1986 ANNUAL REPORT TO ALMOND BOARD OF CALIFORNIA

Project No. 86-M11 - Tree and Crop Research
Pollination

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

Interpretive Summary: We compared the effects of sugar syrup feeding, pollen traps and colony strength on flight activities of honey bees. Feeding sugar syrup during almond bloom somewhat increased pollen foraging as it did during the inclement pollination period of 1983. This suggests that feeding sugar syrup is most beneficial during inclement seasons, especially since we found no significant benefit during the ideal pollination weather years of 1984 and 1985. Pollen traps significantly increased pollen foraging from test colonies as they have done before. These two techniques may be used to improve the pollination efficiency of honey bee hives rented for almond pollination, frequently those with six to eight frames of worker bees. A research update on these techniques was distributed by the Almond Board in October 1986.

A high degree of correlation was again found between cluster size versus intensive frame by frame measures of honey bee colony strengths. Cluster counts, which are less disruptive to honey bee colonies, seem to be satisfactory evaluations of pollination potential. A research update on this was distributed by the Almond Board in August 1986.

Controlled pollination with hive entrance pollen inserts was tested on Mission trees. Fruit set was significantly highest in trees nearest Nonpareil regardless of whether they were near to or away from hives with pollen inserts indicating the overriding importance of pollen transfer between cross-compatible cultivars.

Pieces of carpet were placed at the entrances of honey bee colonies in an almond orchard to determine the amount and viability of pollen deposited by returning foragers. Some were used to contaminate workers from hives caged with almond trees, but only one fruit was produced. Germinations of pollen from carpets, pollen trap screens, trapped pollen and pollen from anthers indicate reductions in viability due to pollen collection, trap type, carpet type and freezer storage.

Osmia lignaria had over 90% emergence from 100 cells, but only 8 cells were provisioned. Remaining adults absconded after the population was moved out of the orchard at the end of bloom. *Osmia cornuta* emerged in synchrony with early bloom, but <50% of the 175 nests showed emergence. Only 22 nests were completed by the end of almond bloom in early March, but females remained active until mid-April and completed 110 new nests.

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Tree Research: Pollination (Project No. 86-M11)
R. W. Thorp, U. C. Davis

Honey Bee Colony Strength Assays:

We continued to gather data comparing cluster versus frame by frame estimates of colony strength in the process of selecting colonies for experiments on the effects of feeding sugar syrup, pollen trapping and colony strength on flight activities.

Materials and Methods: On 4 February, 101 honey bee colonies in an overwintering yard were evaluated for strength using the cluster technique as described in previous reports and in an Almond Board research update for October 1986. Populations of 86 of these colonies were estimated with frame by frame (intensive) counts on 5 and 8 February as described in previous reports. From these 55 colonies were selected for observations of flight activities in relation to sugar syrup feeding, and placement of pollen traps or carpeting at their hive entrances (see below). Final strength estimates were made on 11 and 14 March.

Results: The following is a summary of simple correlation analyses of the various strength parameters measured:

	Intensive Count	Brood Area	Cluster Obs #1	Cluster Obs #2
Brood Area	.573**			
Cluster Observer 1	.842**	.499**		
Cluster Observer 2	.807**	.484**	.934**	
Non-pollen bees	.131	.216	.149	.149
Pollen foragers	.162	.155	.253	.194

**= Significant at P=.01

Tables 1-4 give the percent changes in colony strength measures between initial and final strength counts by treatment group.

In general, feeding sugar syrup increased growth of colonies (significantly so in 6 categories) whereas pollen trapping seemed to depress the rate of growth (significant increases in only 2 categories).

Discussion: As in previous years the correlation between cluster and intensive counts is high, indicating that cluster counts may be used as a rapid means to assess colony strength. The correlation between the two observers making the cluster counts was very high. However, they both called their estimates of the same colony to the same recorder, and thus, may have influenced the others estimate.

To determine whether feeding sugar syrup to colonies with pollen traps would help ameliorate the depressing effects of pollen traps on colony growth, we reexamined our 1984 and 1985 data. Some of our treatments involved contrasts between feeding colonies that had pollen traps and those that did not. We found no significant differences in growth within size categories. However, not all combinations were equally represented in these experiments. Specific tests need to be designed to examine this question.

Honey Bee Management Techniques to Improve Pollination

Colonies measured to compare strength estimates (see above) were used in the following experiments. In a continuing effort to determine whether almond pollination can be increased through various methods of colony management, an experiment was set up to test the effects of feeding sugar syrup, pollen traping and colony strength on flight activities.

Materials and Methods: From the 86 colonies measured for strength by the frame by frame intensive analysis method, 55 colonies were selected for observations of flight in relation to sugar syrup feeding, or placement of pollen traps and carpeting at their hive entrances. On 13 February the colonies were moved into an almond orchard near Dixon, CA. Small front type (Kremer) pollen traps were placed on 15 colonies. These traps were activated on 20, 21, 25-28 February and 3-6 March. Pollen was collected at the end of each of these days, dried in an oven and weighed. On those colonies without pollen traps, "robber screens" (devices to prevent bees from other hives from robbing honey) were placed at their entrances.The robber screens covered about 0.6 of the length of the hive entrance. On the remainder of the entrances, strips of carpeting or fibrous fabric were placed to intercept pollen from incoming bees. These strips, which were attached to the hive entrances with push pins, were removed, and placed in a freezer late in the afternoon. On 20, 21, 24-28 February and 3-6 March, 30 second counts of incoming bees with and without pollen loads were made by placing an 8 mesh hardware screen in front of the entrance as described in previous reports. On 18 and 26 February, 20 colonies were fed with about one gallon of sugar syrup per day.

Results: Results are given in tables 5 and 6. Pollen trapping significantly increased the numbers of pollen foragers by 61.4, 49.5 and 67.9% in the 4, 6 and 8 FOB categories respectively ($P<.05$ for 4 and 6 FOB). Feeding sugar syrup increased the numbers of pollen foragers by 13.8, 36.1 and 32.3% in 4, 6 and 10 FOB categories, but not in the 8 FOB group (increases were not significant with Tukey's range test). Over all strength groups, pollen trapping increased pollen foragers by 59.6%($\pm$9.3) and feeding gave an increase of 20.3%($\pm$16.8).

Pollen traps increased non-pollen foraging 40.0, 99.7 and 66.4% in the 4, 6 and 8 FOB groups respectively ($P<.05$). Feeding sugar syrup increased non-pollen foragers in the 6 and 10 FOB groups by 18.0 and 5.9%, but decreased it in the 4 and 8 FOB groups by 19.0 and 1.7% respectively. Only the change in the 10 FOB category was significant ($P<.045$).

Analyses of flight data of 2 days before feeding, 3 days during feeding and 2 days after feeding showed no significant change in flight number of either pollen or non-pollen foragers.

Discussion: As in the past, pollen trapping proved beneficial in stimulating flight. The fact that both pollen and non-pollen foragers increased, indicates that the foraging force has been supplemented by bees normally involved in other activities in the hive.

The Kremer traps used this year are easier to install than the O.A.C. traps used in the past. A modified version of this trap could probably be produced inexpensively in numbers. A possible disadvantage is that they are not as efficient and do not store as much pollen as some traps thus necessitating more frequent emptying. Modification of

the traps could probably alleviate these problems. [See Almond Board research update for October 1986 for more details].

The fact that feeding increased foraging among pollen foragers, but gave mixed results with non-pollen foragers is difficult to explain. We thought we had noticed "robbing" behavior after feeding in a previous year. "Robbers" would appear like non-pollen foragers and could give distorted counts, especially since certain strength groups (weaker colonies) are more susceptible to robbing. Robber screens to discourage robbing were in place this year. No robbing was noticed, but it is still possible that some robbing flight was mistaken for normal flight. More research on feeding sugar syrup during bloom needs to be done to explain the anomalies noted in flight of non-pollen foragers.

The lack of significant differences before, during and after feeding indicates that effects of feeding on increasing flight activities are subtle and probably through a more long term effect on colony strength related to flight activity.

The low correlations between various colony strength measures and flight are puzzling, and seem to indicate that other factors in addition to strength are contributing to a large amount of the variation in flight.

Pollen Germinability

Germinations of pollen sampled from carpets, pollen trap screens, trap trays and anthers were made to determine the effects of collection date, trap type, carpet type and freezer storage on pollen viability.

Materials and Methods: Pollen was incubated on 1% agar slabs overnight at room temperature in microscope slide boxes with moistened paper towels to keep the humidity high. Slabs were then stained with 0.1% basic fuchsin for 30 seconds and cleared with 0.1% acetic acid in 70% alcohol.

Results: Table 7 shows the differences in germinability of pollen from flowers as compared to pollen from trap grids and trays, carpets and fabric on different dates. Freezing reduced germination of pollen collected on carpet, and in OAC pollen trap trays. Collection and freezing (-20°C for 4 weeks in air tight plastic bags) reduced germination by 47.5% in comparison to almond pollen collected from fresh flowers. Pollen from the white fabric had the highest germination (51.2% $\pm$12.1).

Discussion: There were significant variations in pollen germinability on agar on different dates for the same treatments. There is a general tendancy for germinability to decrease steadily from 24 February on, especially in comparison with that on 20 and 21 February. This may be due to progressive senescence of viability at the end of the season. A shift toward warmer temperatures during this period (maxima of 59° and 60°F on 20 and 21 February versus 69° to 74°F from 24 through 26 February) may have enhanced this trend. Pollen lost much of its germinability after being collected and deposited in pollen trap trays, and on pollen trap grids, carpets and fabric. This may be explained by

the fact that honey bees add nectar and enzymes to pollen as they pack it for transport. Germinability on agar seems inversely related to the amount of exposure to sunlight as seen in samples from 2 February:

Kremer tray	Little exposure	29.8%
Kremer grid	Moderate exposure	14.3%
Blue Fabric	Exposed	11.5%
Carpet	Exposed	11.3%
White Fabric	Exposed	10.0%

Although a trend is apparent, the differences are not statistically significant.

Pollen Deposition on Carpeting at Bee Hive Entrances

Carpeting and other fabric strips pinned to honey bee hive entrance landing boards were used to monitor colony strength and flight activity.

Materials and Methods: Two different types of material (carpet and polyester fabric) were placed at the entrances of 16 hives (4 of each colony strength category: 4, 6, 8 and 10 FOB). These were subsequently examined for the presence of pollen from returning foragers. A piece of material was fixed on the entrance of each hive early in the morning and was removed and placed in a plastic bag late each afternoon. These were returned to the laboratory and stored in a freezer at -20°C for further processing. Data were collected for 3 days. To extract pollen from the strips of material, samples were emersed in 70% ethyl alcohol then sonicated for 10 minutes. A second rinse with alcohol brought the totals used to 100 or 200ml. Spirit-soluble aniline blue stain was added and the solution was allowed to stand for 5 minutes. The solution was filtered through a fine mesh screen to remove debris other than pollen and finally vacuum filtered through a preweighed glass microfiber filter. After all of the liquid had drained through the filter the vacuum was left on for about 30 seconds so that the filter and sample would dry slightly. The filter was then dried for one hour at 40*C and then weighed to determine the increase in weight due to pollen from the original strip of material. Analyses of variance, correlations and regression analyses were used.

Results: There was no significant difference between the two types of carpeting materials. The average amount of pollen extracted from the carpeting materials was significantly different ($F=3.5$, $P<.05$) for the 4 strength groups. The 10 frame colonies were significantly different from the 4 FOB in weight of pollen deposited on the strips of material:

Strength Group	Pollen Weight (g) $\bar{X}$	SD	Pollen Foragers (#) $\bar{X}$	SD
4	.008	.003a	5.60	2.43
6	.013	.003ab	8.74	7.00
8	.014	.004ab	11.91	8.73
10	.016	.004 b	10.27	3.44

[Numbers followed by the same letter are not significantly different (Duncan, $P<.05$)]

The correlation between the amount of pollen and the strength of the colonies was .568. The correlation between the number of pollen foragers and pollen weight was .638 with highly significant relationship ($P<.01$). The regression of pollen weight on the number of pollen flights was significant at ($F=.963$, $P<.001$). [The regression equation is: pollen weight $=.0084 + .0005$ X average number of pollen foragers, Fig. 1).

Using the logarithm of average number of pollen foragers to normalize the data did not show differences, except good scattered distribution of the points around the regression line (Fig. 2)

The regression equation is: pollen weight$= .001 + .013$ X log of average number of pollen foragers with correlation of .689.

Discussion: These data suggest that pollen weight can be used as a good predictor of number of pollen foragers, and possibly colony strength. The relationship of pollen weight and pollen foragers showed that after a certain point the carpet seemed to be saturated with pollen. Excess pollen on the carpet may be redistributed to the orchard by outgoing foragers or may be removed by bees we saw chewing at the materials.

Bee to Bee Pollen Transfer at Colony Entrance

In an attempt to determine whether pollen can be transferred to outgoing bees from pollen-contaminated carpeting, a cage experiment was performed at U.C. Davis.

Materials and Methods: Four screen cages were set up in a plastic greenhouse. Potted almond trees and colonies with 2.5-3 frames of bees were placed in each cage. Strips of carpeting were pinned on hives in the same manner and in the same orchard as our bee management experiments. After several hours of exposure to traffic by foraging bees, the carpets were removed and either placed directly on entrances of caged hives or stored in a freezer until use. Two branches on each tree were covered by limb cages to exclude bees from foraging. These limbs were hand pollinated with commercially collected almond pollen (see insert trials described in another section). Fruit set counts were taken on caged and uncaged limbs of these trees.

Results: Only one fruit was produced on the uncaged limbs on the four trees. The hand pollinated limbs had an average of 29.4% fruit set.

Discussion: If this experiment is any indication, there does not appear to be much effective transfer of pollen from carpets to outgoing bees. We thought we observed bees collecting pollen directly from carpeting in the cages and in the orchard. This behavior has also been noted with pollen inserts, and might reduce the effectiveness of inserts and carpeting unless these bees get the pollen on themselves and later forage on flowers, or transfer it to other bees that later forage. Another possible reason for low fruit set may be, as noted in the germination section, that pollen on carpets and frozen pollen was significantly less viable.

Bloom and Fruit Set Counts

In order to provide data for the ALMOPOL pollination and fruit set model being developed by Drs. G. DeGrandi-Hoffman and G. Loper of the USDA Carl Hayden Bee Laboratory, Tucson, AZ, we gathered data on bloom phenology an fruit set in orchards near Dixon, CA.

Materials and Methods: Starting on 18 February, counts were made of buds and receptive and senescent flowers on 5 cultivars in an orchard near Dixon, CA. Counts were continued on a daily basis as possible until 27 February. Counted limbs were tagged with engineers flagging tape. On 14 April, fruit on tagged limbs were counted.

Results: Table 8 shows the percent bloom and fruit set by cultivar and date. In general, the earliest cultivars suffered most from heavy rains early in the bloom period.

Discussion: Rains early in the season (12 and 14-17 February) prevented bee flight adequate to pollinate receptive flowers. When the weather did finally break, most of the cultivars had already progressed into bloom due to the relatively warm weather accompanying the rains. This may have provided so much forage that bees could not adequately cover it. Fruit sets and yields reflected this almost worst possible scenario. Bloom counts on 21 February were taken from more interior areas of the orchard. They differ quite markedly from those on other dates for the same cultivars suggesting an effect of orchard location.

Orchard Mason Bees, Osmia lignaria and Osmia cornuta

Studies in cooperation with Mr. Phil Torchio, USDA Bee Lab, Logan, UT, continued on the potential for commercial pollination management of Osmia lignaria, the blue orchard mason bee, and Osmia cornuta, the Spanish orchard mason bee. These studies are to determine whether these bees can be used as pollinators of almonds, especially in the face of the threats posed to honey bee pollination services by the tracheal and Varroa mites and the Africanized bee.

Materials and Methods: Osmia lignaria nests from the 1985 season were held at room temperature (ca 75°F) over the summer, placed in a refrigerator (ca 40°F) in August after pupation to overwinter, removed from refrigeration on 10 February and held at room temperature again. Males started emerging on 13 February. Because the weather was not good for flight at that time, the bees were placed back in cold storage in hopes that the weather pattern would improve. Finally, during the drizzly afternoon of 19 February, the bees were placed in the same orchard near Dixon where the bee management experiments were set up. Bees were set out in paper straws placed inside drilled styrofoam cut to fit inside waxed 1/2 gallon milk cartons. The cartons with bees were placed one per tree in a rectangular pattern of trees. Around this rectangle were placed cartons with empty straws to catch dispersing bees. Prior to dawn on the foggy morning of 6 March, after almond bloom was complete in the orchard, nests were moved to the UC Davis farm to allow remaining females to complete their nests.

Osmia cornuta populations were returned to Logan, UT in spring 1985 for analyses of nests. In July 13 boxes with 67 capped nests and 258 empty straws were returned to Davis and placed in an experimental

orchard on the campus farm to test survival through the summer. The remaining 13 boxes with 113 capped nests and 212 empty straws were returned to Davis on 13 December. Both sets of nests (less one of those that spent the summer in Davis that was either blown from its tree or removed by birds) were placed out on 17 December in a square pattern within an orchard south of Dixon, CA where survival had been the best in our 1985 trials. On 7 February, 29 trap nest boxes containing 725 empty straws were set around the periphery of the boxes with filled nests and original nests were inspected for emergence. Observations on flight and nest activity were made on 18 and 24 February, 1, 14 and 28 March, and 5, 11 and 19 April.

Results: Osmia lignaria exhibited 92.7% emergence from 96 cells placed out. Brief inspections on 24 and 28 February and 1 and 3 March showed that the bees continued to emerge. Little activity was noted during any of the nest inspections, but individuals were seen sitting inside the straws. On 1 March, at 11:45 of a foggy morning, a cursory count showed there were 26 males, 9 females and 12 other bees too deep in the straws to determine their sex. When the nests were moved to a new location after the end of almond bloom, most of the females apparently absconded . As a result, only 8 cells with live bees were recovered when the nests were dissected.

Osmia cornuta emergence (23/62 over summer in Davis; 41/113 over summer in Logan) was noted by 7 February, (coinciding with early bloom) and some males and possibly females were active. The first new nests (2) were plugged by 24 February and little new emergence was noted after this date. By 1 March when most of the bloom was finished, only 22 nests had been capped, but males and females were still active so the nests were left in place. The last active male noted was on 28 March, the last female seen was on 11 April by which date 112 new nests (=64% of initial) had been capped. No bees nor new nests were noted on 19 April. Nests held in Davis versus those held in Logan from July into December showed 46.8% and 40.7% emergence respectively. Nests were returned to Logan for analyses on 24 April. The surviving 75 nests containing 56 females and 87 males (=58.1% of the population introduced to the orchard on 17 December 1985) were returned to Davis and set out on the UCD farm to overwinter on 1 October.

Discussion: Osmia lignaria is solitary and does not have stored food to tide it over during inclement weather. It appears to be less likely to survive prolonged periods of inclement weather than does the honey bee. Unless methods can be found for providing them with food and for being able to move them to subsequent crops when their adult flight period extends beyond almond bloom, they may prove difficult to manage for almond pollination.

Osmia cornuta did initiate emergence in good synchrony with almond bloom and little evidence of new emergence could be found beyond 17 days later. However, foraging and nesting activity continued for about 6 weeks beyond almond bloom. Despite this long nesting season the females that emerged did not replace the initial population during the 1986 nesting season. Less than half the original number of nests are available for overwintering and to start the 1987 bloom season. Unless more reliable means of reproducing and increasing populations of these bees can be found, they are not likely to be commercially viable.

Controlled Pollination

Controlled pollination with hive entrance pollen inserts was tested on Mission trees in an almond orchard near Davis with an unfavorable planting pattern.

Materials and Methods: The test orchard was planted to 4 rows of Nonpareil bordered on one side by 2 rows of NePlus Ultra and 4 rows of Mission on the other. The rainy weather during Nonpareil bloom prevented us from applying pollen during the most favorable time for that cultivar, but we were able to conduct the planned experiment in the Mission rows. Commercially collected NePlus Ultra pollen (with anther hulls) was applied via hive entrance pollen inserts on 10 strong honey bee hives at the east end of the 27 acre orchard on 22 and 23 February. Both days were sunny with maximum temperatures of 62° and 68°F respectively. A total of 1,500 grams of material was added to the inserts 7 times at 20 to 45 minute intervals between 12:00 and 15:25 on the 22nd and 9 times at 20 to 50 minute intervals between 11:40 and 16:00 on the 23rd. Bees were flying actively while pollen was being applied. Flower and bud counts were initiated on the 22nd on Nonpareil but dropped after 8 limbs were counted due to its advanced stage of bloom. Flower and bud counts were made on limbs of 5 to 10 Mission trees in the row nearest to and furthest from Nonpareil trees at the east and west ends of the orchard giving four plots. All small buds and scenescent flowers were removed so that later fruit set would reflect the percent of pollination of flowers receptive at the time of pollen application. A minimum of 1,000 blossoms were counted in each plot. Hand pollinations of a total of 49 emasculated flowers on 2 limbs each of 3 Mission trees near the hives with inserts on 23 February compared viability of the pollen used in the inserts with fresh pollen from Nonpareil and no pollen.

Results: The majority of the blossoms on Nonpareil were senescent and there were very few buds. The percent of flowers versus total blossoms ranged from 71.6 to 96.5% (average: 86.8%). The majority of blossoms on Mission were in the receptive and bud categories. The percent of flowers versus total blossoms ranged from 3.3 to 92.2% (average: 56.3%). Fruit set was significantly higher in Mission trees nearest Nonpareil, regardless of whether they were near to (8.0 versus .142%; P=.001) or at the far end away from hives with pollen inserts (11.05 versus 2.75%; P=.034). Fruit set was slightly higher in the end of the orchard away from the hives with pollen inserts. This was significant only for the rows away from Nonpareil trees, but these were all less than 3% fruit set. Hand pollinations produced no fruits from any of the treatments. However, pollen tubes were found penetrating styles of all samples pollinated with each type of pollen indicating they were viable.

Discussion: The results indicate: no apparent effect from the application of pollen via hive entrance pollen inserts; the overriding importance of pollen transfer between cross-compatible cultivars; and the presence of undetermined problems other than pollen viability associated with lack of fruit set in the test orchard.

Anther Counts for Cultivars Collected in 1985

Since 1978 we have amassed a collection of pollen from 21 almond cultivars for study of surface ultrastructural characteristics with the scanning electron microscope. These will form the basis for identification of pollen loads collected by and borne on the body hairs of bees and pollen deposited on stigmas. We continue to collect pollen from additional cultivars as time permits and to prepare them for future study with the SEM.

Materials and Methods: Flowers of 14 cultivars were collected at the Delta College variety trial plots in February 1985 for inclusion in our studies of floral and pollen morphology. Thirteen of these were new to our collection. Flowers were removed from freezer storage, anther were counted on 10 flowers of each cultivar and pollen grains were prepared for morphological studies with the scanning electron microscope.

Results: Anther count means of 10 flowers per cultivar range from a low of 28.3 for Mono to a high of 39.8 for Butte. Most (10 of 14) of the cultivars averaged between 31-35 anthers per flower.

Discussion: The anther counts will aid in future estimates of pollen production per flower in various almond cultivars.

Multiyear Comparisons of Colony Strength Estimates

In order to make generalizations based on the several years of data on strength evaluations of honey bee colonies we used for almond pollination studies, a statistician with a background in almond research was contracted to analyze our data.

The primary objective of this contract was to establish the correlation between the rapid cluster counts and the more intensive colony strength estimates involving frame by frame measurements of worker bees and brood area. Secondary objectives were to determine: 1. if the data could be used to evaluate the effect of observer training on the above correlation; 2. the consistency of the results over the sevaral years of observation; and 3. if any measure of bee population per colony could predict brood area per colony.

Materials and Methods: Data files were entered on a microcomputer and transferred to a mainframe computer for analyses by SAS CORR and SASGRAPH programs. These analyses included only the observations made early in the season since the early estimates of colony strength are the ones used to predict the pollination potential of the colony for the following bloom season. An attempt was made to evaluate the effect of observer training on correlations, but because there were few cases of different observers working on the same colony on the same date not much could be done. However, in 1986 duplicate counts by two different observers were made at the same time on the same colonies and called out to a recorder.

Results: A regression of frames of bees from intensive counts versus cluster extimates shows the least variation in the range of 5 to 10 frame clusters (Fig. 3). In Table 9 parametric and nonparametric analyses of cluster and intensive count data indicate that correlations improved between 1983 and 1986. In 1983 and 1984, for all observers and locations, cluster counts predicted approximately half of the total

variation in intensive bee counts. In 1985 and 1986, cluster counts predicted 65 to 75% of the total variation.

Table 10 shows that in most years the intensive estimate of bee population explained less than 30% of total variation in brood area. Cluster counts had slightly higher correlations to brood area, but the total variation explained was less than 25% in all years except 1985 (Table 11).

Cluster counts by two different observers were very similar in correlation to frames of bees (.81 and .84, P=.01) in 1986, but these may have been biased by the method of recording (see above).

Discussion: Cluster counts predicted between 50 to 75% of variation in colony strength in the 4 years analyzed. The correlation imporved over the four years suggesting that there was a reduction in variability possibly due to learning by the observers or improved methodology. Although the correlations of cluster counts by 2 observers were very close in 1986, this experiment should be repeated in such a manner that one observer can not hear the count called out by the other and possibly be influenced by it.

Area of brood per colony was not highly correlated to either estimation method. These data give little evidence that estimates of adult bee populations will be very effective in predicting brood populations, and thereby colony strength. Possibly too many variables impinge on this relationship at any one time or at least during the highly changeable environmental conditions found at the time almonds bloom. Also, the genetics and health of the queen have an overwhelming influence on strength relationships in the colony.

Probably a more important use for estimates of cluster counts, and intensive bee and brood counts is in predicting bee flight which is crucial to pollination. Some of these analyses can be found in the 1985 Almond Board Annual Report.

Weights of pollen collected over the years in almonds by us and other observers need to be analyzed to see how they compare to colony strength and flight. Theoretically, the amount of pollen collected should reflect not only the total flight, but in particular the flight by pollen collectors which are the most efficient pollinators. However, pollen traps do affect flight, so data collected on colonies with traps may not always be applicable to hives without traps.

Further multiyear analyses of our data should help contribute solutions as to how many honey bee colonies and of what strength does a grower need for best pollination.

Publications

Thorp, R. W., D. L. Briggs and J. White. 1986. Survey of factors affecting pollination and yield in almonds. Almond Facts (Jan/Feb):17, 19.

Thorp, R. W. and B. Curtis. 1986. Tracheal mites of honeybees. Almond Board of California Research Update (August) 2 pp. also in Almond Facts (Sept/Oct):29.

Thorp, R. W. and D. L. Briggs. 1986. Rapid honey bee colony strength evaluation with cluster size measurements. Almond Board of California Research Update (August) 5 pp. also in Almond Facts (Sept/Oct):30-31.

Thorp, R. W. and D. L. Briggs. 1986. Sugar syrup feeding and pollen traps increase bee pollen foraging for almond pollination. Almond Board of California Research Update (October) 4 pp. also in Almond Facts (Nov/Dec):16-17.

Thorp, R. W. 1986. How many honeybees do you need for almond pollination? and Pollination contract. Almond Facts (Nov/Dec):15.

Table 1. Change in colony strength between initial and final counts (N = 5 for all treatments).

Strength Group	Treatment Fed	Treatment Trap	Initial $\bar{X}$	Count S.D.	Final $\bar{X}$	Count S.D.	% Average Change	Initial and Final T-Test
4	No	No	4.3	0.4	5.3	1.6	+25.6	n.s.
	No	Yes	4.5	0.2	5.8	3.2	+29.7	n.s.
	Yes	No	4.5	0.5	5.3	0.8	+18.1	.090
6	No	No	6.2	0.4	8.7	2.1	+43.3	.079
	No	Yes	6.2	0.7	8.0	2.3	+38.4	n.s.
	Yes	No	6.0	0.4	9.8	2.2	+63.3	.019
8	No	No	7.9	0.7	9.6	1.1	+21.5	.021
	No	Yes	7.9	0.5	9.8	2.2	+31.0	n.s.
	Yes	No	7.9	0.5	10.3	1.1	+34.1	.005
10	No	No	10.1	0.8	11.6	1.1	+12.8	n.s.
	Yes	No	10.3	1.0	11.5	0.8	+16.7	n.s.

Table 2. Changes in colony brood area between initial and final counts (N = 5).

Strength Group	Treatment Fed	Treatment Trap	Initial $\bar{X}$	Count S.D.	Final $\bar{X}$	Count S.D.	Average % Change	Initial vs. Final T-Test
4	No	No	378	142	637	206	+ 68.0	.05
	No	Yes	403	147	678	166	+ 50.2	.024
	Yes	No	398	97	759	318	+132.4	.041
6	No	No	563	66	941	226	+ 67.3	.041
	No	Yes	623	171	956	388	+ 43.8	n.s.
	Yes	No	587	70	1101	144	+ 87.6	.0005
8	No	No	681	105	977	133	+ 43.7	.005
	No	Yes	609	84	1072	250	+111.5	.012
	Yes	No	681	106	1060	130	+ 60.9	.001
10	No	No	708	196	1363	201	+ 92.5	.001
	Yes	No	670	168	1092	23	+ 63.0	.001

Table 3. Changes in stored pollen between initial and final counts (N = 5).

Strength Group	Treatment Fed	Treatment Trap	Initial $\bar{X}$	Count S.D.	Final $\bar{X}$	Count S.D.	Average % Change	Initial vs. Final T-Test
4	No	No	22.6	21.7	86.2	84.2	+281.4	.03
	No	Yes	21.8	28.5	46.8	67.7	+114.7	n.s.
	Yes	No	25.8	21.5	74.0	99.4	+186.8	n.s.
6	No	No	80.5	29.6	274.8	246.2[a]	+737.5	.0
	No	Yes	20.5	14.1	63.3	59.8[a]	+225.6	n.s.
	Yes	No	29.8	26.3	168.4	95.7	+461.7	.03
8	No	No	88.6	124.5	232.4	113.9[b]	+185.2	.094
	No	Yes	86.4	100.6	135.4	63.0[b]	+162.3	n.s.
	Yes	No	96.8	60.0	265.0	210.8	+194.7	n.s.
10	No	No	66.8	76.6	202.0	57.8	+202.4	.05
	Yes	No	88.2	68.1	392.2	203.7	+344.7	.05

[a] T-test significant at $P > .04$.

[b] $P > .07$.

Table 4. Changes in stored honey from initial to final count (N = 5).

Strength Group	Treatment Fed	Treatment Trap	Initial $\bar{X}$	Count S.D.	Final $\bar{X}$	Count S.D.	Average % Change	Initial vs. Final T-Test
4	No	No	2.3	1.1	1.9	1.1	-18.2	n.s.
	No	Yes	2.6	1.1	2.2	1.2	-15.3	n.s.
	Yes	No	2.4	1.5	3.3	2.2	+34.7	n.s.
6	No	No	3.7	1.9[a]	2.3	1.5[b]	-38.5	n.s.
	No	Yes	1.9	1.3[a]	1.6	.9[b]	-17.3	n.s.
	Yes	No	2.9	0.5	3.4	1.8	+14.7	n.s.
8	No	No	3.3	1.9	2.3	.9[c]	-30.3	n.s.
	No	Yes	3.9	1.1	3.1	1.0	-20.5	n.s.
	Yes	No	4.1	1.5	4.5	1.1[c]	+ 9.6	n.s.
10	No	No	5.3	2.6	4.0	1.3	-24.4	n.s.
	Yes	No	6.1	2.3	5.6	1.6	- 9.4	n.s.

[a]Significantly different $P > 0.09$.

[b]Significantly different $P > 0.06$.

[c]Significantly different $P > 0.01$.

Table 5. Mean numbers of pollen and non-pollen foragers per 30 second observation of returning bees to hives with traps, feeding and no treatment.

Strength Group (Frames of Bees)	No. of Hives	Treatment Fed	Treatment Trap	Average No. of Pollen Foragers $\bar{X}$ ± SD	Average No. of Non-pollen Foragers $\bar{X}$ ± SD
4	5	No	No	4.6 ± 2.5 A*	10.2 ± 1.7 A
	5	Yes	No	5.3 ± 1.8 AB	8.3 ± 2.7 A
	5	No	Yes	7.5 ± 1.4 B	14.3 ± 2.6 B
6	5	No	No	5.6 ± 1.3 A	9.2 ± 2.8 A
	5	Yes	No	7.6 ± 2.5 AB	10.8 ± 3.7 A
	5	No	Yes	8.4 ± 1.4 B	18.4 ± 3.4 B
8	5	No	No	6.9 ± 3.3 A	11.4 ± 2.3 A
	5	Yes	No	6.5 ± 2.3 A	11.2 ± 1.0 A
	5	No	Yes	11.6 ± 3.8 A	19.0 ± 3.0 B
10	5	No	No	5.8 ± 1.5 A	12.8 ± 4.1 A
	5	Yes	No	7.7 ± 1.3 A	13.6 ± 5.9 A

*In each strength category, means followed by the same letter are not significantly different at $P < .05$ using Tukey range test.

Table 6. Summary of analyses of variance showing the effects of feeding and pollen trapping on the numbers of pollen and non-pollen foragers on different colony strength groups.

Strength Group	Model Tested	F-Test on Number Pollen Foragers d-f.	F-Value	P	F-Test on Number of non-Pollen Foragers d.f.	F-Value	P
4 Frames of bees	Flight = treatment*	2,12	2.88	.095	2,12	8.13	.006
6 Frames of bees	Flight = treatment	2,12	3.09	.083	2,12	10.89	.002
8 Frames of bees	Flight = treatment	2,12	4.01	.046	2,12	19.24	.0002
10 Frames of bees	Flight = feeding	1, 9	4.76	.061	1, 9	5.64	.045

*Treatment was feeding, trapping and control for the first 3 strength groups; and feeding and control only for the 10 FOB group which was analyzed separately.

Table 7. Germinability of almond pollen from different sources and different dates.

Source of Pollen	Date of Collection	Number of Pollen Grain Counted (X 100)	Mean Percentage of Germination	S.D.	Grouping of Means*
Mission flower	2/20	70	88.0	5.1	A
	2/21	31	89.8	4.2	A
	2/25	60	55.8	22.0	C
OAC trap tray	2/21	80	67.0	15.7	B
OAC trap tray	2/24	21	36.4	28.8	D,E
Frozen pollen from OAC trap tray	2/21	60	42.3	11.6	D
Kremer trap grid	2/25	60	42.0	13.5	D
Kremer trap grid	2/26	39	14.3	11.9	H,I,J
Kremer trap tray	2/26	60	29.8	22.7	E,F
Carpet	2/21	74	25.8	10.7	F,G
	2/24	67	20.7	10.5	G,H
	2/25	60	15.4	7.8	I,H
	2/26	74	11.3	5.9	I,J
White fabric	2/20	79	51.2	12.1	C
	2/26	71	10.0	4.6	I,J
Blue fabric	2/21	80	40.3	15.2	D
	2/24	80	17.4	6.9	H,I
	2/25	80	12.3	7.5	I,J
	2/26	79	11.5	5.3	I,J
Polyester acrylic fabric	2/27	70	7.1	3.5	J

*Means with the same letter are not significantly different ($P < .05$) using Tukey's studentized range test for mean separation.

Table 8. Bloom phenology and corresponding fruit set (April 14) in almonds near Dixon, CA, 1986.

Date	Cultivar Ne Plus Ultra		Peerless		Nonpareil		Mission		Thompson	
	% Bloom	% Fruit Set	% Bloom	% Fruit Set	% Bloom	% Fruit Set	% Bloom	% Fruit Set	% Bloom	% Fruit Set
Feb 18	94.9	7.1							17.6	9.2
19			89.6		31.4		68.6		38.1	
20			87.2	3.2	79.7	17.4	75.0	20.6		
21*	85.8	6.4	84.6	4.7	84.2	11.3	25.9	9.7	82.5	25.3
22	94.4	8.7	87.5	5.8	94.4	18.2	94.7	11.6	61.7	22.2
24	99.1	0.0	98.3	3.5	97.2	7.4	92.4	10.0	97.3	8.9
25	98.3	6.0	96.7	3.3	96.6	26.2	100.0	5.3	98.1	9.3
26							98.3	11.9	94.4	21.5
27							100.0	18.6	100.0	12.1
28	(All cultivars had some fruit drop by this date)									
Mean fruit set per season		7.1		4.1		16.1		12.5		15.5

*Counts this date taken from more interior area of orchard.

Table 9. Multiyear correlations between cluster and intensive population estimates (All R values are significant at alpha 0.001)

Year	Pairs observed	Pearson's R	Pearson's R^2	Spearman's R	Spearman's R^2
1983	211	0.70	0.49	0.69	0.48
1984	105	0.70	0.48	0.71	0.51
1985	182	0.80	0.65	0.83	0.69
1986	87	0.80	0.64	0.78	0.61
1983-86	585	0.74	0.55	0.75	0.56

Table 10. Multiyear correlations between brood area and intensive population estimates (All R values are significant at alpha 0.0001)

Year	Pairs observed	Pearson's R	Pearson's R^2	Spearman's R	Spearman's R^2
1983	212	0.56	0.31	0.53	0.28
1984	110	0.49	0.24	0.45	0.20
1985	182	0.74	0.55	0.74	0.55
1986	87	0.56	0.31	0.50	0.25
1983-86	591	0.51	0.26	0.47	0.22

Table 11. Multiyear correlations between brood area and cluster estimates of population (All R values are significant at alpha 0.0001)

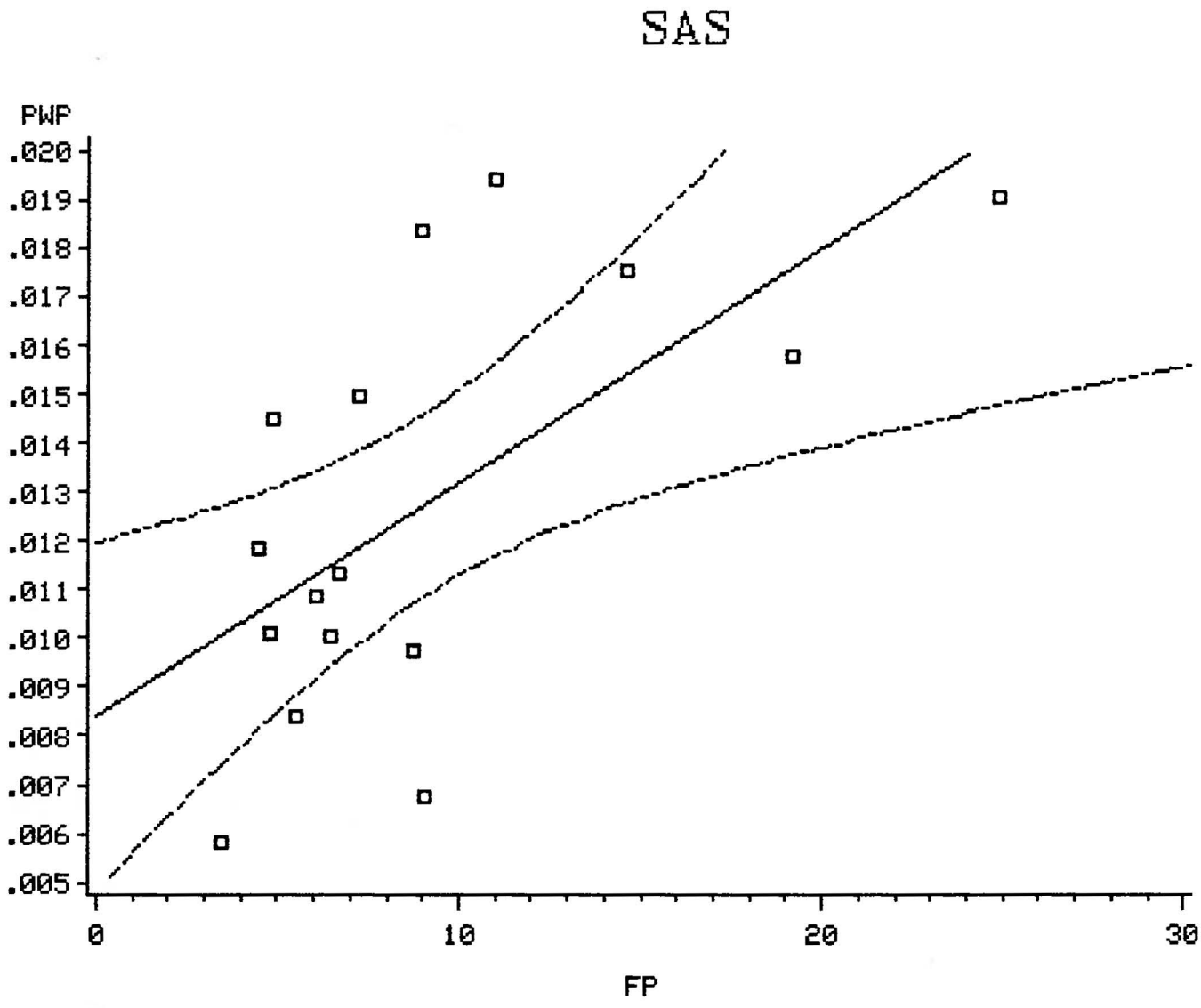
Year	Pairs observed	Pearson's R	Pearson's R^2	Spearman's R	Spearman's R^2
1983	211	0.49	0.24	0.49	0.24
1984	105	0.42	0.18	0.40	0.16
1985	182	0.80	0.65	0.79	0.63
1986	87	0.46	0.22	0.48	0.23
1983-86	585	0.52	0.27	0.47	0.22

Figures

Figure 1. Regression of number of pollen foragers (FP) versus weight of pollen deposited on strips of material at hive entrances (PWP) ($P = <.001$).

Figure 2. Log of number of pollen foragers versus weight of pollen deposited on strips of material at hive entrances.

Figure 3. Regression and confidence limits of frames of bees as estimated by cluster method versus frame-by-frame intensive counts for 1983-1986.


SAS
PWP
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.019
.018
.017
.016
.015
.014
.013
.012
.011
.010
.009
.008
.007
.006
.005
0
10
20
30
FP

Figure 1

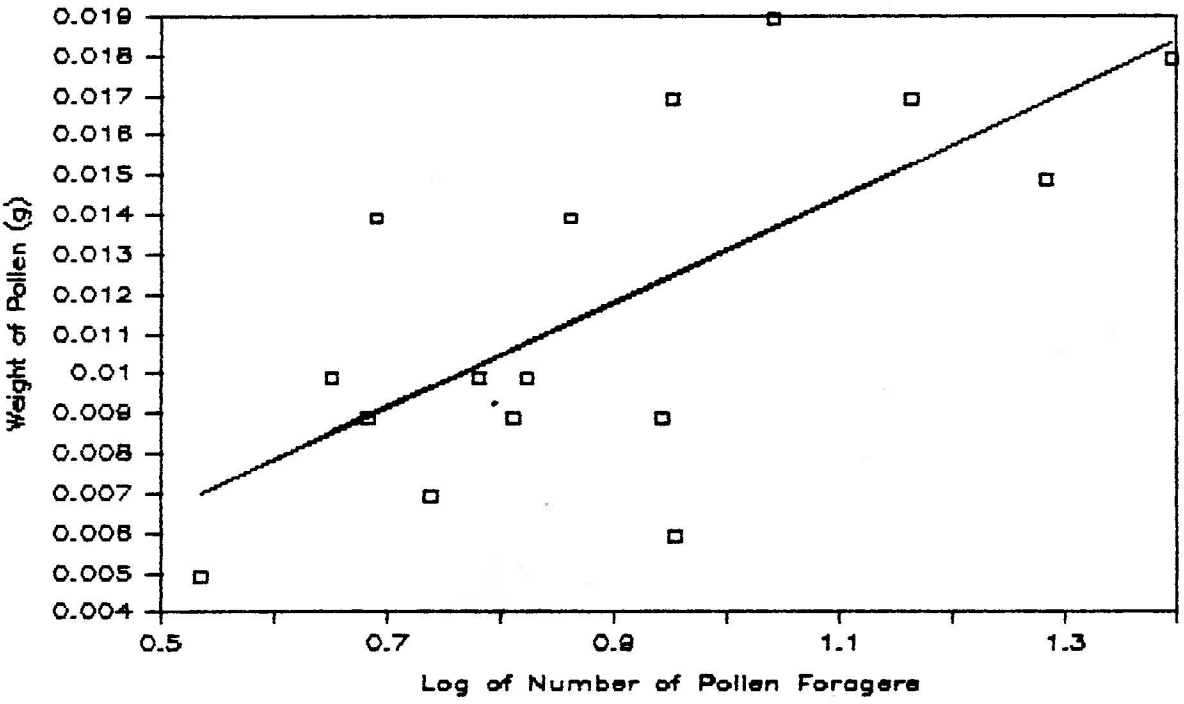
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
Weight of Pollen (g)
0.5
0.7
0.9
1.1
1.3
Log of Number of Pollen Foragers

Figure 2

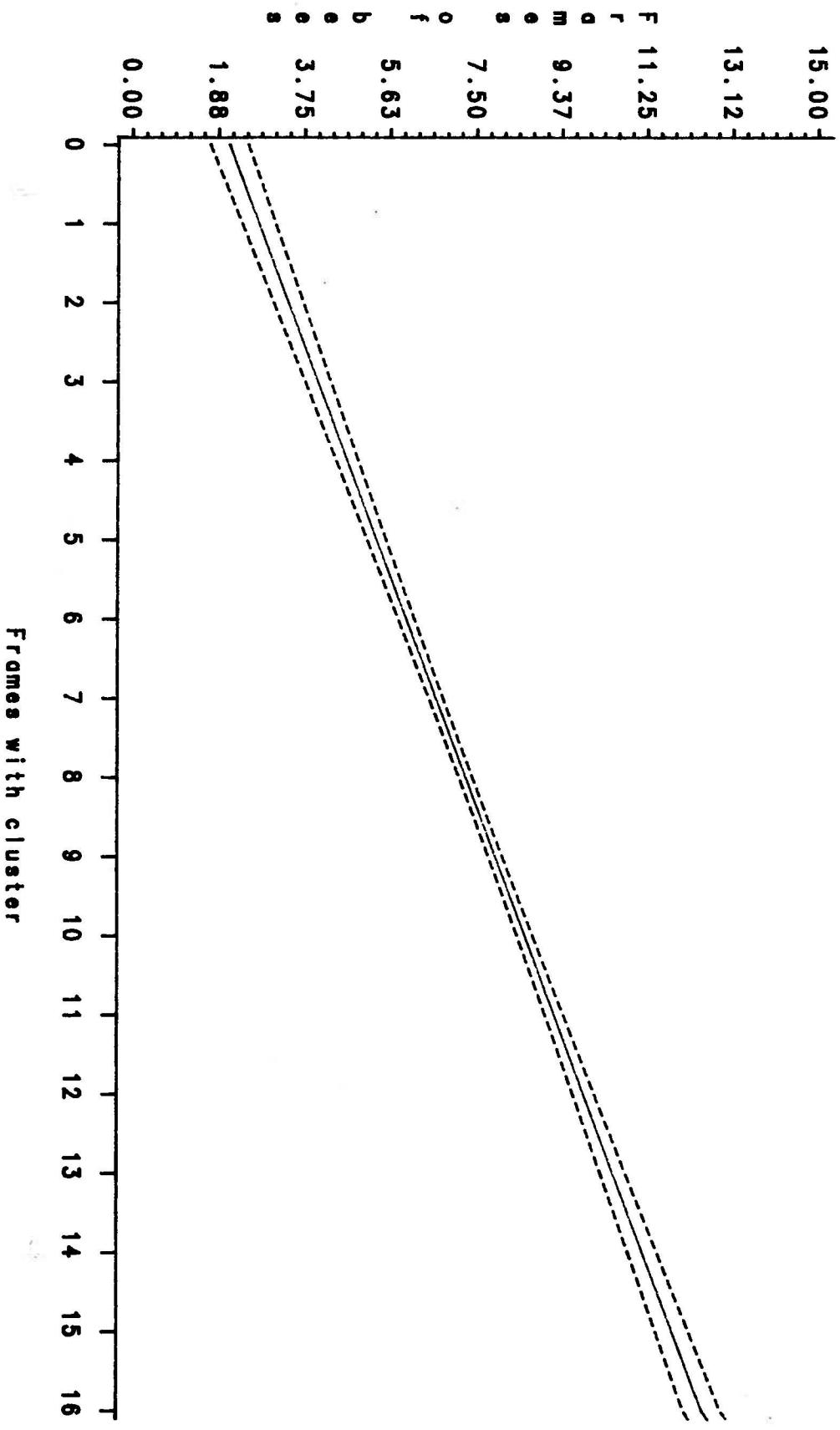
Frames with cluster
Frames of beeswarm
0.00
1.88
3.75
5.63
7.50
9.37
11.25
13.12
15.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Figure 3