1994 ANNUAL RESEARCH REPORT TO ALMOND BOARD OF CALIFORNIA

Project No. 94-F19 Pollination

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Objectives:

1. Develop information on pollination by bees that will result in increased efficiency and greater grower returns.
2. Improve pollination efficiency of rented honey bee colonies.
3. Evaluate and improve management of alternative pollinators.

Summary

Weather- The 1994 bloom season in the Sacramento Valley "exploded" in the warm weather of late February and early March. Most cultivars overlapped well providing excellent conditions for cross-pollination.
Pollen hoarding bees- Cooperative studies with Dr. R. E. Page, Jr. to evaluate pollen hoarding honey bees for almond pollination were postponed to search for additional queens to increase the genetic variability of his stock.
Queen mandibular pheromone- QMP from Canada was sprayed in five replicates of four treatments: 0 (control), 200, 400, and 800 queen equivalents (QE) in an 80 acre orchard near Chico to determine if it would increase honey bee foraging activity and harvest yields. Although analyses showed no statistically significant differences, there were consistent trends: the high dose had the most bee activity; the control had the least fruit set and yield; and the 400 (QE) dose had the most fruit set and yield.
Buds per meter- In a test orchard near Dixon, buds per meter counts were made among five cultivars as part of a long-term study. Bud production in 1994 was generally greater than in 1993 for all cultivars. NePlus, Nonpareil, and Price exhibited alternate bearing over the five year period. This pattern was apparent to a lesser extent in Peerless.
Bloom progression- Bloom of the five cultivars in our test orchard near Dixon started late and progressed rapidly during the warm weather of late February and early March. Most cultivars bloomed simultaneously providing excellent overlap for cross-pollination.
Fruit set- Fruit set was inversely related to buds per meter over the past five years. This pattern was most apparent in those cultivars that showed the strongest alternate bearing.
Orchard mason bees- Small populations of *Osmia lignaria propinqua* produced in almonds and trapped during another project in 1993 were placed in a shelter in almonds on 3 March 1994. No nests were completed during the extremely short bloom season, and nesting continued after almond bloom. Timing of introduction of *Osmia* into an orchard is critical.
Bumble bees- Populations of *Bombus occidentalis* were evaluated for their potential as pollinators of almond at Dixon and at two sites near Arbuckle. Our observations confirm our findings in 1993 that bumble bees work faster, cover more area of bloom per unit time, collect more pollen per individual, leave trees more frequently, and have a higher ratio of pollen foragers than do honey bees.

Introduction

The 1994 almond bloom season in the Sacramento Valley started late and progressed so rapidly that it seemed to "explode" during the warm weather of late February and early March. Most cultivars bloomed simultaneously providing excellent overlap for cross-pollination.

High Pollen Hoarding Honey Bees

Cooperative studies with Dr. R. E. Page, Jr. to evaluate pollen hoarding honey bees for almond pollination were not conducted during the 1994 bloom season. They were postponed so that Dr. Page and his team could search for additional high pollen hoarding colonies as sources of new queens to increase the genetic variability of his stock. Field studies to test the efficiency of these selections for almond pollination are still needed.

Queen Mandibular Pheromone

With funding from Phero Tech, Inc. of Canada, we established test plots at Almont Orchards near Durham, CA. Queen mandibular pheromone (QMP) was applied as four treatments of different doses to five replicated plots each of Nonpareil trees to determine if it would increase honey bee foraging activity and harvest yields.

Methods: Queen mandibular pheromone (QMP) produced by Phero Tech, Inc. of Canada under the trade name, "Fruit Boost" ®, was sprayed on trees of Nonpareil in twenty plots. Four treatments of 0 (control), 200, 400, and 800 queen equivalents (QE) were applied to trees in five replicates in an 80 acre orchard near Chico (Fig. 1). Each plot consisted of 17 Nonpareil trees bounded by a row of Carmel on the east and a row of alternating trees of Butte and Peerless on the west. Buffer zones of 5 to 7 rows existed to the east and west of the treated plots, but there were no buffer areas to the north or south.

Bee visitation was measured on the afternoon of 28 February 1994 prior to the spray application. The sprays were applied in early morning of 3 March and completed by 9:30 AM. Post-spray bee visitations were counted in the mornings and afternoons of 3 and 4 March. That is about 2, 5, 24, and 29 hours after the spray application. A final bee visitation count was made at midday on 7 March, about 100 hours post-spray. Counts consisted of one minute observations of the numbers of bees per tree for five trees per plot. Two observers covered 10 plots each.

Additional counts of numbers of pollen versus nectar foragers were made by counting the first 20 or so foragers in trees in 2 replicate plots of each treatment on 28 February, 3, 4, and 7 March. Most counts were made in mid to late afternoon.

Blossom units were established on five trees per plot on 24 February and on an additional tree per plot on 28 February by counting all buds and flowers on a section of one limb per tree that contained about 100 units. A color coded, numbered flag of engineers tape was tied at the base of each blossom unit count. Bloom progression (phenology) was measured on an additional Nonpareil tree per plot on 24 and 28 February, 3, 4, and 7 March. Again about 100 blossom units were counted and flagged. Fruits were counted on 26 April and 3 August to obtain initial and final nut set.

Harvest yield data were collected on 2 September. In preparation for the harvest (shaking, sweeping, and vacuuming), we reflagged all plots on 26 August. We hand raked the fruits at ends of all plots in preparation for sweeping since there were no buffer areas. Fruits were vacuumed from each plot (row) into a bin. Each bin was taken to a field weighing station, weighed, and the tare weight of the bin was subtracted.

Thirty fruits were taken from subsamples bagged from each plot (bin) giving a total of 150 fruits weighed, then husks were removed to obtain the in-shell weights, and finally the shells were removed to give the nut meat weights. Nut meats had the least variance and were used for comparison between plots.

Results: Analyses showed no statistically significant differences in bee visitation, percent fruit set, harvest yield, and individual fruit weights for any of the treatments (Figs 2-5). However, there were consistent trends: the high dose treatment had the most bee activity (Fig. 2): the control had the least fruit set and yield (Figs. 3 & 4).

Bee visitation was highest in the plots designated to receive the control treatments (0 QE) and lowest in plots designated to receive the 400 QE dose prior to treatment. This pattern remained the same through 2 hours after treatment, but shifted to where the 800 and 200 QE dose treatments had the highest visitation at 5 and 24 hours post-spray, and back to virtually no difference at 100 hours post-spray (Fig. 2).

The average percent of pollen foragers versus nectar foragers was highest, greater than 55%, on 28 February, prior to treatment, when Nonpareil was in about 50% bloom. It was lowest in the control plots (55.9%) and highest in the plots to be sprayed with the 800 (QE) dose. The percent of pollen foragers was less than 17% immediately (4 hours) after treatment with the highest (16.8%) found in the control plots (0 QE) and the lowest (2.3%) occurring in the maximum treatment (800 QE). On 4 March, 26 hours after treatment, the control trees still had the highest percent pollen foragers (40.5%) and the 400 (QE) dose the lowest (16.7%) while the 800 and 200 (QE) doses had 31.0% and 32.6% pollen foragers respectively. On 7 March, the pollen collecting bees had dropped to below 15% of the foragers in Nopareil trees with the fewest in the control and the 800 QE dose plots (6.0% and 9.1% respectively).

Bloom progression (phenology) counts showed Nonpareil to be all in bud on 24 February, nearly 50% bloom on 28 February, 83% on 3 March when the spray treatments were applied, 86.5% on 4 March, and 96% on 7 March. Shifts from the receptive flower stage to the senescent category were equally rapid. Percent senescent flowers averaged: less than 0.14% on 28 February, 11.2% on 3 March, 24.1% on 4 March, and 81.5% on 7 March.

Initial fruit set counted on 26 April showed no significant differences between plots (Fig. 3), but the control plots were the lowest and the 400 queen equivalents the highest. Final fruit set counts on 3 August, after the June drop and just prior to harvest were not much different. Tags on one tree each in two plots could not be relocated, so calculations either involved missing data points or had to be adjusted to account for missing data, and therefore were not included here.

Weights of individual fruits from each plot showed no significant differences between treatments in pooled weights of replicate samples for 150 each whole fruits (="husks"), in-shell, or nut meats. Mean weights of 150 nut meats per treatment of 800, 400, 200, and 0 queen equivalents were: 1.239g, 1.204g, 1.242g, and 1.216g respectively with F-test = 1.45 (3 DF) and p - 0.2272 (596 DF) for a 1-way ANOVA. Larger samples would be needed to conduct a 2-way ANOVA.

Discussion: Although analyses showed no stastically significant differences, there were consistent and promising trends: the high dose replicates had the most bee activity; the control had the least fruit set and yield; and the 400 (QE) dose, the dose recommended for many other crops, had the most fruit set and yield.

The conditions for this trial were less than ideal. The bloom of Nonpareil progressed extremely rapidly once it started, jumping from all buds on 24 February to nearly 50% on 28 February to 83% on 3 March, the date of application. Problems in shipping the pre-mixed spray materials to the grower caused the application to be put on latter than desireable. These factors combined so that there was no time for more than one application.

In spite of the problems encountered, there were noticeable shifts in bee activity following the spray applications. Bees were most abundant in the plots designated to be the control replicates prior to the treatments. At five and 24 hours after treatment bees were most abundant at trees that received the highest doseage of QMP. At 100 hours after the spray application, numbers of bees in the control and 800 QE dose plots were essentially equal and slightly greater than those in the 400 and 200 QE dose plots. The decrease in percent pollen foragers over the season is to be expected since it should be inversely related to the increase in senescent flowers, those no longer presenting pollen. The shift from lowest percent pollen foragers to highest druing the first 24 hours after treatment and then back at 100 hours after treatment in trees in the control plots suggests that the apparent increase in bee activity at trees treated with QMP was an increase in nectar foragers at the expense of pollen foragers. This is probably an artifact of our small sample size. If not, it could present a problem because we have shown in previous research that pollen foragers are more efficient pollinators in almond than are nectar foragers.

The warm dry weather during bloom and the close synchrony of bloom in all cultivars provided ideal conditions for cross-pollination. Such conditions would be expected to reduce any differences between treatments in such a test. The resulting trends suggest that the doseages of QMP applied may enhance pollination in almond and deserve additional testing, especially under less than ideal pollination conditions.

Bud Production, Bloom Progression, and Fruit Set

In the Rotteveel orchard near Dixon, CA, buds per meter and bloom progression counts were made as a basis for determining percent fruit set and phenology patterns among five cultivars in a long-term study. Bud production in 1994 was generally higher than in 1993 for all cultivars. NePlus, Nonpareil, and Price exhibited alternate bearing over the five year period. This pattern is apparent to a lesser extent in Peerless. Again fruit set tends to be inversely related to the initial bud production, especially in cultivars having apparent biennial bearing.

Methods: Buds per meter were counted on one limb each of 10 trees in one row of each cultivar. Starting at the tip of each branch, a meter tape was run toward the base, measuring along each major spur and branch until one meter was reached. A clothes pin was clamped to the branch and all buds were counted from the apex of each limb. A color coded flag of engineers tape replaced the clothes pin and was numbered using a sharpie pen to identifyi each tree.

Bloom progression counts were made every 2 to 4 days along a diagonal (NE-SW) transect across the orchard using five trees per cultivar. More than 100 buds on one limb per tree were counted from the tip and a color coded flag of engineers tape was placed at the base of the section of initial buds counted. Bloom units were classified into three categories: bud (small buds through popcorn stage with petals showing but not separating); flower (from anthesis with petals just opening enough so that a bee can enter and contact stigma = "cup-shaped," through initial petal drop); and senescent flower (with most petals gone, anthers empty, and stigma and style tip darkened).

Initial fruit set was counted on 9 May about 8 weeks after bloom. Final fruit set counts were made on 21 June. Fruits were counted on the tagged limbs in the transect used for the bloom progression counts. Percent fruit set was calculated by dividing the number of large fruits produced and multiplying by 100.

Results: Bud production in 1994 was generally higher than in 1993 for all cultivars (Fig. 6). NePlus, Nonpareil, and Price exhibited alternate bearing over the five year period. This pattern was apparent to a lesser extent in Peerless. The 1994 bloom season was short and progressed rapidly with strong overlap in bloom among all the cultivars (Figs. 7a-c). The sequence of bloom was as in past years with NePlus being the earliest and Mission the latest. Price, Nonpareil, and Peerless were again the middle blooming cultivars even though there was relatively little distinction in time of bloom among any of the five cultivars. Fruit set was inversely related to the buds per meter. This pattern was particularly apparent in those cultivars that showed the strongest alternate bearing over the past five years (Fig. 8).

Discussion: Most of the cultivars in our test orchard continued to exhibit a biennial bearing pattern based on buds per meter production over the past five years. This alternate bearing can influence the bee/flower ratio and percent fruit set.

The 1994 bloom season in our test orchard and in the rest of the Sacramento Valley started late and progressed so rapidly that it seemed to "explode" during the warm weather of late February and early March. Most cultivars bloomed simultaneously providing excellent overlap for cross-pollination.

Alternate bearing expressed by some cultivars usually results in increased percent fruit set in low bud production years, but the reverse in years of high bud production. Percent fruit set was highest in trees with the lowest buds per meter counts. This suggests that trees with low bud densities can compensate by devoting more resources to developing fruit. Trees with low bud and subsequent flower densities may also be more effectively pollinated due to more bees per flower producing more rapid depletion of pollen and nectar resources each day. This could cause increased bee flights between trees and therefore better movement of out-cross pollen in the orchard. However, it suggests that growers should also consider renting more bees during years of high bud densities or other means of increasing bee activity during these years to ensure an adequate bee/flower ratio and to obtain even better fruit set during good flowering years.

Orchard Mason Bees

Small popoulations of *Osmia lignariapropinqua*, the orchard mason bee, produced in almond and trapped during another project in the previous year, were released in an almond orchard near Dixon on 3 March 1994. No nests were completed during the extremely short bloom season. However, nesting continued after almond bloom. Timing of introduction of *Osmia* into an orchard is critical.

Methods: *Osmia* produced in an almond orchard near Dixon in 1993 (ca 260) and those trapped at two sites in spring 1993 (ca 390) were overwintered in a cold room starting in November 1993. They were incubated and released in an orchard near Dixon, CA on 3 March 1994. At the end of almond bloom, the nest domicile was moved to Davis until females ceased nest construction. Straw and stick nest units were x-rayed to determine the number and viability of progeny. Trap-nest sites were in the Sierran foothills of Madera County and the Diablo Range of Contra Costa County. Additonal bee nests (ca 40 containing ca 110 brood cells) were trapped from the two source sites in March-May 1994. All nests produced and trapped in 1994 were put into a cold room in late October 1994 for overwintering for use in spring 1995.

Results: Although there was evidence of emergence (from 309 of 652 brood cells) and foraging, no completed nests were produced by *Osmia* females in the almond orchard during the extremely short bloom season of 1994. Only 3 nests with 13 completed brood cells were produced from females released in almond and allowed to continue nesting after almond bloom. All prepupae of 1994 were destroyed by the parasitoid, *Monodontomerus*.

Few *Osmia* nests (ca 40 containing ca 100 brood cells) were trapped at source sites in 1994, even where good numbers of bees had been produced in previous years.

Discussion: The low numbers of nests completed in almond in 1994 was due to the very short bloom season and the small initial population of bees. The low numbers of nests obtained in source sites in spring 1994 was probably due to drought. Considerable effort should be put into trapping *Osmia* from source sites in spring 1995 for future testing.

Bumble Bees

Populations of *Bombus occidentalis*, the western bumble bee, were evaluated for their potential as pollinators of almond at Dixon and at two sites near Arbuckle. Our observations confirm our findings in 1993 that bumble bees work faster, cover more area of bloom per unit time, collect more pollen per individual, leave trees more frequently, and have a higher ratio of pollen foragers than do honey bees.

Methods: Twenty colonies of *Bombus occidentalis*, the western bumble bee, were provided by Bees West, Inc. and placed in an almond orchard near Dixon, CA on 1 March 1994. The "quad" domicile was designed to house four bumble bee hives so that their entrances would be facing different directions, thus minimizing chances for drift. The hives were sandwiched between two plywood squares strapped together and with a square hole in the center of the bottom board. The entire unit was designed to slip over a 4x4 redwoood post sunk into the ground so that the bottom of the top board rested on the post. Shims between the hole and post held the unit firm. All colonies had about 100 workers initially. Entrance activity was monitored by observing pairs of entrances for 5 minutes for a total of 10 minutes per domicile. Numbers of bees entering with or without pollen and numbers of outgoing workers were recorded. Periodic searches were made for bumble bee workers in the trees to count numbers of flowers visited per minute, distances moved, and number of moves between trees during foraging bouts. Each time a bumble bee was observed for 60 seconds, a honey bee was observed for paired activity comparisons. At Arbuckle, we observed activity at hive entrances and in trees in two orchards with 50 to 100 bumble bee hives. All orchards also had standard complements of honey bee hives in addition to the bumble bees.

Results: The first two days after bumble bee hives were placed in the orchard near Dixon, there were considerable numbers of orientation flights at the hive entrances with bees spiraling in larger loops away from the hive while facing the hive initially. Many bees were noted inspecting the post on which the domicile rested and the trunks of nearby trees. The hives were all open by 09:15 on 1 March and by 14:05 and 15:06 bees were returning with loads of almond pollen in their corbiculae. On 2 March, 27.7% of the bees leaving the hives were still exhibiting orientation flights. All of the incoming bees were carrying loads of almond pollen. By 9 March, the percent of pollen foragers returning with almond pollen had decreased to 50% as most of the fowers on most cultivars were senescent (beyond pollen presentation). The percent of almond pollen dropped rapidly to 10% on 12 March and 0% on 14 March as almond bloom rapidly diminished.

It was again difficult to locate bumble bees in the trees during the bloom season due to their small numbers relative to the mass flowering of almond. Rates of flower visits for 23 one minute observations of bumble bees showed that they worked 1.67 times as fast as honey bees.

Ants became a problem at one of the quads shortly after it was established. A band of tangle foot around the post solved the problem. At the end of almond bloom (14 March), attempts by honey bees to enter and rob syrup and nectar from bumble bee nests increased dramatically.Bumble bee guards were only partly effective at keeping honey bees out of their nests. The removal of most honey bee hives the following morning reduced the problem.

Further observations were made at an orchard neaar Arbuckle on 8 March near the end of bloom in Nonpareil and Carmel, but with some fair bloom remaining on Butte. This orchard was the only orchard in the area with much bloom left and honey bees were dense at the remaining flowers. Bumble bees were still bringing almond pollen back to thier nests. Observations of more than 12 bees at flowers showed they visited up to 10 flowers in 5 seconds and often spent no more than 3-8 seconds per flower. They often left the tree after 2 to 3 flower visits. In addition to the *Bombus occidentalis* from commercial hives, a queen and two workers of *Bombus vosnesenskii* from feral colonies were seen in the orchard. Their rates of visitation were similarly rapid.

At a nearby orchard past most bloom, robbing of bumble bee colonies by honey bees was apparent, especially at entrances exposed to the sun.

Discussion: Our observations continue to confirm our findings in 1993 that bumble bees work faster, cover more area of bloom per unit time, collect more pollen per individual, leafe trees more frequently, and hav a higher ratio of pollen foragers than do honey bees.

Bumble bee nests are prime targets for marauding ants and robbing honey bees. Barriers of tangle foot applied to the domicile posts will keep ants out of the nests. Timing of introduction and removal of bumble bee hives so that sufficient bloom is available for honey bee foragers will keep robbing to a minimum.

Further studies are needed to establish the relative pollination efficiency of bumble bees in comparison with honey bees in almond.

Other Alternative Pollinators

During attempts to observe bumble bee activities in almond trees near Arbuckle, CA on 8 March, we encountered numbers of large blue females of a solitary ground nesting native bee, *Andrena* sp., foraging for pollen on the late bloom. These females moved more rapidly from flower to flower than did worker honey bees. Once they landed on an almond flower they spent considerable time gleaning pollen. Some were also seen to probe senescent flowers for nectar. One male of the *Andrena* sp. was also seen at an almond flower indicating that the population was still rather early in its flight season and may not have become active when the almond bloom first started. Observations suggest that they are efficient pollinators of almond, but they are not common or widespread in orchards. Whether these bees could be feasibly managed for commercial pollination is not known.

Hover flies or flower flies of the family Syrphidae are often seen at almond flowers standing on the reproductive parts. They feed on pollen as a source of protein to build up their ovaries. Their populations fluctuate greatly from one year to the next. Their relative efficiency as pollinators of almond and their potential for management is unknown.

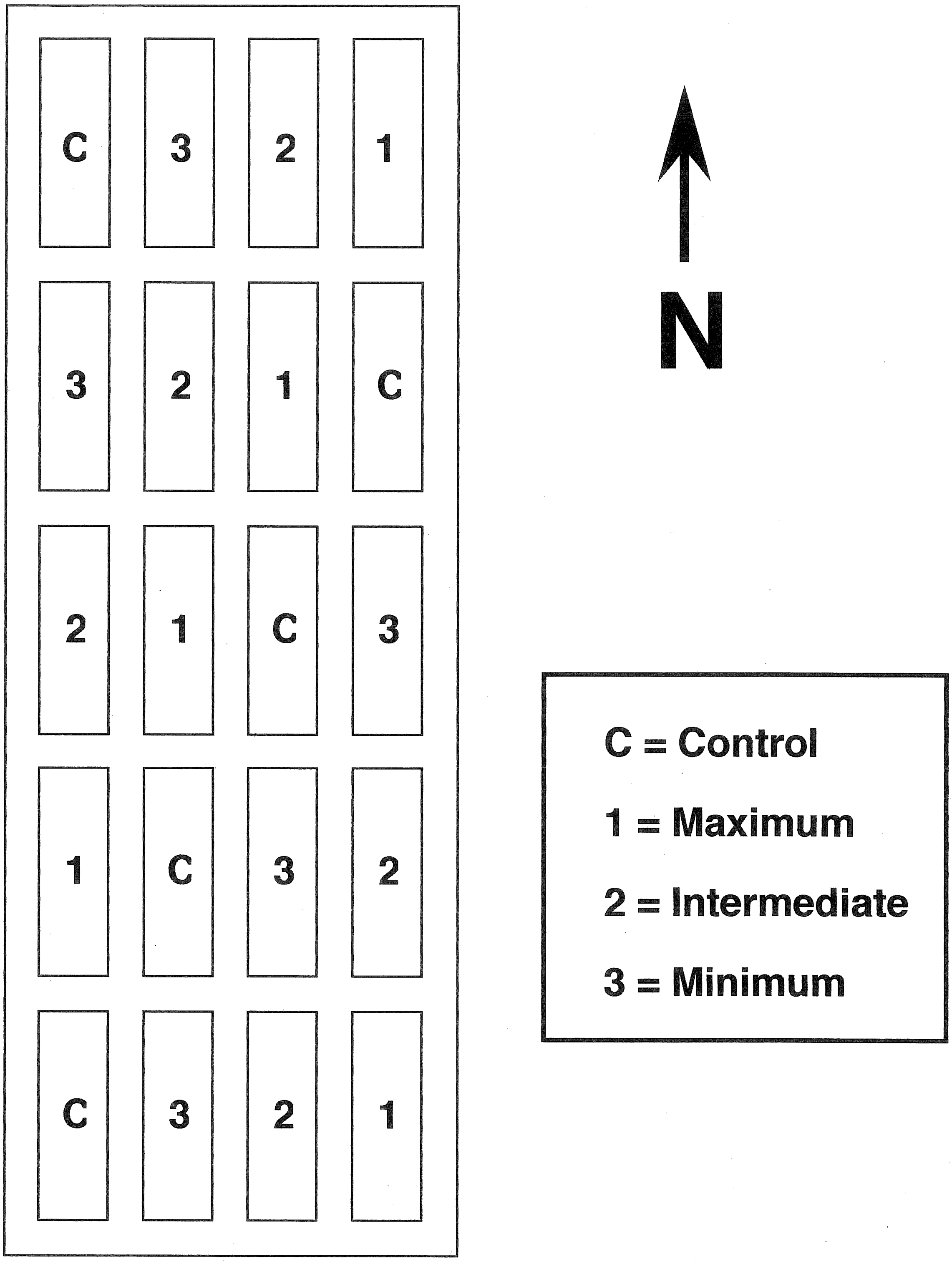

Fig. 1. Orchard plot layout for Queen Mandibular Pheromone trial near Chico, CA.

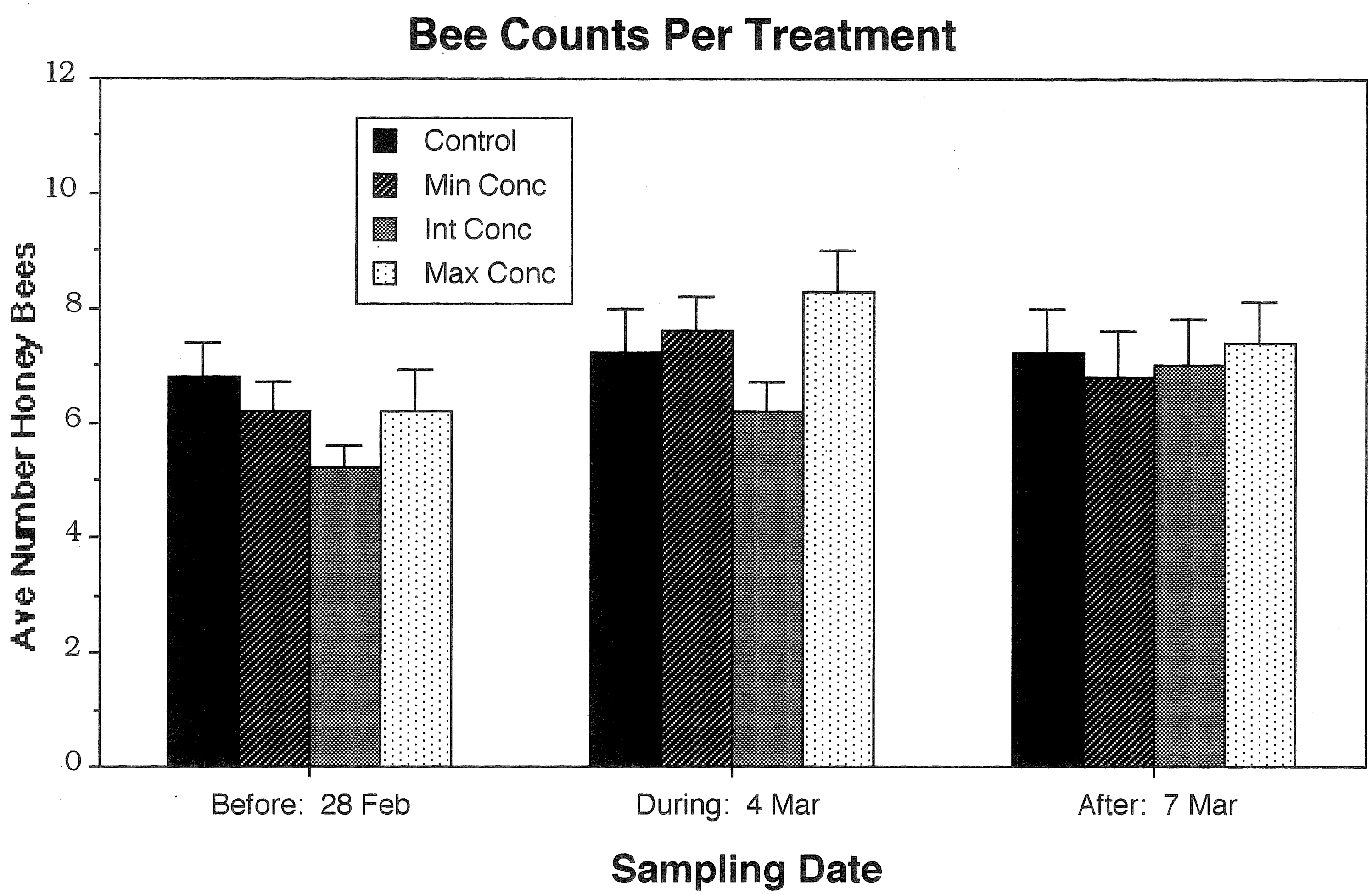

Fig. 2. Honey bee visitation to Nonpareil trees with different doses of Queen Mandibular Pheromone.

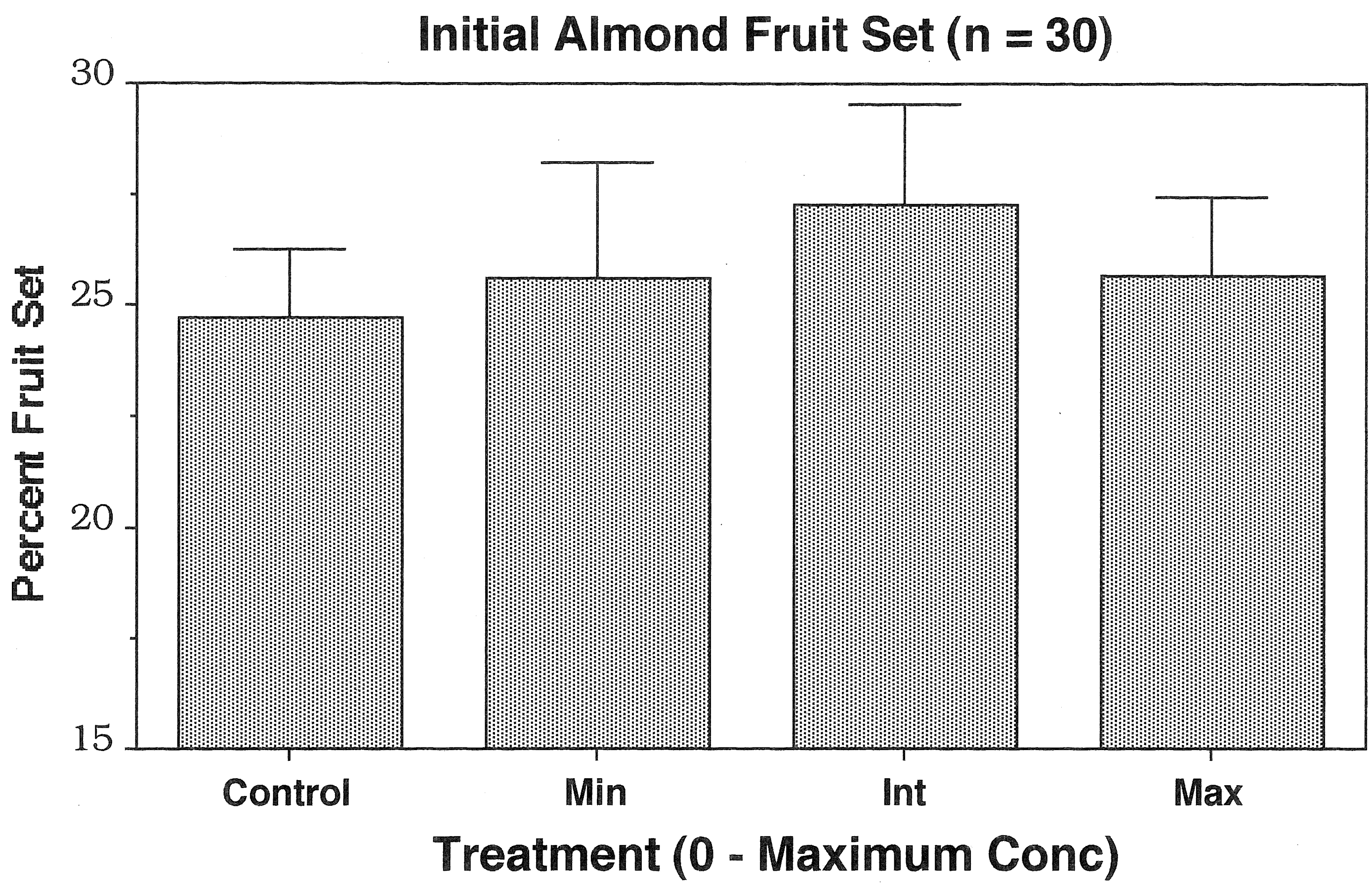

Fig. 3. Initial fruit set in Nonpareil trees with different doses of Queen Mandibular Pheromone.

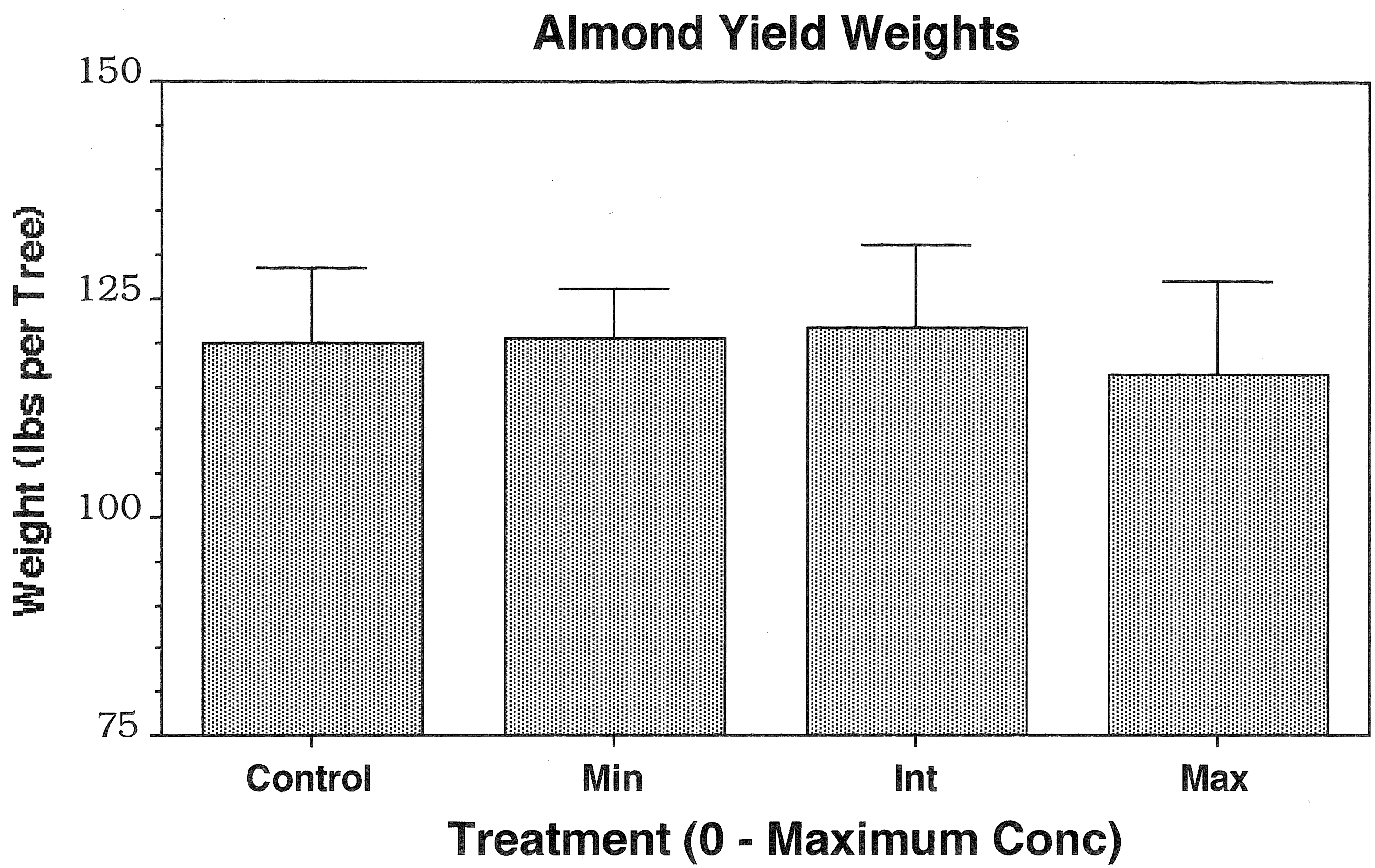

Fig. 4. Harvest yields from Nonpareil tree plots with different doses of Queen Mandibular Pheromone.

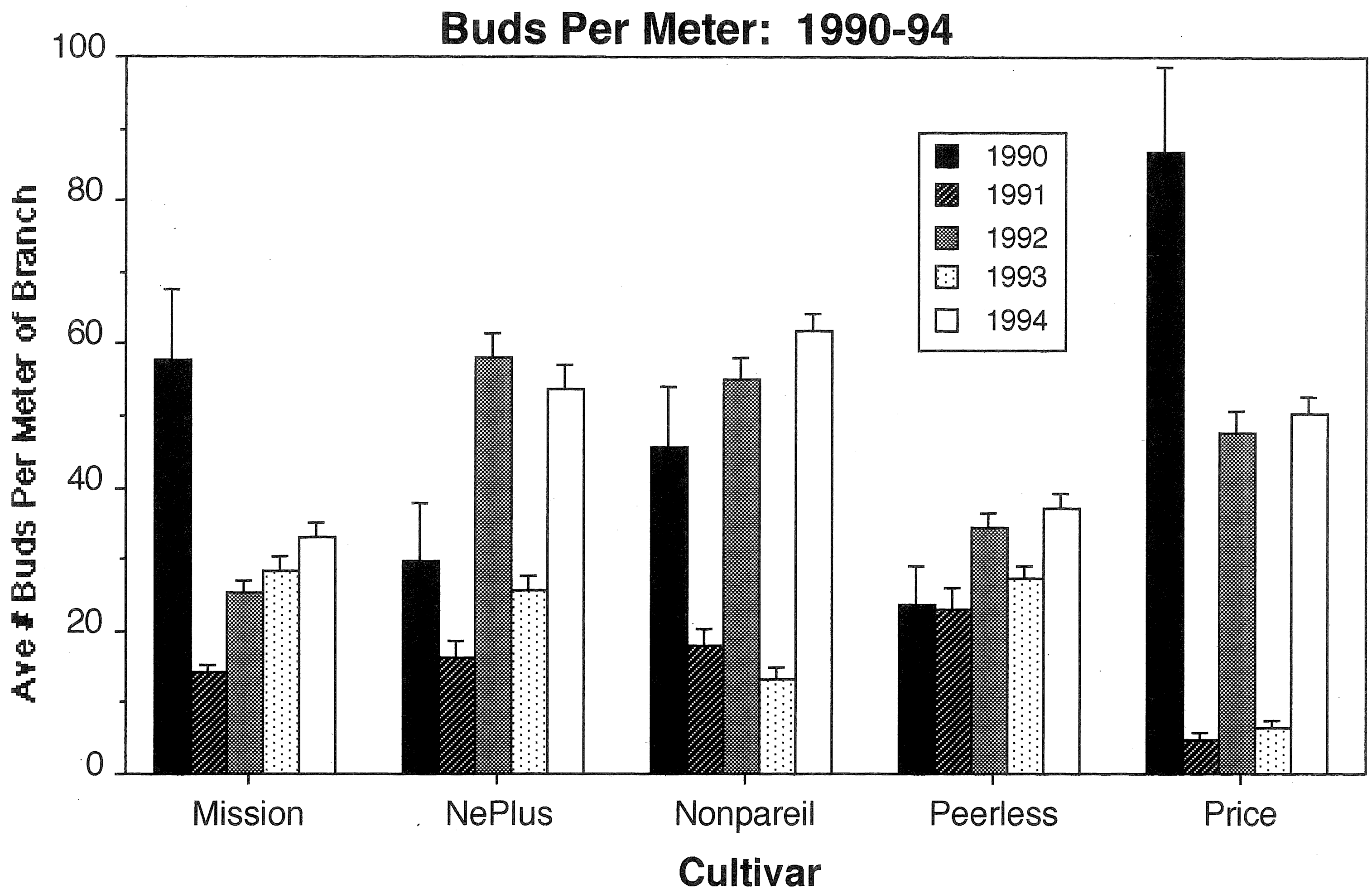

Fig. 5. Buds per meter for five cultivars in an orchard near Dixon, CA for 1990 through 1994.

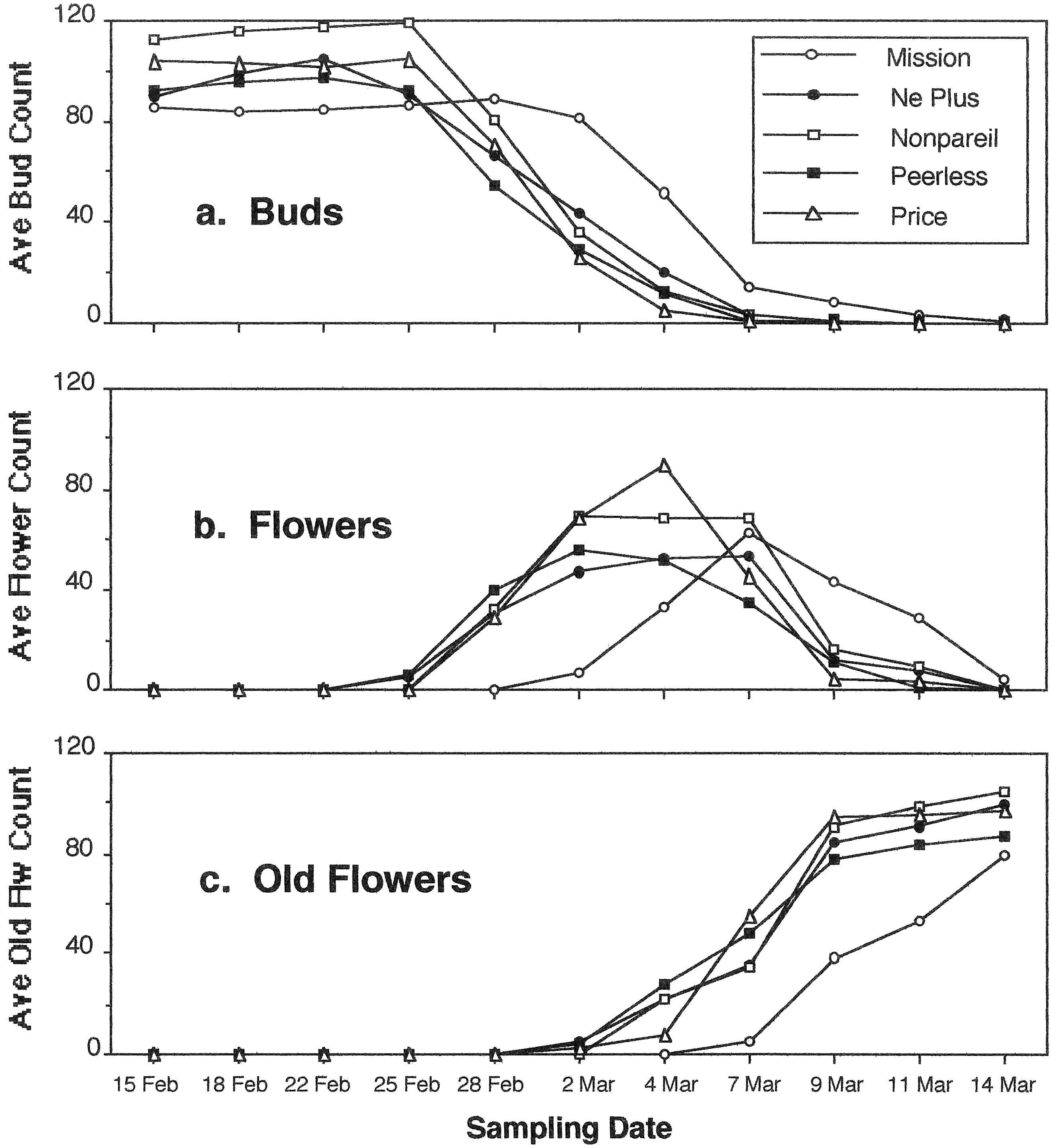

Fig. 6. Bloom progression for five cultivars in an orchard near Dixon, CA for 1994: a) buds, b) flowers, and c) senescent flowers.

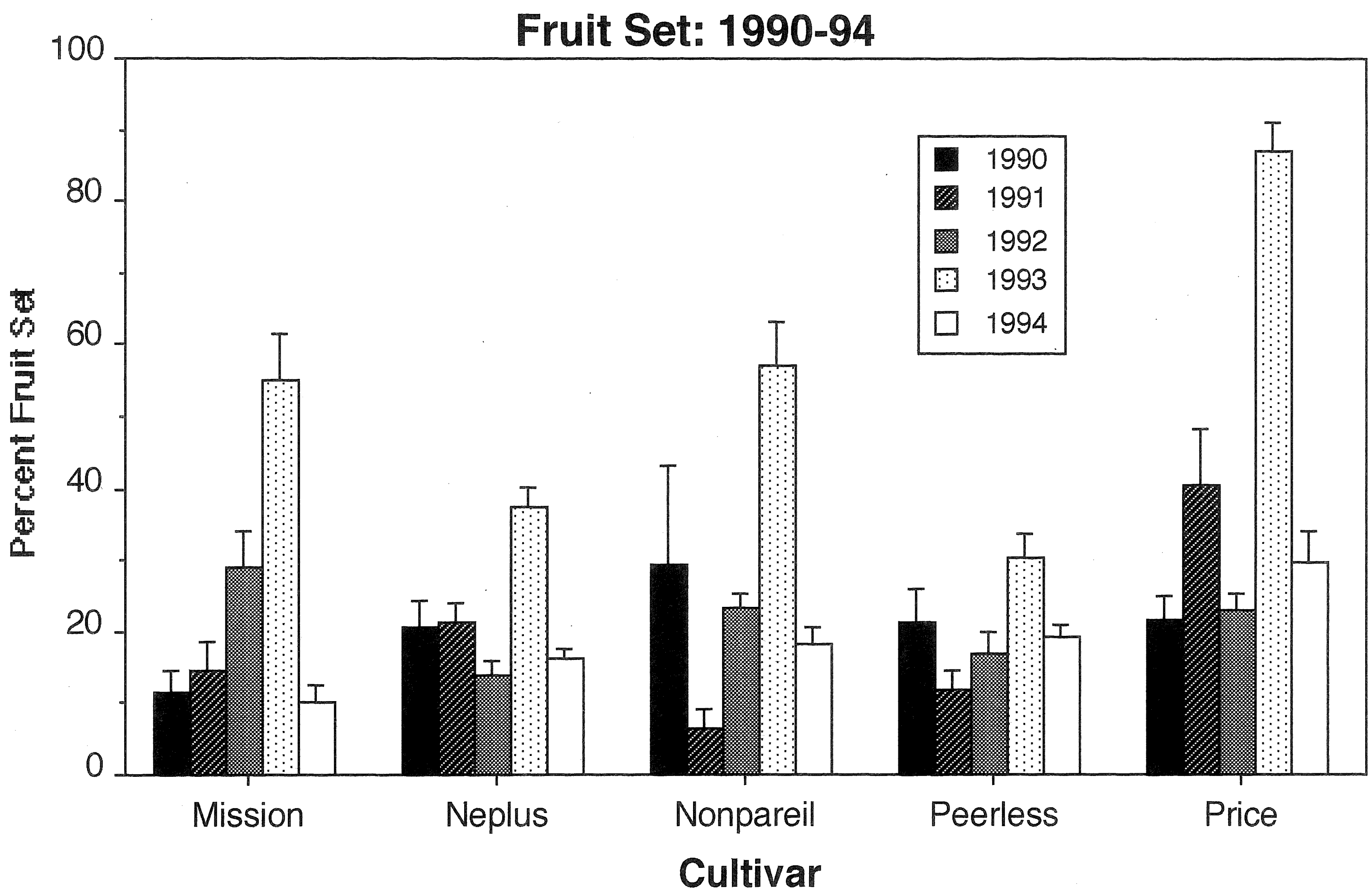

Fig. 7. Fruit set for five cultivars in an orchard near Dixon, CA for 1990 through 1994.