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Improving honey bee pollination efficiency in almonds

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During the 1979 almond pollination season, it became apparent that fewer bees were visiting the center rows than outer rows of large (70-acre, ½- by ¼-mile) orchards near Shafter, California. Pollination specialist S.E. "Mac" McGregor, of the U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS), had noticed the problem and then in June, not long before he died, he and the senior author observed that fewer nuts had developed in the centers of those orchards. These simple observations led to a four-year series of cooperative USDA-ARS/University of California pollination and bee management experiments funded by the USDA-ARS and the Almond Research Board of California.

Our initial goal was to determine why there were fewer bees and nuts in the center of large fields, but eventually studies included methods of improving the pollination efficiency of each apiary (or "bee drop"), each colony, and each forager. All studies were conducted in orchards (eight years old in 1980) near Shafter, each planted to the cultivars Merced, Nonpareil, and Texas Mission in a repeating 1:2:1 row pattern.

Bees placed around smaller orchards, 40 acres or less, are within easy foraging distance of all trees in the orchard. Excellent studies reported by Dr. Norman Gary (UC Davis), using a mark-recapture system with numbered metal tags placed on foraging bees and magnets at hive entrances, established the average flight in almond orchards at about 330 yards (40 rows). To obtain adequate pollination throughout larger orchards, beekeepers usually move some of the colonies into the center of the orchard. In very large orchards — those over about 80 acres — this has been the only known means of getting enough bees to forage in the center. Putting bees inside the orchard has some definite disadvantages for both beekeepers and growers. For the beekeepers, moving colonies into orchards can be time-consuming and difficult or impossible especially in rain or mud. Growers have difficulty moving large equipment through the orchards after the bees are in, with the risk of upset or damaged colonies (and stung or frightened tractor operators).

We conducted studies to find a better distribution. One was in a 70-acre orchard with 100 rows by 50 rows of trees, typical of many orchards in Kern County. Instead of distributing uniform numbers of colonies per bee drop at about ⅒-mile intervals (as is appropriate in alfalfa seed fields), we put fewer colonies on the short sides and near the corners and concentrated the bees near the middle rows. We put 67 percent of the colonies in the middle 20 percent of the long sides (rows 40 to 60). This grouping pattern appears to have increased foraging competition, which led to a more uniform distribution of pollinators in the orchard (fig. 1).

In 1981, we studied an 86-acre orchard with two bee drop patterns. First, we used an extremely inappropriate pattern to accentuate the distribution problem (situation 1, fig. 2). After counting bees per tree across the orchard, we moved these colonies out and replaced them with about the same number of colonies in a different pattern (situation 2). Although several factors influencing bee flight could not be held constant, such as temperature variations, colony strengths, and amount of bloom, we felt that the more uniform distribution of foragers across the orchard in situation 2 was the result of concentrating the colonies. We still encourage putting colonies inside the larger orchards where it is convenient, but this or a similar modified bee drop pattern may be a suitable alternative when necessary.

UC research indicates that pollen foragers are more efficient than nectar collectors as pollinators of almonds. Many previous studies have shown that removing pollen from returning foragers with pollen traps increases pollen gathering by the colony. According to our data, colonies with pollen traps respond by sending out more bees, a higher percentage of which are pollen foragers. In 1983, pollen-trapped colonies collected between 53 and 74 percent more pollen than did untrapped colonies. We knew of no studies, however, on whether use of pollen-trapped colonies increased crop yield.

Results of a 1983 test with trapped colonies suggest a positive effect (table 1), but one year is not long enough to be certain that the traps were responsible. In the relatively poor nut-yield season of 1983, the 70-acre test orchard surrounded with 140 pollen-trapped colonies (7.9 frames of bees per colony) maintained a yield equal to the 1982 yield, but the control orchard surrounded with 146 colonies without pollen traps (7.7 frames of bees per colony) had only 67 percent of its 1982 yield. Pollen traps may have resulted in the significantly higher forager population (27 versus 23.8 bees per tree) and maintenance of nut yield in the test orchard in 1983. A comparison of the 1982 and 1983 data makes it clear that bees per tree are not correlated with nuts per tree, but relative numbers within test and control orchards are consistent; that is, an

TABLE 1. Relationship between honey bee foragers (bees per tree) and nut yields in two years; colonies fitted with pollen traps on one almond orchard in 1983

	Bees/tree*		Nuts/tree (kernel wt.)*	
	Orchard		Orchard	
Year	7 E-H	10 E-H	7 E-H	10 E-H
			kg	*kg*
1982 (no traps)	14.8 c	14.6 c	12.8 a	12.9 a
1983 (traps on 7 E-H only)	27.0 a	23.8 b	12.3 a	8.7 b

*Means with different letters within categories (bees/tree, nuts/tree) are significantly different at the 5 percent level of probability according to Duncan's multiple range test.

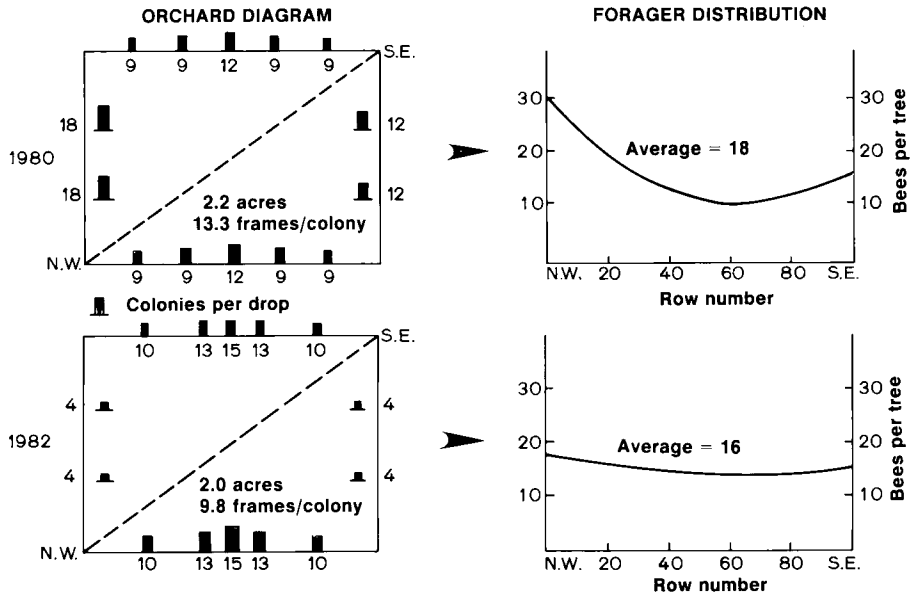

Fig. 1. Drop pattern in which beehives were evenly placed around the perimeter of an almond orchard resulted in fewer honey bees foraging on interior trees. Experimental distribution of hives (lower) achieved more uniform foraging throughout orchard.

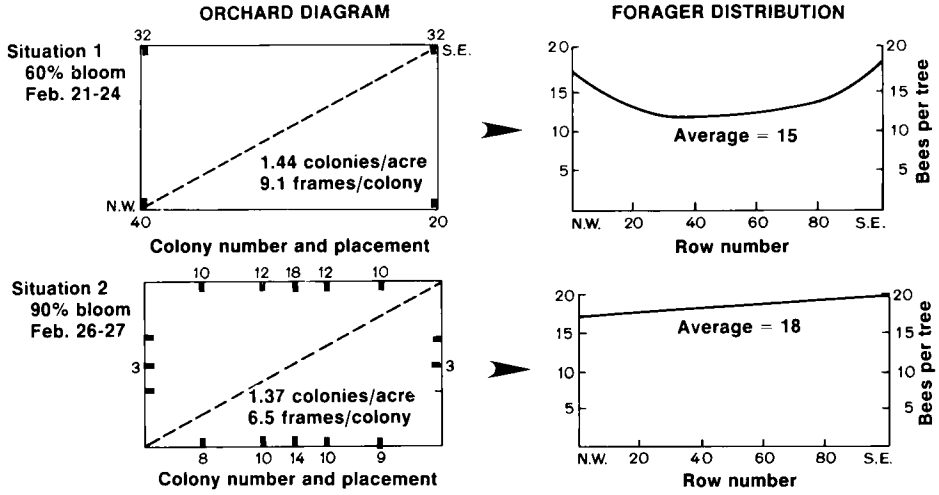

Fig. 2. Deliberately inappropriate distribution of colonies (situation 1), resulted in uneven foraging. Redistributing colonies in an experimental pattern (situation 2) resulted in more uniform foraging, although factors other than distribution could have been responsible.

equal number of bees per tree in 1982 resulted in an equal number of nuts per tree, whereas in 1983 unequal bees per tree resulted in unequal nuts per tree.

Fitting colonies with pollen traps and servicing the traps is never an easy job but may be worthwhile for the beekeeper if good dry pollen is obtained and the traps are not left on the colonies too long. Some studies indicate that colonies fitted with pollen traps for longer than one month have reduced brood-rearing. In our experience, high humidity, fog, and rain make almond pollen trapping difficult. Our results indicate to the almond grower however, that a beekeeper's use of pollen traps will not decrease and may well increase the colonies' effectiveness.

If some viable pollen were accidentally transferred from the body hair of returning pollen foragers to the hair of the nectar foragers while they are in the hive, the transfer would tend to improve the pollination efficiency of nectar collectors. Although in-hive transfer of pollen has recently been reported by Michigan researchers in apple pollination studies and has also been suggested by observations in California almonds, its significance is difficult to prove.

Studies were designed to increase the likelihood of pollen transfer in the hive and to capitalize on it. In one study, a brushlike device at the entrance of the colony removed a little pollen from the body hair of incoming foragers; foragers going out picked it up and deposited it on almond flowers. A second device, similar to a pollen trap, forced bees to crawl over pollen recently scraped from the bees' legs as they went out. Caged trees with no bees (control) averaged 22 nuts per tree (range 22 to 25, n=4) probably from wind-blown pollen. Individual caged trees with hives having the modified entrance averaged 56 nuts (range 35 to 77, n=2).

On both groups of trees, some of the developing nuts were blanks — hulls with no meat. Pollen removed from the hair of honey bees has been shown to have reduced germinability (onion pollen as studied by Dr. Frank Parker, USDA-ARS, Logan, Utah). Although the viability of body-hair pollen was not tested in this study, fresh bee-collected almond pollen (from pollen traps) gave similar results when tested: nut set was only 54 percent as good as with fresh hand-collected almond pollen, and a higher percentage of blanks resulted. The percentage of blanks resulting from hand pollinations was 16.8 percent with bee-collected pollen but only 5.3 percent with hand-collected pollen. When reductions due to less viable pollen and to blanks are combined, the use of bee-collected pollen would result in only 47 percent as many good nuts as would be obtained from hand-collected pollen. Thus, pollen transferred from bee to bee may be viable enough to set some almonds, but more blanks probably would result.

Low viability of pollen, whether the result of poor weather conditions or prolonged exposure while on the honey bee before deposition on almond flowers, may be a cause of blanks. The four caged trees (one tree per cage) that developed an average of 22 nuts per tree when none were expected were apparently minimally pollinated by wind-blown pollen (since after repeated attempts to self-pollinate 132 flowers by hand in one of these cages, not one nut or blank developed). Over 23 percent of these wind-pollinated fruits were blanks. Blanks occur more in some years than in others, even approaching 10 percent of some years' harvests. Low viability of pollen may be part, or all, of the explanation of the problem and may also explain the variable results obtained when hand-collected almond pollen is released by air over orchards.

In summary, not all of these studies have resulted in unequivocal increases in pollination efficiency. However, all of them seem to have some potential yield benefits, depending on orchard size and weather conditions.

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