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This report covers a five-year study and shows that the Bartlett pear, though nearly self-sterile, is self-fruitful in most California orchards because of the production of parthenocarpic fruit. Vegetative parthenocarpy was responsible for most of the seedless fruit produced. Stimulative parthenocarpy due to self-pollination did not give significantly greater fruit sets than those effected by vegetative parthenocarpy alone.

Parthenocarpy means development of the edible fruit without fertilization. Parthenocarpic fruits are seedless. They have been divided into two types—vegetative and stimulative. Vegetative parthenocarpy implies that the fruit developed without pollination, while stimulative parthenocarpy indicates that they developed as a result of the stimulus of pollination.

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POLLINATION AND PARTHENOCARPY IN THE PRODUCTION OF BARTLETT PEARS IN CALIFORNIA[1]

W. H. GRIGGS[2] and BEN T. IWAKIRI[3]

INTRODUCTION

THE BARTLETT, or Williams' Bon Chretien, as it is known in other countries, is undoubtedly the most widely grown pear variety in the world. The classical report of Waite (1894)[4] showed the Bartlett to be nearly self-sterile (also self-unfruitful) in the eastern part of the United States. Since then many workers in this and other countries have studied the pollination requirements of this variety. Their experiments led them to vary their classification as self-fertile (Weldon, 1918; Rawes, 1933), partly to completely self-sterile (Fletcher, 1911; Tufts, 1919; Tufts and Philp, 1923; Florin, 1925; Kamlah, 1928; Luce and Morris, 1928; MacDaniels and Heinicke, 1929; Marshall *et al.*, 1929; Cummings, Jenkins, and Dunning, 1936), partly to completely self-fruitful (Middlebrooke, 1915) ; Hooper, 1921; Reinecke, 1930*a;* Wellington, 1930; Dwyer and Bowman, 1938), and self-incompatible (Wellington *et al.*, 1929). Most of these workers have agreed that cross-pollination will give increased fruit sets over self-pollination. Those who examined the pears for seed content found very few, if any, seeds in the fruit produced by self-pollinated blossoms. The tendency of Bartlett to produce parthenocarpic fruits has also been recorded (Kraus and Kraybill, 1918; Overholser and Latimer, 1924; Kamlah, 1928; Reinecke, 1930*a;* Dwyer and Bowman, 1938; Griggs and Vansell, 1949; DeTar, Griggs, and Crane, 1950; Griggs, Iwakiri, and DeTar, 1951). On the other hand, Gourley and Howlett (1947), in discussing parthenocarpic fruits, stated, "They may infrequently occur in both the apple and pear, but their formation is of little practical importance." Murneek (1952) stated, "Parthenocarpy is a rare phenomenon with the genera Prunus and Malus."

California has over 37,000 acres of Bartletts. Experiment station workers

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[4] See "Literature Cited" for citations, referred to in the text by author and date.

in the state have since 1918 recommended interplanting pollinizers for this variety (Weldon, 1918; Tufts, 1919; Tufts and Philp, 1923), but in spite of this most of the Bartlett orchards are now in solid blocks. Pollinizing varieties have been grafted over, and new plantings are almost invariably solidly to Bartletts. Only a few Bartlett growers make any effort to provide honey bees during the blossoming period. The question arises, therefore, as to what accounts for the high yields of a self-sterile variety planted in solid blocks.

Interest regarding the pollination status of Bartlett was renewed in 1948, when a near crop failure occurred in the orchards of the Sacramento Valley. At that time studies were started to compare orchards in the various pear-producing sections of the state that are planted in solid blocks of Bartlett with those interplanted with pollinizers, and to determine the relative importance of self-pollination, cross-pollination, and vegetative and stimulative parthenocarpy.

This report covers a five-year study and shows that the Bartlett pear, though nearly self-sterile, is self-fruitful in most California orchards because of the production of parthenocarpic fruit. Vegetative parthenocarpy was responsible for most of the seedless fruit produced. Stimulative parthenocarpy due to self-pollination did not give significantly greater fruit sets than those effected by vegetative parthenocarpy alone.

EXPERIMENTAL

Bartlett Orchards Interplanted with Pollinizing Varieties Versus Those Planted Solidly to Bartlett

The light fruit set in 1948 in certain sections of the state, and particularly in the Sacramento Valley, was concluded to be due to adverse weather conditions during the blossoming period. In several orchards it was noted that the fruit set was heavier on the trees next to pollinizing varieties. This led to a survey made near harvest time of 29 orchards representing the pear-growing districts in Contra Costa, El Dorado, Lake, Mendocino, Placer, Sacramento, Santa Clara, Solano, and Yuba counties. The idea was to compare yields and fruit characteristics of orchards in the different sections, and particularly the effect of the presence or absence of pollinizing varieties upon these factors. Fruit samples consisted of ten fruits, picked at random from each of 25 trees within each orchard. In gathering the samples, the pickers usually walked from one corner of an orchard to the opposite corner. The fruit was placed in cold storage and held at 32° F. Later the pears were weighed, measured for length and diameter, and examined for seed content. Following harvest, yield records were obtained from the orchardists.

In 1949 and 1950 the study was extended to include San Joaquin and Sonoma counties. It was limited to two orchards in each county, however, one being interplanted with pollinizers and the other with solid blocks of Bartlett trees, or with very few pollinizers. Fruit set, calculated as the number of fruits set per 100 flowering clusters, was adopted as the measure of fruitfulness because of possible error in the growers' yield records. Fruit set was determined by making blossom-cluster counts on two branches on each of 25 trees in each orchard. Near harvest time the fruits were counted on these branches, and fruit samples were taken for weighing, measuring, and seed counting. The same orchards and trees used in 1949—and also the same branches, except those that had been severely pruned—were again used to obtain similar data in 1950.

The results of the 1948–1950 study are presented in tables 1 and 2. The data were statistically analyzed. The surprising finding was the high percentage of seedless or parthenocarpic fruit in all orchards. In some orchards planted solidly to Bartlett, as high as 99.5 per cent of the pears produced were seedless. During 1948 growers' records showed hardly any differences in yields between orchards interplanted with other varieties and those planted solidly with Bartletts or with very few pollinizers. During 1949 and 1950, however, orchards with pollinizers gave heavier fruit sets than those in solid blocks. There were no significant differences between the weights of fruit for the two types of orchards during the three years. Orchards interplanted with pollinizers had greater numbers of seeds per fruit and lower percentages of seedless or parthenocarpic fruit. Pears from the orchards planted solidly to Bartlett had greater length/diameter ratios than those from the orchards with pollinizers. The difference was not significant in 1948, but was significant at the 5 per cent level in both 1949 and 1950.

The relatively light bloom for 1950 is indicated by the lower number of flower clusters produced by the tagged branches that year. The generally higher percentages of fruits set per 100 flower clusters for 1950 also show the inverse relationship between number of blossoms and percentages of fruit set.

Correlation coefficients were calculated between the following pairs of data shown in tables 1 and 2: (1) numbers of seed per fruit from samples taken in 1948 and grower's yields from the orchards that produced them; (2) numbers of seed per fruit and fruit set for the trees from which the samples were taken during 1949 and 1950; (3) numbers of seed per fruit and fruit weight for the samples taken during each of the three years; (4) numbers of seed per fruit and length/diameter ratios of the fruit for samples taken during each of the three years; (5) numbers of seed per fruit and length of fruit for the samples taken during 1948; and (6) numbers of seed per fruit and diameter of fruit for the samples taken during 1948. These correlations were computed between the pairs of data from the orchards interplanted with pollinizers and also between corresponding pairs of data from those planted solidly to Bartlett. The only significant correlation coefficient was obtained between the numbers of seeds per fruit sampled in 1948 from the orchards interplanted with pollinizers and the length/diameter ratios of this fruit. This positive correlation (1 per cent level) appeared to be a coincidence since, when these same numbers of seeds per fruit were correlated with either the length measurements or the diameter measurements alone, the coefficients were not significant. Also there was no significant correlation between numbers of seed per fruit and the length/diameter ratios of the fruits sampled in 1949 and 1950.

Controlled Pollination Studies

After it was learned that the bulk of California's Bartlett pear crop consists of seedless fruit, experiments were designed to find whether these pears were the result of vegetative or stimulative parthenocarpy and also to determine the relative importance of self-pollination and cross-pollination. Controlled pollination studies were conducted from 1949 through 1952 in Bartlett orchards interplanted with other varieties, as well as in those orchards planted in solid blocks or with very few pollinizers. The orchards were located in El Dorado, Yolo, Sacramento, Lake, and Santa Clara counties. Branch units were used for most of the work, and the blossom treatments consisted of: (1) bagging with heavy muslin bags 35 by 54 inches, (2) emasculation, (3) emasculation and bagging, (4) emasculation and self-pollination by applying Bartlett pollen to the stigmas with a glass rod, and (5) emasculation and cross-pollination by applying Winter Nelis pollen to the stigmas with a glass rod. Winter Nelis pollen was used for all the cross-pollinations because it is known to be an effective pollinizer for Bartlett (Tufts, 1919; Tufts and Philp, 1923). Samples of all pollen used for the hand-pollinations throughout the experiments were tested for germinability on a medium consisting of 2 per cent agar and 15 per cent cane sugar. Winter Nelis pollen gave percentages of germination ranging from 50 to 94 per cent for the four years, while those for Bartlett ranged from 28 to 68 per cent. Natural, or open-pollinated, fruit sets were determined for all trees used in the studies except those completely enclosed with mosquito-tight netting. Before harvest time, fruit samples were gathered from all the branches included in the pollination studies and taken to the laboratory for weighing, measuring, and determining seed content.

The results of the controlled pollination studies are shown in tables 3, 4, and 5. Data from individual orchards for each year were subjected to analysis of variance. The various data for all three years were also combined and statistically analyzed to determine significant differences between grand means or three-year averages for each treatment.

Since the numbers of orchards subjected to each treatment were not constant in 1950 and 1952, no single value representing the difference required for significance between the general means for fruit set, weight, etc. could be shown at the bottom of tables 4 and 5. The difference required for significance between any two general means, made up of unequal numbers of orchard means, was calculated, however, as follows: $t\sqrt{\frac{\text{variance of error}}{n_1} + \frac{\text{variance of error}}{n_2}}$ (Snedecor, 1946).

Fruit Set. There were no significant differences between the fruit sets obtained from blossoms that were emasculated only and blossoms emasculated and self-pollinated. This was indicated when the data were analyzed on either a yearly or a three-year basis. There was also no significant difference when the analysis was limited to data obtained from these two treatments alone. This is noteworthy since the fruit set resulting from blossoms that were emasculated only was assumed to be effected by vegetative parthenocarpy, and any gain in fruit set by blossoms that were emasculated and self-pollinated over blossoms emasculated only was assumed to be due to stimulative parthenocarpy.

Whatever difference occurred in fruit set between blossoms that were bagged only and those emasculated and bagged could be assumed to show stimulation of parthenocarpic set due to emasculation if the blossoms emasculated and bagged gave higher sets; or the comparison of the two treatments could show increased fruit set due to stimulation of self-pollination if the blossoms that were bagged only gave higher sets. A strict comparison of the fruit sets resulting from emasculated blossoms versus those from non-emasculated ones is not entirely fair, since there is always some blossom thinning due to the accidental destruction of blossoms during emasculation. In 1949 (table 3) there were no significant differences in the fruit set resulting from blossoms that were bagged only and those emasculated and bagged. The difference between the two treatments was also not statistically significant in 1950 (table 4), although it undoubtedly shows some stimulation in fruit set due either to emasculation or to the blossom thinning that occurs during the emasculation process.

Also in 1949 (table 3) blossoms emasculated and cross-pollinated with Winter Nelis pollen gave significantly higher sets than those subjected to any of the other treatments. Blossoms that were emasculated and self-pollinated gave significantly higher sets of fruit than blossoms either emasculated and bagged or bagged only.

In 1950 (table 4) the only significant differences between the fruit-sets resulting from the various treatments were as follows: Blossoms emasculated and cross-pollinated gave higher sets (significant at the 1 per cent level) than those that were bagged only. They also gave significantly higher sets (5 per cent level) than blossoms that were either emasculated only or emasculated and bagged.

In 1952 (table 5) the blossoms that were emasculated and cross-pollinated gave significantly higher sets (1 per cent level) than those subjected to any of the other treatments. The open-pollinated blossoms also gave higher sets (significant at the 5 per cent level) than those that were bagged only.

The analysis of variance of the combined data on fruit set for the three years showed that the emasculated and cross-pollinated blossoms gave significantly heavier sets (1 per cent level) than blossoms subjected to any of the other treatments. Open-pollinated blossoms gave significantly higher sets (5 per cent level) than those that were bagged only.

Fruit Weight. Probably little significance should be attached to the differences in the weight of fruit developed under the controlled-pollination treatments, since to avoid loss the samples were gathered considerably ahead of the first commercial picking. Hence the average size of the fruit was often much smaller than that required for marketing, or than the maximum size they would have been expected to attain if allowed to remain on the trees. Analysis of the combined data presented in tables 3, 4, and 5 showed no significant differences in weight of fruit produced under the various treatments. Data for the individual years also showed no significant differences in weight of fruit produced in 1949 and 1952. The individual data for 1950, however, showed that the fruits from the open-pollinated blossoms were heavier (significant at the 1 per cent level) at the time they were gathered than those developing from blossoms that were either emasculated only, or emasculated and self-pollinated. These fruits were also significantly heavier (5 per cent level) than those developed from blossoms that were emasculated and bagged. Pears from blossoms that were emasculated and cross-pollinated were significantly heavier (5 per cent level) than those that developed from emasculated and self-pollinated blossoms. Fruits from blossoms that were bagged only were heavier (significant at the 1 per cent level) than those blossoms that were emasculated and self-pollinated. They were also significantly heavier (5 per cent level) than pears from blossoms that were emasculated only. Differences in fruit set apparently do not account for these differences in weight, since fruit from blossoms giving low percentages of fruit set were not consistently heavier than fruit from blossoms giving high percentages of fruit set.

Number of Seeds per Fruit. The low order of self-fertility of the Bartlett pear is shown by the very few seeds found in the fruit developing from emasculated and self-pollinated blossoms (fig. 3-H). When analyzed on either a yearly or a combined basis, the data showed no significant differences in seed content of the pears resulting from emasculation and self-pollination and those resulting from blossoms that were bagged only, emasculated only, or emasculated and bagged. There were also no significant differences between these treatments when the data from the open-pollinated blossoms and blossoms emasculated and cross-pollinated were excluded from the analysis. The fruit resulting from blossoms emasculated and cross-pollinated contained significantly more seeds (1 per cent level) than those resulting from any of the other treatments except natural pollination.

Seed Viability. In 1952 (table 5) the seeds from the samples taken in connection with the controlled-pollination studies were saved and tested for viability by the method originated by Flemion (1938). Very few seeds were produced by the fruits developing from blossoms emasculated and self-pollinated, emasculated only, or bagged only; and part of them were destroyed when the pears were sliced in the examination for seed content. The non-viable seeds indicate, however, that fruits may develop normal-appearing seeds, which have filled without fertilization and embryo development. Hence, the average numbers of seeds per fruit shown under these treatments in the tables would undoubtedly be even smaller if they were changed to numbers of viable seeds per fruit.

Percentages of Parthenocarpic Fruit. Blossoms that were bagged only, emasculated only, emasculated and bagged, or emasculated and self-pollinated all produced very high percentages of seedless fruit. The differences between the percentages of seedless fruit effected by these treatments were not significant. This was true whether the data were analyzed on either a yearly or a combined basis, or whether the analysis included or excluded data from blossoms open-pollinated and cross-pollinated by hand. Blossoms subjected to these treatments consistently produced higher percentages of seedless fruit than those that were either emasculated and cross-pollinated or open-pollinated.

Fruit Shape. In 1949 (table 3) the length/diameter ratios of the seedless pears resulting from blossoms that were bagged only were significantly greater than those of fruits developing from blossoms that were either emasculated and self-pollinated or emasculated and cross-pollinated. In 1950 (table 4) the length/diameter ratios of the pears developing from the blossoms that were bagged only were significantly larger than those of fruits that developed under any of the other treatments. In 1952 (table 5) they were significantly greater than those of fruits developing from blossoms that were either emasculated only or emasculated and cross-pollinated. When the data for the three years were combined, the analysis of variance showed that the length/diameter ratios of the pears developing from the blossoms that were bagged only were significantly greater than those resulting from blossoms that were emasculated only, emasculated and self-pollinated, or emasculated and cross-pollinated.

The tables also show that the length/diameter ratios of the seeded fruit developing from blossoms that were emasculated and cross-pollinated by hand were consistently smaller than those of fruits that developed from blossoms subjected to the other treatments. In 1949 and 1950 they were significantly smaller than those of fruits developing under all of the other treatments except emasculation only and emasculation and self-pollination. In 1952 they were significantly smaller than those of fruits that developed under all the other treatments.

Bartlett Trees Caged in Compartments With and Without a Colony of Bees

To determine whether or not bees working the blossoms will increase the self-fruitfulness of the Bartlett pear, and also to obtain further information on vegetative and stimulative parthenocarpy, two mature trees were caged with mosquito-tight netting in March, 1951, before any blossoms opened. One of the cages was located at the Gastaldi orchard near Smith Flat (elevation 2,000 feet) and the other at the Hamilton orchard above Camino (elevation 3,000 feet). The cages were made in two sections so that the north half of each tree was separated from the south half by a mosquito-tight partition (fig. 8). On April 2, when the blossoms started opening, a colony of bees was brought from an area in the Sacramento Valley where there are very few pear trees and placed in the south compartment of the caged tree at Smith Flat. Pollen cake and water were supplied. The bees were left in the cage throughout the blooming period and removed April 17. A similar colony was placed in the north compartment of the cage near Camino at the beginning of the blooming period there, April 9, and removed at the end of the blooming period on April 17. Several hundred blossoms were counted within each compartment to determine the fruit set. The following blossom treatments were also made on branch units within both compartments of the caged tree at Smith Flat: (1) bagging with heavy muslin, (2) emasculation, (3) emasculation and self-pollination by applying Bartlett pollen to the stigmas with a glass rod, and (4) emasculation and cross-pollination by applying Winter Nelis pollen to the stigmas with a glass rod. The cages were dismantled on April 27. The same blossom treatments given to the branch units within the cage were repeated on branches of a Bartlett tree growing next to the caged tree at Smith Flat. On July 23 fruit samples were taken from the trees that had been caged and from the tree next to the caged tree at Smith Flat and brought to the laboratory for weighing, measuring, and determination of seed content. Samples of seed from fruit resulting from the variously treated blossoms were stratified during the month of October at 32° F. and then planted in the greenhouse to determine germinability.

Results of the experiments with the caged Bartlett trees are presented in tables 6 and 7. Table 6 shows that the presence of bees did not increase self-fruitfulness in the Bartlett pear since there was no significant difference in the fruit set on the sections of the trees that had been enclosed either with or without the bees. The bees were as free from pear pollen as practicable when they were placed in the cages. The weather was favorable for bee activity during the time they were confined in the compartments, and each blossom was undoubtedly worked dozens of times. Counts of the number of bees on the caged blossoms of each tree at any one time during the day ranged from 30 to 50. It is interesting to note that, regardless of the presence of bees, the south half of each caged tree gave a slightly, but not significantly, higher fruit set than the north half.

Fruit samples taken from the compartments with no bees were heavier at the time they were picked and had higher percentages of seedless fruit than those taken from the compartments where the blossoms were worked by bees. There were no significant differences, however, in the number of seeds per fruit or length/diameter ratios. The only seeds that germinated were a few (20 per cent) from the compartment where bees were included at Smith Flat.

Table 7 shows the results of the various pollination treatments given blossoms within both compartments of the cage at Smith Flat and on an open-pollinated tree near the caged one. The data again show that emasculation and self-pollination failed to increase the fruit set over that obtained from blossoms that were emasculated only. The emasculated and cross-pollinated blossoms gave higher fruit sets and larger numbers of seeds per fruit than those subjected to the other treatments. This is consistent with the results shown in tables 3, 4, and 5. The higher fruit sets effected by the blossoms that were emasculated only or emasculated and self-pollinated over blossoms caged only or bagged only indicate some stimulation due either to emasculation or to flower thinning during emasculation, or both.

The length/diameter ratios again show that cross-pollinated pears are more apple-shaped than parthenocarpic ones, and that pears that develop from blossoms enclosed in a cloth bag during the blooming period are longer than those effected by any of the other treatments (figs. 2-F and 7).

The differences in fruit weight show the relative differences in fruit size at the time of sampling, which was two weeks ahead of the first commercial picking. They indicate a slower development of the fruits set by the blossoms that were emasculated only or emasculated and self-pollinated. The only significant difference, as shown by the F value for location, that could be attributed to the location of branches (inside a compartment with or without a colony of bees, or upon the open-pollinated tree nearby) was between the fruit weights at the time they were sampled.

The relatively high number of viable seeds found in the pears that developed from blossoms caged with the bees and supposedly emasculated only is not consistent with the data presented in tables 3, 4, and 5. The probable explanation is that the large number of bees confined in the half-tree compartment visited and revisited all blossoms regardless of emasculation. Hence they may have cross-pollinated a few of emasculated control blossoms with Winter Nelis pollen, which they picked up from the 142 blossoms emasculated and cross-pollinated by hand.

Seed Content of Rat-Tail Versus Normal Pears

In 1949 it was noted that in Bartlett orchards growing in solid blocks the so-called rat-tail pears tend to have more seeds than normal pears. The rat-tails develop from flowers produced at the tips of current season's growth and are characterized by short necks and very long stems (fig. 4-I). During that year and in 1952 samples of rat-tails and normal pears were gathered from orchards interplanted with pollinizers as well as those planted in solid blocks and examined for seed content. Part of the seeds from the samples collected in 1949 were stratified and tested for germinability. Seeds from the pears gathered in 1952 were tested for viability by the method developed by Flemion (1938).

The results of the study are presented in table 8. The data show that in orchards provided with pollinizers the rat-tails contain fewer seeds than normal pears. This would be expected since the late blossoms would certainly not have so great a chance to be cross-pollinated. The rat-tail pears from solid blocks of Bartlett, on the other hand, contain significantly more seeds than the normal ones. The seed-viability data show that a high proportion of the seeds produced by rat-tails are viable. Hence, the late-season blossoms, from which the rat-tails develop, apparently have a higher degree of self-fertility than flowers that open at the normal time. This conclusion is drawn under the assumption that these late blossoms would have little chance for cross-pollination where no pollinizing varieties are provided.

Harvesting Records of Mature Bartlett Trees with no Provision for Cross-Pollination

To determine whether or not trees that set heavy crops of parthenocarpic fruits could bring them all through to picking size, yield records were kept on four 30-year-old Bartlett trees in the Leary orchard at Ryde, California. These trees are not in the same orchard as those represented in tables 3 and 4 (and located in the Leary orchard near Walnut Grove). It was also of interest to determine whether seeded fruits, produced in an orchard where most of the crop is seedless, reach picking size before the seedless ones. The orchard has no provision for cross-pollination and is rather typical of the hundreds of acres of vigorous and well-managed Bartlett orchards along the Sacramento River. The trees were selected as average for the block. They were picked four times, and yields for the separate pickings were recorded for each tree. The pickers used picking rings $2\frac{3}{8}$ inches in diameter and picked only those fruits that could not be passed through the rings. At each picking, 100 pears were taken at random from the fruit harvested from each tree. The fruit samples were taken to the laboratory and weighed, measured, and examined for seed content.

Data obtained from harvesting the four mature trees are presented in table 9. They show that during the four pickings practically all the pears on these heavy-yielding trees reached the picking size (of greater than $2\frac{3}{8}$ inches in diameter). Since the trees are planted in 20-foot squares, the average of 14.2 boxes per tree would mean that the block produced 34 tons to the acre. The seeded pears did not reach picking size before the seedless ones since there were no significant differences in the average seed content of the pears gathered at the different picking dates. There were also no significant differences in the percentage of seedless fruit between the samples of fruit taken at the four picking dates. The average weight of the pears increased from the first through the third picking, but declined for the fourth. The length/diameter ratio showed a consistent increase throughout the harvesting season.

DISCUSSION

Tables 1 and 2 show that parthenocarpy is responsible for over 80 per cent of the Bartlett pears produced in California orchards planted solidly to Bartlett and over 25 per cent of those produced where pollinizers are interplanted. The practical importance of this phenomenon has not been appreciated (Gourley and Howlett, 1947; Murneek, 1952). Waite (1894) did not use the term parthenocarpy, but he noted the development of a few pears from flowers that were emasculated and not pollinated on the Le Conte and Heathcote varieties. This led him to state, "The possibilities of development without pollen need to be further studied in self-sterile varieties. It may be that these varieties have the tendency to fruit so strongly inherent in them that they do not always need the stimulus of pollen to make them grow, but such cases are probably rare if they occur at all." In his later report, Waite (1898) stated, "The question, therefore, arises as to whether pears which grow to such perfection in California, as Bartlett, Clapps Favorite, and Clairgeau, do not find the climate of that state so favorable as to be self-fertile." Later Noll (1902) introduced the term parthenocarpy, which is now defined as the development of fruit without fertilization of the ovules. Since then workers in California (Overholser and Latimer, 1924), Germany (Kamlah, 1928), South Africa (Reinecke, 1930*a*), and Australia (Dwyer and Bowman, 1938; Robinson, 1938) have learned that Bartlett produces a good portion of its fruit without seeds, but the actual proportions of seeded versus seedless pears had not been determined.

After learning that most of the California Bartletts are seedless, it was interesting to determine how much of the crop was the result of stimulative parthenocarpy, caused by the stimulus of self-pollination, and how much was due to vegetative parthenocarpy, which occurs without any pollination. The third possible cause of seedlessness would be embryo abortion, but this is ruled out because of the high percentages of fruit set from blossoms treated to prevent pollination by emasculation, emasculation and bagging, and emasculation and caging.

The controlled-pollination experiments shown in tables 3, 4, 5, and 7 corroborate the conclusions of many previous workers in showing that the Bartlett is nearly self-sterile. They also show that this variety may be highly self-fruitful because of the production of parthenocarpic fruits. Vegetative parthenocarpy was responsible for most of the seedless fruits. Dwyer and Bowman (1938), working in Australia, wrote, "In certain seasons vegetative parthenocarpy is very evident, whilst in others the stimulation of self-pollination appears necessary to give high self-fruitfulness." During the four seasons included in the present study, stimulative parthenocarpy consistently failed to give significantly higher fruit sets than those effected by vegetative parthenocarpy alone. The difference between the fruit set resulting from blossoms emasculated and self-pollinated and that obtained when the blossoms were emasculated only was assumed to be the result of stimulative parthenocarpy. This difference averaged 1.7 per cent for the three years represented in tables 3, 4, and 5, but was not significant. The data in table 7 show that the emasculated blossoms on trees at Smith Flat actually gave higher fruit sets than similar blossoms emasculated and self-pollinated.

Waite (1894) noted that Bartlett trees "under very fine condition were more capable of self-fecundation." Dwyer and Bowman (1938) stated that vigorous Bartlett trees carried a greater proportion of seedless fruit than less vigorous ones. The results of the present study also indicated a high positive correlation between tree vigor and parthenocarpic fruit production. Blossoms that were either bagged only, emasculated only, or emasculated and bagged, gave higher percentages of fruit set in vigorous orchards, which consistently produce high yields, than similarly treated blossoms in mediocre orchards. The data shown in table 7 show the relatively high fruit sets obtained from emasculated blossoms on representative trees in a high-yielding orchard in El Dorado County. Figure 5 also shows heavy sets of well-developed fruit that set from emasculated blossoms in a high-yielding orchard in the Sacramento River district.

The fact that the Bartlett will set heavy commercial crops of parthenocarpic pears under favorable conditions such as those found in California, South Africa, and Australia, but fails to set commercial crops without cross-pollination in other locations explains why this variety has been classified as self-fertile in one part of the country and self-sterile in another. Waite (1894) classified Bartlett as self-sterile in the Eastern United

States, but stated, "Bartlett and Anjou are not absolutely sterile to their own pollen, but under favorable conditions can set fruits under its influence." The early workers did not use the terms self-fruitful and self-unfruitful, and therefore had no term to distinguish a self-sterile variety, such as Bartlett, which may be self-fruitful because it produces parthenocarpic fruits.

Tufts and Philp (1923) concluded, "Bartlett is to a limited extent self-sterile under interior valley and coastal conditions. Under Sierra Nevada foothill conditions it is almost entirely self-sterile (at least in certain years) and therefore should not be planted without pollinizers." They also stated that in years of heavy bloom, a two or three per cent set may give a satisfactory yield in solidly planted Bartlett orchards. The data from individual orchards presented in tables 3, 4, and 5 reveal that a particular pear-growing section, such as the coastal region, the interior valleys, and the Sierra Nevada foothills of California, is not so limiting in regard to self-fruitfulness as the specific conditions found in an individual orchard. Vigorous orchards on the better soils set good crops of parthenocarpic fruit in any of the pear-growing sections. This is borne out by the thousands of acres of high-yielding Bartlett orchards throughout the state that have no provision for cross-pollination. Neglected orchards or those for any reason low in vigor probably do not set and mature commercial crops of parthenocarpic pears, regardless of location. The orchards in Yolo, Sacramento, and Yuba counties are all representatives of the Sacramento Valley, but they show considerable variation in their ability to set parthenocarpic fruit. Trees in the Leary orchard located near Walnut Grove (tables 3 and 4) gave relatively low percentages of parthenocarpic fruit on both the treated and the open-pollinated branches. These trees are located in the orchard block farthest from the levee, where soil and drainage conditions are not so favorable as in blocks closer to the levee. In contrast to these trees, the ones in the Leary orchard at Ryde (table 9) that gave the high yields of seedless fruit are growing close to the levee and are larger and more vigorous than those at Walnut Grove. The two orchards in Santa Clara County (table 4), representing the coastal region, both set good crops on blossoms that were emasculated but not pollinated. Griggs and Vansell (1949) reported a high parthenocarpic fruit set from emasculated blossoms on Bartlett trees in the Sierra Nevada foothills near Camino in 1948. Tables 3, 4, 5, and 7 show data from four orchards in El Dorado County, all located in the Sierra Nevada foothills. They also show differences in their ability to set parthenocarpic fruit, but the set was usually sufficient for a commercial crop. Trees in the Gastaldi orchard, which have long records of high yields, have consistently given high sets of parthenocarpic fruits. This orchard is interplanted with pollinizing varieties, and bees are provided during each blooming period. The blossoms that have been bagged, emasculated, emasculated and bagged, or emasculated and self-pollinated in this orchard have set fruit, therefore, in spite of the competition from cross-pollinated blossoms on the rest of the trees.

Data shown in tables 3, 4, and 5 indicate small differences in the fruit set of open-pollinated blossoms in orchards provided with pollinizers and those planted solidly to Bartlett, but in these same orchards emasculation and hand-cross-pollination consistently gave significant increases in fruit set. It is obvious, therefore, that the orchardists who have their Bartletts interplanted with other varieties are not getting the maximum benefit of cross-pollination. Greater fruit sets could undoubtedly be obtained by providing more bees so that cross-pollination could be more complete. It should be pointed out, however, that an increased set such as those obtained upon many of the branch units following hand-cross-pollination and as indicated in fig. 6 would be undesirable since it would necessitate thinning. Probably the best method of increasing fruit set in California Bartlett orchards where heavier crops are desirable would be to improve the orchard management practices that tend to increase tree vigor to a state where heavy crops of parthenocarpic pears are set. This conclusion is not in harmony with that of Gardner (1951), who in discussing seedless fruits stated, "It (seedlessness) is not something that can be influenced in any great degree by cultural treatments."

Tufts and Philp (1923) and Reinecke (1930*b*) noted the tendency of low-seeded fruit to shed prematurely, and Dwyer and Bowman (1938) stated that the extent of preharvest shedding is determined very largely by the seed content of the fruit on the tree and furnishes an important reason for providing cross-pollination for Bartletts in New South Wales. With the present standard practice of applying hormone sprays in all Bartlett orchards, regardless of the presence of pollinizing varieties, preharvest shedding of fruit is no longer considered an important problem.

The fruit weights shown in tables 3, 4, 5, and 7 are relatively light because the fruits were picked ahead of the first commercial picking. In general the data show a tendency for the fruit that developed from treatments where the blossoms were not emasculated (natural pollination and bagged only) to be heavier at the time they were picked than fruits that developed from emasculated blossoms. In the process of emasculating pear blossoms, the petals and either all or parts of the calyx, as well as the stamens, are removed by a cut below the point of attachment of the stamens. Emasculation is, therefore, a dwarfing process since the calyx and part of the calyx end are usually missing from fruit that develop from emasculated flowers (figs. 2, 3, 5, and 6). This helps to prevent error because any perfect fruit that might develop from late bloom or blossoms missed during emasculation are easily recognized on experimental branches.

Throughout the controlled-pollination studies, the pears developing from the blossoms that were emasculated and cross-pollinated were usually heavier on the average at the time they were sampled than the parthenocarpic fruits resulting from blossoms that were emasculated only or emasculated and self-pollinated. Bartlett trees are usually picked three to five times. A pear of minimum picking size (slightly over 2⅜ inches in diameter) usually weighs from 125 to 135 grams. One might wonder then if the parthenocarpic pears developing under the treatments shown in tables 3, 4, and 7 would ever have reached picking size. In view of the evidence presented in tables 5 and 9 and in figs. 5 and 7, it seems safe to conclude that they would. In 1952 (table 5), when the fruit was allowed to remain on the trees longer than in previous years, most of the parthenocarpic fruit did reach the minimum picking size. Figure 5 shows large parthenocarpic pears, which developed from blossoms that were emasculated only and were allowed to remain on the tree. Table 9 shows that mature, vigorous Bartlett trees are capable of bringing heavy sets of parthenocarpic pears through to sizes averaging considerably larger than the minimum required for picking. In view of this evidence and from field observations, it is concluded that in most years nearly all pears on a tree of the normal vigor found in most Bartlett orchards of California will reach picking size if hormone sprays are applied to prevent preharvest drop. Pears too small at the first or second picking may be expected to reach harvesting size by the third, fourth, or even fifth picking. Overholser and Latimer (1924) found that seeded Bartlett pears resulting from hand-cross-pollinated blossoms attained the proper stage of maturity for storing about two weeks earlier than those resulting from self-pollinated blossoms. They did not mention size differences, however.

Tables 1 and 2 show that fruits collected from the orchards provided with pollinizers and containing an average of 3.6 seeds per fruit were not significantly heavier than those from the solid blocks containing an average of only 0.4 seed per fruit. There were no significant correlations between numbers of seed per fruit and fruit weight for the samples taken during any of the three years, regardless of the presence or absence of pollinizers. Waite (1894) stated that the average size of the self-pollinated (seedless) pears was less, although many individuals compared favorably with the crosses. He also stated that the pears produced by "self-fertilization" were uniform in shape. Reinecke (1930*b*) found a progressive increase in fruit weight with an increase in seed content of Beurre Hardy and Smith's Hybrid pears. He stated that seeded fruits were also more attractive than seedless ones. Dwyer and Bowman (1938) found that parthenocarpic Bartletts and those of low seed content were usually smaller in size and of much more irregular shape than those of high seed content. Robinson (1938), on the other hand, found a significant increase in weight per fruit as the number of seeds per fruit increased during one season, but the second season the increased seed content per fruit did not produce the same significant increase in weight.

The importance of well-formed Bartlett pears has been pointed out by Tufts and Hansen (1931). The most desirably shaped pears have a length ranging from $1\frac{1}{4}$ to $1\frac{1}{2}$ times their diameter. Pears with length/diameter ratios below 1.25 tend to be apple-shaped and are not so desirable as the longer ones. They found no correlation between seed content and the ratio of length to diameter of the fruit in their 1931 measurements. Later measurements (Tufts and Hansen, 1933) showed a significant negative correlation between length/diameter ratio and the number of seeds per fruit. They also showed that fruit diameter was the main factor influenced by seed content.

Data presented in tables 1 and 2 show no significant correlation between seed content and length/diameter ratios of the fruit taken from orchards planted solidly to Bartlett. There was also no correlation between seed content and length/diameter ratios for fruit taken from orchards provided with pollinizers during 1949 and 1950. A significant positive correlation existed between the numbers of seeds per fruit and length/diameter ratios for fruit taken during 1948 from orchards interplanted with pollinizers (table 1). This is not consistent with any of the data presented in later tables, however, and when the seed content was correlated with either length or diameter measurements alone, the coefficients were insignificant. The data from the three-year survey seem, therefore, to be in agreement with Tufts and Hansen's 1931 findings (Tufts and Hansen, 1931). On the other hand, the data presented in table 2 do show that the mean length/diameter ratios for pears taken from orchards planted solidly to Bartlett and containing only 0.4 seed per fruit had significantly greater length/diameter ratios during 1949 and 1950 than pears taken from orchards interplanted with pollinizers containing 3.9 seeds per fruit. Data from the controlled-pollination experiments shown in tables 3, 4, 5, and 7 also indicate that the seeded fruits resulting from cross-pollinated blossoms have smaller length/diameter ratios and are, therefore, more apple-shaped than those that are seedless or nearly seedless. The data presented here as well as the author's observations in the Bartlett orchards throughout the state also tend to support Waite's observation (Waite, 1894) that seedless Bartletts are uniform in shape. Hence it may be concluded that the parthenocarpic Bartletts in California orchards have a more desirable shape than those containing seeds. Most of the commercially desirable specimens of Bartlett pears that have been photographed for nursery catalogs and for decorative purposes have the characteristic long neck and bell shape of the parthenocarpic pear (figs. 1-B, 2-F, and 4-J). Rarely does one see such a picture of the short-necked specimen with the bulging diameter that characterizes the well-seeded Bartlett (fig. 1-A), or the lopsided ones that usually contain one or two seeds.

SUMMARY AND CONCLUSIONS

The Bartlett (Williams) pear, though practically self-sterile, is self-fruitful in most California orchards because of the production of parthenocarpic fruit. A study of Bartlett orchards in 12 counties from 1948 through 1950 showed that trees planted in solid blocks, or with very few pollinizers, produced an average of 85.3, 88.4, and 75.5 per cent parthenocarpic fruits for the three respective years. Trees in orchards interplanted with pollinizing varieties produced averages of 29.6, 27.6, and 18.5 per cent seedless fruits. In two years out of three the pears from orchards planted solidly to Bartlett had significantly greater length/diameter ratios than those from the orchards interplanted with pollinizers.

Hand-pollination experiments conducted from 1949 through 1952, in ten orchards and representing six counties, showed that vegetative parthenocarpy was responsible for most of the seedless fruit produced. The practical importance of this phenomenon has not been appreciated. Stimulative parthenocarpy due to self-pollination did not give significantly greater fruit sets than those effected by vegetative parthenocarpy alone. The more

vigorous orchards with long records of high yields gave the highest percentages of parthenocarpic fruit set. In California orchards where a heavier fruit set is desirable, the increase could probably be attained, therefore, by improving orchard-management practices that tend to make the trees more vigorous.

Fruit sets were higher from hand-cross-pollination than those resulting from parthenocarpic fruit development. In all orchards, hand-cross-pollination also gave higher fruit sets than open-pollinated branches whether or not pollinizing varieties were present. This indicated that the fruit set could be increased in orchards interplanted with pollinizers by supplying more bees so that cross-pollination could be more complete. Seeded fruit that developed from emasculated and hand-cross-pollinated blossoms reached picking size before the parthenocarpic ones from blossoms that were emasculated only.

Trees caged with mosquito-tight netting in one-half-tree sections, either with or without a colony of bees enclosed, showed that bees working the blossoms failed to increase the self-fruitfulness of the Bartlett pear. It may be concluded, therefore, that bees are of no value in Bartlett orchards unless other varieties are interplanted, or are within bee-flight range, so that cross-pollination may be effected.

Rat-tail pears from solid blocks of Bartlett contain significantly more seeds than normal ones. Hence the late-season blossoms produced at the tips of current season's growth, from which rat-tail pears develop, apparently have a higher degree of self-fertility than flowers opening at the normal time.

Harvesting records and examinations of fruit from four mature Bartlett trees in a high-yielding orchard with no provision for cross-pollination showed that 89.3 per cent of the fruit were seedless. During the four commercial pickings, practically every pear on these heavy-bearing trees reached the minimum marketing size or larger. The seeded pears did not reach picking size before the seedless ones.

Previous workers found the degree of self-fruitfulness of the Bartlett to vary from one area of California to another. The present study indicates that a particular pear-growing section within the state—such as the coastal region, the interior valleys, and the Sierra Nevada foothills—is not so limiting in regard to self-fruitfulness as the specific conditions found in an individual orchard. Well-cared-for orchards set commercial crops of parthenocarpic fruit in all the main pear-growing sections.

The Bartletts' ability to set commercial crops of parthenocarpic pears under favorable conditions, and failure to do so under others, explains the contradictory reports regarding the self-fertility and self-fruitfulness of this variety. Results of pollination studies with varieties tending to produce parthenocarpic fruits should be interpreted on the basis of the number of seeded fruits rather than the total number of fruits set.

Contrary to the belief of previous workers, parthenocarpic Bartlett pears were found on the average to have a more desirable and more uniform shape than those containing seeds.

Most Bartlett growers in California are depending upon the fruit set effected by vegetative parthenocarpy alone. This is considerably less than the set to be expected in the presence of pollinizing varieties and an adequate number of bees. In most years the parthenocarpic set is enough for a commercial crop in the better orchards, but in years when the fruit set is reduced by unfavorable factors, such as the adverse weather conditions occurring in 1948, the value of pollinizers becomes more apparent.

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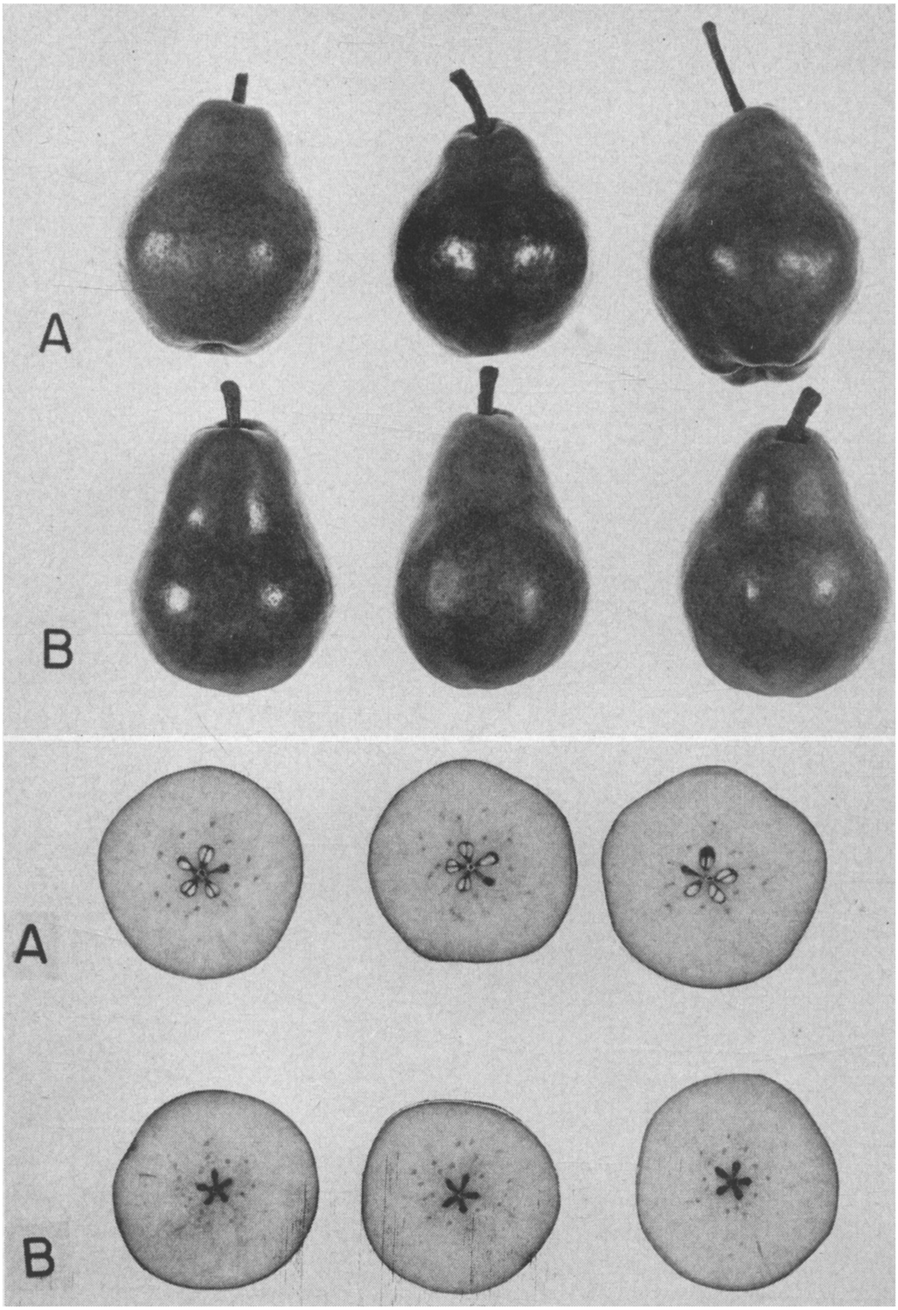

Fig. 1. *Above:* A. Bartlett pears from naturally pollinated blossoms in an orchard interplanted with a pollinizing variety. B. Bartlett pears from naturally pollinated blossoms in an orchard planted solidly to Bartlett. *Below:* Cross-sections of same fruit showing seed content of cross-pollinated fruit and seedless fruit developed in solid blocks of Bartlett. Fruit was picked two days before first commercial picking.

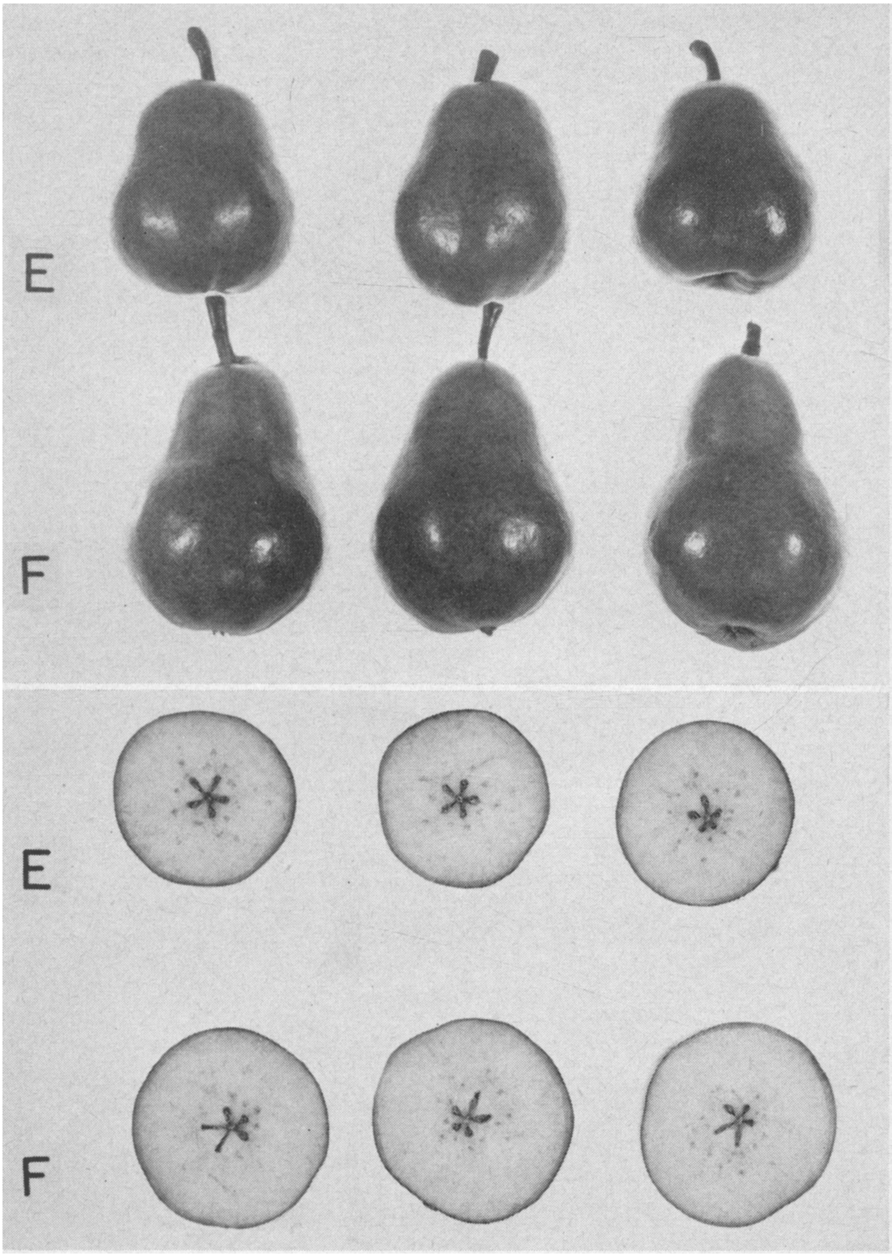

Fig. 2. *Above:* E. Bartlett pears from blossoms that were emasculated only. F. Bartlett pears from blossoms bagged during the blossoming period. Note beautiful shape of these pears. *Below:* Cross-sections of same fruit, showing that they are seedless. Fruit was picked two weeks before first commercial picking.

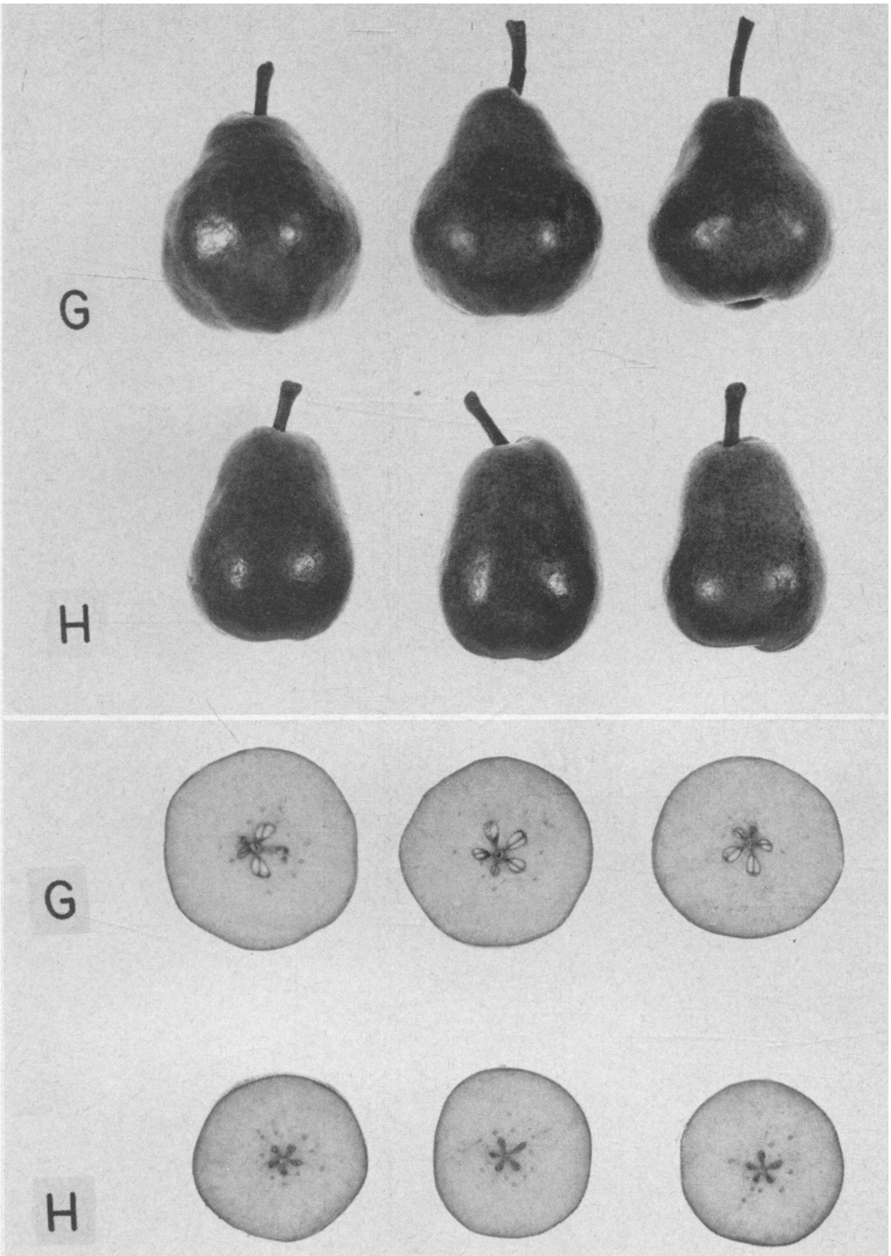

Fig. 3. *Above:* G. Bartlett pears from blossoms emasculated and cross-pollinated with Winter Nelis pollen. H. Bartlett pears from emasculated and self-pollinated blossoms. *Below:* Cross-sections of same fruit, showing seed content of cross-pollinated fruit and seedless fruit developed from blossoms that were self-pollinated. Fruit was picked two weeks before first commercial picking.

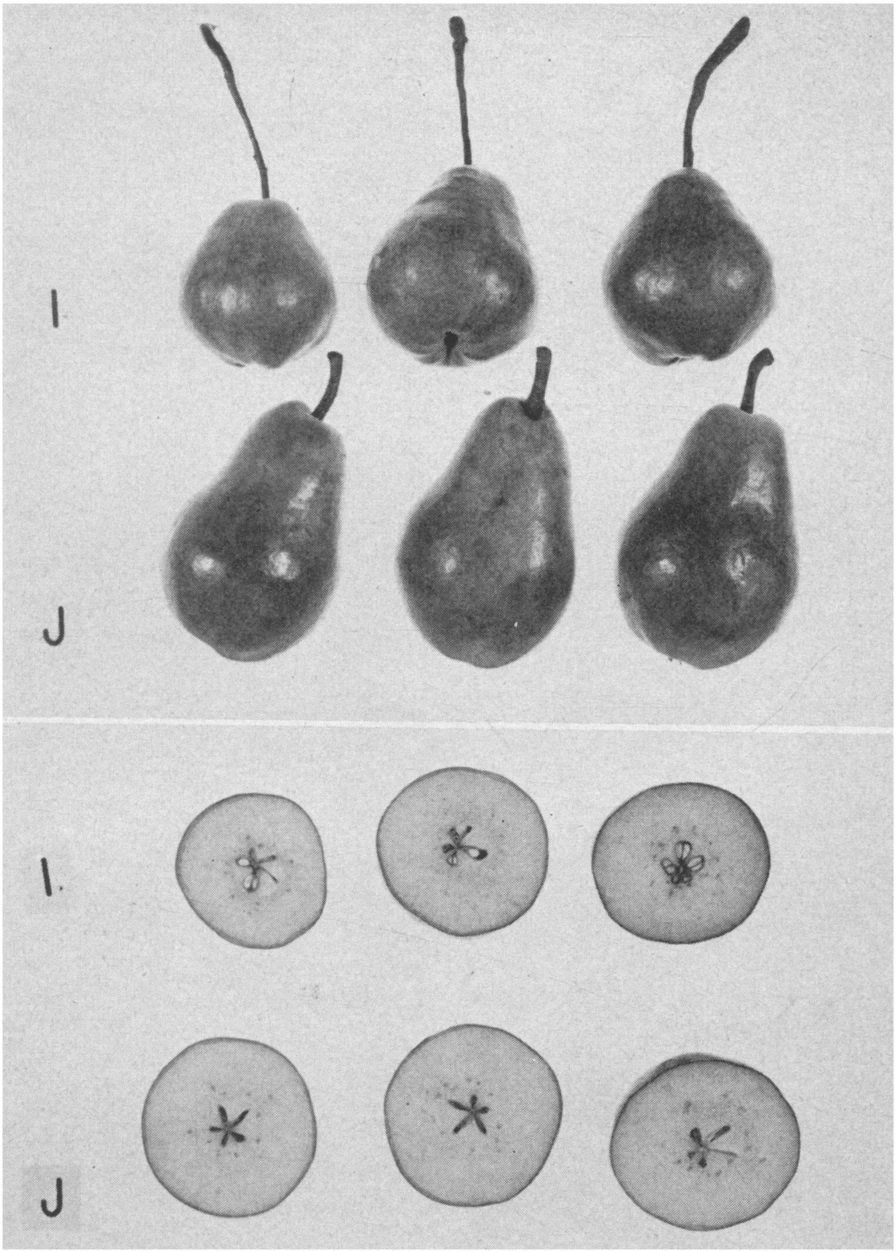

Fig. 4. *Above:* I. Rat-tail pears from late bloom in an orchard planted solidly to Bartlett. J. Normal pears from the same orchard. *Below:* Cross-sections of same fruit, showing seed content of the rat-tails and the typical seedless fruit developed in orchards with no provisions for cross-pollination. Fruit was picked three days before first commercial picking.

Fig. 5. Examples of parthenocarpic fruit set on vigorous Bartlett trees. These pears developed from blossoms that were emasculated only. *Above:* The 215 emasculated blossoms on this branch gave a 9.8 per cent fruit set. All of the fruits were seedless. *Below:* Section of branch upon which 189 emasculated blossoms gave a 20.6 per cent fruit set. All of the fruits were seedless. A large proportion of the leaves were removed. Picture taken three days before first commercial picking.

Fig. 6. Cross-pollinated versus self-pollinated Bartlett pears. *Above:* Section of branch upon which 214 emasculated and cross-pollinated blossoms gave a 53.3 per cent fruit set. These pears contained an average of 8.2 seeds per fruit. *Below:* Section of branch upon which 156 emasculated and self-pollinated blossoms gave a 21.2 per cent fruit set. These pears were all seedless. Picture taken two weeks before first commercial picking.

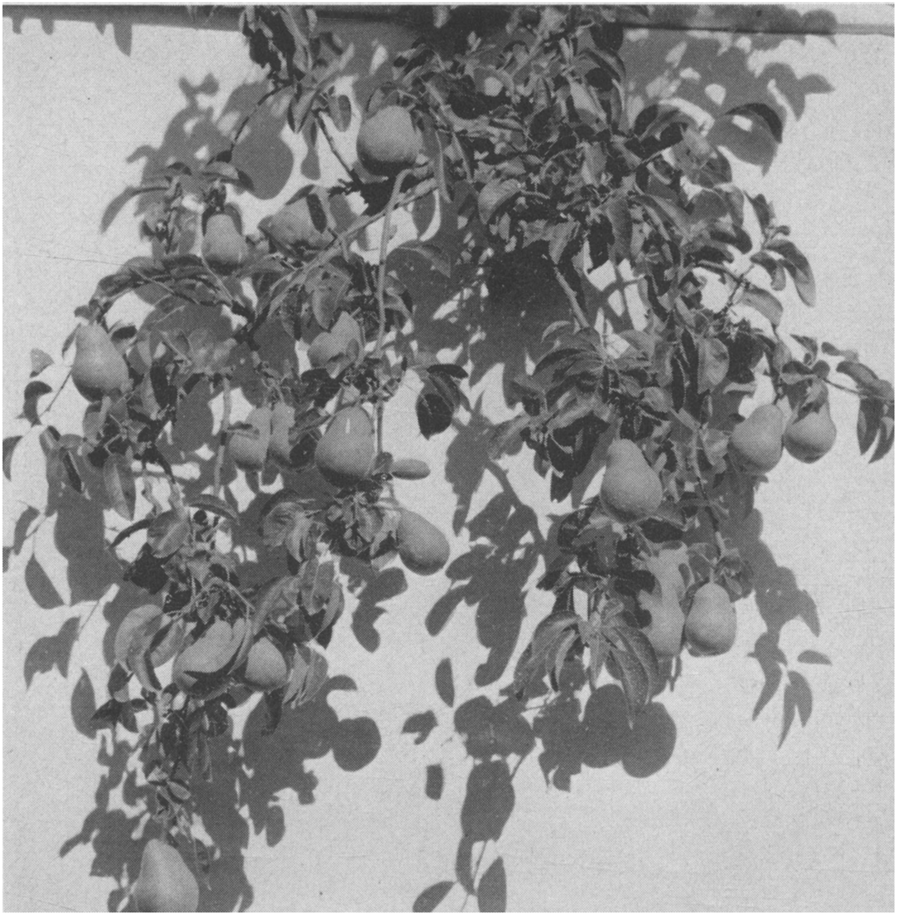

Fig. 7. Bartlett pears on a section of a branch which was bagged during the blossoming period. The branch gave 32 pears from 79 flower clusters. All of the fruits were seedless. Note beautiful shape of these pears. Picture taken five days before first commercial picking.

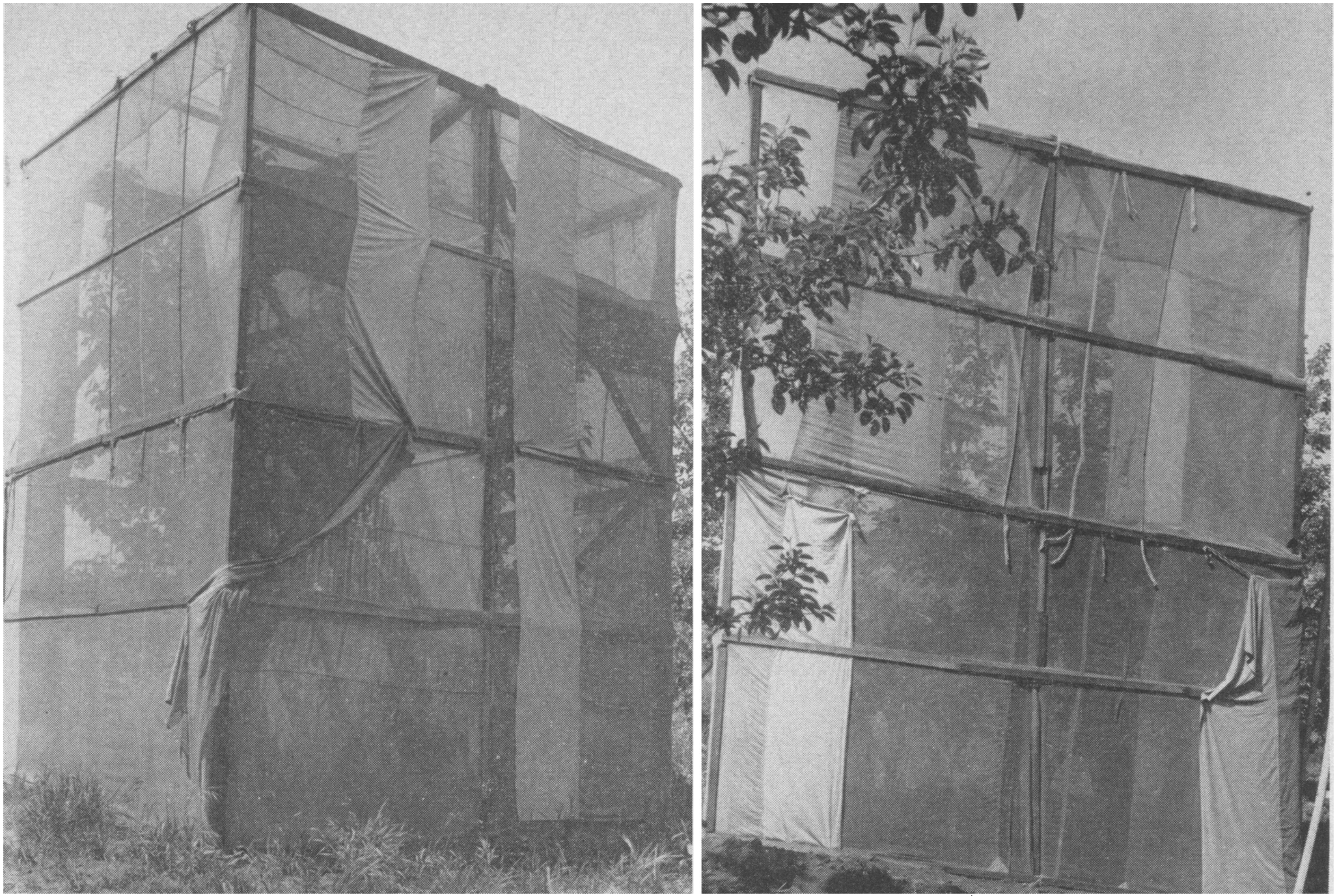

Fig. 8. Bartlett pear trees caged in two sections during the blossoming period to exclude bees from one half of the tree while the other half was enclosed with a colony of bees. *Left:* Cage at Smith Flat where bees were placed in south (left) compartment. *Right:* Cage at Camino where bees were placed in north (right) compartment.

TABLE 1

YIELDS OF BARTLETT PEAR ORCHARDS INTERPLANTED WITH OTHER VARIETIES FOR CROSS-POLLINATION VERSUS THOSE PLANTED IN SOLID BLOCKS OF BARTLETT OR WITH VERY FEW POLLINIZERS, AND FRUIT WEIGHT, SEED CONTENT, AND SHAPE OF FRUIT SAMPLES TAKEN FROM THESE ORCHARDS, 1948

(Means are for 250 pears.)

Location (county)	Natural pollination, pollinizers interplanted					Natural pollination, solid blocks of Bartlett				
	Yield (tons per acre)	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio	Yield (tons per acre)	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio
Mendocino	....	....	....	....	....	15.0	165.0	0.04	98.4	1.10
Mendocino	....	....	....	....	....	14.0	157.4	0.16	87.6	1.10
Lake	....	....	....	....	....	17.0	188.8	0.14	94.7	1.22
Lake	....	....	....	....	....	19.3	144.9	0.07	96.0	1.21
Yuba	12.0	158.8	5.20	1.5	1.21	3.8	158.0	0.23	88.9	1.25
Placer	4.7	158.4	1.60	39.5	1.15	3.1	157.0	2.09	39.5	1.15
Placer	17.0	126.9	4.02	8.0	1.18	....	....	....	....	....
El Dorado	16.0	115.5	2.90	17.5	1.14	8.0	131.6	1.25	52.5	1.19
El Dorado	....	....	....	....	....	5.3	108.0	0.30	95.3	1.23
Sacramento	4.7	186.2	1.42	67.3	1.14	21.3	127.3	0.00	99.6	1.20
Sacramento	5.2	213.4	2.95	26.0	1.16	6.0	176.8	0.01	98.7	1.20
Sacramento	....	....	....	....	....	7.5	145.1	0.04	96.8	1.26
Solano	....	....	....	....	....	14.6	132.7	0.03	97.5	1.22
Solano	....	....	....	....	....	5.5	122.1	0.12	90.0	1.21
Solano	....	....	....	....	....	11.1	175.6	0.04	97.0	1.20
Solano	....	....	....	....	....	3.2	146.2	0.13	93.8	1.24
Solano	....	....	....	....	....	7.3	113.7	0.00	99.5	1.18
Contra Costa	....	....	....	....	....	10.6	134.5	0.38	84.5	1.26
Contra Costa	....	....	....	....	....	11.1	177.2	0.60	63.4	1.20
Santa Clara	16.1	127.1	3.90	11.7	1.19	14.0	164.8	0.27	86.0	1.31
Santa Clara	9.1	119.4	1.24	65.2	1.12	20.8	124.1	0.11	94.2	1.16
Santa Clara	....	....	....	....	....	8.3	131.3	1.40	37.2	1.23
General mean	10.6	150.7	2.90**	29.6	1.16	10.8	146.8	0.35	85.3**	1.21

** Significantly greater at the 1 per cent level than corresponding mean for orchards with opposite pollination conditions.

TABLE 2

FRUIT SET OF BARTLETT PEAR ORCHARDS INTERPLANTED WITH OTHER VARIETIES FOR CROSS-POLLINATION VERSUS THOSE PLANTED IN SOLID BLOCKS OF BARTLETT OR WITH VERY FEW POLLINIZERS, AND FRUIT WEIGHT, SEED CONTENT, AND SHAPE OF FRUIT SAMPLES TAKEN FROM THESE ORCHARDS, 1949 AND 1950

(Means for fruit set are for 25 trees, other means are for 250 pears.)

Location (county)	Year	Natural pollination, pollinizers interplanted: Number of flower clusters	Mean number of fruit per 100 flower clusters	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio	Natural pollination, solid blocks of Bartlett: Number of flower clusters	Mean number of fruit per 100 flower clusters	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio
Mendocino	1949	1,724	40.4	149.0	4.73	3.1	1.32	1,434	34.8	151.6	0.10	93.0	1.38
Mendocino	1950	762	38.4	161.3	2.47	26.0	1.32	646	27.9	146.4	0.27	89.0	1.28
Lake	1949	1,883	51.5	155.8	1.73	60.2	1.42	1,653	63.9	131.2	0.08	96.0	1.42
Lake	1950	1,118	84.2	133.1	3.30	16.0	1.36	1,059	82.3	136.3	0.14	93.0	1.30
Sonoma	1949	1,124	54.8	145.8	0.40	86.0	1.47	1,272	31.4	141.6	0.11	96.9	1.46
Sonoma	1950	901	150.4	137.6	1.95	46.0	1.26	1,016	128.2	134.3	0.35	88.0	1.26
Yuba	1949	1,654	32.7	114.7	1.81	39.0	1.41	2,129	27.1	107.3	0.01	99.0	1.43
Yuba	1950	1,509	40.2	123.4	5.90	7.0	1.25	1,502	35.4	144.2	1.65	36.0	1.26
Placer	1949	1,557	22.5	123.6	0.99	60.6	1.41	2,357	29.1	130.7	0.22	85.7	1.34
Placer	1950	774	81.3	128.6	3.78	13.0	1.22	798	21.8	163.8	0.62	75.0	1.33
El Dorado	1949	2,214	39.4	110.0	3.13	5.0	1.37	1,882	31.6	92.5	0.54	72.3	1.44
El Dorado	1950	499	65.3	139.8	2.03	13.3	1.35	1,038	29.1	163.0	1.47	49.0	1.37
Sacramento	1949	3,177	35.1	115.2	5.31	5.0	1.24	2,640	20.6	88.5	0.07	94.8	1.32
Sacramento	1950	838	100.4	157.8	6.00	2.0	1.21	838	31.9	143.6	0.04	96.0	1.33
Solano	1949	2,472	44.2	99.9	5.06	4.0	1.26	3,092	22.0	96.3	0.17	86.0	1.44
Solano	1950	618	84.0	147.3	1.17	60.0	1.17	1,701	60.8	125.2	0.13	89.0	1.32
Contra Costa	1949	1,832	57.2	97.5	6.03	2.0	1.35	2,004	39.0	101.6	0.42	84.0	1.39
Contra Costa	1950	678	207.5	160.8	7.37	0.0	1.19	841	109.5	151.0	1.06	52.0	1.20
Santa Clara	1949	4,195	48.9	123.4	2.87	38.2	1.25	4,183	49.1	117.6	0.26	91.0	1.36
Santa Clara	1950	2,264	71.6	148.4	5.04	20.0	1.16	1,691	115.0	133.0	0.36	84.0	1.32
Yolo	1949	2,045	28.3	80.5	8.21	0.0	1.24	.....	....	.....	....	....	....
Yolo	1950	803	66.1	162.5	7.24	0.0	1.17	.....	....	.....	....	....	....
San Joaquin	1949	.....	....	.....	....	....	....	4,477	22.4	97.2	0.31	74.0	1.48
San Joaquin	1950	.....	....	.....	....	....	....	2,363	34.7	133.6	0.36	80.0	1.29
General mean 1949			41.4*	119.6	3.66**	27.6	1.34		33.7	114.2	0.21	88.4**	1.40*
General mean 1950			89.9*	145.5	4.20**	18.5	1.24		61.5	143.1	0.59	75.5**	1.30*
1949–1950 mean			65.6**	132.6	3.93**	23.0	1.29		47.6	128.6	0.40	82.0**	1.35**

* Significantly greater at the 5 per cent level than corresponding mean for orchards with opposite pollination conditions.
** Significantly greater at the 1 per cent level than corresponding mean for orchards with opposite pollination conditions.

TABLE 3

EFFECT OF POLLINATION TREATMENT ON FRUIT SET, WEIGHT, SEED CONTENT, AND SHAPE OF BARTLETT PEARS, 1949

(Means for fruit set are for from two to five trees.)

Treatment and orchard	County	Number of blossoms	Mean fruit set (per cent)	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio
Natural pollination (pollinizers interplanted)							
Gastaldi	El Dorado	5,555	5.7	98.9	1.88	44.8	1.42
University	Yolo	3,894	11.0	115.0	5.37	1.7	1.24
General mean			8.4	107.0	3.62	23.2	1.33
Natural pollination (solid blocks of Bartlett)							
Spencer	El Dorado	3,890	5.7	73.5	0.86	63.7	1.49
Leary	Sacramento	1,994	3.0	84.1	0.08	92.7	1.26
General mean			4.4	78.8	0.47	78.2	1.38
Pooled general mean for natural pollination			6.4	92.9	2.05	50.7	1.35
Blossoms bagged only							
Gastaldi	El Dorado	610	1.4	89.6	0.00	100.0	1.47
University	Yolo	1,230	1.2	90.1	0.07	73.3	1.37
Spencer	El Dorado	1,945	2.5	83.7	0.01	93.2	1.52
Leary	Sacramento	1,120	1.7	107.5	0.00	100.0	1.20
General mean			1.7	92.7	0.02	91.6	1.39
Blossoms emasculated only							
Gastaldi	El Dorado	1,098	7.5	79.4	0.05	95.8	1.27
University	Yolo	991	6.3	96.3	0.15	88.1	1.26
Spencer	El Dorado	1,493	5.1	57.9	0.00	96.9	1.44
Leary	Sacramento	593	0.5	65.5	0.50	50.0	1.26
General mean			4.8	74.8	0.18	82.7	1.31
Blossoms emasculated and bagged							
Gastaldi	El Dorado	169	1.7	67.5	0.00	100.0	1.33
University	Yolo	980	0.1	84.0	0.00	100.0	1.29
Spencer	El Dorado	392	4.8	64.0	0.00	100.0	1.42
Leary	Sacramento	458	1.5	98.3	0.00	100.0	1.34
General mean			2.0	78.4	0.00	100.0	1.34
Blossoms emasculated and Bartlett pollen applied by hand							
Gastaldi	El Dorado	419	6.4	77.9	0.07	95.3	1.33
University	Yolo	495	9.0	104.9	1.00	62.6	1.16
Spencer	El Dorado	476	7.1	59.4	0.00	100.0	1.44
Leary	Sacramento	500	7.3	65.2	0.17	83.3	1.21
General mean			7.4	76.8	0.31	85.3	1.28
Blossoms emasculated and Winter Nelis pollen applied by hand							
Gastaldi	El Dorado	156	11.7	69.7	2.10	25.0	1.32
University	Yolo	398	25.4	123.4	6.45	1.7	1.11
Spencer	El Dorado	438	14.8	68.9	0.81	53.5	1.43
Leary	Sacramento	543	19.5	83.6	6.45	11.2	1.11
General mean			17.8	86.4	4.00	22.8	1.24
F value for treatments			14.6**	1.6	5.0**	9.0**	3.3*
F value for location			1.4	7.4**	2.0	2.5	20.5**
Difference required for significance between general means							
5 per cent level			4.7	....	2.2	29.6	0.09
1 per cent level			6.5	....	3.0	40.9	....

* Significant beyond the 5 per cent level.
** Significant beyond the 1 per cent level.

TABLE 4

EFFECT OF POLLINATION TREATMENT ON FRUIT SET, WEIGHT, SEED CONTENT, AND SHAPE OF BARTLETT PEARS, 1950

(Means are for from one to five trees.)

Treatment and orchard	County	Number of blossoms	Mean fruit set (per cent)	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio
Natural pollination (pollinizers interplanted)							
Gastaldi	El Dorado	1,415	17.9	143.7	2.40	35.0	1.27
Davey	El Dorado	713	9.7	168.3	1.74	56.0	1.30
Hamilton	El Dorado	1,975	8.8	139.8	2.03	13.3	1.35
Blanchard	Santa Clara	835	7.8	112.5	4.05	15.0	1.26
University	Yolo	515	13.2	162.5	7.24	0.0	1.17
General mean	....		11.5	145.4	3.49	23.9	1.27
Natural pollination (solid blocks of Bartlett)							
Benson	Lake	1,655	18.2	125.9	0.00	100.0	1.39
Weston	Santa Clara	395	23.6	134.4	0.00	100.0	1.22
Gilbert	Sacramento	528	4.0	137.6	0.30	76.0	1.34
Leary	Sacramento	2,020	2.9	92.2	0.04	71.7	1.31
General mean	....		12.2	122.5	0.08	86.9	1.32
Pooled general mean for natural pollination	....		11.8	135.2	1.98	51.9	1.29
Blossoms bagged only							
Gastaldi	El Dorado	630	6.5	125.7	0.00	100.0	1.39
Davey	El Dorado	160	5.6	103.2	0.00	100.0	1.43
Hamilton	El Dorado	480	0.2	170.0	0.00	100.0	1.30
Blanchard	Santa Clara	225	0.0	.....	....	....	....
University	Yolo	340	0.3	165.2	0.00	100.0	1.37
Benson	Lake	305	6.5	105.9	0.00	100.0	1.47
Weston	Santa Clara	150	12.0	153.1	0.00	100.0	1.28
Gilbert	Sacramento	450	3.8	140.0	0.00	100.0	1.38
Leary	Sacramento	685	0.5	96.7	0.00	100.0	1.32
General mean	....		3.9	132.5	0.00	100.0	1.37
Blossoms emasculated only							
Gastaldi	El Dorado	265	12.8	107.6	0.00	100.0	1.26
Davey	El Dorado	334	5.1	84.4	0.00	100.0	1.25
Hamilton	El Dorado	973	4.0	141.5	0.00	100.0	1.23
Blanchard	Santa Clara	180	18.3	96.8	0.54	72.7	1.19
University	Yolo	169	0.0	.....	....	....	....
Benson	Lake	369	23.9	104.5	0.00	100.0	1.25
Weston	Santa Clara	....	....	.....	....	....	....
Gilbert	Sacramento	....	....	.....	....	....	....
Leary	Sacramento	1,107	0.9	71.7	0.00	100.0	1.24
General mean	....		9.3	101.1	0.09	95.4	1.24
Blossoms emasculated and bagged							
Gastaldi	El Dorado	258	13.0	119.2	0.00	100.0	1.28
Davey	El Dorado	112	7.1	127.3	0.00	100.0	1.33
Hamilton	El Dorado	290	0.4	116.0	0.00	100.0	1.26
Blanchard	Santa Clara	125	9.6	106.0	0.00	100.0	1.26

TABLE 4 (*Continued*)

EFFECT OF POLLINATION TREATMENT ON FRUIT SET, WEIGHT, SEED CONTENT, AND SHAPE OF BARTLETT PEARS, 1950

(Means are for from one to five trees.)

Treatment and orchard *Blossoms emasculated and bagged (Continued)*	County	Number of blossoms	Mean fruit set (per cent)	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio
University	Yolo	150	0.0	.....	....	....	....
Benson	Lake	166	10.2	102.6	0.00	100.0	1.39
Weston	Santa Clara	128	11.4	123.7	0.00	100.0	1.22
Gilbert	Sacramento	....	....	.....	....	....	....
Leary	Sacramento	512	1.7	77.5	0.00	100.0	1.22
General mean	....		6.7	110.3	0.00	100.0	1.28
Blossoms emasculated and Bartlett pollen applied by hand							
Gastaldi	El Dorado	379	12.9	121.6	0.05	95.0	1.22
Davey	El Dorado	....	....	.....	....	....	....
Hamilton	El Dorado	348	3.4	117.2	0.00	100.0	1.18
Blanchard	Santa Clara	207	9.2	84.0	0.50	80.0	1.23
University	Yolo	210	0.0	.....	....	....	....
Benson	Lake	358	35.9	94.8	0.00	100.0	1.22
Weston	Santa Clara	160	16.6	106.1	0.05	94.5	1.14
Gilbert	Sacramento	....	....	.....	....	....	....
Leary	Sacramento	912	0.4	77.0	0.75	50.0	1.17
General mean	....		11.2	100.1	0.22	86.6	1.19
Blossoms emasculated and Winter Nelis pollen applied by hand							
Gastaldi	El Dorado	256	25.0	130.8	3.18	15.0	1.15
Davey	El Dorado	....	....	.....	....	....	....
Hamilton	El Dorado	845	3.4	125.1	0.02	97.8	1.31
Blanchard	Santa Clara	207	29.0	132.8	6.30	0.0	1.10
University	Yolo	188	1.1	.....	....	....	....
Benson	Lake	366	29.1	119.6	0.99	36.2	1.23
Weston	Santa Clara	184	50.0	140.4	7.91	0.0	1.02
Gilbert	Sacramento	....	....	.....	....	....	....
Leary	Sacramento	716	5.6	97.6	2.36	4.1	1.24
General mean	....		20.4	124.4	3.46	25.5	1.18
F value for treatment			2.4*	3.5*	5.2**	10.9**	8.2**
F value for location			5.1**	6.0**	1.1	0.6	2.1

* Significant beyond the 5 per cent level.
** Significant beyond the 1 per cent level.

TABLE 5

EFFECT OF POLLINATION TREATMENT ON FRUIT SET, WEIGHT, SEED CONTENT, AND SHAPE OF BARTLETT PEARS, 1952

(Means for fruit set are for 5 trees except in the University orchard, where only 3 trees were used.)

Treatment and orchard	County	Number of blossoms	Mean fruit set (per cent)	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio	Number of seeds tested	Viable seeds (per cent)
Natural pollination (pollinizers interplanted)									
Gastaldi	El Dorado	1,848	12.3	156.0	2.09	32.6	1.24	25	100
University	Yolo	1,565	7.4	133.4	5.48	0.0	1.13	27	100
General mean	....		9.8	144.7	3.78	16.3	1.18		100
Natural pollination (solid blocks of Bartlett)									
Benson	Lake	2,697	19.8	148.7	0.07	94.5	1.30	4	75
New England	Yuba	2,310	6.5	139.9	1.26	52.6	1.29	..	...
General mean	....		13.2	144.3	0.66	73.6	1.30		100
Pooled general mean for open-pollination	....		11.5	144.5	2.22	44.9	1.24		100
Blossoms bagged only									
Gastaldi	El Dorado	1,377	3.9	151.1	0.26	76.6	1.37	..	...
University	Yolo	1,087	0.5	110.2	0.17	83.3	1.17	1	100
Benson	Lake	786	12.5	138.9	0.00	100.0	1.34	..	...
New England	Yuba	1,210	6.8	136.6	0.00	100.0	1.31	..	...
General mean	....		5.9	134.2	0.11	90.0	1.30		100
Blossoms emasculated only									
Gastaldi	El Dorado	1,204	9.6	124.1	0.04	95.7	1.24	1	100
University	Yolo	505	0.0	.....	....	....	....	..	...
Benson	Lake	1,248	14.2	141.4	0.00	100.0	1.20	..	...
New England	Yuba	692	10.7	118.5	0.00	100.0	1.22	1	0
General mean	....		8.6	128.0	0.01	98.6	1.22		50
Blossoms emasculated and Bartlett pollen applied by hand									
Gastaldi	El Dorado	1,053	8.4	118.0	0.00	100.0	1.24	..	...
University	Yolo	601	6.0	126.4	0.00	100.0	1.22	..	...
Benson	Lake	969	12.8	145.8	0.03	96.8	1.26	..	...
New England	Yuba	.....	....	.....	....	....	....	..	...
General mean	....		9.1	130.0	0.01	98.9	1.24		
Blossoms emasculated and Winter Nelis pollen applied by hand									
Gastaldi	El Dorado	1,025	36.3	148.0	7.75	0.0	1.08	30	100
University	Yolo	426	42.6	126.6	7.26	0.0	1.01	..	...
Benson	Lake	818	40.3	147.8	6.24	0.0	1.17	..	...
New England	Yuba	867	16.7	135.7	6.15	0.0	1.14	..	...
General mean	....		34.0	139.5	6.85	0.0	1.10		100
F value for treatment			9.8**	1.0	23.8**	17.6**	4.7*		
F value for location			0.5	2.6	0.3	0.4	1.7		

* Significant beyond the 5 per cent level.
** Significant beyond the 1 per cent level.

TABLE 6

FRUIT SET OF SECTIONS OF BARTLETT PEAR TREES CAGED TO EXCLUDE BEES FROM ONE HALF OF THE TREE WHILE THE OTHER HALF WAS ENCLOSED WITH A COLONY OF BEES, AND WEIGHT, SEED CONTENT, AND SHAPE OF FRUIT SAMPLES TAKEN FROM THESE TREES

Treatment and orchard location	Number of blossoms and location (south or north)	Mean fruit set (per cent)	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio	Seed germination (per cent)
Half of caged tree with a colony of bees included							
Smith Flat	1,445 South	9.6	82.2	0.14	87.8	1.29	20.0
Camino	2,321 North	7.2	93.7	0.38	73.5	1.22	0.0
General mean		8.4	88.0	0.26	80.6	1.26	10.0
Half of caged tree with bees excluded							
Smith Flat	2,565 North	8.6	95.7**	0.03	96.9**	1.25	0.0
Camino	2,204 South	8.0	99.0	0.33	72.2	1.24	0.0
General mean		8.3	97.4**	0.18	84.6*	1.24	0.0

* Significantly greater at the 5 per cent level than corresponding mean for other half of the tree.
** Significantly greater at the 1 per cent level than corresponding mean for other half of the tree.

TABLE 7

EFFECT OF POLLINATION TREATMENT ON BRANCH UNITS OF A CAGED AND AN EXPOSED BARTLETT PEAR TREE IN AN ORCHARD INTERPLANTED WITH POLLINIZING VARIETIES

(Gastaldi orchard, elevation 2,400 feet, Smith Flat, 1951)

Treatment, additional treatment, and location of branches	Number of blossoms	Mean fruit set (per cent)	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio	Seed germination (per cent)
Natural pollination							
South half of caged tree with a colony of bees included	1,445	9.6	82.2	0.14	87.8	1.29	20.0
North half of caged tree with bees excluded	2,565	8.6	95.7	0.03	96.9	1.25	0.0
Open-pollinated tree near by	679	9.4	78.7	1.49	67.4	1.24	25.0
General mean		9.2	85.5	0.55	84.0	1.26	15.0
Blossoms bagged only							
South half of caged tree with a colony of bees included	215	9.8	87.7	0.00	100.0	1.33	....
North half of caged tree with bees excluded	230	6.5	95.1	0.00	100.0	1.31	....
Open-pollinated tree nearby	190	3.7	78.5	0.00	100.0	1.29	....
General mean		6.7	87.1	0.00	100.0	1.31	....
Blossoms emasculated only							
South half of caged tree with a colony of bees included	386	17.1	68.2	0.44	68.8	1.23	33.3
North half of caged tree with bees excluded	246	11.8	72.4	0.09	90.9	1.24	0.0
Open-pollinated tree near by	647	13.3	58.4	0.07	92.7	1.21	0.0
General mean		14.1	66.3	0.20	84.1	1.23	11.1
Blossoms emasculated and Bartlett pollen applied by hand							
South half of caged tree with a colony of bees included	148	15.5	77.6	0.12	87.5	1.25	0.0
North half of caged tree with bees excluded	153	9.8	70.3	1.00	27.8	1.19	0.0
Open-pollinated tree nearby	115	6.9	49.6	0.50	60.0	1.18	40.0
General mean		10.7	65.8	0.54	58.4	1.21	13.3
Blossoms emasculated and Winter Nelis pollen applied by hand							
South half of caged tree with a colony of bees included	142	22.5	92.1	8.38	0.0	1.05	12.0
North half of caged tree with bees excluded	123	22.8	99.4	8.54	0.0	1.07	4.0
Open-pollinated tree nearby	207	29.4	70.0	6.70	2.2	1.08	40.0
General mean		24.9	87.2	7.87	0.7	1.07	18.7
F value for treatments		15.6**	11.5**	72.5**	14.6**	49.8**	0.1
F value for location		1.3	15.6**	0.9	0.1	2.2	2.5
Difference required for significance between general means for treatments:							
5 per cent level		5.9	10.8	1.30	33.3	0.04	....
1 per cent level		8.5	15.7	1.88	48.5	0.06	....

** Significant beyond the 1 per cent level.

TABLE 8

A COMPARISON OF THE SEED CONTENT OF RAT-TAIL (LATE-BLOOM) AND NORMAL BARTLETT PEARS TAKEN FROM ORCHARDS PLANTED WITH AND WITHOUT PROVISION FOR CROSS-POLLINATION

Treatment and type of fruit	Orchard location	Year	Mean number of seeds per fruit	Seed viability (per cent)
Natural pollination, pollinizers interplanted				
Rat-tail	Davis	1949	1.19	34.6
Rat-tail	Davis	1952	0.58	100.0
Rat-tail	Smith Flat	1952	1.17	96.0
Mean			0.98	....
Normal	Davis	1949	8.43**	28.0
Normal	Davis	1952	5.55**	100.0
Normal	Smith Flat	1952	2.88*	100.0
Mean			5.62	....
Natural pollination, solid blocks of Bartlett				
Rat-tail	Kelseyville	1949	0.88**	47.5
Rat-tail	Kelseyville	1952	0.82**	100.0
Rat-tail	Mills	1952	0.82**	100.0
Rat-tail	Walnut Grove	1952	0.36**	100.0
Mean			0.72**	....
Normal	Kelseyville	1949	0.09	....
Normal	Kelseyville	1952	0.06	88.9
Normal	Mills	1952	0.33	52.9
Normal	Walnut Grove	1952	0.11	....
Mean			0.15	....

* Significantly greater at the 5 per cent level than corresponding mean for the opposite type of fruit with the same pollination condition.

** Significantly greater at the 1 per cent level than corresponding mean for the opposite type of fruit with the same pollination condition.

TABLE 9

HARVESTING RECORDS OF MATURE BARTLETT PEAR TREES WITH NO PROVISION FOR CROSS-POLLINATION, AND WEIGHT, SEED CONTENT, AND SHAPE OF FRUIT SAMPLES TAKEN AT EACH PICKING

(Leary Ranch, Ryde, California.)

Date of harvest (1952)	Tree	Yield of pears 2⅜ inches in diameter or larger (field lugs)[a]	Yield of pears smaller than 2⅜ inches in diameter (field lugs)[a]	Mean weight per fruit (grams)	Mean number of seeds per fruit	Mean percentage seedless fruit	Mean length/diameter ratio
July 7	1	2.0	...	135.6	0.12	91.2	1.17
	2	1.0	...	127.8	0.08	91.5	1.16
	3	1.2	...	139.2	0.17	85.2	1.21
	4	0.9	...	130.5	0.07	94.5	1.18
Mean..........		1.3	...	133.3	0.11	90.6	1.18
July 16	1	4.4	...	151.7	0.12	90.0	1.21
	2	2.6	...	138.3	0.17	90.0	1.22
	3	5.1	...	150.2	0.38	76.9	1.20
	4	3.4	...	145.1	0.11	90.2	1.25
Mean..........		3.9	...	146.3	0.20	86.8	1.22
August 1	1	6.0	...	172.3	0.10	90.2	1.22
	2	7.0	...	169.3	0.04	96.1	1.30
	3	7.5	...	190.4	0.06	94.1	1.27
	4	4.0	...	174.6	0.15	90.7	1.28
Mean..........		6.1	...	176.6	0.09	92.8	1.27
August 13	1	2.2	0.3	225.0	0.12	90.0	1.30
	2	4.2	0.2	147.8	0.17	86.5	1.28
	3	2.1	0.1	171.9	0.13	88.5	1.29
	4	3.0	0.6	151.3	0.29	82.7	1.32
Mean..........		2.9	0.3	174.0	0.18	86.9	1.30
Total	1	14.6	0.3				
	2	14.8	0.2				
	3	15.9	0.1				
	4	11.3	0.6				
General mean		14.2	0.3	157.6	0.14	89.3	1.24
F value for picking dates..................................				6.1*	1.5	1.8	17.8**
Difference required for significance between means:							
5 per cent level..................................				27.4	....	....	0.04
1 per cent level..................................				....	....	....	0.06

[a] The field lugs contained about 44 pounds.
* Significant beyond the 5 per cent level.
** Significant beyond the 1 per cent level.

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