irrigated treatment D, which had initially been growing twice as rapidly. Later, as the soil water content in D decreased and approached the wilting point, growth in D slowed while A maintained its rate. A temporary increase in growth rate of D in late July was associated with a period of unseasonably cool weather which diminished the effect of the soil water deficit on the water balance in the tree. However, with the return of higher temperatures the growth rate in D was again markedly reduced.

Conclusions

In each of the four years of the study, both the soil water supply and crop load, whether in a high crop or a low crop year, influenced rate of trunk growth and total seasonal growth.

Trunk growth was primarily influenced by soil water and secondarily by crop load. This was apparent in the low-rainfall years of 1964 and 1966, during which C and D reached the wilting point in mid-season. Trunk growth was stopped and resumed only after irrigation of treatment C in late June. Even then growth in C never equaled the rate in plots A and B which were irrigated much earlier in the season. This indicates that irrigations applied late in mid-season have much less effect on current rates of trunk growth than those applied early in the irrigation season.

Early irrigations

In all four years, early irrigations (in May and June) increased trunk growth rate in treatments A and B, even though the average soil water content through the top 4 ft of soil was well above the wilting point (30 to 40 per cent available water remained) at time of irrigation. Later irrigations in plots A and B, whether at intervals of two or four weeks, did not increase growth rate further, but merely maintained the rate established earlier.

This study indicates that high crop density in almonds increases the need for irrigation, especially early in the season. During years of low crop density, trunk growth rates may be maintained with a schedule of less frequent irrigations.

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HONEY BEE POLLINATION OF ALFALFA SEED

improved by supplemental feeding

BOB SHEESLEY • BERNARD PODUSKA

Results of these Fresno County experiments indicate possible advantages to both alfalfa seed growers and beekeepers from the use of supplemental feeding, and requeening of bee colonies used in alfalfa pollination.

ALFALFA SEED GROWERS in Fresno County produced 22 per cent of the United States' alfalfa seed on 10 per cent of its seed acreage in 1967. Pollination of this crop in Fresno County requires 150,000 honey bee colonies during the three-month period of June, July, and August.

Seed growers are continually looking for practical management procedures to improve seed yields. Pollination during the 10-to-12-week alfalfa seed setting period depends upon a continuing supply of new bees to replace worn out or dead field workers. Colonies entering seed alfalfa for pollination need actively laying queens with brood of all stages and enough workers to serve the colony and to pollinate the alfalfa flowers.

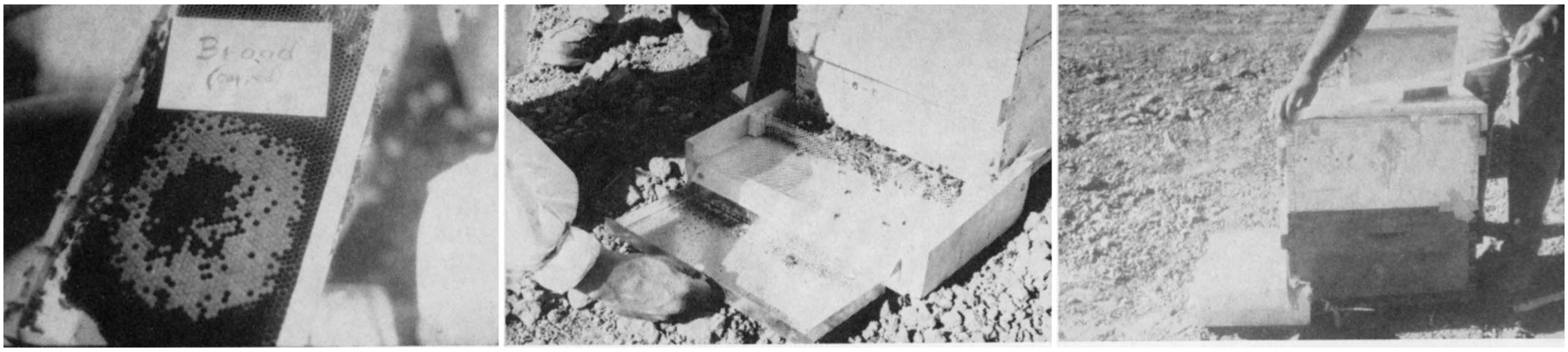
Recent tests have demonstrated that a January feeding of natural pollen mixed with drivert sugar mixed with 1 per cent natural pollen stimulated egg laying. This food supplement was fed before natural pollen was available, and resulted in larger bee populations in time for almond pollination.

Another experiment was conducted recently in Fresno County to explore answers to the following questions: (1) can pollination of alfalfa blossoms be increased by feeding honey bees prior to bloom or during bloom?; and (2) what happens to the strength of brood, and pollen collecting abilities of honey bee colonies while in seed alfalfa?

Results reported here are from this single experiment conducted under one set of conditions. The consistency of results does suggest they are valid for this set of conditions. However, there are many variables in field experiments of this type. For this reason it is unlikely that the same results will be obtained with extremely different bee populations, or different environmental and pesticide situations.

Sixty colonies of bees were divided into four test treatment groups of 15 colonies each. Each test group included five strong colonies, five of medium strength, and five weaker colonies. These original strength ratings were based on actual brood area measurements on May 28, two weeks before they were moved to the alfalfa seed field. Natural pollen had been available to all colonies since January 13. The colonies were further assigned to five equal replications to determine any pollen collection differences due to the effect of physical locations in the alfalfa seed field.

The four treatment groups in the experiment were: (1) the control group of bees, receiving no food; (2) those receiving $1\frac{1}{2}$ lbs. of drivert sugar with 1 per cent pollen fed dry on May 29, two weeks before they entered the alfalfa seed field; (3) those receiving the same



Strength ratings of honey bee colonies were based on area measurements of the open and capped brood, left photo. Front entrance traps were used to collect pollen, requiring bees to enter the colony through a perforated aluminum screen, center photo. To prevent escape, all colonies were kept sealed with masking tape, allowing entrance only through the pollen trap, right photo.

drivert sugar with 1 per cent pollen feeding as in treatment 2, and in addition 1½ lbs of the same feed in dry form on June 18 and another 1½ lbs of the same feed in a water-syrup form on July 18; and (4) bees receiving the same three feedings of drivert sugar with 1 per cent pollen as in treatment 3, plus 1 lb of a pollen food supplement fed as a watered paste on June 18 and again on July 18. The food supplement consisted of 5.3 per cent natural pollen, 65.7 per cent soyflower, and 29 per cent sugar.

Two kinds of measurements were taken in the experiment. First, all 60 colonies were rated for strength three times during the pollination period. These ratings were based on measurements of the total square inches of open and capped brood. The first of these "field strength" ratings was on June 18, three weeks after the original treatment strength ratings had been made (May 28) and nine days after the bees entered the alfalfa seed field. The second rating was one month later, on July 18. The final rating was August 6, three days before termination of the project.

The second type of measurement taken was the weight of pollen collected from each colony. Front entrance pollen traps were used, requiring bees to enter the colony through an aluminium screen. pollen was collected two consecutive days a week out of each of the nine weeks of the alfalfa bloom period. This allowed the colonies a five-day rest between trapping periods. To prevent escape, all colonies were kept sealed with masking tape, with entrance only allowed through the pollen trap.

Even with completely sealed colonies and day time field temperatures consistently over 100° F, the foundation wax on frames did not sag. The paste form of pollen supplement food (soyflower, sugar, and pollen) fed to group 4, hardened and became very brittle in these high temperatures. This material had to be scraped off of the frames at the conclusion of the experiment.

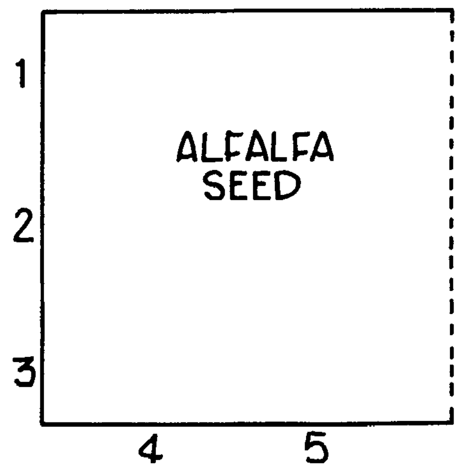
The dry form of drivert sugar with 1 per cent pollen was accepted readily by the bees on May 29, but was carried out of the colonies when fed in the dry form to groups 3 and 4 on June 18. The liquid syrup form of this same feed was readily accepted when fed to groups 3 and 4 on July 18.

Relative weights of pollen collected from group 2 totaled 15 per cent more pollen than from the control; from group 3, 1 per cent more than from the control; and from group 4, 15 per cent less was collected than from the control. In the experiment no benefit was found, either in brood development or in pollen collection, from treatment 4 which included the supplemental feedings of soyflower, sugar, and pollen mixed together. No attempt was made to measure the amounts of food supplements stored during the experiment by the colonies of group 4. Possibly some was stored and used in lieu of the gathering of more natural pollen to meet the colony's needs.

No additional benefit in pollen collection was obtained by feeding drivert sugar with 1 per cent pollen during the alfalfa bloom period in treatment 3. Different results might be obtained if this material were fed in liquid rather than dry form. Colonies in group 2 provided more bees than any other treatment during the alfalfa pollination period (see table 1). On July 18 group 2 had 32 per cent more brood area than the control treatment colonies.

The pattern of pollen collected at different areas of the field is shown with the plot sketch of the five experiment replications as positioned around the alfalfa seed field. Several groups of colonies not in the experiment were located in a line running east from replication 5. To the left of the sketch are listed the relative amounts of polen collected in each replication. The test colonies were located in straight rows around the outside edge of the seed field. The results suggest a possible drifting of bees to the colonies in replications located at the end of each row. No attempt was made in the experiment to mark individual bees and trace their movements.

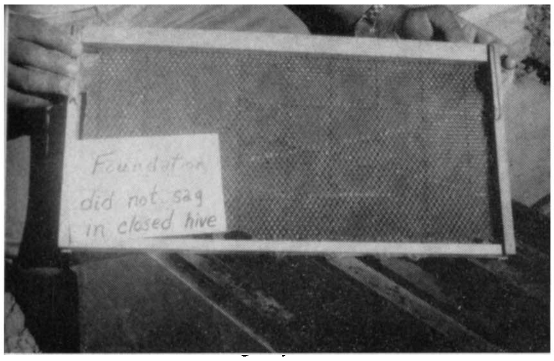
PLOT SKETCH WITH POLLEN COLLECTION PERCENTAGES FOR REPLICATION LOCATIONS IN ALFALFA SEED TEST FIELD

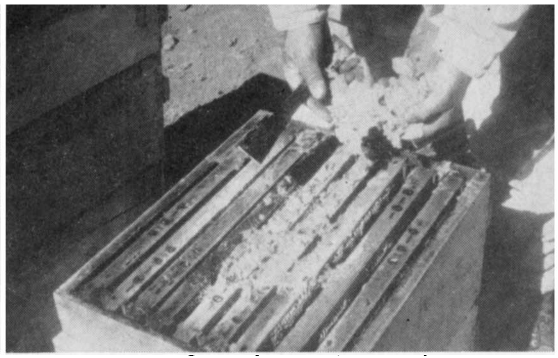


2	41
3	74
4	100
5	45

About 17 per cent of the total pollen collected in the experiment was identified as alfalfa pollen. The major competitive bloom was safflower. Although the experiment was located two miles away from the nearest safflower field, pollen from safflower bloom was collected on the second day after the bees were delivered to the alfalfa seed field. This reflects the need for, and potential benefits, to be gained from a "preference bee" for alfalfa pollination.

A severe bee kill was caused in the experiment by an insecticide application on June 18 to the nearest safflower field, two miles from the experiment. This kill was reflected in the pollen collection and brood development patterns of colonies in all treatments. The graph gives the pollen collection results of each of the nine





pollen was accepted readily by bees on May 29, but was carried out of the colonies when fed dry on June 18, right photo.

weekly collection periods. The June 18 kill of field worker bees is reflected in the June 21 pollen collection. These results show the importance of an actively laying queen and a continuing source of emerging worker bees during the long alfalfa seed pollination period.

After the June 18 insecticide application, a brood gap of five days was observed in the experiment colonies. Another five-day brood gap was observed in July after an insecticide application to the alfalfa seed fields for lygus and mite control. Perhaps the queens were responding to the lack of food brought to the colonies by not laying many eggs for the five-day period.

The second alfalfa bloom started about July 17 and peaked on about August 1. This is reflected sharply in the results for these dates as shown in the graph.

Changes in the average brood strength of all sixty colonies during the 70-day experiment are shown in table 2. The difference between the May 28 and August 6 brood measurements indicates a 69 per cent brood reduction during this period. Some of this loss can be attributed to the pollen trapping. A reasonable estimate of loss from trapping alone would be about 10 per cent of the original strength. This means that approximately 60 per cent of the original brood strength was lost because of causes other than pollen trapping during the alfalfa pollination operation.

To help determine what happens to the strength of brood and pollen collecting abilities of the bee colonies, letter grades were given each colony after each of the brood measurements. The strongest 20 colonies were rated as "A's," the 20 colonies of medium strength were "B's," and the weakest 20 colonies were graded "C." Table 3 shows the relative amounts of pollen collected on July 17 and August 8 compared with the strength ratings established within two days of each pollen collection. The average weight of pollen collected is expressed in table 3 as a percentage of the pollen collected by the "A"

TABLE 1. COLONY BROOD STRENGTH AVERAGES

Treatment	5/28	6/18	7/18		8/6	
	sq.in.	sq.in.	sq.in.	% of control	sq.in.	% of control
(1) Control	986	987	426	100	381	100
(2)	No Differences		563	132	419	110
(3)			450	106	419	110
(4)			407	96	357	94

TABLE 2. COLONY BROOD STRENGTH CHANGES DURING ALFALFA SEED POLLINATION

Date of Measurement	Average area of Brood sq. in.	Brood Area % of May 28
May 28	977	100
June 18	898	92
July 18	368	38
August 6	304	31

TABLE 3. POLLEN COLLECTED FROM COLONIES OF DIFFERENT STRENGTHS

Strength Ratings*	Brood: July 18 Pollen: July 17	Brood: Aug. 6 Pollen: Aug. 8
	Pollen Collected as % of "A"s	
A	100	100
B	55	55
C	27	13

*Average Square Inches of Brood Area:

	May 28	July 18	August 6
A's =	1,304	655	546
B's =	972	401	348
C's =	656	96	51

strength colonies. The results shown for the "C" strength colonies have been adjusted to omit any queenless colonies. A direct relationship between brood area and the amount of pollen collected is shown in these results.

No effort was made to equalize the queens for age or genetics before or during the experiment. The colonies used were similar to those many beekeepers use commerically in alfalfa seed pollination. The relative strength rating of individual colonies (A, B, or C) did not stay the same for most colonies during the 70-day period between the May 28 and August 6 brood measurements.

Five of the original "A" strength colonies were still in the "A" column at the end of 70 days. Nine of the original A's dropped to a "B" strength rating, and six original A's were rated as C's at the end of the experiment on August 6. The changes which occurred in the relative strength ratings of the original B's and C's are also listed.

Of the 20 weakest colonies rated as C's on August 6, 13 were queenless colonies. These 13 colonies were either completely dead or had very weak populations. Four of these same queenless colonies had been rated as A's, five as B's, and four as C's on May 28. The many extreme changes in relative colony strength during this experiment indicate the importance of the queen bee in colonies offered for alfalfa seed pollination—and the value of requeening. Additional research is needed to determine how often requeening should be done and the best timing of this management operation to assure maximum pollination for bee-pollinated crops.

When the expenses of feed materials, time, equipment, and overhead are totaled it costs between 25c and 30c to feed a colony 1½ lbs of drivert sugar with 1 per cent pollen before moving to alfalfa seed pollination. The expense of annually requeening each colony varies with queen stock, availability of queens, and labor costs. A reasonable average figure to use for Fresno County is $2.25 per colony if queens are purchased in the spring or $1.50 if requeening is done in the fall of the year.

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POLLEN COLLECTION GRAPH FOR NINE WEEKLY COLLECTION PERIODS IN ALFALFA SEED TEST PLOTS

FIGURE B