1992 ANNUAL RESEARCH REPORT TO ALMOND BOARD OF CALIFORNIA

Project No. 92-F17 - Pollination

Project Leader: Dr. Robbin W. Thorp
Department of entomology
University of California
Davis, CA 95616

Cooperating Personnel: K. Lorenzen, J. Barthell, B. Root-Kelley, R. E. Page, Jr.

Objectives: 1) To develop information on pollination by bees which will result in increased production and greater grower returns. 2) To imporve pollination efficiency of rented honey bee colonies. 3) Evaluate and improve management of alternative pollinators.

Summary

Buds per meter: All cultivars in our test orchard near Dixon had more buds per meter in 1992 than in 1991. Strongest differences were in NePlus, Nonpareil and Price. Buds per meter were Fewer than in 1990 for Mission and Price, but more than in 1990 for NePlus, Nonpareil and Peerless. Low bud production in 1991 suggests biennial bearing. This response is most strongly seen in Price and Nonpareil and least so in Peerless.
Fruit set: Percent fruit set was highest in Mission and lowest in NePlus. This inverse relationship with buds per meter confirms patterns observed in 1991. These suggest that information on initial flower production and weather need to be considered when using percent fruit set as an indicator of pollination efficiency. Examination of stigmas from abortive fruits suggests that lack of pollination may be one cause of fruit drop.
Bloom progression: The bloom season in our test orchard near Dixon started later than in 1991 and was extremely compact. NePlus initiated flowering about 20 February and was the only cultivar in good bloom by 26 February. Nonpareil, Peerless and Price all peaked about 2 March and finished by 9 March. Bloom on Price declined the most rapidly on 4 March. Mission peaked about 2 March, but did not decline until about 6 March and still retained some bloom on 9 March.
Intertree flight activities: Observations of honey bee flight within and between trees of the same and different cultivars were continued to augment our cumulative database. As in previous studies, most bee flights are between flowers within a tree. When there is a strong difference in percent bloom among cultivars, most bees fly between trees of the cultivar in best bloom. When bloom is nearly equal between the cultivars, most flight is between trees of two cultivars. This confirms our earlier observations that in addition to distance between trees, intertree flights are strongly influenced by synchrony of bloom.
Pollen hoarding honey bees: Evaluation of high pollen hoarding strains of *Apis* were conducted in a cooperative study with Dr. R. E. Page, Jr. in an orchard near Dunnigan. We collected foragers returning to hives to determine the numbers and percentages of pollen vs. non-pollen forager populations. Pollen load sizes and types of pollen collected (almond vs other) were evaluated. Bees from high pollen hoarding colonies brought in 1.8 times as much pollen as those from commercial colonies indicating that pollination efficiency of colonies used in almonds can be enhanced through genetic selection. Detailed results and conclusions are presented in Dr. Page's report.

Orchard mason bees: Populations of *Osmia lignaria propinqua* collected in foothill sites in 1991 were released in our test orchard near Dixon. Some renesting was obtained during the abbreviated bloom season. Additional nests were acquired from foothill sites in 1992. Bees in nests moved to Davis in late May exhibited ability to survive the mild 1992 summer temperatures in the Central Valley as well as those left in the original site. Nests (cocoons) with diapausing adults will be stored overwinter in a cold room at UCD. They will be incubated and release in a test orchard in 1993.
Bumble bees: Spring queens of five species of bumble bees were collected and introduced into nest boxes in a warm room at UCD in an attempt to induce colony foundation. Few queens became broody and initiated nests. None successfully established colonies. End of season nests of *Bombus sonorus* were collected near Newcastle and at Davis to collect fall queens and males for mating and overwintering studies. Due to the difficulties in establishing colonies, it would be best to obtain colonies from a commercial bumble bee supplier for 1993 field evaluations in almonds.

Introduction

Our studies in the 1992 bloom season were conducted in two different orchards. The same 30 acre orchard near Davis used in our studies of the past several years was used for bud counts, fruit set, intertree flights of honey bees and field evaluation of orchard mason bees. This orchard contains five cultivars: NePlus, Nonapreil, Peerless, Price, and Mission in a hexagonal planting with every other row being Nonpareil. The second orchard, where we evaluated high pollen hoarding colonies versus commercial honey bees in cooperation with Dr. R. E. Page was near Dunnigan. Weather was cool with above average rain between 9-22 February. This produced a late and compact bloom season. Brief rains occurred in early to mid March during bloom.

Bud and Nut Set Counts

Bud and nut set counts were continued in the 30 acre orchard near Davis used in previous studies providing a 3 year comparison.

Methods: Buds per meter of branch were counted on five limbs each on 10 trees of five cultivars on 24 February 1992. Buds and flowers for nut set calcualtions were counted on one limb each of 10 per cultivar on 25 February. Initial nut set was counted on 1 May. Results are compared with those of 1990 and 1991. Stigmas were collected from flowers with developing fruits and those with small fruits that would not develop and examined by scanning electron microscopy (SEM) to determine if differences in pollen load could be detected as indication of pollination status.

Results: Buds per meter in 1992 were greater for all cultivars than in 1991 (Fig. 1). They were also greater than those for NePlus Nonpareil and Peerless in 1990, but less than those for Price and Mission in 1990 (Fig. 1). Percent fruit set in 1992 was greater for Nonpareil, Peerless and Mission than in 1991 and for Mission than in 1990 (Fig. 2). Preliminary evaluation by SEM of stigmas from well developed versus abortive fruits showed that pollen grains were present on stigmas of well developed fruits (Fig. 3), but not apparent on stigmas of abortive fruits (Fig. 4).

Discussion: Our three year record of bud production in our test orchard show biennial pattern with 1991 being the low year (Fig. 1). Percent fruit set reflects a combination of factors including effects of weather on pollination and bloom synchrony. Clearly, initial bloom availability needs to be taken into account before any comparisons of actual nut production can be made. Bloom production not only influences flowers that can produce nuts, but also the amount of cross-compatible pollen available for dispersal by bees. Absence of pollen on stigmas of abortive fruits suggests that lack of pollination may be at least one cause of fruit drop. This deserves further investigation.

Bloom Progression

The bloom season for 1992 started late and was very compact. It was interrupted by two brief periods of rain in early March.

Methods: Buds, viable flowers, and senescent blooms were counted on one limb each of five trees per cultivar on 26 February, 2, 4 6 and 9 March 1992 (Fig. 5).

Results: Neplus initiated bloom first, peaking by 26 February. Nonpareil, Peerless and Price all peaked about 2 March and finished by 9 March. Price declined most rapidly on 4 March. Mission bloomed latest with some bloom still present on 9 March. There was considerable overlap in bloom of all five cultivars during the compact bloom season of spring 1992 (Fig. 5).

Discussion: The bloom sequences were normal in 1992. The late season resulted in a very compact season with considerable overlap (synchrony) of bloom. Bloom synchrony benefits pollination through availability of pollen, receptive flowers, and maximum intertree bee flight between cultivars (see below). However, a short, compact bloom season restricts the window of time for bees to move pollen between trees.

Intertree Flight Activities

Bee-mediated pollen movements between almond trees of different cultivars is necessary to produce a commercial crop. Our previous data have shown that distance between trees and bloom synchrony are important determinants as to which tree a bee will fly to next when it leaves a tree. These data were based on observations in orchards with well defined rows of cultivars including those with two or more adjacent rows of a single cultivar. Current studies are based on an orchard with hexagonal or equilateral plantings to diversify and increase our long-term database.

Methods: Measurements were made of movements of foraging honey bees between trees within and across rows in an orchard with hexagonal or equilateral plantings of five cultivars with Nonpareil in every other row. Activity within trees was measured by counting bees during 60 second walks around trees of two adjacent cultivars. These were followed immediately by 60 second counts of flights between trees within rows of each pair of cultivars and between trees across adjacent rows of cultivars. Most measures were made between NePlus and Nonpareil and between Nonpareil and Mission as in 1990. Additional counts were made between Nonpareil and Peerless and Nonpareil and Price.

Results: Most movements by bees were within trees. Numbers of bees foraging within trees shifted through the season in relation to the amount of bloom available on a cultivar. When bloom percentage differs most between two cultivars, most bees fly between trees of the cultivar in greatest bloom (e.g., Nonpareil-Mission on 2 March, both near peak:

	Within		Between		
	N	M	N	M	N/M
Total	47	58	12	3	15
Mean	9.4	11.6	2.4	0.6	3).

When bloom is nearly equal between cultivars, most flight is across rows, between trees of two cultivars. (e.g., NePlus-Nonpareil on 26 February with NePlus at peak and Nonpareil starting:

	Within		Between		
	NP	N	NP	N	NP/N
Total	320	115	35	20	29
Mean	21.3	7.7	2.3	1.3	1.9)

Discussion: Canopies of trees in this orchard with its hexagonal or equilateral planting were as close or sometimes closer between trees of different cultivars (across rows) than between trees of the same cultivar (within rows). Pruning and canopy shape typical of the cultivar (e.g., erect growth in Mission, spreading branches in Nonpareil) often resulted in greater distances between canopies within rows of Mission than between trees of Mission and Nonpareil. In this hexagonal planted orchard then, distance between trees was not as important a factor as was bloom synchrony. Although more limited and often missing the cross-over point in relative bloom due to the extremely compact bloom season, results from 1992 confirm our earlier observations that in addition to distance between trees, intertree flights are strongly influenced by synchrony of bloom.

Pollen Hoarding Honey Bees

Our previous research has shown that pollen foraging honey bees are most efficient at transfering pollen within almond orchards. Selections of high pollen hoarding strains of honey bees have been made by Dr. R. E. Page, Jr., Department of Entomology, University of California, Davis. Cooperative studies with Dr. Page were initiated in 1991 and continued in 1992 to evaluate the performance of these genetic strains of honey bees in almond pollination.

Methods: In an orchard near Dunnigan comparisons were made of foraging activities of bees from colonies selected for high pollen hoarding versus commercial colonies. Total foragers, and those with pollen or nectar loads plus pollen type, pollen load sizes, and nectar loads of bees returning to hives were measured. Returning bees were collected by vacuum at entrances blocked with screens. Pollen loads were sorted by color to determine type and weighed to determine size.

Results: The results of these evaluations are to be found in the report to the Almond Board by Dr. Page. Summarily, we found that high pollen hoarding colonies collected about 1.8 times more pollen than did commercial colonies and that the majority of this pollen was from almonds.

Discussion: Evaluations of high pollen hoarding genetic selections of honey bees show that this genetic strain collects more almond pollen than commercial colonies in the same orchards. This enhances their value by increasing their efficiency for pollination of almonds.

Orchard Mason Bees

Our previous research in cooperation with Philip F. Torchio, USDA-ARS, Logan, Utah has shown that orchard mason bees, *Osmia lignaria propinqua*, are efficient pollinators of almonds in California. The major problem with their use has been obtaining adequate renesting and reproduction of populations in almond orchards. We have reestablished investigations on the management of these bees as alternative pollinators to be used to augment potentialy declining honey bee populations.

Methods: Populations trapped during other monitoring programs at sites in the southern Sierra foothills and Inner Coast ranges in 1991 were released in an almond orchard near Davis in late February 1992. Additional nests were trapped at the same sites during spring 1992. Some of the nests from the southern Sierra foothills were transferred to Davis and set out to determine whether the hotter conditions in the summer in the Central Valley might cause increased mortality. Some were held at room temperature in the lab at U. C. Davis throughout the summer. Nests were x-rayed to determine contents, survival, developmetal stages. Some were dissected and cocoons removed and bulked. Nests are being stored in a cool room at about 10^{o}C over winter and will be incubated and released in almonds in spring 1993.

Results: From the bees released in 1991, fewer bees were recovered than were released. Survival of bees from nests provisioned in the almond orchard and of those held over summer in Davis was as good as that of bees from nests provisioned in native habitats (Fig. 6). X-rays and subsequent dissections showed the presence of postdefecating larvae in some nests held under each summer condition (Fig 7). Depredators and parasites including: spider beetles, *Ptinus* (Ptinidae); blister beetles, *Tricrania* (Meloidae); and sapygid wasps, *Sapyga* (Sapygidae) were found in nests trapped from native sites.

Discussion: The low reproduction of *Osmia* in almonds in 1992 was probably due to the late and very compact bloom season that was mostly completed before much nesting by *Osmia* had occurred. Numbers of nests trapped in native habitats in 1992 was higher than in 1991 due to better weather for foraging in March and April 1992. *Osmia lignaria propinqua* normally overwinter as adults, but we found postdefecating larvae in some nests held under each summer condition indicating that parsivoltinism occurs in this species in California populations. In addition to developing management procedures to ensure reproduction during almond bloom, mass trapping to establish initial managed populations and control of nest depredators and parasites will need to be undertaken if orchard mason bees are to be successfully utilized for almond pollination.

Bumble Bees

In the search for alternative pollinators to augment honey bee populations in almond pollination, attention was given to the potential use of bumble bees. Usually only queens are found at the time almonds are in bloom because bumble bee colonies are annual, i.e., initiated each year by individual queens emerging from winter hibernation following mating and insemination at the end of the colony season. However, recent advances in producing colonies in confinement "out-of-season" for glasshouse pollination of tomatoes in Europe makes the evaluation of the pollination efficiency of bumble bees in almonds feasible.

Methods: Over 30 queens of five species of bumble bees, *Bombus occidentalis*, *bifarius*, *crotchii*, *californicus*, and *vosnesenskii*, were collected at various sites in California during spring 1992 in conjunction with other projects. These were refrigerated in the field and returned to the lab at U. C. Davis where they were introduced into nesting boxes in a warm, dark room. Queens were provided with 50% sugar syrup and a ball of pollen trapped from honey bee colonies to stimulate them to become broody and initiate egg laying. In fall 1992, two colonies of *Bombus sonorus* were excavated, one near Newcastle and the other on the U. C. Davis campus. Queens and males from these were released in to a large cage where they could feed, mate and, the queens could initiate hibernation. These can be used for hibernation studies and additional colony initiation research.

Results: Only a few queens of *B. vosnesenskii, occidentalis*, and *crotchii* became broody and attempted to initiate nests under confinement. None successfully established nests in the laboratory. In nests of *B. sonorus* we found parasites of adult workers including conopid flies of the genus *Physocephala* and its hyperparasite *Pediobius* (Eulophidae).

Discussion: Our lack of success in rearing bumble bee colonies in spring 1992 is due to several factors. The earliest queens were provided with frozen pollen collected from previous years. This is not as desirable as using fresh pollen. Some nests were disrupted by pests including ants and Indian meal moths (*Plodia*). It became quickly apparent that successful rearing of bumble bee colonies requires a greater effort in time, better controlled rearing facilities, and more money to do an adequate job than we were able to do with our limited resources. It is not the kind of operation that can be done as a sideline project as we attempted to do. Rearing bumble bees requires adequate staff, facilities and intensive full time care. Fortunately there is a private company, Plant Sciences, Inc., that has made great strides in rearing bumble bees in California in cooperation with a Dutch firm, Koppert B.V., that has been a leader in developing the technology for rearing bumble bees for glasshouse pollination of tomatoes in Europe. Plant Sciences has assured me that they will have adequate numbers of colonies available for evaluation research during almond bloom in spring 1993. Future efforts on our part will be best spent in field evaluation of pollination efficiency of bumble bees in almonds, rather that attempting to rear colonies.

Field collected colonies of bumble bees occur too late in the season to be of direct value for almond pollination. They also have well developed parasite and nest associate populations that can be avoided by rearing colonies in confinement. The temperment (highly defensive) and biology (pocket-maker) make *B. sonorus* difficult to manage and to rear. It is also primarily a species of southern distribution and summer flight. All factors considered, it does not seem a good choice for use in almond pollination. *Bombus terrestris* of Europe has been the species of choice for rearing and management for glasshouse pollination. In California, the closely related *B. occidentalis* has proven easiest to rear. It also occurs in north coastal climates and flies well under relatively inclement weather including: cool, windy, foggy, drizzly conditions. *Bombus vosnesenskii* has also been successfully reared by Plant Sciences and is an early flying species whose queens we have observed foraging on almond blossoms. Both of these species are good candidates for evaluation in almond pollination.

Publications

DeGrandi-Hoffman, G., R. W. Thorp, G. Loper and D. Eisikowitch. 1992. Identification and distribution of cross-pollinating honey-bees on almonds. J. Appl. Ecol. 29:238-246.

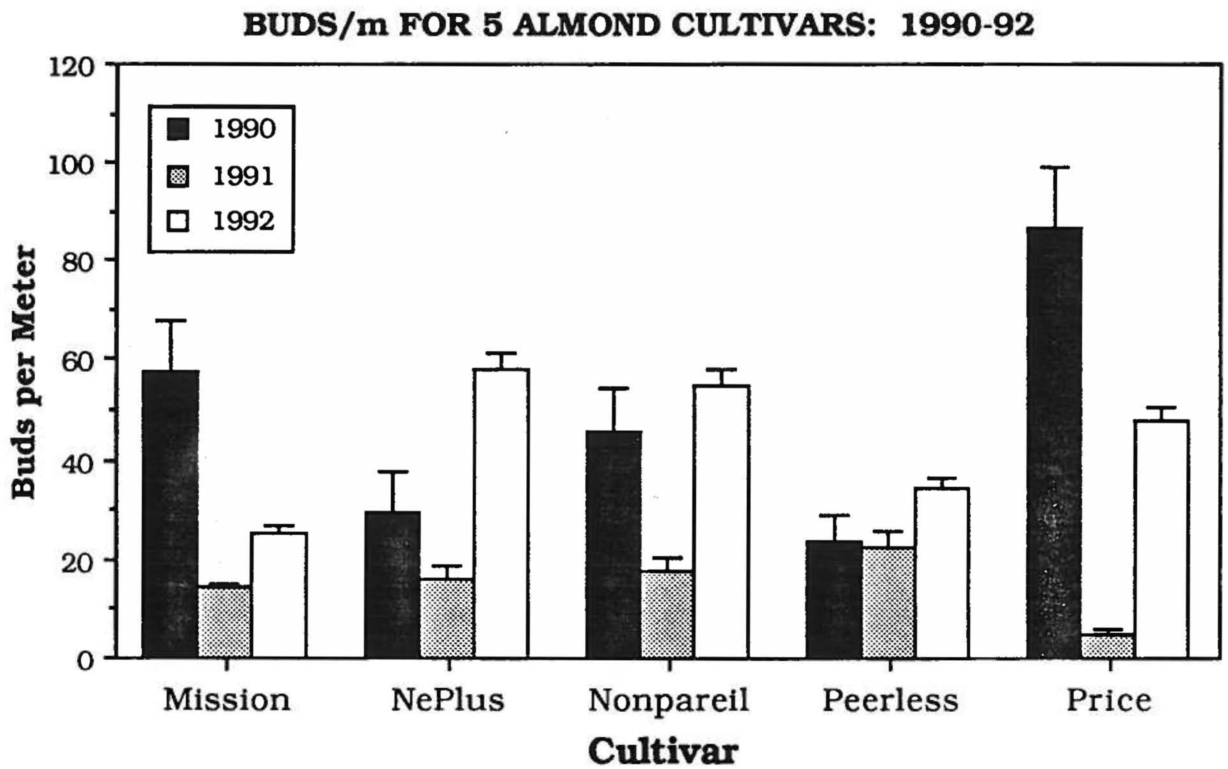

Fig. 1. Buds per meter production for five cultivars in an almond orchard near Davis, CA 1990-1992.

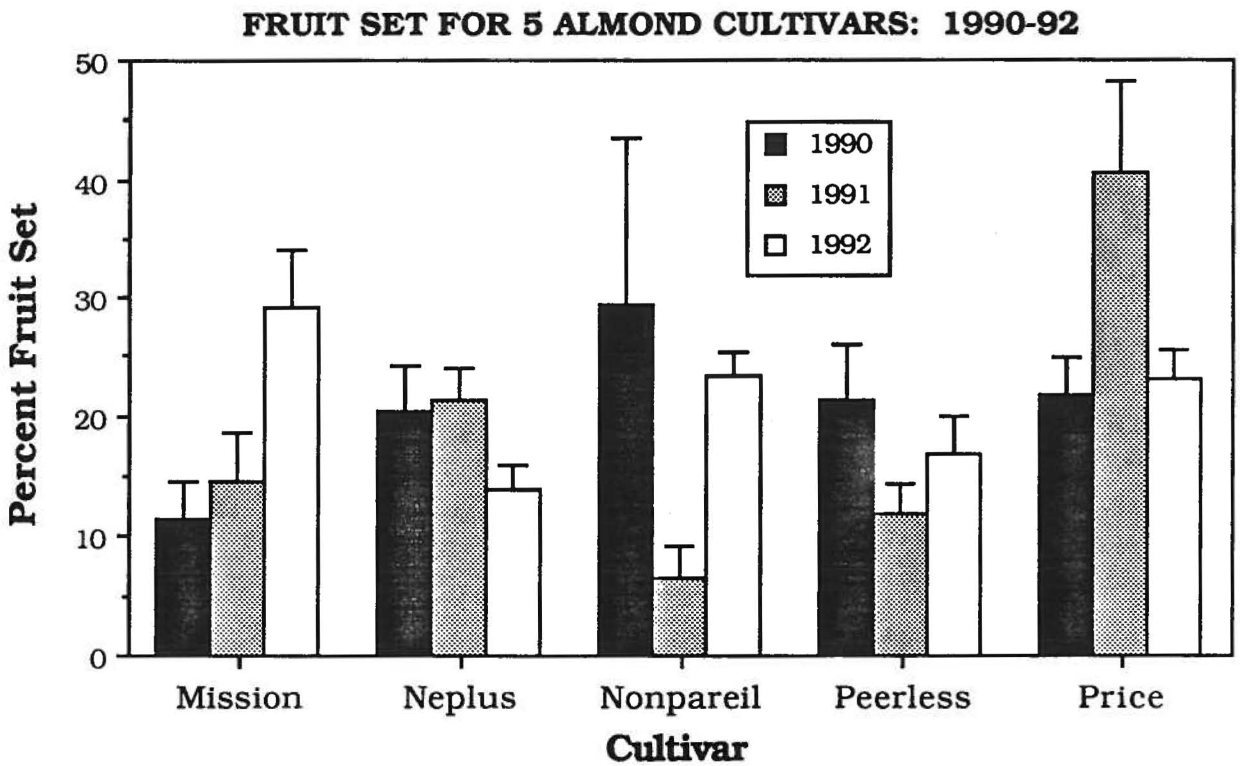

Fig. 2. Fruit set for five cultivars in an almond orchard near Davis, CA 1990-1992.

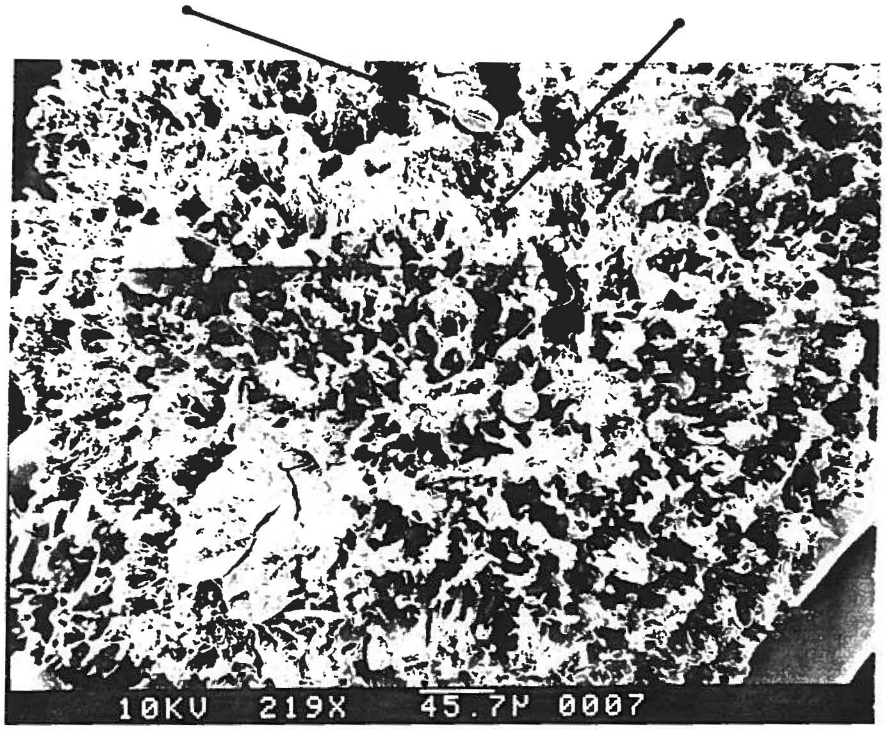

Fig. 3. Scanning electron micrograph of a stigma from a maturing almond fruit showing presence of pollen grains (arrows).

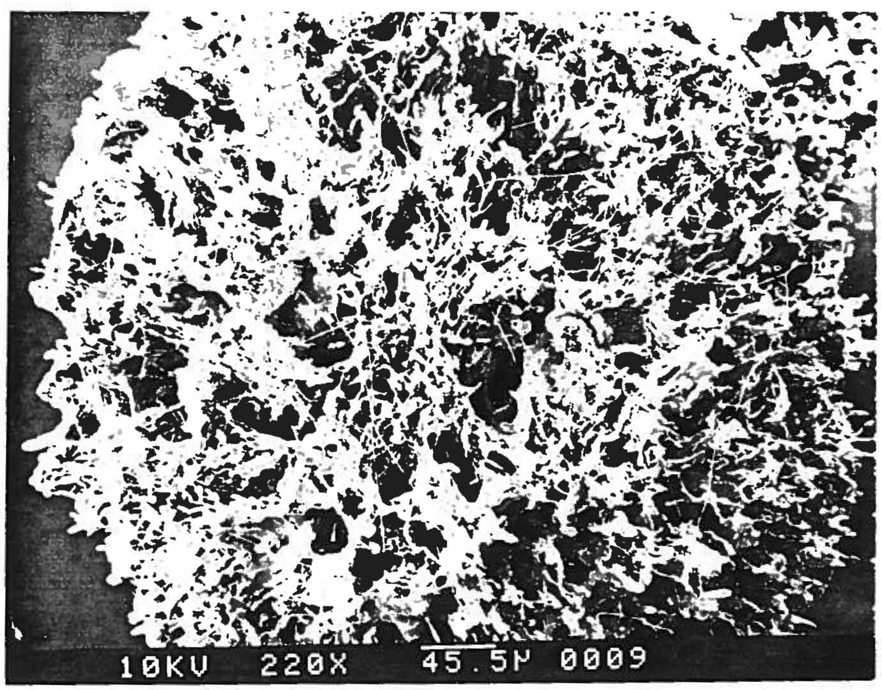

Fig. 4. Scanning electron micrograph of a stigma from maturing almond fruit illustrating absence of pollen grains.

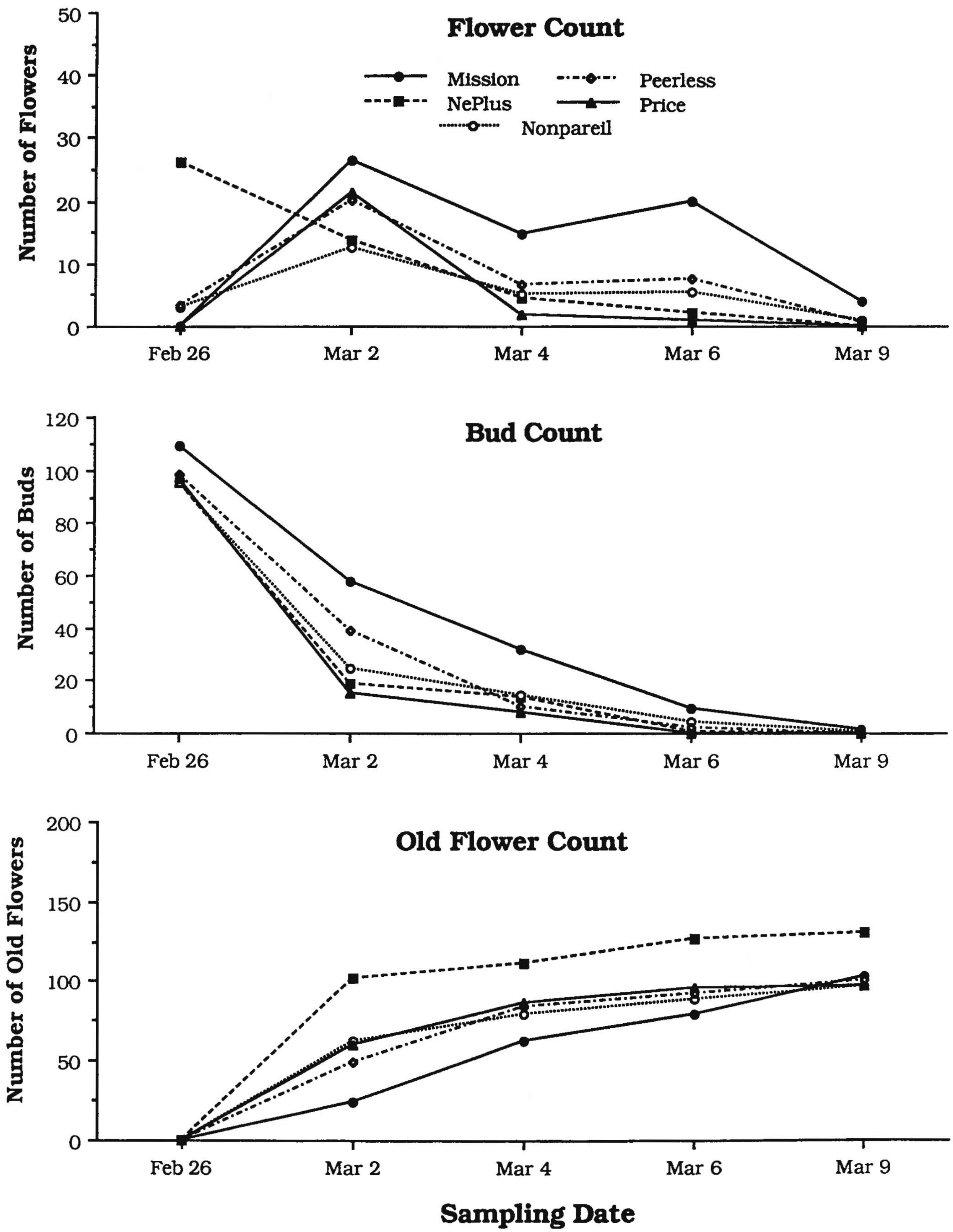

Fig. 5. Bloom progression of five cultivars in an almond orchard near Davis, CA 1992. Upper: receptive flowers. Middle: buds. Lower: senescing, post-receptive flowers.

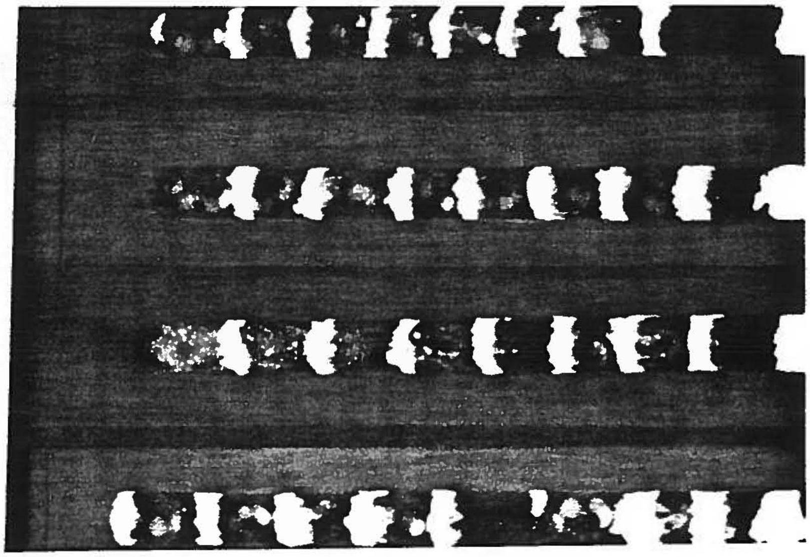

Fig. 6. X-ray illustrating survival and maturation to overwintering adults of the orchard mason bee, *Osmia lignaria propinqua*, held over summer in Davis in 1992.

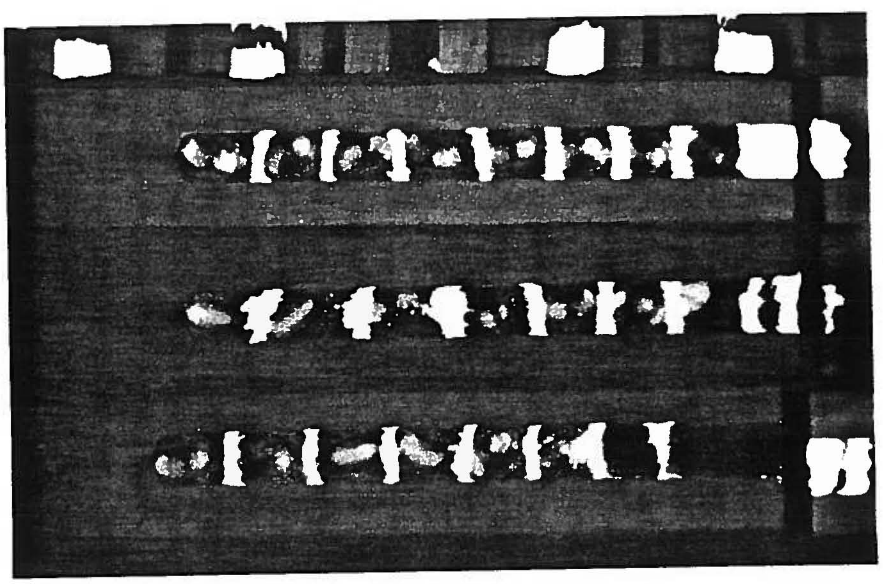

Fig. 7. X-rays showing the presence of postdefecating (parsivoltine) larvae in the bottom two nests of the orchard mason bee, *Osmia lignaria propinqua* in California in 1992.