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Pear Pollination Studies in Oregon

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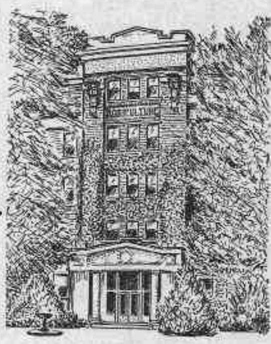

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Introduction

Commercial pear production in Oregon is concentrated in two areas, the Medford area of the Rogue River Valley, and the Hood River area. Production has been continuous for scores of years, and practices associated with this industry have changed with the increase of pertinent knowledge on insect and disease control, and with the changes in the economic status of varieties.

Considerable work was done on pear pollination throughout the western states during the 1920's and 1930's, and the information obtained was widely circulated. This is evident from the general use of pollinizer interplants, buds, and grafts in many of the older orchards of the area. However, during the last decade the available information on pollination practices appears to have been overlooked or underestimated, for new plantings are being made without regard for this phase of orchard management.

The Medford area has undergone the greatest producer change-over due to the expanding pear industry, and the supplanting of older producers by their succeeding generation. It is believed that a problem is being encountered here in securing consistently high pear yields.

The yield problem has produced a great deal of difference of opinion in the Medford area, for orchards of the same age, having similar if not the same soil types, range from 50 percent below the production average to 50 percent above it year after year. Several of the high-yielding orchards have been solid block plantings of a single variety, and many of the better orchards have not "introduced" bees for a score of years. The observations have led to a generally held conclusion by the many producers that neither pollinizer varieties nor pollinating agents are necessary for continued optimum yields. This is not meant to imply that nutrition, irrigation, and cultural practices fail to contribute to yield variability, but merely that this project represents a preliminary investigation of the role of pollination in pear production in orchards where the other factors meet current recommendations.

References to seedless pears have appeared in the literature for many years and, in previous investigations conducted in Oregon, attention is called to the severe effects this factor may have on the shape and character of the fruit in extreme cases. These investigations involved a few orchards generally isolated from pollinizer varieties where seedlessness was accompanied by serious deformity of the fruit and a manifest tendency toward premature dropping.

The present investigations have shown, however, that while seedlessness is highly prevalent at both Hood River and Medford, its effect appears to be of but little consequence so far as shape, size, quality, and keepability of the fruit is concerned. Cuttings of Anjou and Bosc fruits from orchards and packing plants in these areas of this program revealed that up to 80 percent of the total yield of some orchards was seedless and that up to approximately 40 percent of all Anjou fruits in the Rogue River Valley was seedless. While more than one factor may contribute to seedlessness the major factor, at least in the varieties studied, is undoubtedly lack of cross-pollination.

This research was initiated to determine the role of adequate pollination in effecting optimum pear yields, and to investigate its influence on the causes and qualities of seedless fruits. The investigations were directed at the four major commercial varieties in these two areas, Anjou, Bosc, Bartlett, and Comice, with special attention focused upon Anjou. Data included in this report were accumulated during the period 1953 to 1957 from the Rogue River and Hood River Valleys.

Literature Review

An abundance of literature has been published on the intervarietal compatibility and incompatibility of pears. Because of the nature of the problem, it is not surprising to note the inconsistency of conclusions drawn by workers in different areas of the world, or even different areas of the same state, as is evidenced by the work of Tufts and Philip (1925) in California. Indeed, it would be surprising if the compatibility data obtained from the same area at 25 year intervals would exhibit a close correlation. Thus, it would serve no useful purpose to attempt to evaluate data obtained from pollination studies in different regions, at different periods during the last half century. Most of the emphasis in the fertility studies has been on Bartlett, as it is by far the most widely-grown pear in the United States, but information is also available on a number of other varieties.

Schanderl (1937) working with 198 varieties of pears in Germany found no pear variety sufficiently self-fruitful to be adequate for commercial yields and noted but a single variety, Buerré Napoleon, that failed to produce seeds even with cross-pollination. Asami (1926) reported that most varieties of pears grown in Japan are self-sterile.

In Bartlett pears, Tufts and Philip (1925) found that this variety was almost entirely self-sterile in the Sierra Nevada foothills of California, while in the interior valleys and coastal areas of the state it was self-sterile only to a limited extent. They recommended that Winter Nelis be used as the pollinizer variety in all areas, but that various other varieties were satisfactory pollinizers in its absence. Fletcher (1909-1910) reports that both Bartlett and Kieffer were largely self-sterile in Virginia and Michigan and recommends Anjou, Lawrence, and Duchess as pollinizers. In Oregon, Kraus (1912) advised the interplanting of Anjou, Clairgeau, and Howell with Bartlett to effect cross-pollination, while Kim (1946) found Winter Nelis, Fall Butter, and Comice to be the most cross-fruitful in the same state. Kim, in the same paper, reported Bosc to be cross-unfruitful with Bartlett, while Tufts and Philip (1925) recommended Bosc as a pollinizer in the interior valley and Sierra foothills of California. Marshall et al (1929) found only Flemish Beauty to be self-fruitful, and also recommended Bosc, Conference, Flemish Beauty, and Howell as Bartlett pollinizers.

Tufts and Philip (1925) recommended that pollinizers be provided for Anjou in all regions in which they were grown in California. Brown and Childs (1929) concluded that Anjou is self-sterile in the Hood River area of Oregon and recommended Bartlett, Easter, and Fall Butter as pollinizers. Kim (1946) working in the Willamette Valley of Oregon found that Anjou is self-unfruitful and that Bartlett was its most effective pollinizer followed by Bosc and Winter Nelis.

Tufts and Philip reported that they considered Bosc to be self-sterile under foothill conditions and self-fertile at the coast.

They also considered Comice to be self-sterile in the foothills of the Sierras but classed this variety as self-fertile in the interior valleys.

Cummings et al (1936) concluded that the sterility of Bartlett is not constant, and that it varied from season to season and from place to place. They also indicated that seed formation can be used as a measure of fertility within this variety and that only occasionally are seeds formed in selfed fruit.

Waite (1895), Reineke (1930), Cummings et al (1936), and Tydeman (1937) working with several varieties of pears reported that self-pollination resulted in fewer seeds than cross-pollination in pears. Kim (1946) observed that in Bartlett, none of the selfed or open-pollinated fruit contained seeds, while all of the crossed florets yielded an average of 5 seeds. Waite (1895) and Kim (1946) reported that the abnormal shape of Bartlett is due primarily to the absence of cross-pollination. Cummings et al (1936) indicated that they were unable to determine whether the fruit resulting from their selfing is actually attributable to selfing or parthenocarpy, for their observations on the progress of the pollen tube in selfed florets showed that it never reached the embryo sac. Brown and Childs (1929) stated that Anjou will occasionally set fruit without crossing in the Hood River area during seasons with extremely favorable weather conditions, and that such fruits are seedless.

Kim (1946) reported that selfed and emasculated Bartlett fruits are generally smaller than those fruits resulting from cross-pollination, and that selfing generally resulted in a lower total fruit set.

The influence of foreign pollen on the shape and quality of fruit has received a great deal of consideration by past investigators. Bach (1928 a, 1928 b), Zederbauer (1926), Nebel (1932, 1936), Nebel and Trump (1932), and Nebel and Kertesz (1934) claimed xenia and metaxenia in apples affects the shape, keeping quality, size, acidity, and color. Wicks (1918) and Gowen (1920) denied that these effects can be found. Waite (1895), Reinecke (1930), and Kim (1946) reported changes in the shape of pears due to foreign pollen, while Tufts and Hansen (1931, 1933) stated that the effects of xenia and metaxenia in pears cannot be observed. Fletcher (1909-1910) concluded that the kind of pollen used in crossing influenced size of pears, but was of the opinion that the variation in shape was due more to the environmental conditions in which the fruit matured.

Definition of Terms

Certain terms need defining to indicate the sense in which they have been used in this paper. Certain terms have conflicting interpretations when used by horticulturists as contrasted to entomologists, while others appear to be used indiscriminately in horticulture.

In this paper, the author prefers the definitions much as outlined by Kraus (1915).

Self-fertile bears the connotation that progeny are produced by an individual when it has been pollinated or fertilized with its own pollen, and produces one or more viable seeds.

Self-fruitful implies that a plant is able to produce mature seedless fruit, or progeny having seeds that are not viable, when pollinated with its own pollen. Very often this term has been used to include those fruits that mature without exposure to any pollen. As the failure of several varieties of pears to produce seeds may result from either selfing or from the complete absence of pollen, it is felt that some restriction of the term is necessary.

Parthenocarpy indicates the production of seeded or seedless mature fruit without the influence of any pollen. It has been suggested in several articles cited above that parthenocarpy be applied to the process by which any seedless fruit is formed. The derivation of the word from the Greek *parthenos* and *karpos,* literally meaning fruit of the virgin, would restrict the usage of this term as suggested above.

The interpretations of Swingle (1926) and Nebel (1930) on the applications of the words xenia and metaxenia are used in this paper. **Xenia** is the influence of foreign pollen on the embryo and endosperm; **metaxenia** applies to the influence of foreign pollen on fruit tissues other than the endosperm.

Pollinator and pollinizer are used synonymously in horticultural literature to designate the source of the male gamete. It is unfortunate and somewhat confusing that "pollinator" is used in this respect for, in entomological parlance, the term has a restricted meaning, the disseminator of pollen. As the condition exists in which one term has different implications in two closely allied agricultural sciences, it is imperative that some effort be made to clarify its use. It would appear undesirable to reject either or both of the terms, but necessary to stabilize their use in the future. Since debate on current usage in horticulture results in an impasse, and the historical origin of the suffixes "-ator" and "-izer" yields no conclusive restrictive evidence, the decision must be somewhat arbitrary. The verb "pollinate" is defined by Webster as "to perform pollination on," therefore the addition of the Latin suffix "-or" connotes "one that performs pollination on." On the other hand the suffix "-ize," in its restricted sense has its origin in the Greek suffix "-izein," which carries the active implication of "making." The derivation would thus suggest that "pollinizer" be applied to "the maker of pollen," which in its horticultural source would be the androecium.

On the basis of its usage in entomology and from what can be determined on its derivation, **pollinator** refers to the organism that performs the pollination, or the pollen-disseminating agent. **Pollinizer** in this paper is restricted to refer to the pollen source.

Methods

Fifteen different areas of investigation are covered in the following pages, and some of the methods employed have specific applicability to only a single section. Where this applies, the methods are cited briefly in the introductory paragraph to that section. The general methods bearing on several topics are included below.

Cross-pollination in all varieties was accomplished by isolating the florets just prior to their breaking into open bloom and applying the pollen from the male parent by means of a camel's hair brush.

The pollen used in making the crosses was selected from the florets of the male parent in which the anthers had just ruptured. Samples in all cases were taken directly from the field rather than through forcing pollen maturity under laboratory conditions.

Self-pollination was done in essentially the same manner but a distinction was made when using pollen from the same tree and using it from different trees of the same variety. The selfing experiments were always conducted upon emasculated florets to prevent accidental pollen transmission subsequent to the treatment. Further trials were conducted in which a number of florets were bagged while all of the bloom was in the popcorn stage to permit the macrogametophyte to be exposed only to pollen from its own or adjacent florets of the same cluster. This permitted the evaluation of three types of selfing: pollen from the same floret, pollen from a different floret of the same tree, and pollen from another tree of the same variety.

Emasculation was done by carefully removing the anthers while the floret was still in the popcorn stage. The florets so treated were then bagged with a good grade of muslin to prevent contamination by foreign pollen. Care was taken not to damage the stigma, style, or ovary during the removal of the male flower parts.

All of the crossed, selfed, and emasculated florets were covered with a good grade of muslin and the muslin left intact until petal fall was complete.

The total number of florets used in the crossing and selfing tests was low, and the data that were accumulated could be subject to some misinterpretation, particularly if the crossing was done on a single branch of each tree. In all trials crossing, selfing, and emasculation were done on a single large branch of a given tree, and these tests were replicated on branches of approximately equal size on the same tree and on several other trees throughout the orchard. Some branches proved to be nonbearing branches, for none of the crosses, selfs, or emasculations took; neither did the branch bear at the base or apex, where it was left under open pollination. As this phenomenon occurred frequently throughout the four years of the program, it was considered to be a transient physiological response, rather than any indication of floret receptivity to pollination or lack thereof. This may account for some of the variation in effectiveness of cross-pollination experienced by Tufts and Philip (1925) and Kim (1946) for they found that many of their crosses between varieties ranged from 0.0 to 27.2% in effectiveness, even when these were done in the same geographical area and at the same time. It was felt that using small samples and replicating with greater frequency would tend to level off the influence of nonyielding by individual branches.

No more than three florets were used on each cluster for selfing, crossing, or emasculation tests. This was done to insure standardization of the potential bearing ability of each cluster. The retention capacity of a cluster is rarely over three fruits, and usually only one or two. Thus, it would seem anomalous to calculate the effectiveness of crossings and selfings made on any more fruit than a single cluster would normally bear.

Pollen germination tests were conducted regularly throughout the course of the program and none of the pollen used in the selfs or crosses was found to lack high germination standards.

The shape of pears is of necessity a subjective evaluation. Typically pears of the Bartlett and Bosc varieties could be called obtuse-oblong pyriform, but deviations about the norm occur to extremes. The evaluation of shape in this paper is thus based on recognizably different forms represented by the extremes of continuous clines. Typical and bull-neck are the terms used representing acceptable and unacceptable forms. Even more difficulty is experienced in attempting to classify Anjou and Comice as to shape for the typical form of each tends to a short, thick neck. The atypical fruits of these varieties are noted and comments made on the shape of each.

RESULTS AND DISCUSSION

Seedless Pears—Their Cause and Quality

Opinions have been expressed that seedless pears, when they occur, are small in size and lack the typical bell-shaped character of their seeded counterparts. Various other undesirable qualities have been attributed to such fruits through the last 10 years. However, some evidence had been accumulated by various workers within the state that certain of these conclusions were not in agreement with observations that had been made.

Seedless pears have been known to occur both in the Medford area and the Hood River Valley of Oregon. The amount of seedlessness was at first considered to be very low in both areas; however, the cutting of several thousand pears during 1954 and 1955 proved that in many of the solid block stands, as much as 92 percent of the total crop was seedless. Certain solid blocks in the Hood River area showed a similar amount of seedlessness, but the incidence in that area was generally much lower.

Emphasis in this study was placed primarily upon the variety Anjou, as certain unaccountable total yield problems were being encountered by various orchardists in the Medford area, and as this variety makes up the largest acreage planting in that region.

Anjou

Selfing, emasculating, and crossing were done on Anjous from 1954 to 1957, and the data are recorded in Table 1.

Table 1. THE EFFECT OF SELFING, EMASCULATION, AND CROSSING ON FRUIT AND SEED FORMATION IN ANJOU PEARS.

Treatment	Total number of florets	Number of clusters	Pears at 1 month	Harvested pears		Seeded	1 Seed	Seed-less
				%	*No.*			
Selfed	921	311	293	13.0	120	0	3	117
Emasculated	434	183	220	2.8	12	0	0	12
X Bartlett ..	408	152	177	28.4	116	112	4	0
X Comice	150	48	96	28.7	43	43	0	0
X Bosc	150	72	58	24.7	37	37	0	0

It would appear from these data that any of the three other varieties of pears grown commercially in Oregon are satisfactory pollinizers of Anjou if they reached peak blooms simultaneously or if there was sufficient overlap of bloom to permit adequate cross-pollination. This, however, is not always the case.

These data are in disagreement with that of Kim (1946) obtained in the Willamette Valley of Oregon, and appear to contradict the conclusion of Brown and Childs (1929) that Anjou is self-unfruitful. The contradiction with data of the latter authors, however, is questionable, for in the introduction to their paper they state that this variety will set fruit without apparent crossing during extremely favorable weather conditions. It is difficult to compare the present data with that of either of the above authors, because the methods of selecting the total number of florets for the trials are not clearly indicated in either paper. In addition, Brown and Childs state the number of florets used in percentages and Kim makes reference to Anjou only to supplement his studies on Bartlett.

The selfing tests recorded in Table 1 agree with trials of Tufts and Philip conducted in the interior valley of California. In that area, approximately 6, 1, and 20 percent of the selfed florets yielded fruit in the three years of investigation. On the basis of our data, the Anjou is considered to be self-fruitful in both the Hood River and Medford areas, but tends to be self-sterile.

Usually Bartlett will overlap with Anjou, and in some years both Bosc and Comice are well into bloom while Anjou is just past its peak. There have been years in which Bartlett has contributed but lightly to the cross pollination of Anjou, and vice versa, but in such

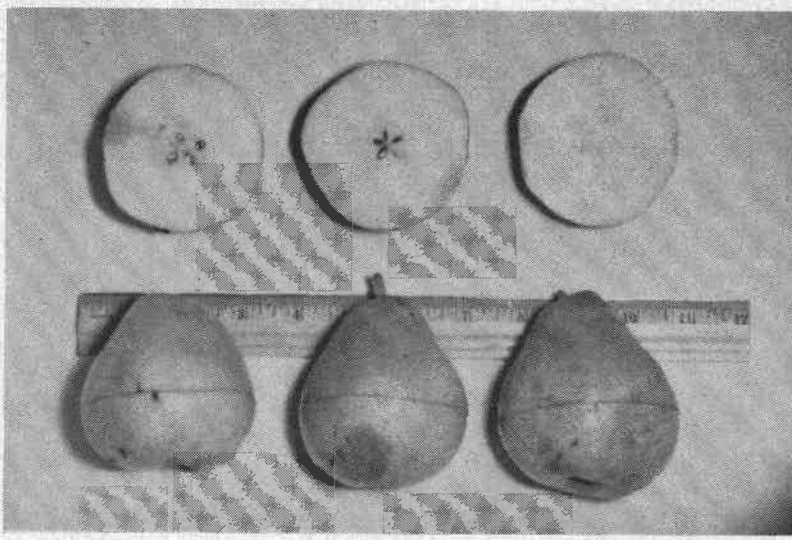

FIGURE 1. From right to left, three cut Anjou pears illustrating size and shape of seedless, 1-seeded, and fully-seeded fruits.

years either Bosc or Comice presents sufficient bloom for adequate crossing. The data support the conclusions of Kim (1946) and Brown and Childs (1929) that Bartlett is an effective pollinizer of Anjou.

Approximately 8 percent of all of the florets selfed resulted in fruit at harvest time. The selfing and fruit set that were obtained under the full-tree cages, as indicated on Table 2, supplement these data on the degree of fruitfulness that can be realized with no cross-pollination. It is noteworthy that all but three fruits that formed as a result of selfing were seedless and that these fruits had but a single seed. The information recorded in Table 2 on the fruit taken from full-tree cages verifies the conclusion held in this paper that all selfed Anjou florets will yield either seedless fruit or fruit with but a single seed.

Size and shape of seedless Anjou pears. As indicated above opinions have prevailed that seedless Anjous could be readily separated from seeded fruit on the basis of their size and shape. The average weight of 940 totally seedless pears taken from the Medford area was 208.8 grams while the average weight of 975 Anjous having more than one seed was 204.3 grams. This difference is hardly significant, but does indicate that size difference in Anjou is not a factor governed to any extent by cross-pollination.

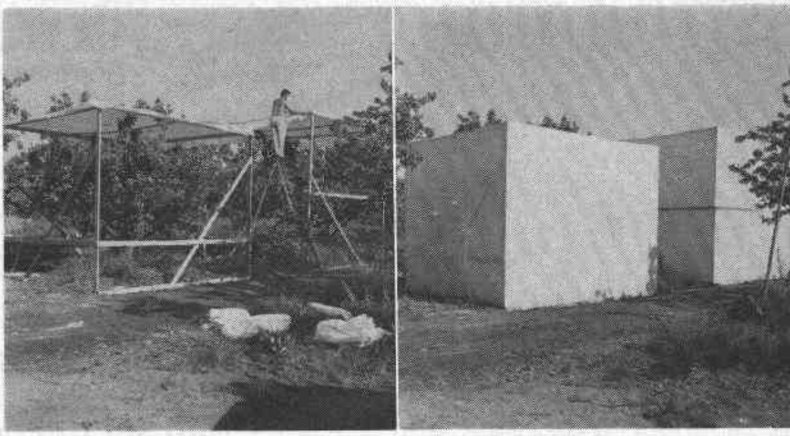

FIGURE 2. Full-tree cages constructed over Anjou trees, in two stages of construction.

It is difficult to evaluate mathematically the various shapes that have been observed in the Anjou variety. Rarely is a pear found that could be termed typically "pyriform," although the tendency toward a bell shape is certainly prevalent. Over 5,000 asymmetrical pears were cut during the period of these investigations and there was no correlation between deformity and the presence or absence of seeds. Figure 1 illustrates three cut Anjous, one fully seeded, one with a single seed, and the third seedless. It can be noted that there is no appreciable difference in diameter or shape among the three.

Table 2. The Effect of Full-tree Cages on the Yield and Seed in Anjou Pears.

Tree plus	Seeded pears			1 seed			Seedless pears			Total yield		
	1955	1956	1957	1955	1956	1957	1955	1956	1957	1955	1956	1957
Bees and Bartlett bouquet	181	384	222	17	52	53	2	3	17	450*	439	292†
Bees	0	0	‡	7	26	‡	193	142	‡	400*	168	‡
Nothing	0	0	0	6	0	1	194	136	35	450*	136	36

* These figures based on total yield in lugs; only 200 pears were selected from each tree for analysis in 1955.

† This low yield is attributable in part to our inability to introduce bouquets into the cage during the last half of the bloom.

‡ In 1957, this tree was covered with polyethylene and the extremes of temperature in the cage were such that the tree lost all of its fruit and foliage.

Full-tree cages. Using the presence of seedless fruit as a measure of selfing in Anjous, it was possible to determine the influence of self-pollination on the total yield of a tree, and to evaluate the necessity of the presence of pollinizer varieties for optimum fruit yield.

To test this hypothesis, full-tree cages were constructed about three small trees in the Medford area. These trees were selected from an orchard which had had a history of good to excellent fruit yields, and in which a pollinizer variety was available within two rows of any tree in the block. Small trees were selected for convenience in cage construction, and each tree was covered with a heavy grade of muslin while the florets were all in the popcorn or early pink stage (Figure 2). The heavy grade muslin was used to prevent the possibility of contamination by any airborne pear pollen. Into one cage was placed a colony of honey bees that had not been exposed to pears previous to their introduction, plus three strong bouquets of Bartlett bloom. The Bartlett bouquets were changed every seven days during the blooming period. It was intended that such management would present the greatest possibility of maximum cross-pollination. A single colony of honey bees was introduced into the second cage, omitting the pollinizer bouquet. The third cage was kept tightly sealed and thoroughly aerosoled with several insecticides to prevent any newly emergent flies or beetles from effecting pollen transmissal.

The cages were removed after all the bloom had passed and small fruit was noticeable. Counts on total yield and samples of the pears from each tree were taken at harvest (Table 2).

By a cursory examination of the three trees at harvest in 1955, it was impossible to distinguish among the treatments. The yield and size of fruit on each tree was, for all practical purposes, identical.

Treating the same three trees in an identical manner in 1956 resulted in a total yield decline of 58 percent in the cage containing only bees, and a decline of 69.8 percent in the cage having just the tree. The cage containing both the bees and the pollinator bouquet had approximately the same yield as the previous year.

Replication on the same trees in 1957 caused a continued decline in yield on the tree lacking bees and pollinizer variety. The total yield from this tree during 1957 was 36 pears, a reduction of 92 percent from the yield in 1955. Through an unfortunate decision the tree containing only the bees was covered with polyethylene in 1957, and the extremely low temperatures at night coupled with the extremely high temperatures during the day cost us all of our data, and perhaps even a loss of the tree itself. The check tree containing bees and pollinizer yielded approximately 65 percent of the 1955 and 1956 crops, and this has been attributed, in part, to our inability to supply pollinizer bouquets during the last half of the bloom period. The 5- to 6-fold increase in the incidence of seedless pears taken from this cage would tend to lend some credence to this conclusion.

The data from Table 2 support the data obtained in the crossing and selfing experiments cited earlier. No fully-seeded fruit was obtained from either of the cages lacking the pollinizer variety during the three years that the cages were in place. The ratio of completely seedless to single-seeded fruit corresponds closely to the data acquired through selfing experiments in this variety.

Both caged trees were treated identically with the trees in the remainder of the orchard, except for the 2- to 3-week period in which the cages were in place. The fertilization, irrigation, spray, and cultural programs were in no way affected by the caging, thus it can be said that pollination was the only recognized variable. It has been reported by Hartman (1957) that a pear variety may be self-fruitful under favorable nutritional conditions, but self-unfruitful when its nutritional status is unfavorable. In his investigation on Bartletts in the Willamette Valley of Oregon, Hartman found that variety would set and retain a heavy crop of pears on the on-year without cross-pollination, but failed to do so on the off-year when the vitality of the tree was presumedly low. This conclusion did not apply to this variety under the conditions of the test considered, for the vitality of the pollinizer-free tree was maintained at a high level by regular fertilization and the yield continued to decline during the three years. No biennial yielding tendency could be observed.

It would thus appear that cross-pollination is necessary in Anjous for continued high fruit production and for the formation of seeded fruit. The desirability of the latter is still subject to some question.

Bosc

The observations on Bosc during 1954, indicated that it responded much like Anjou to crossing and selfing. The number of seedless fruits found upon cutting pears taken from orchards in which the pollinizer varieties were limited, corresponded closely with the number of seedless Anjous taken under similar conditions.

The data resulting from selfing, emasculation, and crossing, done in both the Medford and the Hood River areas during 1955, 1956, and 1957, are presented in Table 3.

The response of Bosc to selfing is very similar to that recorded for Anjou (Table 1). These data represent cumulative results of more than 100 replications on an equal number of trees, and our experience with this variety was much the same as recorded for Anjou. In many instances entire branches of a single tree bore no fruit when florets were selfed, emasculated, crossed, or left for open pollination.

Table 3. THE EFFECT OF SELFING, EMASCULATION, AND CROSSING ON FRUIT AND SEED FORMATION IN BOSC.

Treatment	Total number of florets	Number of clusters	Pears at 1 month	Harvested pears		Seeded	1 seed	Seedless
				No.	%			
Selfed	400	236	135	32	8.0	0	0	32
Emasculated	332	133	147	3	0.9	0	0	3
X Anjou	100	50	97	41	41.0	41	0	0
X Bartlett	100	50	94	55	55.0	55	0	0
X Comice	120	60	99	54	45.0	54	0	0

This feature may account for the contrasting results obtained by Tufts and Philip (1925), for their data also indicate variable responses to selfing in this variety. They report that in two sites no fruits were formed in over 700 selfings; the second selfing of over 500 florets resulted in 2.1 percent yield; and the third on over 400 florets yielded 20 percent fruit.

The data on emasculated florets indicate that some fruit does set parthenocarpically, but the number of such fruits realized is very small. It is believed that most of the seedless fruit in Bosc is the result of selfing, with a small percentage of seedlessness attributable to parthenocarpy.

There appears to be little difference in the compatibility between Bosc and the other three varieties used as pollinizers. Forty to fifty-five percent of the crossings using Anjou, Bartlett, and Comice as the pollinizer proved fruitful. Under natural conditions, however, Anjou and Comice undoubtedly contributed most, if not all, of the available pollen for Bosc. The Bartlett bloom is usually over by the time Bosc reaches full bloom.

Size and shape in seeded and seedless Bosc. As in Anjous, there is no correlation between size of pear and seedlessness. Very large pears occur in equal frequency among the seeded and seedless fruit. Similarly the shape of the fruit is not affected with any constancy by the presence or absence of seeds. Figure 3 shows three pears, one fully seeded, one with a single seed, and the third seedless. The seedless pear in this figure is a typical example of the shape of oversized pears. All of the oversized pears examined have a more bull-neck form than those of moderate to large size, and this shape does not appear to be influenced solely by the presence or absence of seeds. The tree-fruit horticulturists in Medford and Hood River, as well as the investigator have not been able to determine the seed condition using shape as a criterion in well over 3,000 fruits examined. This

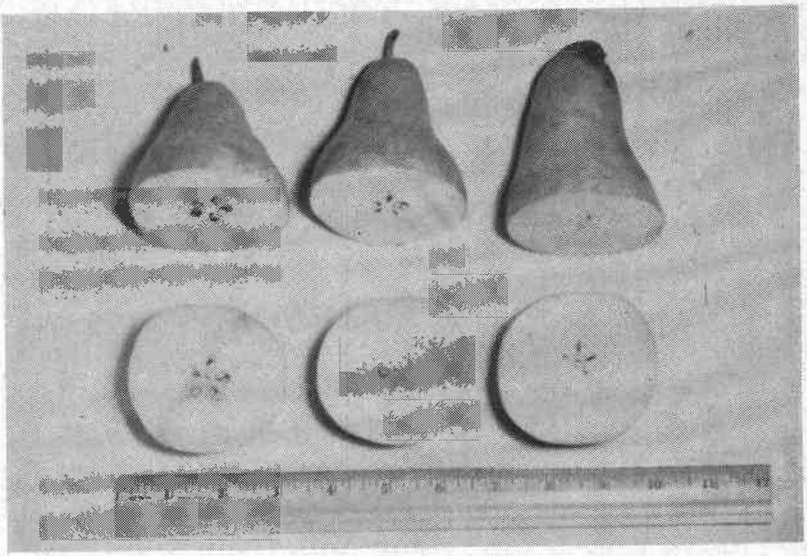

FIGURE 3. From right to left, three cut Bosc pears illustrating size and shape of seedless, 1-seeded, and fully-seeded fruits.

appears to be in contradiction to some unpublished data recorded by the Southern Oregon Branch Experiment Station years ago. At that time it was noted that an isolated orchard planted solidly to Bosc consistently produced seedless fruit that was decidedly "bullnecked" in shape with a manifest tendency toward premature dropping. In this particular case the condition appears to have been remedied by grafting in suitable pollinizers.

The above incident may indicate that cross pollination of some florets may hormonally influence the development of selfed florets on the same tree. If this were so, it would account for the obvious typical pyriform shape of seedless Bosc pears now being taken from trees on which some cross-pollination has occurred.

Comice

A series of experiments were inaugurated on Comice during 1956 and 1957 to compare the degree of self-fertility and cross-fertility of this variety.

These data indicate that selfing results in seedless fruit in Comice as in the previous two varieties; however, the degree of self-fruitfulness found is considerably less than in either Bosc or Anjou. Cutting of mature fruit at random in orchards throughout the state would tend to verify this conclusion, for seedless Comice were much more difficult to find. Tufts and Philip (1925) also found a low fruit yield

Table 4. THE EFFECT OF SELFING, EMASCULATION, AND CROSSING ON FRUIT AND SEED FORMATION IN COMICE PEARS.

Treatment	Total number of florets	Number of clusters	Pears at 1 month	Harvested pears		Seeded	1 seed	Seedless
				No.	%			
Selfed	710	330	173	13	1.8	0	2	11
Emasculated	324	152	137	4	1.2 (1 tree)	0	0	4
X Anjou	105	61	63	12	11.4	12	0	0
X Bosc	100	50	91	15	15.0	15	0	0
X Bartlett	100	50	95	8	8.0	8	0	0

in their selfed Comice with their fruit yields ranging between 0 and 6.5 percent of the total florets selfed.

The 324 emasculated florets yielded 4 fruits at harvest and all of these were seedless. This compares closely with the emasculation done on Bosc, and parthenocarpic set must be considered as a minor contribution to the total seedless fruit production.

Crossing Comice with the other three pear varieties gave markedly lower yields than their reciprocal crosses. The cause of this is not completely understood. However, even with this apparent reduction in intervarietal compatibility, the yields of Comice have been comparable with the other varieties grown in the same area. There is little conclusive evidence that can be drawn from the data in Table 4, but there is an indication that Bartlett could not be recommended as a good pollinizer variety for Comice. The peak bloom of Comice coincides most closely with Bosc, and occasionally with Anjou, and there appears to be little difference between the two in their effectiveness.

These observations agree with the report of Tufts and Philip (1925) that Comice is self-fruitful in the interior valleys of California, but contradicts their conclusions on the self-unfruitfulness of this variety under coastal conditions. These data lend weight to the conclusion that self-fruitfulness is not everywhere a constant condition even in the same variety.

Shape and size of seedless Comice pears: Figure 4 illustrates the fully-seeded, single-seeded and seedless condition in Comice. More variation in size and shape has been found within the fully-seeded pears than between the seeded and seedless samples analyzed. There is a tendency for the seedless fruit to be slightly larger than the seeded in Comice, but this size difference is not significant. This variety lacks the typical pyriform shape of either Bosc or Bartlett

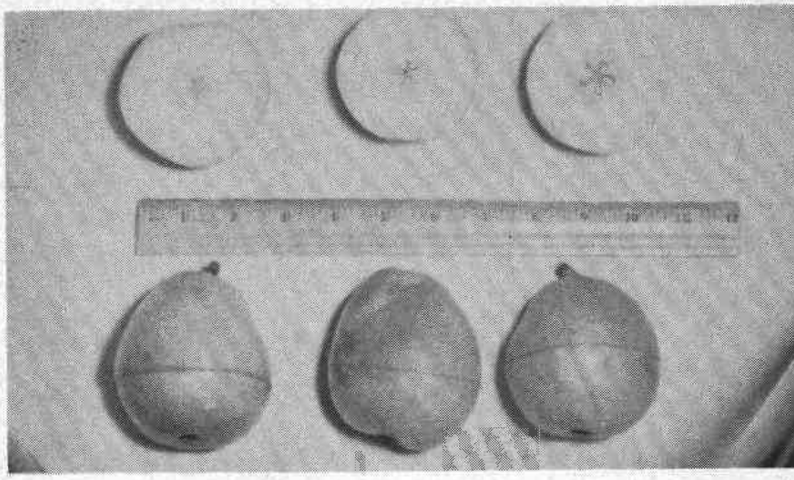

FIGURE 4. From left to right, three cut Comice pears illustrating size and shape of seedless, 1-seeded, and fully-seeded fruits.

and throughout the 4 years of this project it has not been possible to distinguish between seeded and seedless fruits on shape alone. Most of the runts or otherwise deformed pears that have been taken at harvest have proved to be fully-seeded fruits, a finding contrary to the general belief held about seedless pears.

Bartlett

Selfing, emasculation, and crossing experiments were conducted on Bartletts in the Hood River and Medford areas during 1955, 1956, and 1957.

Contrasting with the data obtained from selfing on the other three varieties, the incidence of seeded pears resulting from selfing of Bart-

Table 5. Effect of Selfing, Emasculation, and Crossing on Seed and Fruit Formation in Bartlett Pears.

Treatment	Total number of florets	Number of clusters	Pears at 1 month	Harvested pears		Seeded	1 seed	Seedless
				No.	%			
Selfed	450	203	86	39	8.7	12	6	21
Emasculated	354	141	122	9	2.5	3	0	6
X Anjou	180	59	63	56	31.1	51	5	0
X Comice	100	50	45	41	41.0	41	0	0
X Bosc	100	50	49	38	38.0	38	0	0

lett was high. This feature has been recorded by Cummings et al (1936) for Bartlett in the eastern states, and they report securing numbers of seeds from selfed florets. Garcia and Fite (1928) also report Bartlett as being self-fertile in New Mexico, as do Tufts and Philip (1925) in certain areas of California. Kim (1946) working in the Willamette Valley of Oregon reports that all of the selfings on this variety yielded fruit with no seeds, an observation that is not supported by this author, or the investigations cited immediately above. It should be noted that in some areas of California and throughout much of the United States where Bartletts are grown, they have been reported as being self-sterile.

In Oregon, the ratio of harvested fruit to selfed florets was approximately the same in the two areas under observation, and was the same in each of the three years in which work was done. Compared to the crossings that were made, the yield that resulted from selfing was low, although much higher than selfing done on the other three varieties.

Emasculated florets yielded more fruits per floret than Anjou, Bosc, or Comice, and this was the only variety in which seeded pears resulted from emasculation. As in the other varieties parthenocarpy undoubtedly contributes to, but is not the principal cause, of seedless fruits.

All of the varieties tested in crossing proved to be effective pollinizers of Bartlett, but in normal years Bosc and Comice bloom too late to be of much value.

Size and shape of seedless Bartlett pears. The observations of Cummings et al that there "seemed to be no relation between fruit numbers or weight to the ratio between good and poor seed" could be paraphrased to "no relation between fruit size and presence or absence of seed" under Oregon conditions.

More than a thousand off-shaped pears were cut from orchard-run Bartletts during 1955 and 1956. Of these, 63 percent proved to be fully seeded and 37 percent had one seed or none. These data are hardly conclusive; however, they indicate that the cause of malformation in pears is not to be attributed solely to the absence of cross-pollination.

These observations differ from those of Kim (1946) who found evidence of both xenia and metaxenia shortly after pollination of the flower blossoms. His comprehensive cytological examinations revealed that the development (crossing) or the non-development (selfing) of the embryo appeared to be correlated with the rate of cell division and cell enlargement in the immediate vicinity of the carpels. The resulting crossed florets yielded typically pyriform fruit, while the selfed yielded bull-necked. No attempt is made here to account for these obvious differences in response of this variety to cross- and self-pollination, but this author must agree with Tufts and Hansen (1931, 1933) that such effects were not noted.

Storage quality of seeded and seedless pears

For some time the feeling has existed among some that the storage quality of seedless pears may be inferior to that of fruit which normally has seeds. Research work done on Willamette Valley Bartlett pears by Hansen and Hartman years ago did indicate that in the cases of seriously misshapen seedless fruit, which was inclined to drop prematurely from the trees, the storage life was impaired to some extent. This fruit proved to be very susceptible to storage wilt and its storage life was shortened to some extent.

In the present investigation, however, the storage tests carried on have revealed no observable differences between seeded and unseeded fruit from the Medford area. In the lots under observation, the longevity of the fruit was not affected by seedlessness and the seedless fruit retained its quality as long as did the fruit that had seeds.

Brown core results in a pear that shows discoloration around the core area. In some lots of pears examined the area affected most intensely was that immediately around the core, but in many pears it extended beyond the gritty ring, and if the pears were left in storage beyond the middle of March, the entire pear would break down.

During the winter of 1955 when the "brown core" trouble was first observed in Anjou pears packed in polyethylene bags, the impression prevailed for a time that only the seedless fruit was showing signs of decay. To check this possibility, pears from three trees that had been caged were placed in polythylene bags and stored in a commercial storage plant. These pears were examined for brown core during February and March. The amount of the trouble is recorded in Table 6.

These data correspond closely with unpublished data obtained by Higdon (1955). Apparently there is no correlation between the seedlessness and the incidence of brown core in Anjou pears.

Table 6. THE INCIDENCE OF BROWN CORE IN SEEDED AND UNSEEDED ANJOU PEARS PACKED IN POLYETHYLENE BAGS.

Pears	Brown core		No brown core		Percent affected	
	1955	1956	1955	1956	1955	1956
Seeded	14	11	86	89	14.0	11.0
Seedless	17	21	183	79	8.5	10.5

Flavor and texture of seeded and seedless pears

In the fall of 1956, the four varieties, Anjou, Bosc, Bartlett, and Comice, were subjected to flavor, texture, and sugar evaluation by the Food Technology Department at Oregon State College. The tests were repeated in 1957, but with Bartlett excluded.

All three varieties were placed in ripening rooms at staggered intervals, so as to bring them to suitable eating condition simultaneously. The pears were cut in half to determine their condition, and the seedless and seeded pears were separated. The halves were diced and mixed thoroughly just prior to their evaluation.

The reducing sugars were determined using the potassium ferrocyanide colorimetric method, the total sugars by refractometry, the dry matter by placing in a vacuum oven at 70 degrees C for 24 hours, and the acid by titrating with sodium hydroxide to an end point of 8 with a pH meter.

In both years each variety was compared separately for flavor and texture difference by serving the samples to panels of 15 and 23 members. The duplicate samples for analyses were ground immediately and the determinations listed in Table 8 were made simultaneously. The data in the table represent the mean of duplicate samples from the composite.

Table 8. PEAR VARIETY EVALUATION.

Variety	Soluble solids		Reducing sugars		Total sugars		Total acid as malic		Dry matter	
	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957
			%	%	%	%	%	%		%
Anjou	15.7	14.1	11.4	9.81	11.4	11.20	.050	.228	......	16.65
(seeded)		13.9		9.81		11.16		.222		16.45
Anjou	15.3	14.4	10.8	10.02	10.8	11.20	.047	.209	......	17.06
(seedless)		13.9		9.92		11.34		.218		16.45
Bosc	16.3	16.2	6.0	8.27	14.2	13.26	.028	.101	......	18.71
(seeded)		16.0		8.16		13.32		.110		18.17
Bosc	16.6	16.2	8.0	8.14	14.6	13.44	.037	.113	......	18.29
(seedless)		16.1		8.16		13.44		.123		18.13
Bartlett	14.2		8.9		10.5		.064		......	
(seeded)										
Bartlett	14.0		9.3		11.1		.060		......	
(seedless)										
Comice	15.9	15.6	11.1	10.51	12.0	12.64	.049	.186	......	17.84
(seeded)		15.4		10.38		12.54		1.85		17.84
Comice	15.7	15.5	10.5	9.94	12.3	11.78	.045	.165	......	17.19
(seedless)		14.7		9.86		11.78		.159		17.06

In both years the panel concluded that under the conditions of the test there was no difference in the quality between the seedless and the seeded fruit in any of the varieties tested.

All four varieties, and especially Bartlett and Bosc, were kept in storage well beyond the periods of time it was recommended they be retained. It was assumed that this would magnify the effect of a quality deficiency, if such existed in seedless fruit. Neither the flavor trials nor the analyses for soluble sugars, reducing sugars, total acids, or dry matter revealed any differences.

Effect of Cross-Pollination on Anjou Pear Yields

The variation in total yield of pears has prompted a great deal of speculation on the necessity of cross-pollination, particularly in the Medford area. Orchardists of that area feel that cross-pollination is incidental to achieving optimum fruit set, and this has prompted the planting of solid blocks of single varieties in recent years.

Many and varied factors are known to affect fruit set in pears; i.e., fertilization, irrigation, spraying, and pruning have been mentioned previously in this paper. As older Anjou trees are notoriously poor bearers if not properly managed, care was taken to select data from orchards in which the trees had high vitality and which were subjected to currently acceptable management practices. It was felt that through the use of orchards having similar cultural and chemical treatment, an indication of the effect of pollination on fruit yield could be detected.

In the preliminary phases of the project, five orchards were selected which offered a representative cross-section of the conditions encountered.

Two of the orchards were solid-block Anjous and were known as habitually poor yielders. They were both located well away from the virgin hillsides, and there was an abundance of competing bloom, primarily mustard and chickweed, all through the area in which these orchards are located. The owners of both of these blocks had indicated that only the extreme edges and the tops of the trees had given consistently good yield.

A third orchard was selected as representing an intermediate condition, for in this solid-block Anjou, a number of Bartlett, Bosc, and Old Home had been budded and grafted in. The yields on this orchard had been about average for the five years prior to the initiation of this study. No bees had been introduced into the area, but a fair to good population of bees was noted in the trees during the course of investigations.

The fourth orchard was a solid block of Anjous having excellent yields for several years. This orchard is located adjacent to virgin hillsides, and the trees are young or heavily pruned back so that a semi-trailer could pass between the rows. There were no pollinizers intermixed, but Bartletts, Bosc, and Comice could be found in blocks on two sides.

The fifth orchard was selected to represent near optimum conditions in pollinizer and pollinator numbers. The entire orchard was located adjacent to virgin hills and it had been a consistently excellent yielder. The owner had imported bees at the rate of one colony per acre and these were located through the orchard in groups of ten. The distribution of pollinizers was subject to some variation, but there were never more than four rows of a single variety in sequence. Usually the block was found to have three or four rows of Bartlett, followed by three or four rows of Anjou, three or four rows of Bosc, and three or four rows of Comice. The trees in the block were well spaced and heavily pruned.

The orchards selected are summarized in Table 9.

Table 9. TYPE OF ORCHARDS USED IN POLLINATION STUDY.

Orchard	Type	Pruning	Age	Distance of rows	Yield
#1	solid-block	none	old	close	poor
#2	solid-block	little	old	close	poor-fair
#3	solid-block with pollinizer grafts	light-heavy	old	wide	good
#4	solid-block	heavy	young	wide	excellent
#5	mixed pollinizers	heavy	mixed	wide	excellent

In the preliminary phases of this program it was assumed that cross-pollination was essential to effect a continuous optimum yield in pears. Thus, in order to evaluate the factors affecting optimum cross-pollination, attention was directed primarily to the role of the tree and the influence of the pollinator in this symbiotic relationship. Insofar as was possible each phase of the program was conducted so that the data coming from the observations were suitable for comparison.

Nectar concentration studies

Very early in this program it was observed that there was a considerable difference in the bee populations of the five orchards under observation (see below), and that there existed a direct correlation between the pollinator count and the resulting fruit yield. This observation immediately led to the unfounded conclusion that the better fruit yield was a direct result of a more attractive floret in certain orchards.

Tests were made on the sugar concentration of the nectar from 400 florets each year during 1955 and 1956. The samples were taken between 10 a.m. and 11 a.m. each morning and read with a hand refractometer. Several attempts were made to obtain nectar concentration readings during midafternoon, but most of these failed due to insufficient nectar in the floret at that time.

The pear floret is a notoriously poor nectar yielder, both in quality and quantity. All of the readings obtained varied from 7 to 21 percent sugar, with 96 percent of the total falling between 7 and 17 percent. A few of the readings that were obtained during the afternoon ranged as high as 34 percent; however, the amount of nectar was so low that very few nectar collecting honey bees were in the trees.

In those orchards that were the poorer fruit yielders, no attempt had been made to control the competing bloom on the orchard floor, and these areas were overgrown with mustard and chickweed. Both of these plants were sampled for nectar concentration and the sugar content of mustard ranged from 48 to 64 percent, and that of chickweed from 51 to 58 percent. In addition there was never any difficulty in finding sufficient nectar for analysis. Honey bees inherently seek out the greatest supply of nectar with the highest sugar concentration and thus, where the supply of bees was not exceptionally high, the bees were all found working the competing bloom. Only in areas where the population of honey bees was high enough to overpopulate the orchard floor cover was there evidence of numbers in the trees.

In the orchards that had yielded good to excellent, numbers 3, 4, and 5 from Table 9, the floor was either well cultivated prior to bloom or mowing had been done. The total bee populations in two of these three orchards were not high; however, the removal of the competition in and surrounding the orchard had forced the bees to the trees.

A host of other ornamentals and wild flowers served as competition to pears in bee attraction, but never were their numbers great enough to present a serious problem.

The presence of blooming ground cover in the orchard presented one of the more serious contributions to bee kill, prior to and following the bloom. Much of the insecticides applied to the tree settles on this ground cover and any of the wild or commercial bees in the area working this bloom are usually lost. The loss is most serious to the apiarist and when it occurs prior to bloom it often reduces the bee population to such an extent that the fruit grower, interested in cross-pollination, has depleted the pollinator population to nil.

Pollen competition

Pear pollen, unlike pear nectar, is readily accessible to pollinating insects, and honey bees collected it freely in all of the orchards under observation. Several methods were used to determine the amount and source of the pollen being collected by honey bees. Pollen traps were used effectively in most yard apiaries, but to determine the hourly habits of the bees it was necessary to place a coarse-meshed screen over the hive entrance and collect the pollen-laden bees as they attempted to pass through.

In orchards 3, 4, and 5, 55 percent of the pollen collected was pear, about 28 percent was mustard, 6 percent commercial plum, and 11 percent undetermined. The pollen taken from colonies of bees in the proximity of orchards 1 and 2 was 73 percent mustard, 24 percent pear and 3 percent undetermined. The undetermined pollen cited includes a variety of pollens and some pollen that had germinated prior to our examination. The germinated pollen could have been from any one or all of the sources tested.

It can be appreciated that pear and mustard are the primary pollen sources for the honey bee in the Medford area, with minor amounts coming from commercial plums and a small amount from dandelion. Chickweed although used extensively for nectar was not found to be a contributor of pollen. This is in agreement with our earlier observations and the reports of other workers with pollen and nectar plants. (Scullen and Vansell, 1942.)

Pollinator concentration and yield

As a preliminary step, the presence or absence of honey bees in orchards with high yields and those with low yields was determined. Apparently pear growers who had not placed bees in immediate proximity to pears were under the impression that their orchard was beeless. Many of these men had been securing high yields for several years and presumed that they were achieving the yields without the presence of pollinators.

Counts were made on the 5 orchards under observation in 1954 and 1955, noting the number of bees per tree during one minute periods. This was done by using a stopwatch and slowly moving about the tree, recording the number of bees. While this was not a precise measure of the total bee population of a given tree, it did give comparable figures from orchard to orchard. To compensate partially for the differences that were found in the size of the trees, the number of pears per terminal four foot length of lower limb were recorded previous to the first drop. Lower limbs were selected as it is in this area that the poorer yields are most readily observed.

Table 10. Average Bee Counts per Tree per Minute, and Pears per 4-foot Lower Limb

Orchard	Bees 1954	Bees 1955	Pears 1954	Pears 1955	Total yield
#1	2.07	1.86	5.56	3.03	poor
#2	1.43	1.81	4.25	3.96	poor
#3	5.75	4.83	14.0	6.91	good
#4	11.75	9.32	32.2	34.13	excellent
#5	11.04	12.68	25.66	22.68	excellent

The indications from these data are that there appears to be a correlation between the number of bees in the trees at peak bloom and the number of pears on the trees previous to blossom drop. There is a differential June drop that is not indicated on the table; however, the total yield is indicative of the harvested crop.

These indications as stated in the previous paragraph could be accepted at their face value, if it were stipulated that "all other things are equal." This is not the case in any of the orchards under observation, for such things as tree size, proximity of pollinizer varieties, ground cover, and general condition of the tree vary from orchard to orchard and within each orchard.

The use of attractants to stimulate bee pollination

The attractiveness of several compounds including sugar, molasses, and sugar and poly-bor have been reported on in published and unpublished literature during the last half century. The use of such methods to entice honey bees to work given crops has been tried by the author on certain legumes in the past without any particular success, but all of these crops on which it has been used previously differed from pears in that they were the source of abundant nectar with a high sugar concentration.

Sugar and molasses solutions were made up in 1954 so that the sugar concentration was sufficiently high to offer competition to the nectar sources in the wild plants. Six trees were selected in each of orchards number 1, number 2, and number 5, and pollinator counts were made in midafternoon prior to application. One and one-half gallons of molasses was applied to each of 6 trees at the rate of 21 pounds per 10 gallons of water; the same amount of a 50 percent sugar solution was applied to another 2 trees in each of the 3 plots; and the third application was identical with the second except for the addition of 6 ounces of poly-bor.

Observations and bee counts were made at 2-hour intervals for 2 days, on the sprayed trees and on the adjacent checks. No observable differences were noted in the bee population among the treated trees, or between the treated trees and checks. The only observable difference coincided with a behavioral pattern noted in legume crops, and that was that many of the bees working the treated trees were engaged in collecting the sugar and molasses from leaves, petals, and even twigs. This actually reduced the total number of bees working the florets.

Habits and range of honey bee in pears

Reports have been made by orchardists that good to excellent yields have resulted in seasons during which there have been only one or two good bee activity days. Many of the producers have felt that during such seasons honey bee activity was too low to account for the crossing realized, and that some factor other than pollinators must account for this.

The habits and the range of individual honey bees were determined by observing individual bees in the trees. During the period that a single bee could be kept under observation, the number of florets visited, the number of clusters visited, and the range of a bee from tree to tree were recorded. Habits of nectar- and pollen-gathering bees were recorded separately. Their faithfulness to a given area was determined by marking 50 bees from each tree on 3 successive days during 1954 and 1955. The bees observed during the first afternoon were marked with a red dye applied to the thorax, those observed during the second day were spotted with bright blue, and those of the third day with yellow. It was necessary to use trees located in different parts of the orchard to avoid marking a single bee with more than one color. All of the tagging was done during the hours of 12 noon to 1:00 p.m. Observations were then made for an hour on the afternoons following the markings, and on successive afternoons for 4 days. Record was made of the number of marked bees that returned to the tree on which they were marked, or that appeared on any of the 4 trees immediately adjacent to this tree. These bees were caught and retained in an insect net until observations were completed. They were released each day following the conclusion of the observation, but some mortality undoubtedly resulted from this method.

The activities of both the pollen- and nectar-gathering honey bees were very similar in all of the visitations as recorded in Table 11. As the nectar gatherers were observed to have abundant pollen about the head and thorax, it is highly probable that a great deal of pollination is done accidentally by these bees in the course of their visitations to each floret.

Table 11. HONEY BEE RANGE AND VISITS TO PEARS.

Bees	Number of bees	Average number of florets	Average time/bee	Average number of clusters visited	Average number of trees visited
Nectar gatherers....	150	9.1	1 min.	6.3	1.4
Pollen gatherers....	150	10.25	1 min.	5.0	1.2

From the table it can be seen that the pollen gatherers in the three orchards averaged slightly over 10 visitations per floret per minute. This would mean that were this population to hold for an entire day, as it appears to do, 600 florets would be visited per hour per bee, or 3,600 in a 6-hour period. In the two orchards which had yielded well in previous years, number 4 and number 5, the 1-minute observation indicated that there were approximately three pollen gatherers per tree during the minute in which the counts were made. This figure has already been indicated to be low as it is impossible to make anything but comparative rather than actual counts for a given tree. However, assuming this to be an actual count for computation purposes, and assuming that nectar-gathering honey bees play no part in pollination (also felt to be an erroneous assumption), the pollen gatherers would visit about 10,800 florets in a single 6-hour day. Were only one-quarter of the visited florets to set fruit, the yield would be twice the average yield for that area when based on an average of 15 boxes of 110 count per tree. It is logical then, to assume that such a population would be high enough to set a complete crop in a single good bee-flying day.

It is also interesting to note that during these rather short periods in which each bee was observed, she restricted her area of operation primarily to one tree. Those bees that did leave the tree invariably began working the adjacent tree.

Table 12. FIDELITY OF POLLEN-COLLECTING HONEY BEES TO A SINGLE TREE.

Tree	Number of bees marked	Bees seen same day	Bees seen 2d day	Bees seen 3d day	Bees seen 4th day
#1	50	21	14	2	8
#2	50	18	9	9	6
#3	50	32	16	7	4

The observations on marked bees in orchard number 5, tend to confirm the above conclusions. Although the total recovery of marked bees from the tree on which they were marked was rather low after the first day, the data indicate that honey bees are territorialistic in habit. This is the normal habit of the honey bee, for they work a restricted area thoroughly rather than move about from tree to tree throughout the orchard. It can be appreciated from these habits that the close proximity of a pollinizer variety is essential to an optimum incidence of cross-pollination. The effect of position of the pollinizer variety is covered more completely later in this paper.

Receptivity of Anjou pear florets to cross-pollination

It has been held that the pear floret is receptive to cross-pollination for very short periods of time, and the duration of this receptivity is sharply influenced by weather conditions at the time of anthesis. Many workers (Hartman, 1957) believe that the floret is receptive for only half a day when weather conditions are bright and warm, while others feel the receptivity may last for two or three days. Cummings et al (1936) report that the most favorable period for cross-pollination in Bartlett "seems to be from one to two days before anthesis up to full anthesis."

Table 13. Receptivity of Bagged Anjou Florets to Cross-pollination in 1954.

Time crossed	Total florets crossed	Pears formed at 1 month	Pears harvested
April 10	2	2	1
April 11, 9 :00 a.m.	2	2	2
1 :00 p.m.	2	2	2
3 :00 p.m.	2	1	1
5 :00 p.m.	2	2	2
April 12, 1 :00 p.m.	2	2	2
April 13, 1 :00 p.m.	1	0	0
April 14, 1 :00 p.m.	1	1	1
April 15, 1 :00 p.m.	2	0	0
April 16, 1 :00 p.m.	1	1	1
April 17, 1 :00 p.m.	1	1	1

The length of time each floret is receptive to crossing is of considerable importance in pollination. If the bees were restricted to the hive due to inclement weather, and were able to engage in pollination for only one or two days during the blooming season, then most of the florets must be receptive to cross-pollination during that brief period. Anjous lend themselves well to such diagnosis for the selfed and parthenocarpic fruits are seedless, while the crossed fruit is seeded.

It would have been desirable, in fact essential for conclusive evidence, to determine floret receptivity to cross-pollination on florets that remained exposed to the same environmental influence as those on the remainder of the trees. This, however, was impossible because of the number of pollinating insects in all of the orchards under observation, and because of the possibility of windborne pollination. It was necessary to enclose each of the clusters to be tested in muslin to avoid contamination by foreign pollen. Thus, the length of time that the tested florets remained receptive was possibly conditioned by the fact that the tests were conducted in a controlled microhabitat induced by the bag. The effect of drying winds on floret receptivity was a factor eliminated through the use of this technique. Although the data secured from the tests lack the desired objectivity, they do serve to indicate what effect the conditions of the trial impose on receptivity.

The tests were conducted in the Medford area on Anjou pears in 1954 and 1955. In the 1954 trials, all of the florets in a cluster were removed except two, while the bloom was still in the popcorn stage. Ten additional clusters of the same maturity were treated identically and then each cluster was bagged in muslin. The first floret was crossed with Bartlett pollen on April 10, and then rebagged to prevent contamination. The following day four other clusters were crossed with Bartlett pollen at 3-hour intervals and immediately rebagged. Starting on April 12, one cluster was opened and crossed each day until April 17.

Table 14. Receptivity of Bagged Anjou Florets to Cross-pollination (1955).

Date	Total florets		Mature fruit harvested	
	Crossed	Selfed	Crossed (seeds)	Selfed (seedless)
April 23	2	2	1	1
April 25	2	2	2	0
April 27	2	2	2	0
April 29	2	2	1	0
May 1	2	2	2	0
" 3	2	2	2	1
" 5	2	2	2	0
" 7	2	2	1	1
" 9	2	2	2	1
" 11	2	2	1	1
" 11	2	2	2	1
" 11	2	2	1	0

It was apparent from the data accrued in 1954 that the potential period of receptivity was longer than the trial period of 7 days.

In 1955, 12 clusters of pear blossoms were enclosed in muslin bags while the florets were still in the early pink and popcorn stages. Within each of the clusters, all but 4 of the florets were removed. Two of the florets in each bag were tagged and crossed with Bartlett pollen and the remaining 2 selfed with Anjou pollen. The test was begun on April 23 and continued at 2-day intervals until May 15.

It is obvious that bagging in muslin has caused the floret to be suspended in its own microhabitat, not necessarily that in which the other florets on the same tree were exposed. It is not possible to estimate the extent to which the bag contributed to the longevity, but it would be comparable with existing evidence from full-tree cages to feel that both the temperature and the humidity were higher within the bag than without. If this is so, then the increased temperature would contribute to the short-lived receptivity of the floret, while the increase in humidity would extend its longevity. Whether these two conflicting factors tend to balance each other has yet to be determined.

In both years the bags were left in place until petal fall was complete in the entire area. The duration of the 1954 test was 7 days. In 1955 crossing and selfing were continued for 19 days (May 11) at which time all of the petals had fallen. On this date the remaining 3 clusters were crossed and selfed and then rebagged.

The data obtained from both experiments reveal that bagged Anjou florets are receptive to cross-pollination for extended periods of time, even after petal fall has occurred. All of the fruits resulting from the crosses were fully seeded and all of the fruits resulting from the selfs were seedless.

An interesting facet of this phase of the program is a computation of the total fruit that was realized from all of the crosses and selfs made on the four pear varieties. Of the 2,545 selfings made, only 210 fruits remained on the tree to maturity, whereas 535 fruits were realized from the 1,737 crosses. If this information can be applied to conditions as they exist in nature it would indicate that 30.8 percent of all of the crossed florets will result in mature fruit, while only 8.2 percent of selfed florets are successful. The incidence of crossing would then be of utmost importance, or almost a necessity, to orchardists who have experienced low or erratic yields in pears.

Windborne pollen

It is generally accepted that windborne pear pollen plays no role in the cross-pollination of pears. However, observations and cuttings made on solid block Anjous during 1954 and again in 1955 indicate that fully-seeded pears occur scattered throughout the orchard, particularly in the peripheral rows and in the tops of the trees. Several solid block Anjous were examined that were lying adjacent to a solid block of Bartlett or Bosc, and in the cuttings taken from the Anjous, the incidence of seeded fruit is exceptionally high in those rows immediately adjacent to the pollinizer variety. The proportion of seeded to seedless fruit drops off sharply as one proceeds away from the pollinizer and there are few seeded pears by the sixth row. The number of seeded pears on the tree tops is highest in those solid blocks that are surrounded by mixed plantings or solid blocks of other pollinizers.

There are two possible explanations for this phenomenon. One is that pear pollen is not windborne, and these seeded fruits result merely from pollinating insects working the pollinizer and the Anjou during a single pollen-collecting trip. This could account for the high number of seeded fruits taken from the trees adjacent to the pollinizer. However, it is difficult to account for the number of seeded Anjous taken from the peripheral rows of solid block plantings, particularly when these rows are removed from a pollinizer by distances of over one-half mile. The occurrence of seeded fruit on the tops of the trees throughout the solid blocks is likewise difficult to account for when the habits of the pollen-collecting honey bees are such that they restrict themselves to a very limited area of operation. The only other possibility that exists to account for these observations is that some pear pollen is wind transmitted. The rather erratic pattern in the occurrence of seedless fruit, and the rather general distribution of seeded fruit throughout the solid blocks could be much more satisfactorily explained if this were so.

In 1955, microscope slides covered lightly with glycerine were set out within two orchards, and at distances of one-quarter, one-half, and three-quarters of a mile from the nearest orchard. On the particular day that these tests were conducted the temperature was 49° to 51°, the sky was overcast, and there was an intermittent drizzle. The wind was strong, with gusts up to 30 miles per hour. The slides were attached vertically to 4-foot stakes and were left in place for 6 hours. The results are given in Table 15.

Pear pollen was found on all slides set out during 1955, and this study was expanded during 1956. To prevent pollen-grain germination, or other proliferation of the pollen grains, the slides were placed overnight in 6 sites in each of 2 orchards. The sites included: a lower limb of a pear tree in the orchard, with the slide attached horizontally; the horizontal attachment of a slide to a post 6 feet high, located between 2 rows of pears; the vertical attachment of a slide 16 feet high on a utility pole located immediately adjacent to the orchard; horizontal slides on a 14-foot high building roof, 50 feet distant from the nearest orchard; the vertical attachment of a slide to a 4-foot stake located in the middle of a field one-quarter of a mile away from the nearest pears and facing into the prevailing wind; and a vertical slide on this same 4-foot stake, but protected by the stake from the prevailing wind.

The slides were placed out at 4:00 p.m. in the evening and collected the following morning by 10:00 a.m. This series was duplicated during the same week and the total number of pollen grains on 5 areas of 0.064 square cm. was counted on each slide. After the duplicate set of slides had been analyzed, the average number of pollen grains per 0.064 square cm. was determined for the two trials and the data are recorded in Table 15.

Table 15. PEAR POLLEN DISSEMINATION BY WIND.

Location of slides	Time of exposure	Temperature extremes	Average number pear pollen grains/0.064 sq. cm.
Tree limb in orchard......	overnight	34-71	145.8
6-foot post in orchard....	overnight	34-71	42.4
16-foot utility pole...........	overnight	34-71	39.0
Roof, 50 feet away..........	overnight	34-71	47.4
¼ mile, on 4-foot post (facing wind)	overnight	34-71	47.0
¼ mile, on 4-foot post (protected from wind)	overnight	34-71	13.8
½ mile away from pears..	6 hours	48-51	7.2
¾ mile away from pears..	6 hours	48-51	3.0

These data in themselves, are not to be considered conclusive evidence that wind-disseminated pollen is a major means of accomplishing cross-pollination. Rather, it does indicate that considerable amounts of pear pollen are windborne, and that some of the unexplainable cross-pollination may be attributable to this cause. As all of the experimental work was done during weather periods that were most unfavorable to normal wind pollination, it is conceivable that during hot, dry periods of the day, the amount of windborne pollen could exceed the recorded figures by five or six fold.

It is interesting to speculate on the reasons why windborne pollen does not appear to be as effective as insect-borne pollen in effecting cross-pollination. The above data show that windborne pollen is very prevalent within the orchard and is widely distributed throughout the area, yet the incidence of seeded fruit is high only on those trees immediately adjacent to the pollinizer. It is possible that the stigma lacks strong adhesive properties and the pollen must be mechanically brushed on it before being sufficiently well attached for germination and penetration.

Effect of tree spacing and pollinizer location on effective cross-pollination

From observations and data accumulated during the four years of this project it is apparent that pear trees must be adequately spaced and properly pruned before maximum cross-pollination can result. Intertwining of trees and dense trees present an obstacle to bee penetration. Early in this paper it is reported that some cross-pollination may result from windborne pollen, but most of this crossing is directly attributable to pollinating insects. Several hundred counts of bees and pears were made on intertwining branches and on open branches of the same tree during the course of the investigations. All of these counts show an inverse correlation between density of the area and number of bees and pears. In older orchards which had not been pruned regularly, or pruned very lightly, the lower parts of the trees invariably had very low bee populations and low fruit yields. However, when a tree was removed from the center of the orchard, and the space left unplanted or replanted to a smaller tree, both the bee population and the friut set were more uniform over the adjacent trees.

All of the better yielding orchards observed were those in which spacing was of sufficient distance to permit pollinator visitations over the entire tree, or those in which trees were heavily pruned, which resulted in the same effect. In addition, these same practices permit greater penetration of sunlight to the lower limbs, which similarly enhances blossom retention and increases the possibility of the stronger buds remaining on the tree to fruit maturity.

Various orchard plans are used throughout the state, attempting to secure the maximum amount of cross-pollination with a limited number of pollinizers. The strict adherence to a minimum number of pollinizers can be appreciated where the pollinizer variety is of no commercial value, but, as all of the four major varieties as well as the newly accepted varieties of pears grown in Oregon are good pollinizers and have a good market, restrictions placed on their numbers seem to be faulty economics.

In order to determine the most effective method of pollinizer placement, a number of Anjou pears were sampled from various sites throughout orchards in which different pollinizer plans had been utilized. Additional notations were made on the size of the fruit to supplement the information on the correlation between size and presence or absence of seeds.

The size categories are arbitrary and the pears were merely designated as large, medium, and small. The pears were taken at random from field-pack lugs as they were located under each tree. In each sample the proximity of the nearest pollinizer is indicated.

Orchards number 1 and number 2 (see page 23) were selected as examples of solid-block stands, with adjacent Bartlett and Comice plantings.

Table 16. Relationships Between Location of Pollinizer Variety and Effectiveness of Cross-pollination in Anjou Pears, with Indications of Size. Solid Block.

Orchard number 1	Seeded pears				Seedless pears			
	Large	Medium	Small	Total	Large	Medium	Small	Total
(Row 1 is adjacent to 2 rows of Bartletts. Row 2 moves into solid Anjou.)								
Row 1........	5	7	2	14	4	4	3	11
Row 2........	7	7	2	16	3	5	1	9
Row 3........	5	19	1	25	9	16	2	27
Row 6........	10	14	3	27	12	27	10	49
Row 10........	6	18	3	27	7	28	2	37
Row 13........	8	17	–	25	14	20	2	36
Total	41	82	11	134	49	100	20	169

Orchard number 2	Seeded pears				Seedless pears			
	Large	Medium	Small	Total	Large	Medium	Small	Total
(Solid-block Anjous adjacent to block of Comice; Row 1 is next to Comice.)								
Row 1........	1	3	1	5	2	2	1	5
Row 5........	0	1	1	2	3	4	1	8
Row 7........	0	1	0	1	3	3	3	9
Row 9........	1	2	0	3	1	4	2	7
Row 12........	0	0	0	0	4	3	3	10
Total	2	7	2	11	13	16	10	39

The incidence of seedless pears increases as samples are taken in successive rows away from the pollinizer. This is more obvious in orchard number 2 than number 1, and this may be attributed, at least in part, to a block of Bosc on the second side of number 1.

It also is evident that there is little difference in the size ratios between the seeded and seedless pears.

Table 17 presents the data on seedlessness in orchard number 3. Here pollinizer varieties are scattered throughout the orchard as grafts or buds in a solid Anjou block.

Table 17. Relationship Between Location of Pollinizer Variety and Effectiveness of Cross-pollination in Anjou Pears, with Indications of Size. Buds and Grafts in Solid Block.

Orchard number 3	Seeded pears				Seedless pears			
	Large	Medium	Small	Total	Large	Medium	Small	Total
A-27 pollinizer C-27..	5	16	2	23	12	28	4	44
A-23 pollinizer C-22 Bartlett	1	3	0	4	21	43	2	66
E-26 pollinizer C-27 Bartlett; Bosc C-25	4	36	15	55	5	39	19	63
I-25 pollinizer H-22 Bartlett	10	40	10	60	8	30	4	42
L-24 pollinizer M-24, M-25 Bartlett	7	62	8	77	3	15	1	19
Total	27	157	35	219	49	155	30	234

In this block the rows are numbered alphabetically from east to west, and numerically from south to north. Thus tree A-27 is two rows east of tree C-27; tree L-24 is adjacent to tree M-24; and M-25 is in the row adjacent to L-24, but one tree over.

This orchard presents a much more lucid picture of the effect of pollinizer placement on seedlessness. In the sample taken from tree A-23, with the pollinizer variety located 2 rows in and 1 row over, the yield was 66 seedless pears to 4 seeded. On tree L-24, having Bartlett pollinizers located adjacent to it and another nearby, there were 77 seeded pears to only 19 seedless. These data indicate that the number of pollinizers provided in this orchard was insufficient to provide optimum crossing.

An entirely different pattern was obtained from samples taken in orchard number 5. Here, as stated earlier, there is a highly diversified varietal pattern, with Anjou, Bartlett, Bosc, and Comice occupying alternate 2- or 3-row blocks.

Table 18. RELATIONSHIPS BETWEEN LOCATION OF POLLINIZER VARIETY AND EFFECTIVENESS OF CROSS-POLLINATION IN ANJOU PEARS. ALTERNATING 2-AND 3-ROW BLOCKS OF 4 VARIETIES.

Orchard number 5	Seeded pears				Seedless pears			
	Large	Medium	Small	Total	Large	Medium	Small	Total
(Alternating rows of pear varieties.)								
Row 3	4	4	2	10	0	0	0	0
Row 4	3	6	1	10	0	0	0	0
Row 4	4	3	2	9	0	1	0	1
Row 2	2	6	1	9	0	0	1	1
Row 2	3	4	0	7	2	1	0	3
Row 2	4	5	1	10	0	0	0	0
Row 12	2	3	3	8	1	0	1	2
Row 16	5	3	1	9	1	0	0	1
Row 21	4	4	1	9	0	0	1	1
Row 14	3	4	3	10	0	0	0	0
Total	34	42	15	91	4	2	3	9

Of the 100 samples taken from 10 trees, there were a total of 91 full-seeded pears and 9 seedless. This probably is as near to the optimum pollinizer condition as can be practically realized.

Samplings of mature pears were also made from an experimental block in the Hood River area. The experimental block had been established in an attempt to secure maximum cross-pollination and the 3 varieties, Bosc, Anjou, and Bartlett were distributed at random. Samples of 10 and 25 pears were cut from 14 locations throughout the block and the data is recorded in Table 19.

Table 19. THE EFFECT OF POLLINIZER LOCATION ON INCIDENCE OF SEEDED AND SEEDLESS PEARS.

Variety, and the four immediately adjacent trees	Seeded pears	Seedless pears
Bosc (A A Bo Bo)	5	5
Anjou (A A A Bo)	6	4
Bosc (Bo Bo Bo Ba)	2	8
Bosc (Bo Bo Bo A)	2	8
Bosc (Bo Ba Ba Ba)	8	2
Bosc (Ba Ba A A)	9	1
Bosc (Bo Ba Ba A)	7	3
Anjou (Bo Bo Bo A)	8	2
Anjou (A Ba A Ba)	9	1
Anjou (Ba Ba Ba A)	10	0
Anjou (A A A Ba)	11	14
Anjou (a) A * A Ba	8	17
Anjou (b) A A * Ba	17	8
Bosc (Bo * Bo A)	0	15

A—Anjou, Bo—Bosc, Ba—Bartlett.
* Indicates area from which sample was taken.

From the data recorded above it can be seen that where Bartlett surrounds Anjou on two or three sides the fruit is mostly seeded, but where Anjou is adjacent to two or more Anjou trees the number of seedless fruits is greater than the seeded. The samples labeled as Anjou (a) and Anjou (b) are taken from opposite sides of the same tree and the incidence of seeded and seedless fruit is indicative of the proximity of a pollinizer variety.

It would thus appear that no matter how complete the admixture of pollinizer varieties may be, there will always be some seedless fruit. This may be attributed in part to the restricted ranges of the pollinating insects, and in part to density of windborne pollen. However, the greater the varietal intermixture throughout a given block, the better is the possibility of the orchardist achieving continued high yields.

It is not the purpose of this paper to recommend future varietal selections for orchard interplants, but only to indicate the ratios of effective cross-pollinizers. Several of the high-yielding more completely cross-pollinated orchards have used 2- or 3-row blocks of varietal interplants, with Bartlett, Anjou, and Bosc occurring in sequence (Figure 5). In this plan Anjou bloom normally overlaps with

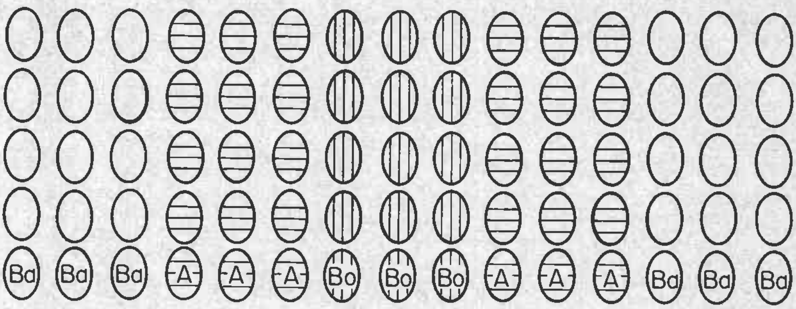

FIGURE 5. Diagramatic representation of a plan to insure maximum cross-pollination through pollinizer placement.

that of Bartlett early and that of Bosc later. The presence of all varieties provides adequate assurance that if the bloom of Anjou is delayed during a particular season, it will still have Bosc pollen available. This method of pollinizer location would not present the picking problems that must be faced with randomized pollinizers, as blocks of 2 or 3 rows could be picked in their entirety.

This type of plan can be effectively used with any compatible pollinizing varieties of pears and the factor governing their selection should be the time at which each comes into peak bloom.

Again it must be emphasized that the varieties cited in the pollinizer plans immediately above are not to be considered as varietal recommendations, but are merely examples of the mechanics of pollinizer interplants. The current economic status of Bosc, plus its susceptibility to the stony pit virus is likely to weigh heavily against its future planting. Similarly Comice demands certain restrictive soil types and cannot be included in all orchard plans. Newer varieties such as Packhams Triumph, Red Bartlett, and Seckel are rapidly gaining favor in some areas, and continued investigations will undoubtedly produce other strains in the future. The degree of compatibility and the coincidence of blooming with existing varieties will have to be determined for each new variety in turn, but this should not affect the mechanics of the plan as outlined here.

Pollinator population and placement

In most orchards with a clean groundfloor and without excessive amounts of competing bloom, especially mustard and chickweed, one colony of honey bees per acre provides an adequate pollinator population.

If the competing bloom both on the orchard floor and in the area surrounding the orchard is high, the bee population must be sufficiently high to compensate for the more attractive competition and to force the bees into the trees. This competition can be controlled in the orchard by either mowing or cultivating prior to the onset of bloom, or less desirably, by the application of a weedicide. The competition is most critical in the orchard itself, for if honey bees are located about the block as individual stands, they will work much of the bloom in close proximity to the hive, and probably provide adequate cross-pollination. It is appreciated that little can be done to limit the amount of competing bloom in areas outside the orchard itself, and it is felt that this is unnecessary in a clean orchard if the bees are spaced throughout the orchard, rather than being located to one side. The habits of the honey bee are such that they will work the bloom nearest the hive before venturing further afield; thus one colony per acre should be interpreted precisely—one colony of bees located in each acre of orchard.

Summary and Conclusions

1. Seedlessness in the varieties Anjou, Bosc, and Comice is the result of self-pollinated florets. Self-pollinated Bartletts yield both seeded and seedless fruit.
2. No significant difference was found in size or shape of fruit resulting from selfed and crossed florets in any of the four varieties in the course of this investigation.
3. Under Oregon conditions the four major pear varieties, Bartlett, Anjou, Bosc, and Comice appear to exhibit similar compatibilities as staminate and pistillate parents.
4. No difference in the keeping qualities of seeded and seedless Anjou pears was noted in the course of these investigations.
5. Flavor, sugar, and texture evaluations of Anjou, Bosc, Comice, and Bartlett revealed no differences between the seeded and seedless fruit.
6. Full-tree cages over Anjou trees for 3 successive years resulted in a 92 percent decline in yield by the third year on that tree which was kept free of other pollens and pollinating insects.
7. The sugar concentration of the nectar of pears ranges between 7 and 21 percent. In the orchard areas, the principal nectar competitors were mustard and chickweed, both having the sugar content of the nectar about 50 percent.

8. The principal pollen competitors were found to be mustard and commercial plum. In orchards lacking these competing plants on the orchard floor, 55 percent of all of the honey bee-collected pollen was pear. In orchards having an abundance of mustard beneath the trees and between the rows, 73 percent of all the pollen collected was from mustard.

9. There was a direct correlation between bee populations in the trees and total fruit yield on all orchards.

10. The use of honey bee attractants, such as molasses, sugar, and sugar and poly-bor failed to increase the total number of honey bees in the trees.

11. The habits of the honey bees in the trees were kept under observation and through computation it was determined that only a part of a single good bee-flying day was required for adequate cross-pollination. Numbers of bees were marked in trees and their return to the area in which they were tagged was reported. These taggings revealed that honey bees work a very restricted area during a pollen or nectar gathering trip, and exhibit strong fidelity to a specified area.

12. Bagging of Anjou florets in the popcorn stage, and crossing individual florets at intervals through the bloom period, indicated that bagged pear florets are receptive to cross-pollination for a period up to, and perhaps beyond 19 days.

13. On the basis of 2,545 selfings and 1,737 crosses, it was found that 30.8 percent of the crossed florets hung on to maturity, while only 8.2 percent of the selfings were successful. This may account for some of the low or erratic yields in solid block stands.

14. Considerable amounts of pear pollen are windborne and may account for some of the unexplainable cross-pollination in the plots observed.

15. Observations and data accumulated indicate that there is probably no completely satisfactory pollinizer arrangement that would assure total cross-pollination, but an arrangement is suggested for the most practical method of obtaining maximum cross-pollination.

16. It is suggested that one colony of honey bees located on each acre of pear orchard will provide adequate pollinator populations, except where there is high competition on the orchard floor.

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