81-L6

RECEIVED
DEC 31 1981
ALMOND BOARD

1981 Annual Report on Almond Pollination Research Sponsored by the Almond Board of California

Title: Tree Research: Pollination (Project No. 81-L6)

Prepared by: Dr. Robbin Thorp, Project Leader, Department of Entomology, University of California, Davis

Personnel: D. Briggs, O. Kaftanoglu, M. Klungness, L. Nagamine, T. Parisian, J. Skinner, E. Sugden, R. Waegell, and T. Webster

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

Interpretive Summary:

A statewide pollination survey of the 1980 almond crop revealed that about 11% of variation in yield can be explained by the number of hives per acre and orchard age. In 1980, 51% of growers felt that poor weather was their biggest pollination problem. An intensive survey of several orchards in the Dixon area, indicated that bees do not fly as far in cool, damp weather, and therefore growers need to put in sufficient bees with adequate distribution to insure against bad weather. A model using regression analysis suggested that bees are drifting from high bee density orchards to low bee density orchards. Aerial photography is promising as means of assessing the total amount of bloom available, and thus, the total colonies needed within the flight range of the bee. About 90% of surveyed colonies were above the four frame minimum standard. Colonies gained an average of 2.6 frames of bees each during the almond bloom period. A technique which would allow the growers to estimate strength of hives in their orchards is being developed. Pollen traps resulted in a slight increase in the percentage of pollen collectors, but a decrease in total numbers of foragers possibly because of bee drift.

POLLINATION SURVEY OF THE 1980 and 1981 CROP

A survey is being conducted on the 1980 and 1981 crops to determine the relative importance of orchard age, size, planting scheme, colony strength, number, and distribution, plus competing bloom on yield.

Experimental Procedure

Survey forms and covering letters were distributed with the generous support of Almond Board personnel, Farm Advisors, Cooperative Extension and project personnel, and others at the 1980 and 1981 Almond Board research conferences, the Pomology Short Course on Almonds, and at four grower meetings.

Results

Many of the forms have not been received from growers yet. We are still holding the survey open for those growers who would like to participate in the 1980 and 1981 surveys. Forms may be obtained by writing or calling:

Dr. Robbin Thorp
Department of Entomology
University of California
Davis, CA 95616
(916) 752-0480 or 2802

Preliminary regression analysis of data for 140 orchards can be seen in Table 1. The cold damp weather in 1980 was listed as the biggest pollination problem for that year by 51% of the growers. Others felt that poor planting schemes, varietal difficulties, colony strength, neighbors without bees, beekeeper placement of bees and competing bloom were their biggest pollination problems.

Pollination Survey of Several Orchards

The main focus of research in 1981 was a survey of 40 orchards (840 acres) near Dixon, CA. In this survey the following parameters were measured or observed:

1) Colony strength-cluster size, frames of bees, square inches of brood
2) Colony numbers and distribution
3) Bee flight activities at colonies - numbers and ratios of pollen and nectar collectors
4) Sources of pollen and nectar, i.e., almond or other plants
5) Bloom percentage and density
6) Percent fruit set and yield

The goal of the survey was to find whether correlations exist between strength, density and distribution of honey bee colonies; the density of bees foraging in almonds; bloom density; percent fruit set; and yield.

Experimental Procedure

Random "cluster" samples were taken at the beginning of bloom in one third of the 1222 colonies placed in the surveyed orchards. "Cluster" counts were taken at the end of the bloom period on 58% of those colonies sampled earlier. The "cluster" counts consisted of removing the hive cover when bees were not foraging (once foraging begins the cluster expands, and consistent counts are difficult). The number of frames and partial frames covered with bees, as viewed from the top of the frame, is recorded. On one third of the colonies that had cluster counts at the beginning of bloom, "frame" and "brood" counts were done. With "frame" counts, every frame is removed from the hive; and from the side view, the number of frames covered or partially covered with bees (to the nearest 1/4 frame) is recorded. While the frames are out, the number of square inches of brood is recorded.

Numbers and locations of hives were noted on maps of each of the orchards. On Feb. 23 and 27, flights were made over all of the orchards in a small plane. During the flights, 35mm photographs were taken in black and white, and color. Black and white prints were made of the orchards. The prints give a permanent record of the hive location, the comparative stage of bloom between the varieties, and the relative density of bloom between orchards. The relative amount of bloom in different orchards was estimated using a Quantimet image analyzer which measured the relative whiteness shown in the aerial photos of the orchards. On other copies of the photos, the variety of each tree was noted using a colored symbol.

In selected orchards, 15 second counts of the number of bees foraging per tree, were made by walking (or standing for younger trees) along the south side of the tree canopy and counting every bee observed in the tree. At least ten trees were observed per counted variety in each time period. In some of the selected orchards, 30 second samples of incoming foragers were taken to determine the rate of incoming flight, the ratio of pollen to nectar collectors, and whether almond or other plant pollen and nectar were being collected.

Counts were taken of at least 100 total buds and blooms per limb on four trees per variety (2 limbs per tree) for observations of fruit set in late April. Yield data were obtained from the growers.

Results

Table 2 shows the effects of colony density and distance on fruit set under varying weather conditions. Orchards with no hives and with about 1.7 hives per acre that were within 1 1/4 mile of an orchard with 3 hives per acre, yielded about equal fruit set (24%) during the good flight weather found in Mission bloom. However, during the poor flight weather found in

Nonpareil and Drake bloom, there were significantly lower fruit sets in the orchards with fewer hives per acre especially at greater distances from the highest bee density orchard (14.7% for orchards with about 1.7 hives per acre and 4.1% for orchards with no hives).

Although data on bee counts in trees is not as complete as fruit set counts, they tend to confirm the fruit set count data. Table 3 shows bee counts taken during peak Nonpareil bloom (poor weather) in the same orchards referred to in Table 2. The orchard with 1.7 bees per acre has slightly fewer bees than the orchard at 1/2 miles with no bees. Fruit set plots were not always coincident with bee count plots so there may have been some localized differences in attractiveness that caused this anomaly.

Yield data were not as clear as fruit set data possibly because of different management practices and soil types which affected yield more than fruit set (Table 4). The average yield in all orchards was 990 lb/acre (23.8 lb/tree). Yield data will be analyzed in more detail when all figures are in from growers.

Regression analyses tended to support data in Table 2. Graph 1 shows that fruit set is more sensitive to the number of hives per acre in average weather, found when most of the varieties were blooming, than in the good weather when Mission variety was blooming.

Regression analyses were conducted to determine how fruit set responded to increasing numbers of hives per acre in different age orchards (Graph 2). Unfortunately, there were only four young orchards in the sample, but if these are any indication, young orchards appear to respond better to increasing hive density than do older orchards.

A mathematical model was developed to try to determine what effect inter-orchard movement of bees (called "drift" in this report) might have on fruit set in orchards less than 1/2 mile apart. Factors considered important in the model were:

1) distance between orchards
2) hives/acre in the different orchards
3) orchard size.

To determine whether an orchard could be expected to gain or lose bees to other orchards, the expected drift from or to orchards within 1/2 mile was totalled. Graph 3 indicates that percent fruit set is affected as if drift is occurring, i.e., orchards thought to be gaining bees from neighboring orchards had high fruit set, and those thought to be losing bees had low fruit set.

Another factor which might have influenced drift differentially throughout the bloom period, is the relative attractiveness of bloom in the various orchards. The attractiveness would probably be determined mostly by the relative stages of bloom and the total bloom in an orchard. Unfortunately, we do not have enough aerial photographs correlated with percent bloom counts taken on the same date on the ground to determine whether aerial photography can be used to find the relative amount of bloom available to bees. Counts with the image analyzer of aerial photographs varied less than 1% for different counts on the same subplots.

The results of cluster counts of colony strength on the 58% of the sampled colonies that were still in the orchards at the end of bloom are shown in Table 5. Approximately 90% of the colonies sampled were above the 4 frame minimum standard. Colonies increased in strength an average of 2.6 frames per hive. Interestingly, the very strong and the very weak colonies remained about the same strength at the end of the bloom. Side-view counts of individual frames were consistently about 30% lower than the cluster counts. Brood counts were more variable and need further analysis.

Table 6 shows the results of counts of returning foragers to the hive. As expected, the stronger colonies had higher numbers of foragers. Unexpectedly, the number of foragers per frame of bees was lower in stronger hives than in the weaker hives. These results are based on a small number of counts, and need to be repeated. The overall average percentage of pollen collectors observed at the hive was 55.3%. On a time available basis, pollen samples and nectar samples from incoming bees will be examined to see what percentage were foraging on almonds.

POLLEN TRAP STUDY - 1980

Introduction

Previous studies have shown that pollen collectors are more effective pollinators than nectar collectors in almonds. There is some indication in the literature that pollen traps may affect the ratio of pollen to nectar-collecting bees. The results of experiments on the effect of pollen traps on bees have given mixed results possibly because of differences in weather, time of year, crop, and hive condition. This study was undertaken to determine what effect pollen trapping might have on the percentage of pollen-collecting bees foraging in almonds.

Materials and Methods

Pollen traps (Gary-Lorenzen design) were placed on the front of 20 hives at about the time of early bloom in almonds. Ten of the hives had the trap screen removed from the pollen trap and served as controls. Colony strength was assessed at the beginning of bloom and only colonies with 6-7 frames of bees were used. Brood strength was not made equal. During flight weather, incoming foragers were captured and frozen within 60 sec. on dry ice. These bees were later examined in the lab by expressing the honey stomachs onto filter paper to determine if they were collecting nectar or water. The pollen baskets of the bees were observed to see if the bees were collecting pollen.

Results

The ratio of pollen to nectar collectors was .57 for the trap colonies and .52 for the controls. Or, on a percentage basis, the trapped colonies had 36.7% (40/109) pollen collectors and the controls 34.4% (93/177) pollen collectors. When those bees collecting both pollen and nectar are considered as pollen collecting bees, the pollen trap colonies have 59.2%

(100/169) pollen collectors and the controls have 57.6% (240/417). As can be seen from the totals (169 vs. 417), the pollen trap colonies had less than half number of foragers as controls. This may be due to the fact that the flight conditions were poor for orienting bees in 1980. Bees from trap colonies may have drifted to non-trap colonies throughout the orchard.

NECTAR FLUORESCENCE

A limited number of trials were performed on Fremontia with techniques mentioned in previous reports to determine if bees are using the fluorescence in almond and Fremontia nectar as a cue to availability of nectar in the flower. A preliminary analysis of tests in which odor components were extracted from nectar and compared with unextracted nectar, indicate that bees are using both odor and fluorescence as cues.

EARLY DETERMINATION OF EFFECTIVE POLLINATION

As part of a continuing search for an easy way to determine whether a blossom has been pollinated, pollinated and non-pollinated flowers were observed.

Experimental Procedure

Almond limbs were cut from trees, and recut under and kept in spring water. The limbs were kept inside an unheated building. Six early dehiscent flowers of each of the five varieties were hand pollinated with dehisced anthers of compatible varieties. These flowers plus an equal number of unpollinated flowers were observed for six days and changes in stigma and pistil were recorded.

Results

Table 7 shows the average darkening of stigma and withering of the pistil that has occurred by the sixth day. In all varieties the pistil darkened faster in pollinated flowers. There was a very slight increase in the amount of withering in the pollinated flowers.

Discussion

The 1980 statewide almond pollination survey indicates that orchard age and hives per acre account for about 11% variation in yield during a poor pollination year. Possibly, when more survey forms are returned, a larger portion of variation in yield can be ascribed to colony density.

Fruit set data on a portion of the Dixon orchards suggest that bees do not fly as far in inclement weather. Regression analyses of all orchards in the survey, collaborate the above by indicating an inter-orchard drift of bees especially in good weather. Yield data suggest the same trend but are not as clear possibly because of the influence of other variables, such as orchard management techniques and soil type, between fruit set counts (April) and harvest. A factor for management techniques is being developed which should help compensate for the effect of management on yield. Also, fruit set counts were done on small plots whereas yields were done on the whole orchard. We were not always confident in some yield figures because of the possibility of different orchards and varieties being lumped by the harvesters (who were not always the orchard owners). An alternative explanation of the uniformly high fruit set in Mission is the possibility that the longer bees are in an orchard, the farther they tend to fly as they learn more of the surroundings. In 1982, when we plan to repeat the survey, the weather pattern for the varieties may be different, and the possible effect of bee learning can be determined.

Aerial photography combined with image analysis, could become a useful tool for growers to determine on an area-wide basis the number of colonies needed for pollination. Percent bloom counts taken on the ground need to be correlated with percent white area determined by image analysis of aerial photos taken of orchards with varying tree ages, canopy sizes, planting schemes, etc.

The limited number of bee counts in trees tended to support the idea that bees fly or drift farther in good flight weather. More extensive counts need to be done in 1982.

Curiously, the hives with the largest and smallest numbers of frames did not increase as much as those in the middle range. Possibly the largest colonies do not have enough room in the hive to expand. The small hives may be below some crucial threshhold strength needed for expansion. There may have been some factor in bee management, such as feeding or shaking for packages that affected these results. A factor for bee management techniques needs to be developed in 1982.

A limited number of observations of bees returning to colonies of various strengths indicate that weaker colonies have fewer foragers. However, weaker colonies had larger numbers of foragers per frame of bees. This latter finding appears to contradict earlier studies using pollen traps and flight cones that showed stronger colonies have disproportionately more foragers. This experiment needs to be repeated on a larger scale to test its validity.

A technique and formula is being developed which, hopefully, will allow the grower to assess the strength of colonies in the orchard through bee cluster counts and/or counts of bees at the hive entrance.

All of the above mentioned factors, and possibly others could be fed into an integrated computer model such as Dale Kester is proposing. Assuming a workable model is produced, individual or groups of growers, farm advisors, consultants, researchers and others could determine the pollination needs for an orchard or several orchards. If in the distant future long range weather forcasting can be added to the model, growers might be able to anticipate their pollination needs months in advance.

The pollen trap study indicated a slight increase in pollen collectors in trap colonies over non-trap colonies. If funding is approved from another source, the study will be repeated with more suitable traps and better isolation of the trap colonies. This should prevent drift of bees to non-trap colonies.

Observations on the comparative aging of pollinated and unpollinated flowers confirmed similar studies in 1979 which showed that pollinated flowers age more rapidly. These observations may prove useful in developing an easy, early method of determining whether flowers have been pollinated.

Publications

Thorp, R. W. 1978. Bee management for almond pollination. p. 57-61. In Micke, W. and D. E. Kester, eds. Almond orchard management. Div. Agr. Sci., Univ. Calif., Priced Publ. 4092. 150p.

Thorp, R. W. 1979. Honey bee foraging behavior in California almond orchards. Proc. IVth Internat. Pollin. Symp., College Park, MD. (1978), MD. Agric. Exp. Sta. Spec. Misc. Publ. 1:385-392.

Erickson, E. H., R. W. Thorp and D. L. Briggs, J. R. Estes, and C. H. Schrader, R. J. Daun, and M. Marks. 1979. Characterization of floral nectars by high-performance liquid chromatography. J. Apic. Res. 18(2):148-152.

Thorp, R. W. 1980. Pollination. Almond Facts 45(1):54-55.

Table 1. Hives per acre and age as related to yield (2 way regression analysis).

Variety	r^2	Pr(F)
Nonpariel	.215	94.3
Mission	.244	84.0 N.S.
All varieties	.114	99.9 ***

Table 2. Effect of colony numbers and distance on fruit set under different weather conditions.

Hives per Acre	Distance to Highest Bee Density (Miles)	% Fruit Set Weather-Poor Nonpareil	% Fruit Set Poor Drake	% Fruit Set Good Mission
3.0	1/4	23.8***	24.0***	22.0 N.S.
1.6	1/2	16.0	15.0	27.0
1.8	3/4	16.5	11.6	22.0
None	1/2	3.9	---	25.5
None	1 1/4	4.5	4.0	12.1

*** Highly significant

Table 3. Effect of colony numbers and distance on numbers of bees foraging in almond trees.

Hives per Acre	Distance to Highest Bee Density (Miles)	Bees per Tree
3.0	1/4	5.0
1.7	1/2 to 3/4	2.1
None	1/2	2.2
None	1 1/4	1.4

Table 4. Effect of colony numbers and distance on yield under different weather conditions.

Hives per Acre	Distance to Highest Bee Density (Miles)	Yield (lbs./tree)			
		Weather-poor	Poor	Poor	Good
		Peerless	Nonpareil	Drake	Mission
3.0	1/4	27.6	30.1	24.2	20.7
1.6	1/2	11.0	30.4	26.8	25.2
1.8	3/4	16.1	19.4	19.2	14.3
None	1/2	22.5	21.0	14.7	34.8
None	1 1/4	Not harvested	-	-	-

Table 5. Comparative colony strength at the beginning and end of almond bloom as assessed by cluster counts.

Frames of Bees	% at this Strength (n=243)	Change in Strength Over Bloom Period (Frames)
1-3	11.5	+ .1
4-5	25.1	+ 3.2
6-7	25.9	+ 3.4
8-9	14.8	+ 2.4
10-11	11.1	+ 1.4
12-13	11.5	- 0.6

Table 6. Cluster strength as related to number of bees returning to hive.

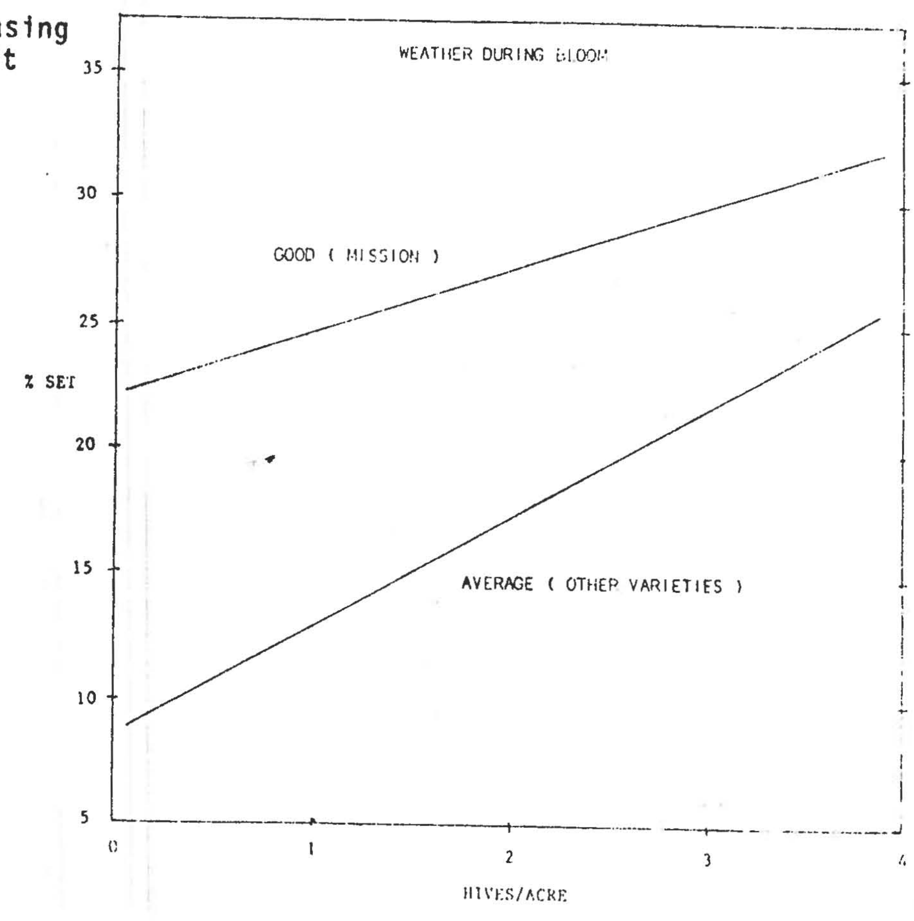
Hive Strength (Frames of Bees)	(Number of Hives)	Mean Number Bees Returning to Hive in 30 Sec.*	Mean Number Bees Returning per Mean No. of Frames
1 - 4.5	(4)	9.5	4.9
5 - 8	(13)	19.0	2.7
9 - 12	(9)	23.7	2.3
13 - 16	(15)	25.6	1.9

* six 30 sec. periods observed.

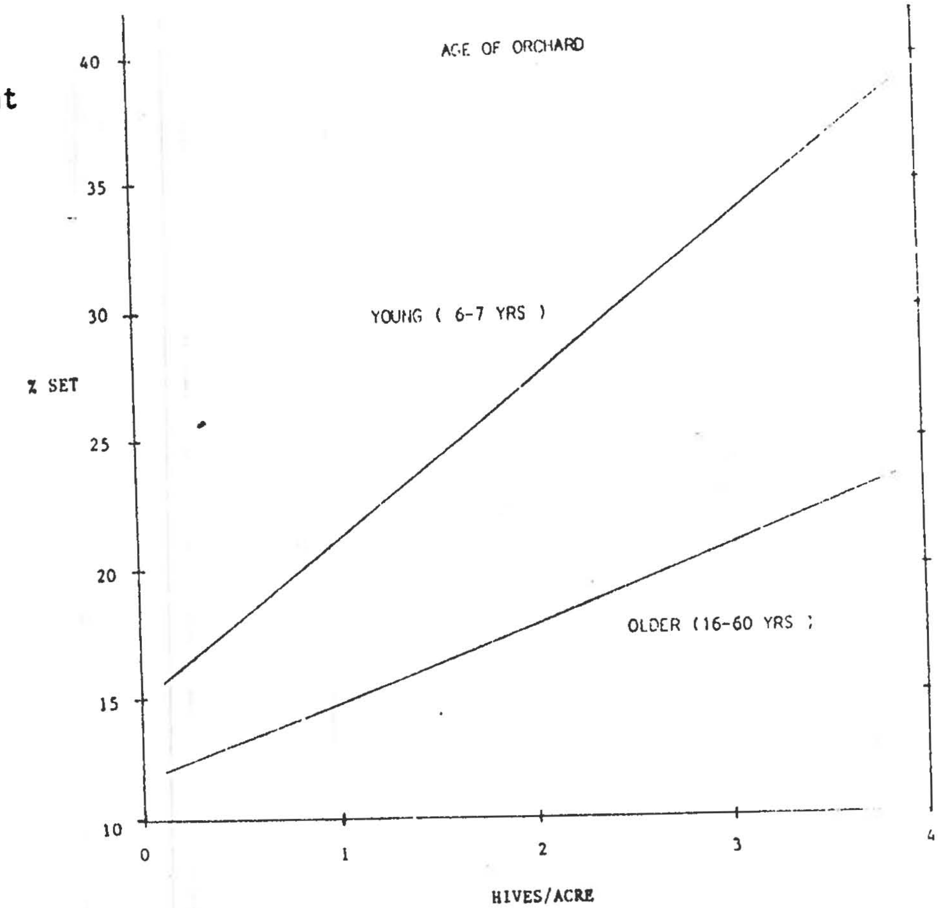
Table 7. Aging in pollinated versus non-pollinated almond blossoms as indicated by darkening of stigma and withering of pistil. (Light green - 1, dark green - 2, light brown - 3, brown - 4, and dark brown - 5).

	Pollinated (n-29)		Non-pollinated (n-30)	
Variety	Mean Darkening of Stigma	Total Amount of Withering at Tips of Pistils (inches)	Mean Darkening	Total Amount of Withering at Tips of Pistils
Ne Plus	4.0	.31	3.7	.25
Peerless	3.8	.13	2.8	.13
Nonpareil	3.4	None	1.8	.06
Thompson	3.0	None	1.7	none
Mission	4.5	.69	3.0	.56
Mean	3.7	Total 1.13	2.6	1.00

Graph 1. The effect of increasing hive density on fruit set under different weather conditions



Graph 2. Effect of increasing hive density upon % fruit set in different age orchards.



Graph 3. The influence of inter-orchard bee drift (under different bee densities) upon fruit set.