and bottom boxes about 1-2 times per hour from 9 A.M. to 5 P.M. One hive of each pair had a one inch wide strip of tape covering the top part of the entrance reducing the opening from 1.5 to about 0.5 inches.

Results: In the pollen traps with the full 1.5 inch entrances, there was a significant difference ($p<.05$) between the temperatures in the top box (78.0 ± 1.8) and the bottom box (71.5 ± 1.3) during the period between 9-11 A.M. No other significant differences were found in the two groups of colonies. No correlation was found between strength of the colony and temperature outside of the cluster.

Discussion: From the results of this pilot experiment, it appears that the larger entrances in the O.A.C. pollen traps significantly lower the temperatures in lower boxes of hives during cool weather possibly adversely affecting colony foraging and strength. Therefore, during cool weather conditions, the O.A.C. trap should have the entrance restricted, or another type of trap should be used. Or, the brood nest and cluster of bees should probably be placed away from the entrance in the top box.

C. Effects of colony examination on hive temperature.

One of the reasons a quick and simple method for estimating colony strength is being sought (e.g., the "cluster" technique mentioned in another section of this report) is that it is commonly believed that opening colonies for the prolonged period needed for intensive counts during the cooler temperatures present during almond pollination can adversely affect the colony. Therefore, a pilot experiment was set up to see what the changes in colony temperature are after examination and how long these changes last.

Experimental procedure: The temperatures of three colonies were recorded before and after intensive bee strength counts were made on them on April 7. The temperature inside the cluster was recorded every 5 min. for the first hour and every 30 min. for the second hour.

Results: The beginning average colony temperature was 92.2 (±1.8)°F for the top box and 87.8 (±4.3)°F for the bottom box. After the colonies were examined (about 2 P.M. with ambient air at 73°F), the internal temperature dropped 5.0 (±5.4)°F during the first 5 to 10 min. After that the internal temperature started to rise until it had reached the maximum temperature of 96.0 (±4.0)°F for the top box and 9.10 (±4.0)°F for the bottom within 30 to 45 min. The temperature dropped back down to its normal average hive temperature within 50 to 90 min. During the period, the average outside temperature in the shade was 69.4 (±2.3)°F.

Discussion: These data suggest that colony manipulation during cool weather can have a significant effect on hive temperature and therefore possibly on colony health and foraging. More work should be done to see if there are any short or long term detrimental effects of examining colonies under various temperatures.

Mail Survey of 1982 Almond Crop

For the third year we conducted a survey of almond growers in order to define pollination problems and to seek solutions. We also hope that eventually a model can be developed of the almond pollination system from these surveys and our field research that will help predict the number and strength of hives needed under specific conditions. The survey form was expanded and modified on the basis of the 1980 and 1981 surveys to include more factors that affect pollination.

Experimental Procedure: Between August 15-17, 1983, we mailed survey forms, cover letters explaining the forms, return envelopes, and a summary sheet of results from our past surveys to a sample of almond growers from lists graciously supplied by the Almond Board of California and the California Almond Growers

Exchange. A second mailing was made on September 7-8 to 20% of those growers who did not respond to the first survey. The returned forms have been partially tallied and analyzed.

Results: Forms were sent to 694 growers. We received responses from 200 growers (about 25 percent) covering 217 orchards. Of these, data for only 139 orchards were complete enough to be useable for our analyses. The mean age of the 139 orchards was 14.8 years. Regression analyses that have been completed on data from the survey include hives and frames of bees per acre, orchard age and yield. Correlations with yield were only $r^2 = 2.5$ for orchard age, $r^2 = 8.0$ for hives per acre and $r^2 = 8.8$ when these were combined. Frames of bees per acre gave the best correlation ($r^2 = 30.2$) and this increased only slightly when combined with orchard age ($r^2 = 31.1$). The average net yield is directly correlated with hives per acre groupings (correlation = 0.94) (Fig. 8).

Discussion: Frames of bees per acre is the most significant variable, of the ones thus far analyzed from the survey, 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 (Fig. 8). Although this correlation between hives per acre and yield was high, there was much variation. There is also much room for error in some of the more subjective questions in the survey. With a mail survey such as this one, we may be getting a biased sample of the better growers who would probably be more likely to take the time to respond. For this reason, and to increase the size of the response, phone and face-to-face surveys of non-respondents may be necessary. However, there is still much information that can be gleaned from this survey since we have been able to analyze only about 1/3 of the questions.

Effects of Amount of Compatible Pollen on Almond Stigmas on Fruit Set

Theoretically almonds require only one compatible pollen grain to reach a stigma for successful pollination and fruit set. However for many plants it is becoming clear that excess pollen grains may enhance successful pollination. We initiated preliminary hand pollination tests to seek possible correlations between stigmatic pollen loads and fruit set in almonds.

Experimental Procedure: Cages were placed over 3 limbs per tree of 4 to 5 trees each of Peerless and Nonpareil on 16 Feb. 1983 and of Mission and Thompson on 22 Feb. in an orchard near Dixon, CA. Due to weather and time limitations, hand pollinations were done on only 4 trees of Peerless and 2 trees of Mission. Spurs with two receptive flowers each were individually tagged on 12 caged Peerless limbs on 21 Feb. All other flowers and buds were removed. Flowers on 6 Mission limbs were pruned to one receptive flower per spur, emasculated prior to dehiscence and tagged with numbered strips of tape. One of each pair of Peerless flowers was hand pollinated on 22 (9 limbs) and 24 (3 limbs) Feb. The amount of pollen applied was crudely varied by daubing each stigma with 1, 2 or 3 freshly dehisced anthers from Nonpareil. A magnifying visor was used to determine more accurately the amount of freshly dehisced Thompson pollen applied to Mission stigmas on 3 (5 limbs) and 4 (1 limb) March. The amount was varied by covering one-third, one-half or all the stigma surface. Some flowers were not pollinated as controls. About 4 days from pollination are required for the pollen tubes to penetrate the ovaries. The terminal 3-5 mm of the style was removed (from Peerless on 1 March and from Mission on 8 March) and stored (in gelatine capsules for Peerless and between layers of scotch tape for Mission) for subsequent analyses of numbers of pollen grains actually applied to each stigma. These analyses are to be done by Dr. Steve Buchmann, USDA Bee Research Lab., Tucson, AZ. Counts of fruits set on the experimental limbs were made on 26 April. Additional fruit counts on the terminal 1 meter of several limbs were made to compare crops of several cultivars in the Dixon area.

Results: Analyses of actual amounts of pollen grains applied are not complete at this time. Fruit set was generally high on Peerless, but showed no correlation with crude differences in pollen amounts (Table 8). A direct correlation with amount of the stigma covered with pollen and fruit set was found with Mission (Table 8).

Discussion: Although we did find a correlation with amount of pollen applied and fruit set in Mission the numbers are too low to be statistically significant and serve as no more than an indication that amounts of pollen may be critical. The low numbers are primarily due to the poor weather for pollination and fruit development during the later part of the 1983 bloom season in northern California. This was confirmed by our additional fruit set counts which showed the early blooming Nonpareil and Peerless had 2 to 4 times as many nuts per meter of limb as did the late blooming Thompson and Mission cultivars. The lack of correlation to different levels of pollen applied to Peerless stigmas may be due to our inability to control application amounts or our having applied above the minimum amount necessary in all categories. The actual counts of pollen grains applied may provide more clear cut evaluations. These studies suggest further testing is worthwhile.

Publications

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Webster, T. C., R. W. Thorp, D. Briggs, J. Skinner and T. Parisian. Effects of pollen traps on honey bee foraging and brood rearing during almond and prune pollination (prepared, peer reviewed, for submission to J. Amer. Soc. Hort. Sci.).

Loper, G. M., R. W. Thorp, J. H. Martin and R. L. Berdel. Effect of pollen traps on total pollen collection and honey bee colony development in almonds (in co-author review, for submission to Amer. Bee. J.).

Table 1. Relationship Between Cluster Size and Actual Frames of Bees

Cluster Size Category	Actual Frames of Bees	Number Observed	Std. Dev.
0-2	2.2	39	1.15
3-4	3.9	73	1.46
5-6	6.1	53	1.97
7-8	7.4	54	2.18
9-10	7.8	46	2.20
11-12	10.1	36	2.28
13-14	11.6	23	2.84
15-16	11.9	11	2.82

Table 2. Increase in colony strength during the week prior to pollen trap activation in almonds (17-24 Feb. 1983).

	Frames of bees Group	N	Mean Strength [Frames]	Increase	% Increase	Significance
Frames of bees	0-4	(6)	3.7 (±0.3)	0.92	25.0%	
	4-6	(6)	5.2 (±0.2)	1.10	21.4%	
	8-10	(3)	8.8 (±0.7)	0.80	9.1%	
			[in.^{2}]			
Total Brood (in.^{2})	0-4	(5)	389 (±74)	173	44.5%	p<.02
	4-6	(6)	536 (±133)	209	39.0%	p<.04
	8-10	(3)	857 (±167)	195	22.8%	
Capped Brood (in.^{2})	0-4	(5)	216 (±106)	136	63.0%	p<.05
	4-6	(6)	224 (±105)	220	98.0%	p<.007
	8-10	(3)	417 (±96)	245	58.8%	
Pollen (in.^{2})	0-4	(5)	109 (±61)	125	115.5%	
	4-6	(6)	68 (±62)	275	402.9%	p<.03
	8-10	(3)	267 (±197)	321	120.1%	

Table 3. Increase in strength after pollen traps activated (Feb. 24-April 8) adult bees only.

Frames of Bees Group	N	Average Frames per Hive (Beginning)	Changes in Frames	% Change in Frames
2-4	(5)	3.2 (±0.6)	2.3	71.9
4-6	(6)	4.6 (±0.6)	2.0	43.5
6-8	(4)	6.7 (±0.7)	4.6	68.7
8-10	(4)	9.4 (±0.7)	-0.2	-2.1
10-12	(3)	11.0 (±0.6)	1.0	9.1

Table 4. Pollen income in traps by colony strength category during almond pollination Feb. 24-March 10, 1983.

Frames of Bees Group	N	Average Frames of Bees per Category	Average Pollen Collected per Hive (Grams Dry Wt.)	% Change from Next Lower Category	
				Frames of Bee	Pollen Collected
2-4	(4)	3.2	130.1 (±110.7)	-	-
4-6	(6)	4.6	185.9 (±87.5)	43.8	43.1
6-8	(4)	6.7	297.6 (±85.7)	45.7	60.2
8-10	(4)	9.4	378.8 (±405.2)	40.3	27.2
10-12	(2)	11.2	368.5 (±199.2)	19.1	-2.6
Average All Colonies			253.9 (±207.1)		
Average per colony per day (15 days)			16.9		

Table 5. Effects of sucrose feeding on pollen foraging in almonds by strength category.

Strength Group	Treatment	No. of Observations	Average Pollen Foragers per 30 sec.	Std. Dev.	Significance Level
0-6.0	Fed	168	2.95	4.04	.0105
	Unfed	248	1.95	3.66	
6.1-10.0	Fed	456	3.09	4.03	.0001
	Unfed	375	2.07	3.53	
10.1-15.0	Fed	171	2.73	3.27	.7103
	Unfed	164	2.59	3.59	

Table 6. Change in Total Strength of two queen colonies.

	Mean Frames		
Type	Beginning	Ending	% Change
Small Screen	7.5 (± 2.1)	9.7 (± 2.8)	+ 28.9
Large Screen	6.4 (± 2.3)	7.8 (± 3.0)	+ 20.7
Queen Excluder	6.5 (± 1.5)	6.4 (± 1.1)	- 1.4

Table 7. Temperatures outside clusters in top or bottom colonies of two queen colonies regressed against independent variables.

	Independent Variables				
Temperatures outside cluster in:	Strength in Colonies			Ambient air temp.	r^2
	Both	Top	Bottom		
Top Box	x				2.6
	x		x		3.1
	x			x	16.4
	x		x	x	15.3
Bottom Box	x				- 1.1
	x			x	48.3
	x	x		x	47.4

Table 8. Colony temperature as affected by size and distribution of bees (Group A-11.8 frames; B-6.2 frames mostly in top box; 6.7 frames mostly bottom box).

Time of Day	Outside Temperature		COLONY TEMPERATURE ($\bar{x}$)					
			Group (A)		Group (B)		Group (C)	
	$\bar{x}$	Std. Dev.	$\bar{x}$	Std. Dev.	$\bar{x}$	Std. Dev.	$\bar{x}$	Std. Dev.
9 A.M.	63.2	2.6	80.9	3.2	73.8	3.2	71.8	3.9
10	66.7	2.8	86.6	2.7	75.0	5.9	74.7	10.3
11	65.2	2.8	85.9	5.1	76.6	6.8	74.5	6.6
12 P.M.	64.3	2.7	88.6	6.2	77.2	3.1	73.9	4.5
1	67.6	3.5	91.1	4.7	81.5	6.7	78.8	5.9
2	66.9	4.3	82.4	1.6	81.1	4.2	79.0	4.8
3	65.8	3.0	90.5	4.5	81.7	4.2	79.0	6.3
4	63.6	2.4	89.4	5.1	83.7	4.3	78.8	4.8
Mean	65.4	1.6	89.0	5.0	80.2	5.8	77.7	5.8

Table 9. Fruit sets in relation to different amounts of pollen applied to stigmas of Peerless and Mission.

	Relative Amounts of Pollen Applied				Total of Pollinated
	0	1	2	3	
Peerless					
Fruits/Flowers	0/138	37/62	19/48	26/50	82/160
% Set	0	59.7	39.6	52.0	51.25
Mission					
Fruits/Flowers	0/24	1/19	2/18	4/19	7/56
% Set	0	5.3	11.1	21.1	12.5

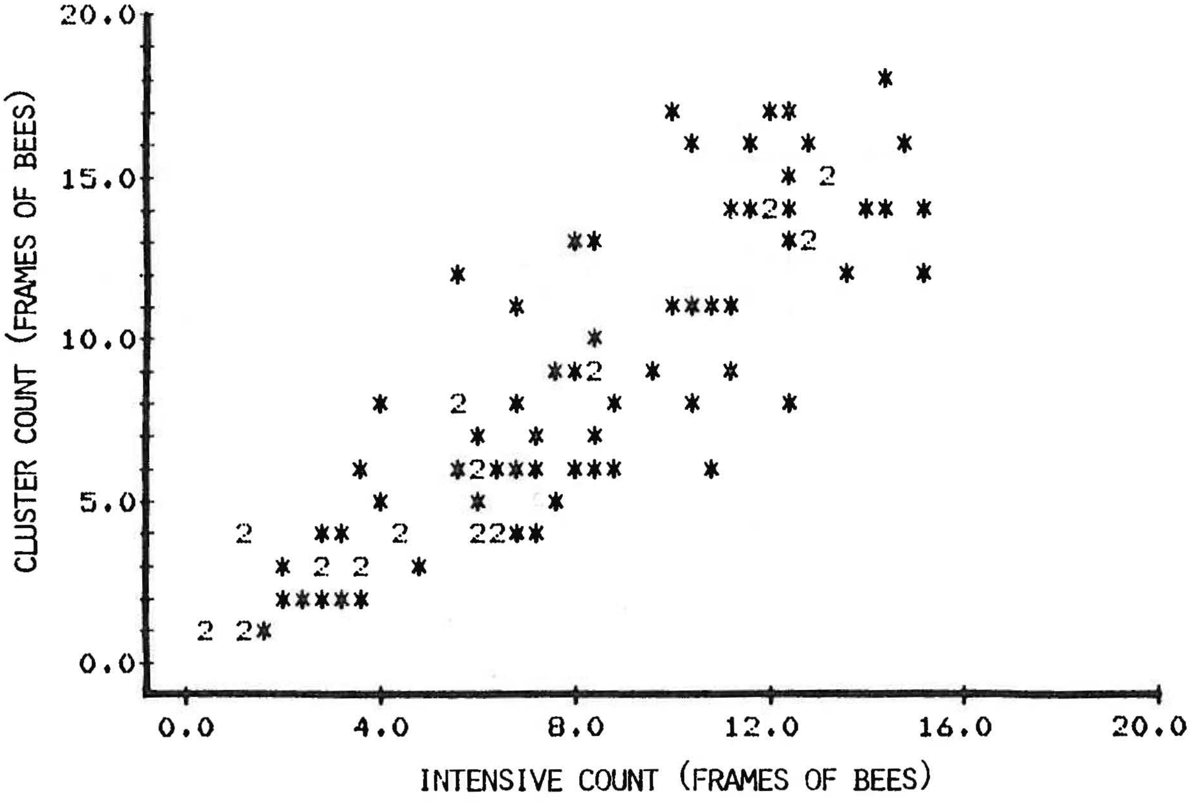


Fig. 1 QUICK CLUSTER COUNTS AND INTENSIVE INSPECTIONS OF HIVES (CORR..875)

Fig. 2

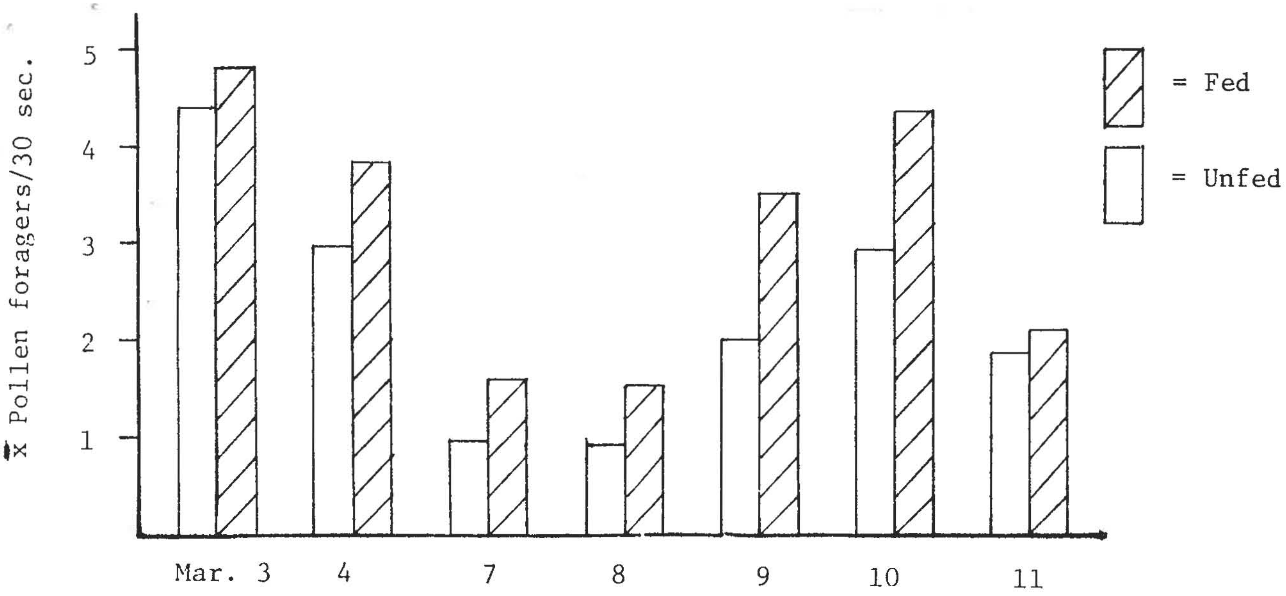
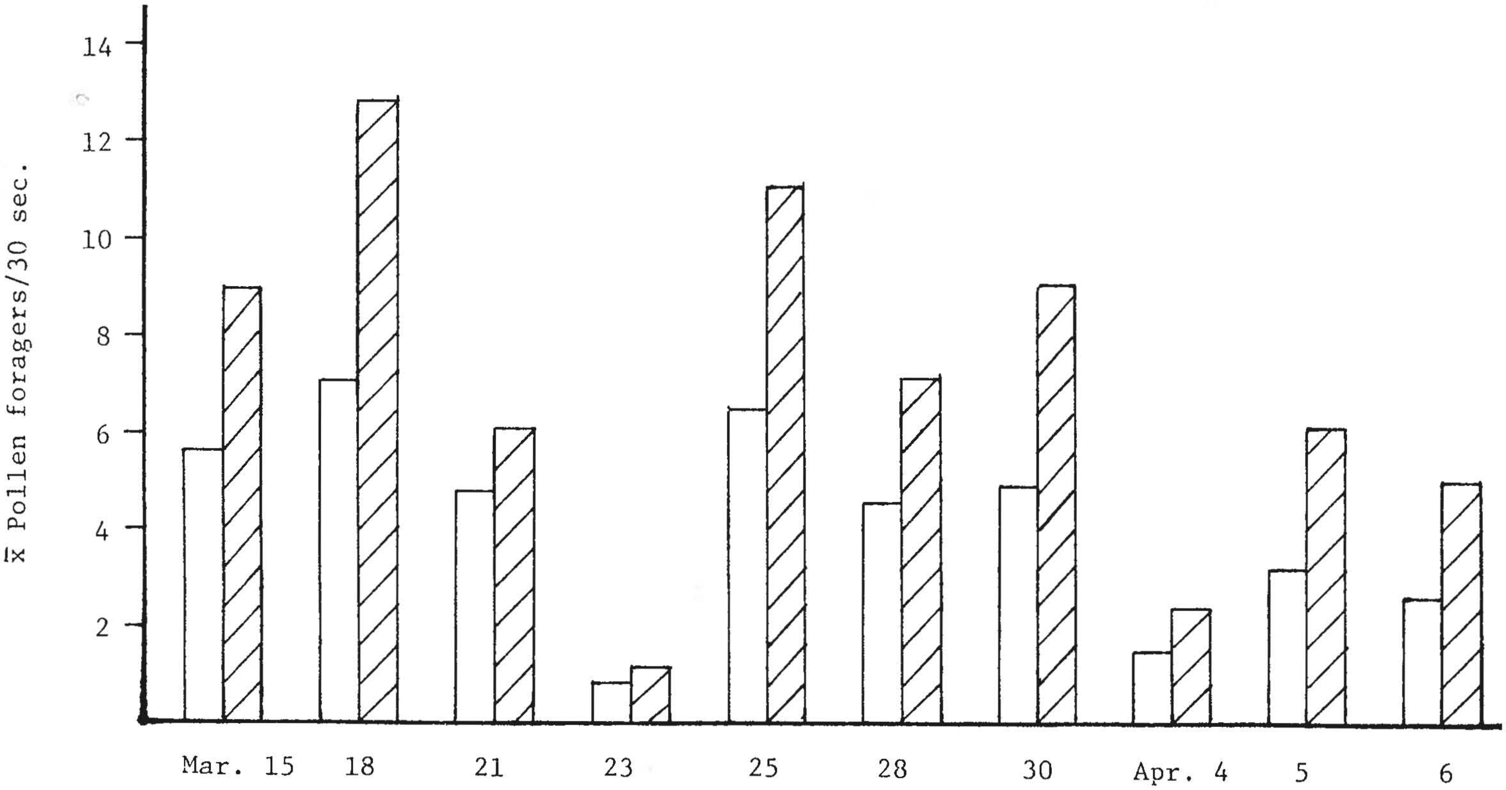


Fig. 3



Figs. 2 and 3. Comparisons of mean pollen foragers per 30 second observations between 3-11 March in almonds (Fig. 2) and between 15 March and 6 April post almond period (Fig. 3).

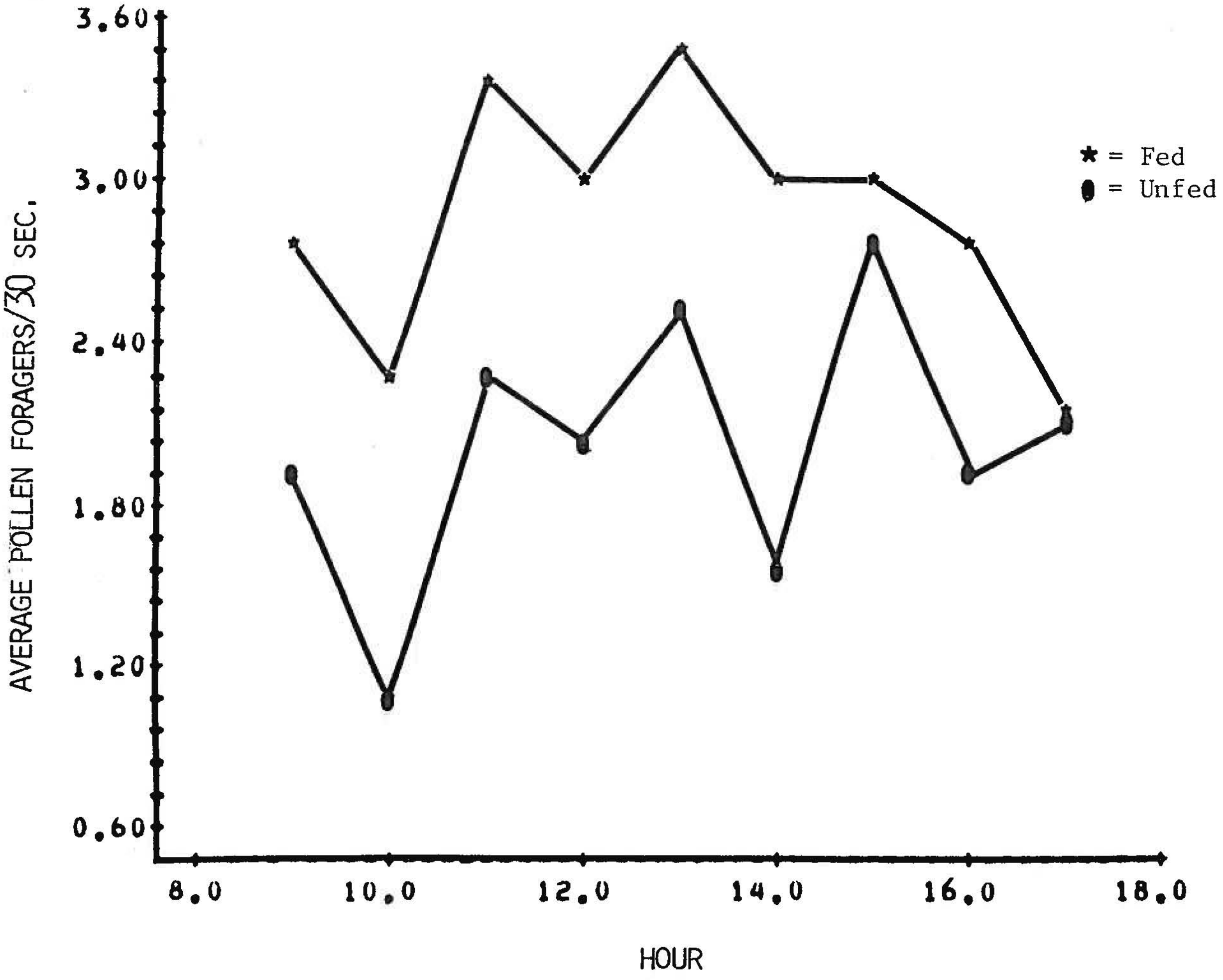


Fig. 4 POLLEN FORAGERS RETURNING TO FED AND UNFED COLONIES AS A FUNCTION OF TIME. IN ALMONDS

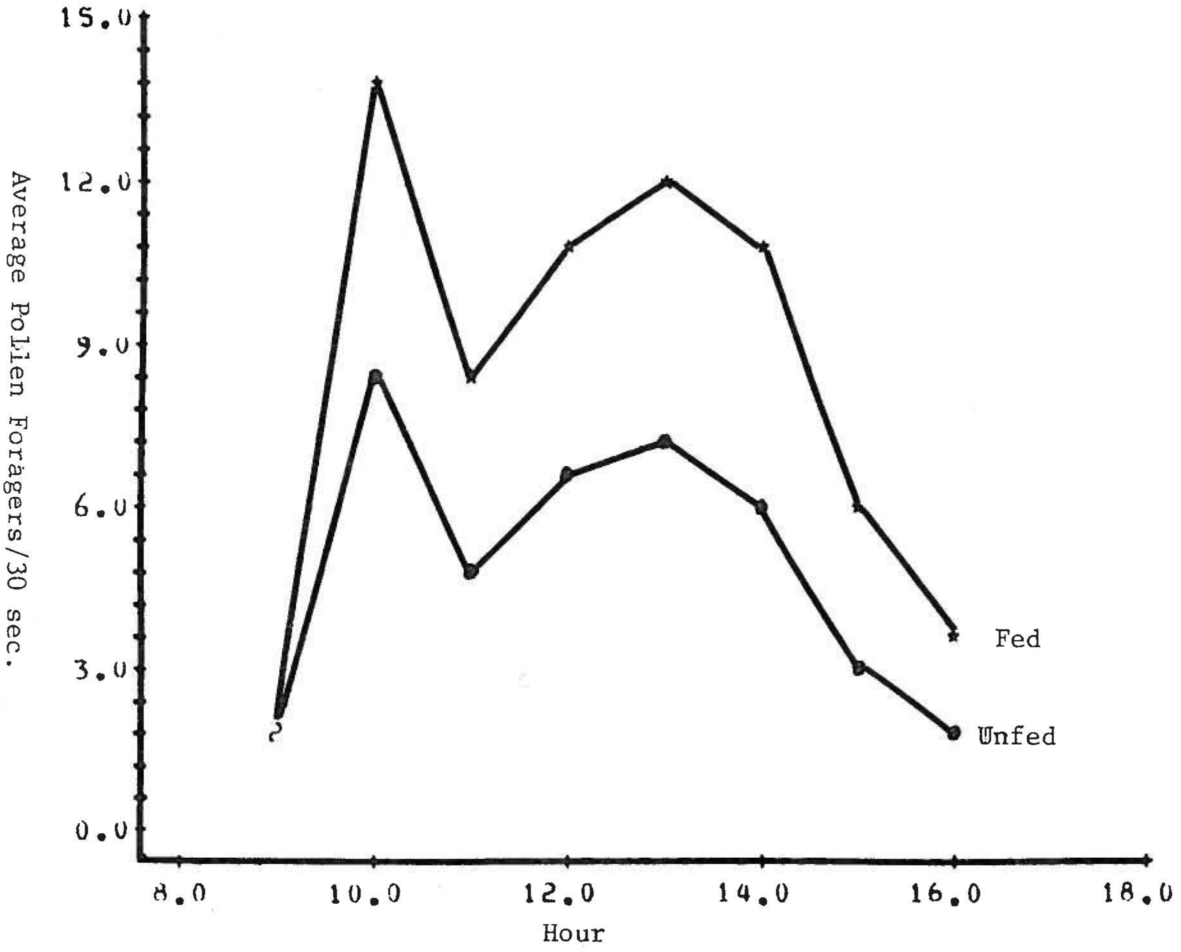


Fig. 5. POLLEN FORAGERS RETURNING TO FED AND UNFED COLONIES IN AN HOURLY BASIS [POST-ALMOND PERIOD].

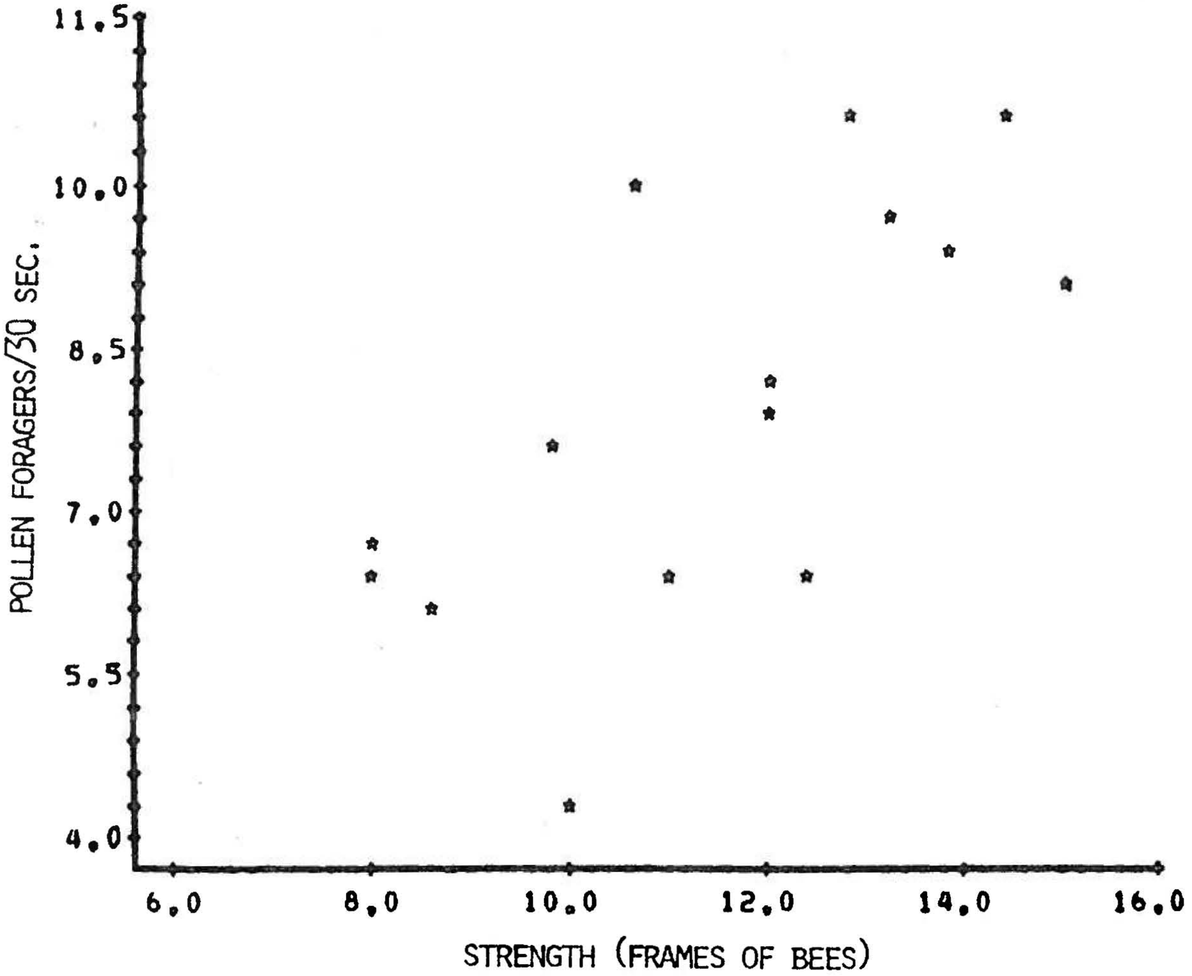


Fig. 6. POLLEN FORAGING VS. HIVE STRENGTH IN FED COLONIES

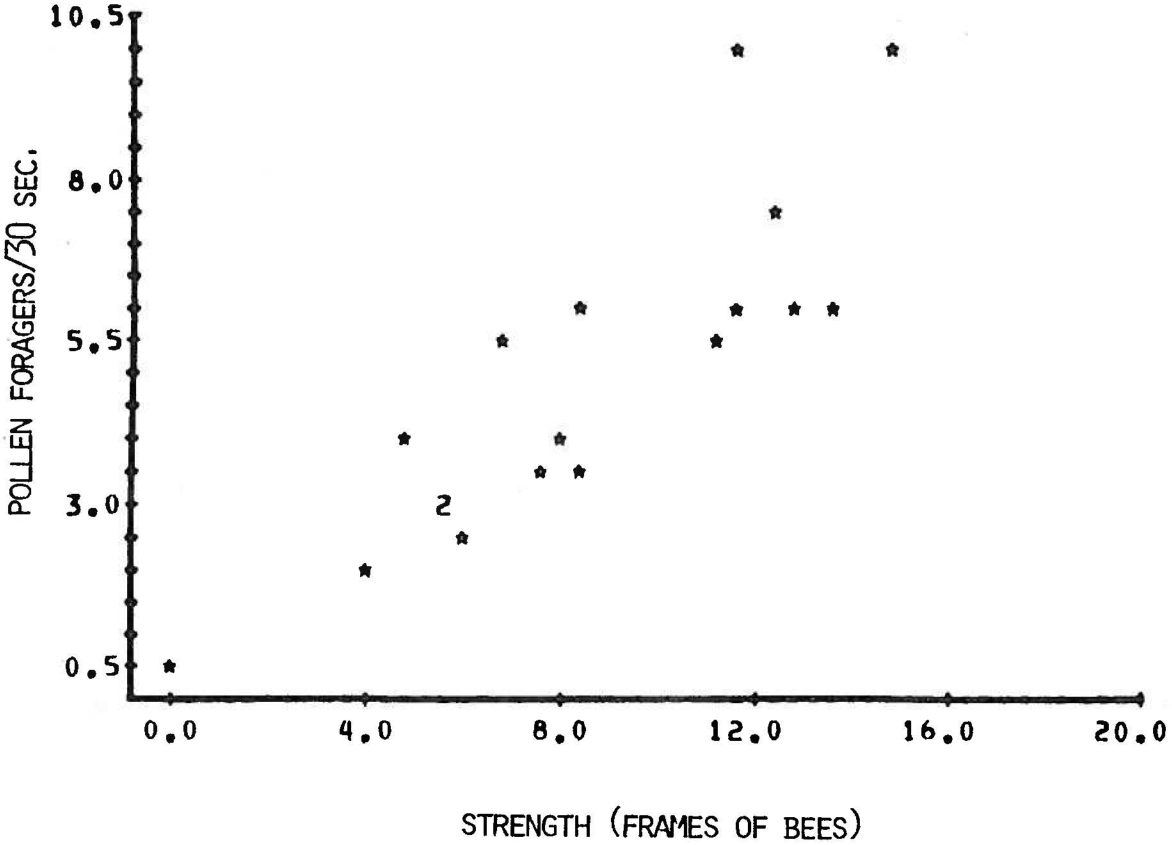


Fig. 7. POLLEN FORAGING VS. HIVE STRENGTH IN UNFED HIVES

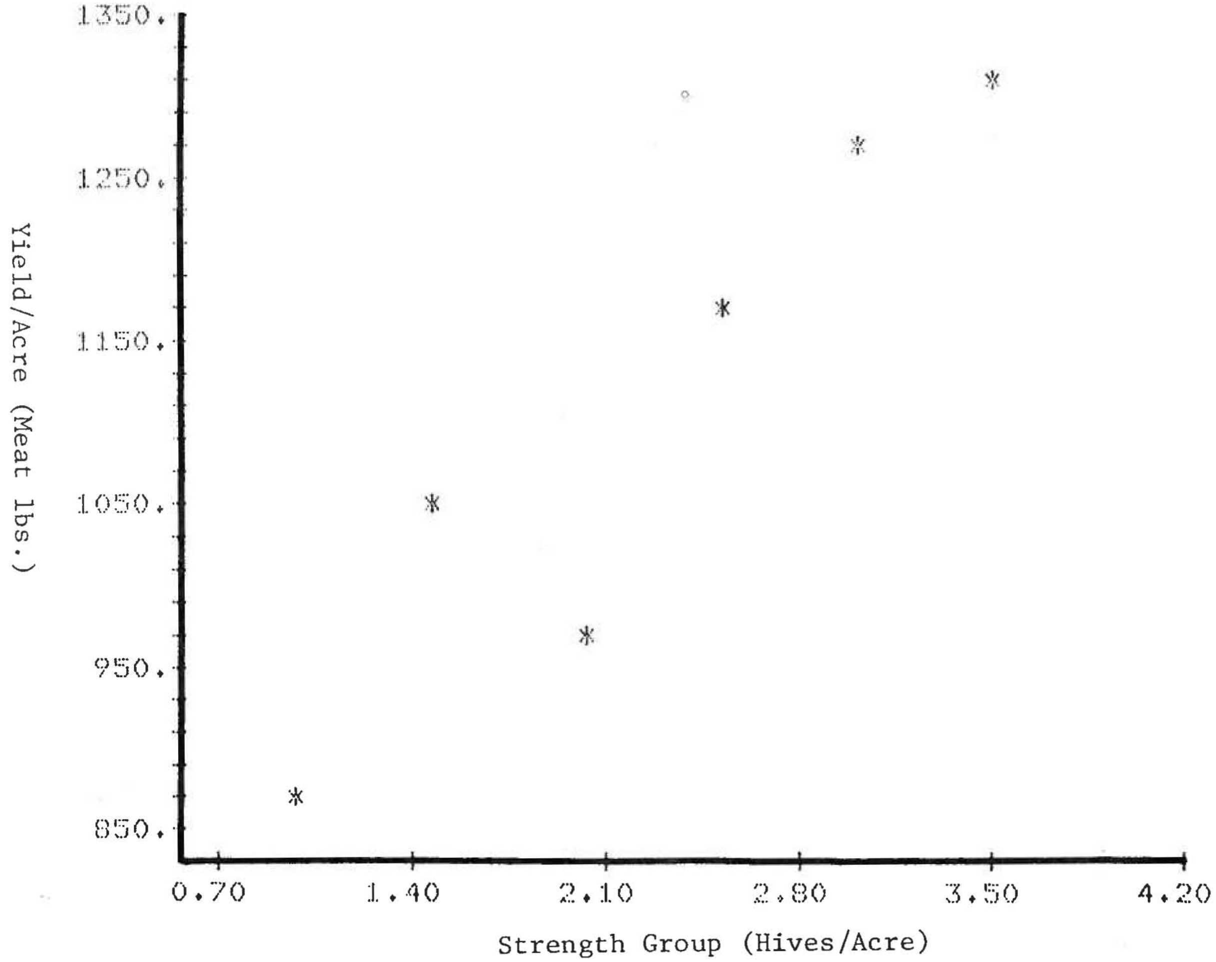


Fig. 8. AVERAGE ALMOND YIELD PER ACRE AS A FUNCTION OF COLONY STRENGTH GROUPS

G. M. Loper - 1983 Annual Report

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Project No. 83-M8
Pollination

R. W. Thorp (Davis, CA)
G. M. Loper (USDA-Tucson, AZ)

1. Objectives of 1983 Research

A. To continue testing a modified drop pattern of colonies placed around a 70 acre orchard to obtain uniform honey bee foraging and nut yields.

B. To determine the effect of pollen traps on honey bee flight, brood-rearing, pollen storage, forager density (bees/tree) and nut yields.

C. To determine the relative "efficiency" (i.e., pollen removal efficiency) of 3 pollen trap designs and 3 wire sizes.

D. To determine the effect of an empty shallow (with drawn comb) and queen excluders placed on the bottom of the colony on honey bee flight and pollen storage.

2. Interpretive Summary

The experimentally modified drop pattern around a 70-acre (1/2 x 1/4 mile) orchard again resulted in an increased number of foragers in the center of the orchard. This means a more uniform distribution of foragers across the orchard was attained merely by "bunching" the colony placement. This bunching of colonies (8 frames of bees or more per colony) evidently increased forager competition in the trees near the colonies and resulted in more bees flying further and improving pollination in the center of the orchard. Since our correlations between foragers/tree and nut yields/tree were again highly significant in 1983, improved foraging resulted in improved nut yields.

An experiment with colonies fitted with pollen traps resulted in slightly increased numbers of foragers (and % pollen collectors) measured at the hive and increased pollen income/colony by a factor of 1.8. Trapping did not significantly affect the numbers or distribution of foragers in the target orchard. It is clear that traps on colonies do not have a detrimental effect on nut yields, but traps that are too "efficient" in removing incoming pollen (above approximately 50%) have a detrimental effect on broodrearing. This affect does not reduce the pollination performance of the colony while in the almond orchard, but does reduce the colonies' subsequent performance. Our data indicate that less efficient traps (approximately 11% effective in removing pollen) not only stimulated foraging but also did not affect broodrearing.

A separate experiment tested the pollen removing efficiency of and suitability of 5 slightly different pollen traps. The results showed that both design and wire size can be modified to manipulate pollen trapping efficiency. These factors must be controlled in future studies in order to get meaningful results.

Putting a shallow hive body supplied with frames of empty drawn comb with and without a queen excluder on the bottom of strong colonies did not significantly increase either rate of flight or pollen storage. No pollen was deposited in the frames of the empty shallow.

3. Experimental Procedure

A. Modified drop pattern around 70 acre, 1/2 x 1/4 mile orchards. The same "test" and "control" orchards studied in 1980 and 1982 were used again in 1983. The "control" orchard received the normal drop pattern (essentially 24 drops of 6 colonies each evenly spaced about 275' apart) whereas the "control" orchard had the same modified drop pattern as in 1982 except: 1) every colony was fitted with a bottom pollen trap and 2) 36 USDA test colonies replaced 36 of the usual beekeepers' colonies. The pollen traps were placed on the colonies 2 weeks r to almond bloom.

As in previous years, estimates of bees/tree were made on all trees on the diagonal whenever the ambient temperature was above 18°C. In early August, the Non Pareil trees in both orchards were shaken and nut yields/tree were determined. Data was analyzed comparing bees/tree and nuts/tree, especially comparing the results of 1983 with those of 1982.

B. Effect of pollen traps on colony behavior and response. Each colony around the "test" orchard was fitted with a pollen trap. However, as a control, some colonies were fitted with "ineffective" traps having wire grids either removed or with grids having 4 holes to the inch (too large to remove pollen pellets but still an "obstruction").

The Gary flight cone was used to estimate rate of flight from trapped and untrapped colonies and estimates of percent pollen foragers were made by temporarily closing off the entrance and vacuuming the bees into a plastic bag which was then quick-frozen on dry ice. Later, counts of bees with and without pollen loads were made on each sample. The 36 USDA colonies were subdivided to determine the effect of 2 weeks of pollen trapping vs 6 weeks of pollen trapping on broodrearing. All USDA colonies were returned to Tucson on March 1, 1983. Data was analyzed to determine the effect of the various treatments on total pollen flow, broodrearing, forager rate-of-flight, and percent pollen foragers.

C. Effect of wire size and trap design on pollen trap efficiency. Two modifications of the O.A.C. trap plus another trap using a perforated metal plate (instead of wire grids) were tested. One O.A.C. type design was further modified by having some traps with wire grids made from .023", .037" or .045" diameter wire (all with 5 holes/inch). Estimates of pollen trap "efficiency" were made by taping off all entrances, emptying the trays and then allowing 50 pollen-laden bees to enter. When 50 bees had entered, the entrance was again closed for 2 minutes to allow the pollen-laden bees to crawl through the pollen removing grid (or perforated plate). Then, the tray was again emptied and pollen pellets counted.

D. Effect of an empty shallow with and without a queen excluder on pollen storage and rate-of-flight. Colonies of uniform strength were selected for one of 3 treatments (12 colonies in each treatment): 1) control - no change; 2) 1 shallow super with drawn comb as the bottom box; 3) same as 2) plus a queen excluder above the empty shallow. Data on brood, pollen storage, rate-of-flight, percent pollen foragers and pollen in the empty shallows were taken.

Results

A. Effect of modified drop pattern on distribution of foragers and nut yield.

I replaced 36 of the beekeepers' colonies with 36 USDA, sister-queen colonies (to use in a long-term pollen trapping study, see results of B objective). Originally, I had expected that the USDA colonies would be of nearly equal strength (8 frames/colony), however, pesticide residues in the USDA colonies severely limited build-up and the colonies averaged only 3.4 frames of bees/colony. The colonies were used any way with placement of 18 near the NW corner and 18 near the SW corner of the orchard. Bee and nut counts were taken on the diagonal from NW to SE. The bees/tree and nuts/tree (Fig. 1b) both reflect the poor pollination performance of the weak colonies near the NW corner of the orchard. Forager density in the "test" orchard (with pollen traps and the modified colony placement, Fig. 2) averaged 26 bees/tree and the distribution across the diagonal shows a pronounced "dip" at rows 10-25. The weak sister-queen colonies were placed at rows 20 and 25. There was also an unexpected decrease from row 85 to 100 near the SE corner. In the "control" orchard (no pollen traps, "normal" colony placement (Fig. 1a)), the forager density averaged 25 bees/tree and the distribution again showed the "dip" in numbers of foragers in the middle of the orchard.

1983 Almond Pollination Study

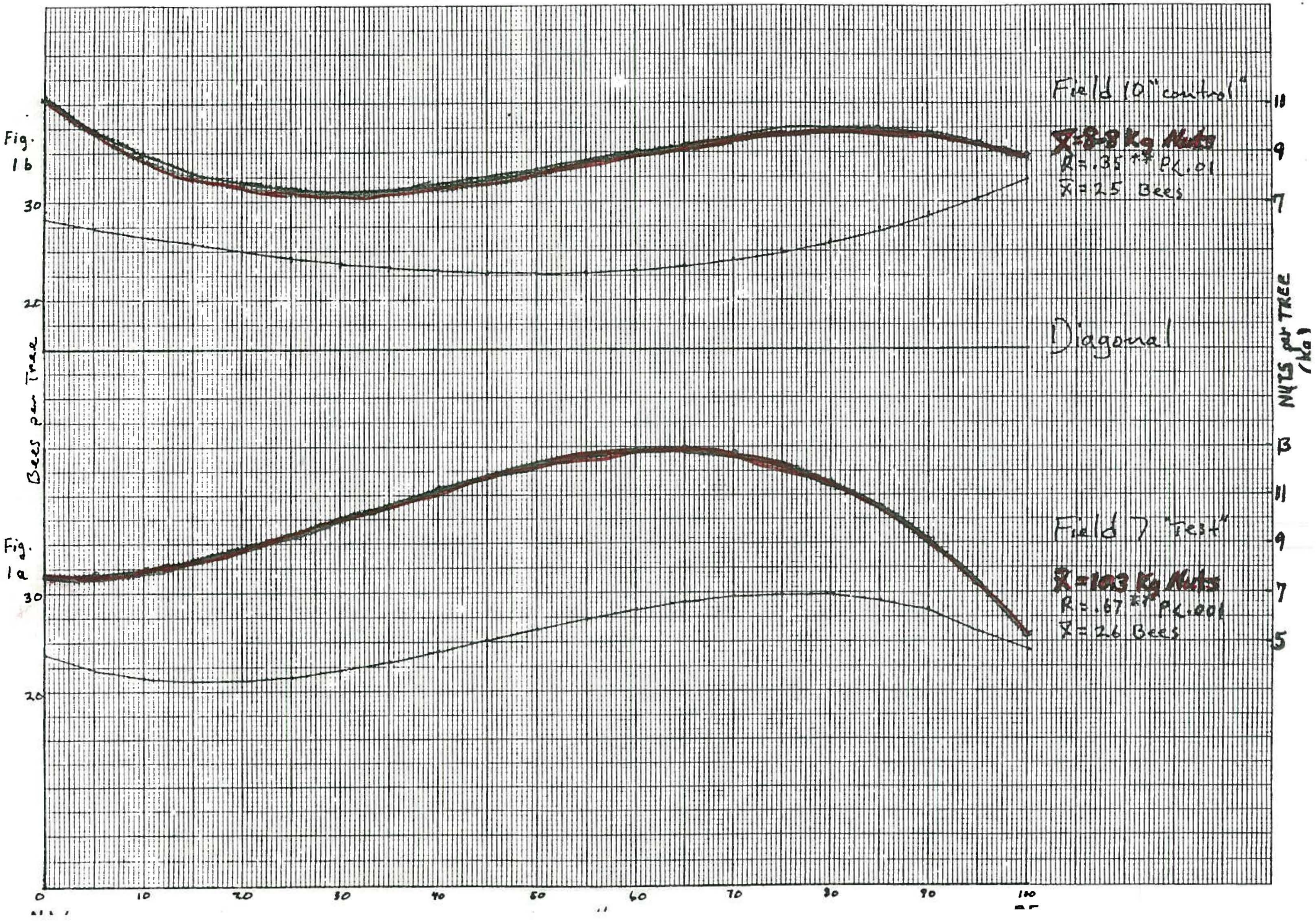
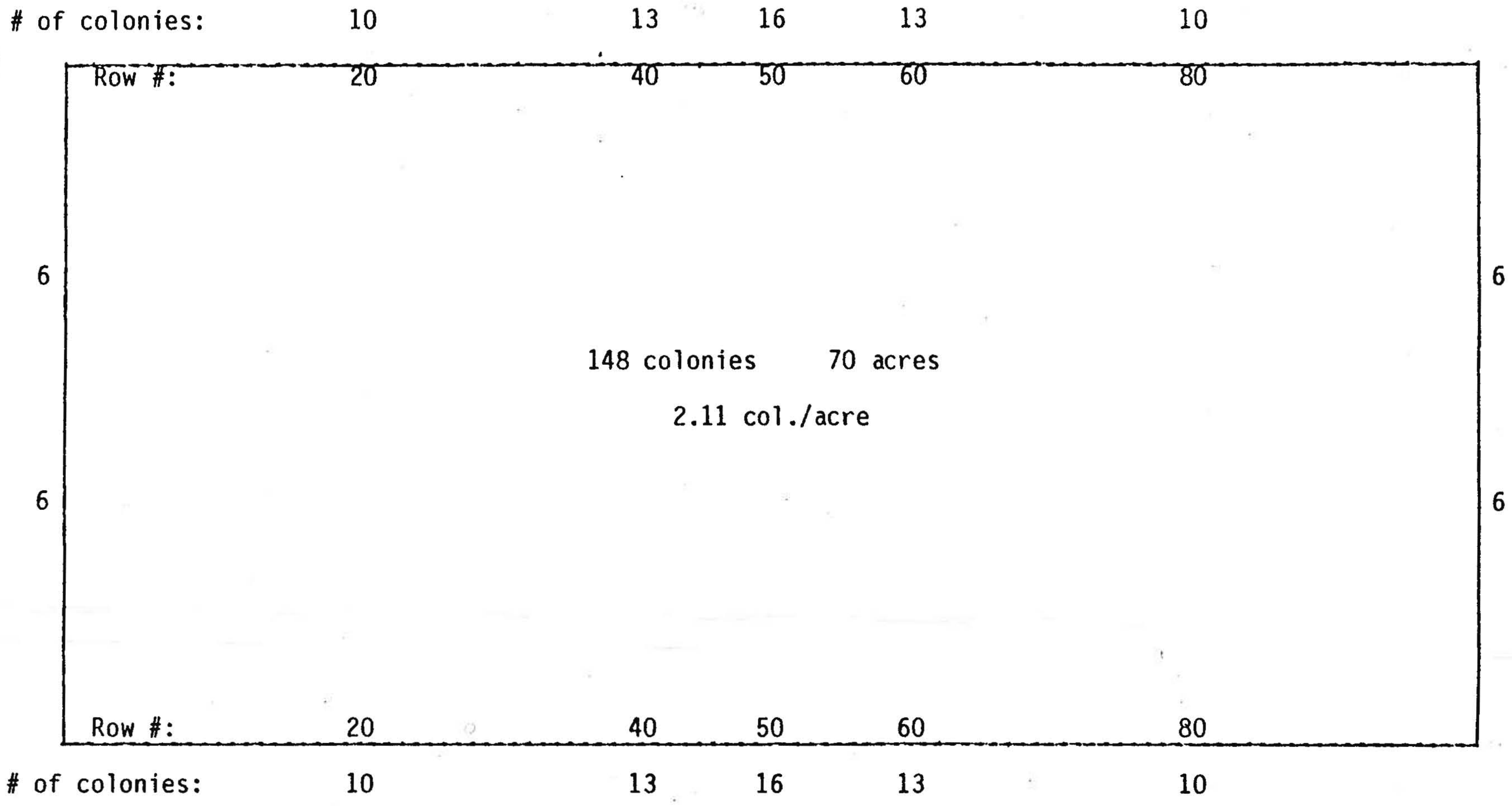


Fig. 2

Colony Drop Proposal for Improved Foraging in Large Orchards



Proposal A

Nut yields in the "test" orchard averaged 22.7 lbs per tree and the nut yield curve was closely correlated with the bees/tree data (R=.67**). In the "control" orchard, nut yields were 19.4 lbs per tree, and although the nut yield curve was significantly correlated with the bees/tree curve (R=.35**), the fit was not as tight as in the test orchard. Nut yields in 1982 for these orchards were 29.5 and 25.9 lbs ("test" vs "control").

It has recently occurred to me that only considering the average nut yields is not the most sensitive measure of the effect of colony placement in these studies. Since forager distribution with normal colony placement always shows a "dip" between rows 40 and 60, and the forager distribution from the modified colony placement usually shows little or no "dip" there, then bee- and nut-counts averaged only from row 30-70 would be a more sensitive measure of the results. Fig. 3 shows comparisons of bees and nuts for both 1982 and 1983 calculated from just the middle 40 rows. In 1982, when the "dip" in foragers in the "control" orchard was less pronounced than in 1983, bees/tree and nuts/tree were equal. However, in 1983, significantly more bees arrived in the middle of the "test" orchard and a significantly higher nut yield was maintained even under poorer weather conditions. It cannot be discerned, from this data, whether the presence of pollen traps on all colonies around the "test" orchard contributed to this higher yield.

Fig. 2 shows the experimental colony placement used in 1982 and 1983. Of the 62 colonies placed along the long side, 67.7% are placed between rows 40-60 (20% of the orchard length). A similar plan is shown in Fig. 4 which would be more convenient for the average beekeeper. In this plan, 36 of the 60 colonies (60%) of the colonies are placed between rows 40-60. An additional pallet of 4 colonies at row 50 would also be a good distribution plan. this would result in 62.5% of the colonies between rows 40-60 and an average of 2.17 colonies per acre.

Fig. 3

COLONY PLACEMENT IN ALMONDS

1982 AND 1983

Av. ROWS 40-60

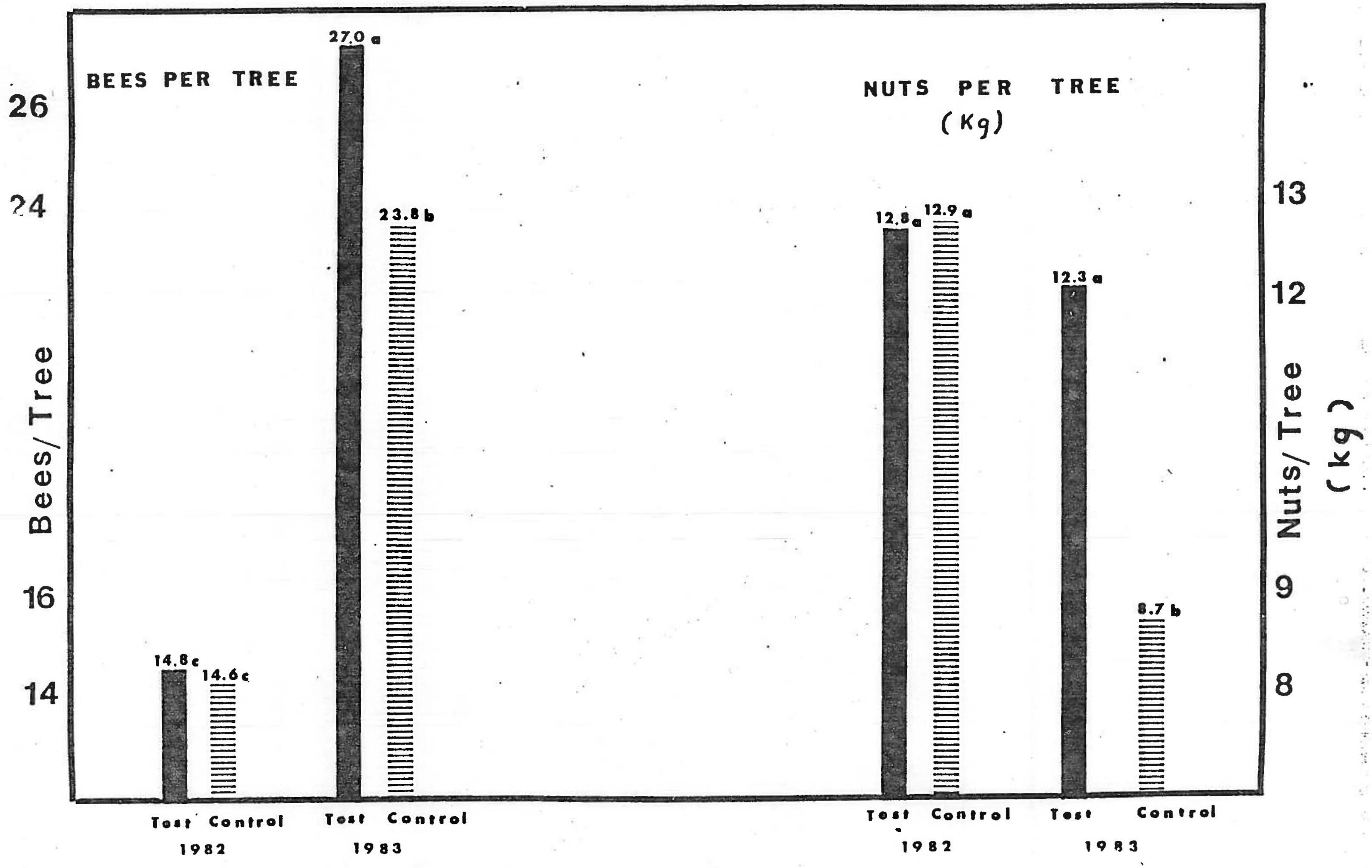
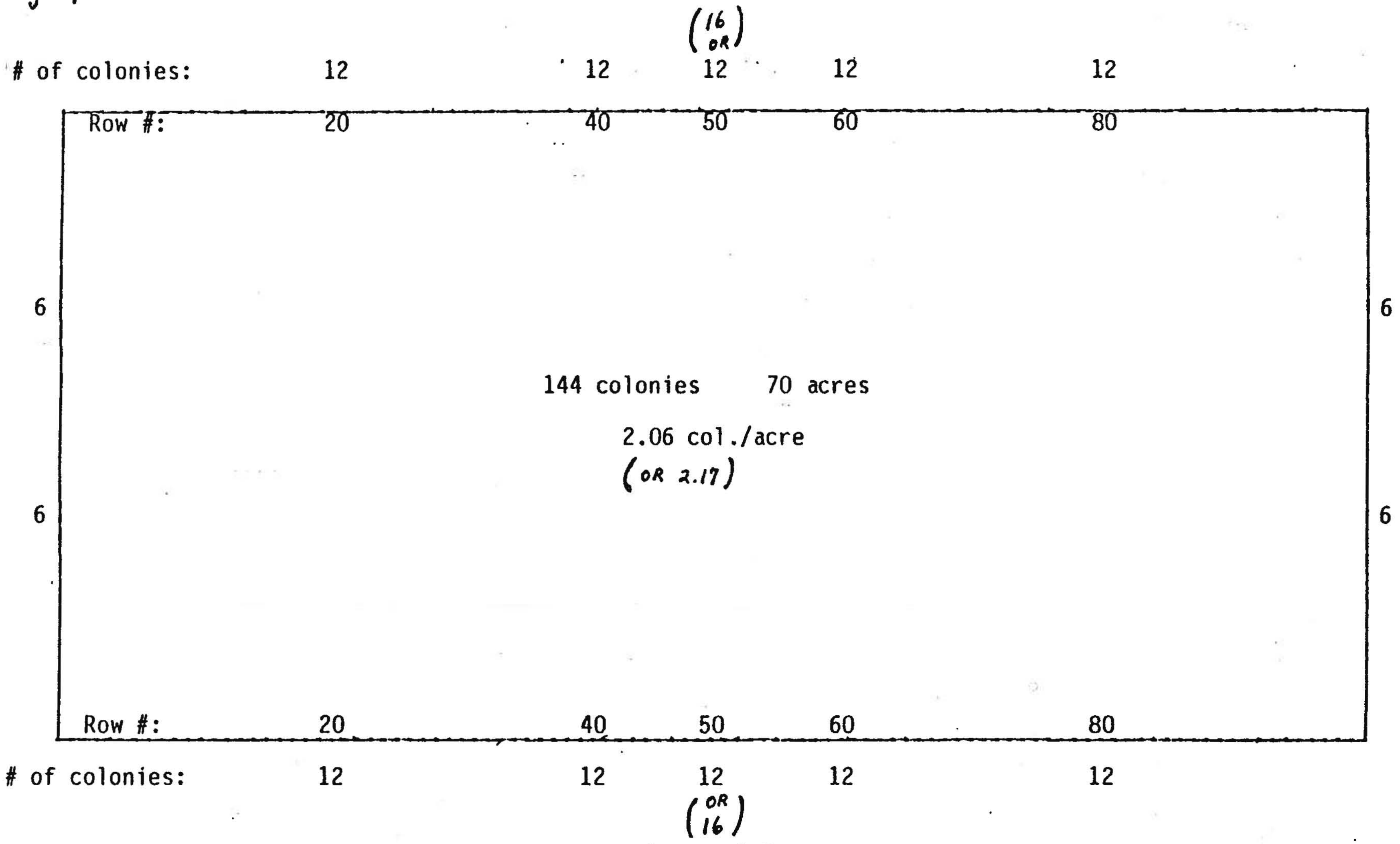


Fig. 4

Colony Drop Proposal for Improved Foraging in Large Orchards



Proposal B

After 3 years of experimental studies with the modified colony placement plan shown in Fig. 2, I find that this placement, for 70 acre orchards, improves the uniformity of forager distribution and nut yield and eliminates the need to actually place colonies in the center of such an orchard. I believe that the close placement of these colonies increases inter-bee competition resulting in an increased foraging flight distance. It should be mentioned that I generally worked with strong colonies - 8 frames/colony (or more), and that weaker colonies may still not send out enough foragers to accomplish similar results.

B. Table 1 shows the effects of traps (3.4 frame, sister-queen (USDA) colonies and 8 frame, commercial colonies) on pollen collection and broodrearing. In contrast to the 1982 results, trapped colonies had much less comb pollen but a lot of trapped pollen. When totaled, results in 1983 were similar to those of 1982 in that colonies with traps collected 47 to 59% more pollen that untrapped colonies. However, in 1983, sealed broodrearing was approximately 38% less in trapped colonies. The area of unsealed brood decreased from the observation of Feb. 15 to that of Feb. 26 except in the stronger non-trapped colonies. Generally, the decrease was greatest in the trapped colonies. Table 2 presents rate of flight (ROF) and percent pollen foragers (PPF) data obtained in 1983 on trapped and untrapped colonies. Although the values were always higher (both ROF and PPF) for the trapped colonies, the apparent beneficial ratios ("stimulation") from trapping were less than the values obtained for ROF in 1982. Again, treatment effects were similar across colony strengths and sources of bees.

Since the pollen storage and broodrearing results were so different between 1982 and 1983, an explanation was sought. One obvious difference was in the amount of pollen collected in the trap (approx. 13 g/col/day in 1982; and 56 g/col/day in 1983). In 1982, the percentage of pollen trapped (vs the total pollen; trapped plus comb) was calculated to be 11.6% (Table 3). In 1983, this

Table 1. Effect of pollen trapping on total pollen collection and brood rearing: Two colony strengths and two sources of bees. February 15-26, 1983. Almonds; Wasco, CA.

		Pollen (grams)†				Brood (cm^2)†		Brood (cm^2)†	
Colony Strength*	Experiment and				Ratio	(Estimates of 2/26/83		(Estimates of 3/8/83)	
(# Frames of Bees)	Treatment**	Comb	Trapped	Total	T/NO T	Sealed	Unsealed	Sealed	Unseale
				Experiment I					
3.4 ± .5	TRAP (n=9)	141 ± 142	620 ± 261	761	} 1.47	1829 ± 365	1677 ± 267	1181 ± 469	-320 ± 37
3.4 ± .5	"NO TRAP" (n=9)	501 ± 477	18 ± 6	519		2594 ± 1307	1759 ± 511	1919 ± 1371	-249 ± 37
				Experiment II					
8.6 ± 1.6	TRAP (n=8)	945 ± 447	1068 ± 278	2013	} 1.59	2811 ± 1397	1767 ± 537	1103 ± 410	-96 ± 56
8.2 ± 1.2	"NO TRAP" (n=9)	1259 ± 660	9 ± 3	1268		3530 ± 1911	1996 ± 498	1743 ± 763	404 ± 56

* Experiment I USDA Sister Queen Colonies; 9 colonies per treatment;
Experiment II Commercial Colonies; 8 colonies with traps, 9 without.

** "NO TRAP"; ineffective trap-like device, with wire grids having 4 holes/inch.

† Values given are the differences between estimates on February 26 or March 8, minus the estimates on February 15.
Means ± standard deviation.

Table 2. Effect of pollen trap on rate of flight and percent pollen foragers: Two colony strengths and two sources of bees. February 1983. Almonds; Wasco, CA.

		Rate of Flight*				Rate of Flight*		
	Treatment**	# Bees/30 Sec.			Treatment	# Bees/30 sec.		
Colony strength	USDA	Date		Colony strength	Commercial	Date		
(# frames of bees)	Sister Queen	2/18	2/21	(# frames of bees)	Colonies	2/18	2/21	2/24
4.1 ± 1.5	TRAP (n=15)	83 ± 78	122 ± 58	8.2 ± .8	TRAP (n=5)	178 ± 85	221 ± 65	75 ± 52
3.5 ± 0.7	"NO TRAP" (n=11)	65 ± 54	108 ± 43	8.0 ± 0	"NO TRAP" (n=5)	131 ± 59	174 ± 55	43 ± 26
Apparent Beneficial Ratio of Trapped Colony		1.28	1.13			1.36	1.27	1.74

		Percent Pollen Foragers†				Percent Pollen Foragers†
		2/17	2/20			2/20
3.4 ± .5	TRAP (n=10)	62.6 ± 16.1	48.4 ± 21.4	8.2 ± .8	TRAP (n=5)	60.2 ± 14.4
3.1 ± 1.3	"NO TRAP" (n=9)	57.6 ± 11.7	39.1 ± 10.4	8.0 ± 0	"NO TRAP" (n=5)	43.6 ± 7.7
Apparent Beneficial Ratio of Trapped Colony		1.09	1.24			1.38

---

* Rate of flight estimated using the Gary flight cone for 30 seconds/colony.

** "NO TRAP"; ineffective trap-like device, with wire grids having 4 holes/inch.

† Percent pollen foragers estimated from bees vacuumed from temporarily closed entrances; bees in plastic bags immediately frozen on dry ice.

Table 3. Estimated pollen collection efficiencies of traps in 1982 and 1983. Almonds; Wasco, CA.

Colony strength (# frames of bees)	Pollen (grams) Trap	Comb	Total	Efficiency % Trapped
1982				
4 - 5 (n=3)	89	569	658	13.5
8 - 9 (n=8)	224	1636	1860	12.0
12 - 14 (n=9)	256	2474	2730	9.4
				Av. 11.6
1983				
3 - 4 (n=9)	620	141	761	81.5
8 - 9 (n=8)	1068	945	2013	53.1
				Av. 67.3

estimate on the newer traps averaged 67.3%. This latter estimate agreed closely with another estimate (63.6%) made on these traps by counting the pollen loads left in the drawer after known numbers of pollen-laden bees had entered.

No measurements of the long-term (2 or more brood cycles) effects of the less-efficient traps were made in 1982. However, in 1983, this was studied and even the detrimental effects of the 67% efficient traps were not extremely severe (Table 4). The colonies with traps for only the almond bloom averaged 608 cm^2 less brood and the colonies trapped for 2 brood cycles averaged 1088 cm^2 less brood than those without traps (estimated just before the 2nd brood cycle emerged). This was less of an effect than what we had expected based on the short term differences seen and reported in Table 1. In this test, only the comb pollen was estimated (records of trapped pollen were not kept after the almond bloom). Pollen, especially from <u>Brassica</u> spp., was readily available near the Tucson apiary location in March, 1983. Thus, after 40-41 days of pollen trapping, the trapped colonies had more stored comb pollen than the untrapped colonies due to the combined effects of stimulated pollen collection and less broodrearing.

Our experience with conducting experiments studying the effects of pollen traps on honey bee colonies has resulted in some general observations as well as specific results. We believe that a number of colony management factors must be recognized and experimental parameters standardized before meaningful results can be obtained. Inconclusive results and/or opposite results in our studies and those of other researchers probably stem from not having recognized or standardized these parameters. For example, we think that drifting of bees away from the weaker 4-5 frame colonies in 1982 was accentuated by having 6 colonies on each pallet; i.e, the colonies were very close together and not all the colonies in the apiary were fitted with traps. In our opinion, any study of the effects of pollen traps must consider the following factors:

Table 4. Long term (2 brood cycles) effect of pollen trapping on brood production and comb pollen storage. February - March, 1983. Almonds: Wasco, CA.

Treatment (n=7)	Colony Strength* (# frames of bees)	Brood (cm^2)**			Pollen (cm^2)
		Sealed	Unsealed	Total	
TRAPS ON:					
Almonds only (n=7) (Feb. 15-26)	10.1 ± 3.8	3897 ± 924	4248 ± 911	8146 ± 1742	580 ± 494
2 Brood cycles (n=7) (Feb. 15-March 26)	10.7 ± 2.1	3604 ± 685	4062 ± 631	7666 ± 1031	647 ± 355
NO TRAPS (n=7)	11.3 ± 2.7	4359 ± 534	4395 ± 886	8754 ± 998	312 ± 163

* Estimated on March 25-26.

** Values given are the differences between estimates on March 26, minus the estimates on February 15. Means ± standard deviation. Colonies were returned to Tucson area on March 1.

1) All colonies in the test should be made uniform in regards to colony strength, honey and pollen stores and extent and stage of broodrearing. All equipment should be "tight" - so bees have to enter through the trap.

2) All colonies in the test apiaries should be fitted with traps at least 1 week before the expected pollen flow (some colonies never adapt to the trap and should be eliminated from the apiary).

3) Individual colonies in the apiary should be visually "distinctive", either by color markings or colony orientation (or both) to reduce drifting.

4) Some careful estimates of the pollen removal efficiency of the trap(s) must be made and reported.

5) Both the pollen trapped and that in comb storage must be measured.

6) Future studies should also refine measurement techniques to improve uniformity and also to estimate the quantity of pollen consumed during the duration of the test.

In general, placing pollen traps on colonies increased pollen collection by stimulating increased flight and possibly increased percentage of pollen foragers. This is in close agreement with the recent studies of Dr. R. Thorp. With traps of approximately 11% pollen removing efficiency, the traps resulted in increased comb pollen storage and little effect on short-term (almond bloom) broodrearing. However, traps with approximately 67% efficiency resulted in less comb pollen storage and reduced (short-term) broodrearing. Apparently, longer term effects of pollen trapping will depend on the availability of pollen and rates of brood-rearing. With sufficient pollen flow, trapped colonies will have more room for egg laying and broodrearing.

In some cases of heavy pollen flow, untrapped colonies can "plug out" with pollen and restrict broodrearing. Perhaps traps with 20-30% pollen removal efficiency will permit optimum pollen collection without adverse broodrearing effects over both the short term and the long term.

Colonies rented for almond pollination provide a rather unique opportunity to study and perhaps capitalize on the stimulatory effects of pollen traps. There are not many crops which absolutely require insect cross pollination and are at the same time attractive and sole pollen sources. In almonds (and perhaps in tree fruits and sunflowers), increased pollen foraging means increased pollination of the "target" crop rather than just general pollen foraging. As discussed in the results section of Objective A (above), forager numbers (bees/tree) in the orchard surrounded by colonies with pollen traps were essentially the same as in the orchard without pollen traps ("control" orchard). Nut yields in 1983 generally, (and in the control orchard), were only 67% of the 1982 yields probably due to poor weather conditions during the last week of bloom. Nut yields in the "test" orchard (with pollen traps) were 80.5% of the 1982 yields. This slightly better yield in the "test" orchard could be due to several non-pollinator related factors (fertilization, insect control, etc.) especially since the orchard yield averages were in a similar relationship in 1982 (i.e., control being approximately 85% of the "test" yield).

C. Relative efficiency of pollen traps.

Table 5 presents the data and statistical significance of 5 days of observations. Data are presented from only one colony fitted with a .045" wire since a great deal of confusion and outside clustering occurred on the 2 other colonies, apparently only because those 2 colonies were facing South (towards the sun) while the others were facing East. The restricted entrance area of the commercial .023", .037" and .045" traps apparently resulted in insufficient ventilation; ambient temperatures were often in the 22-25°C range and with an excellent nectar flow (and "weak" almond nectar sugar content of 11-13% TDS), heat stress and ventilation requirements were high. The F-value derived from the ANOVA of the data on Column 1 (data from mid-morning to early afternoon) was 7.86

Table 5. Pollen removal efficiency of several types of pollen traps. Almond bloom, 1983.

			Percent Efficiency
			Data Obtained
Trap type	# of colonies	# of Replications	Mid-morning to early afternoon
USDA, .023" wire	4	6	63.6 ± 14.9a*
Commercial, .023" wire	3	6	58.4 ± 15.8a
" " .037" wire	3	11	58.8 ± 12.2a
" " .045" wire	1	4	42.0 ± 2.7ab
" " perforated plate	4	13	33.3 ± 16.0bc

* Means ± standard deviation; treatments having different letters within tests vary significantly according to Duncan's multiple range test.

(required = 3.91 at .01 probability level). The Duncan multiple range test showed that the perforated plate was significantly less efficient (at the .05 level of probability) than the USDA and the commercial, .023" and .037" traps. It would appear that the latter 3 traps were equally efficient; the .045" was less efficient, and the perforated plate was the least efficient. All comparisons must be made under uniform time of day, pollen flow, and temperature conditions.

Although the wire diameter of the .037" (0.9 mm) was less than that of the .045" (1.1 mm) wire, because of the coating on the .037" wire (especially in the corners) the wire to wire distances were essentially the same. There was a general "roughness" to the surface of both the .023" and .037" wires, but the .045" wire was of a different, precoated material that was much smoother. This may have made the .045" wire trap less efficient (42 vs 58%). The greater space between the grids of the .023" and .037" wire traps (7.4 mm) vs the USDA .023" wire trap (6.35 mm) is probably responsible for the slightly less efficiency of the non-USDA traps (58 vs 64%). The fact that the USDA .023" diameter trap had a larger wire-to-wire dimension (4.6 mm) vs 4.1 for the .037" and .045" traps but was apparently still the most efficient trap would seem to indicate that between grid spacing is more important than small differences in hole size. For very practical reasons, a large entrance for bees is helpful, especially on larger colonies, both to reduce confusion at the entrance and to provide better ventilation for the colony.

In a separate test, I studied the trap effects on colonies fitted with traps similar to those reported here which varied from 65% (USDA) to 11% (commercial) efficient. Both traps seemed to stimulate total pollen collection by increasing pollen foraging but while the 11% trap did not affect broodrearing, the 68% trap reduced broodrearing by 38% after only 10 days. The relative efficiency of any trap(s) used is a controlling parameter and should be reported in any behavioral study.

D. Empty shallow with and without a queen excluder.

Originally, the idea behind this experiment was based on 2 observations (not in almonds): 1) that bees in a heavy pollen flow will sometimes "unload" it at the first opportunity (instead of only around the brood) and, 2) that the above behavior may be enhanced if there is an "obstruction" between the empty comb and the brood chamber. Instead of a wire grid (as in pollen traps), a queen excluder was used as the "obstruction" in this study.

Table 6 gives a summary of the data. Initial colony strength (in terms of frames covered with bees), brood, and pollen were uniform. Pollen storage around the brood chamber increased about 550 square inches. Although there was a trend toward increased pollen storage and rate-of-flight favoring the shallow-supered treatments, the differences were not statistically important. Essentially no pollen was "unloaded" in the combs of the shallow super.

Table 6. Results of shallow super study - Almonds, 1983.

		Square inches of:				
				Δ Pollen** (brood chamber)	Pollen (in shallow)	
Treatment	Population	Pollen	Brood			ROF*
Control (date)						
2/15)	13.7	213	479	519	0	(2/17) - 134.6
(2/19)	12.5					(2/19) - 157.1
Shallow						
(2/15)	13.2	231	424	564	0	(2/17) - 167.2
(2/19)	12.2					(2/19) - 179.8
Shallow and excluder						
(2/15)	13.1	223	433	572	0	(2/17) - 152.9
(2/19)	12.8					(2/19) - 178.4

* ROF = Rate of Flight; bees/30 sec. using the Gary flight cone.

** Δ Pollen = increase in square inches of pollen from 2/15 to 2/28.

Manuscripts

1. Relative pollen removal efficiencies of pollen traps. G. M. Loper for Apidologie (in peer review).
2. Effect of pollen traps on total pollen collection and honey bee colony development in almonds. G. M. Loper, R. Thorp, J. H. Martin and R. L. Berdel. For Am. Bee J. (in co-author review).
3. Effect of colony distribution around 70 acre almond orchards on honey bee forager distribution and nut yields. G. M. Loper, R. L. Berdel and B. Vaissiere. (In preparation).