POLLINATION STUDIES ON THE CULTIVATED BLUEBERRY *VACCINIUM CORYMBOSUM* LINNAEUS

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ABSTRACT

POLLINATION STUDIES ON THE CULTIVATED BLUEBERRY
Vaccinium corymbosum Linnaeus

by Joseph Edward Dorr

During the spring and summer of 1964 pollination studies on the cultivated blueberry, *Vaccinium corymbosum* Linnaeus, were conducted in southern Michigan. Objectives of the study were to check the effectiveness of honey bees, *Apis mellifera* Linnaeus as pollinators and to evaluate any advantages of cross-pollinating varieties. Observations of wild bees in regard to their abundance and varietal preference were also made.

At the research site in Van Buren County near Grand Junction, Michigan, experiments were conducted to test honey bee pollination effectiveness. Cages were set up over cultivated Jersey bushes into which a colony of honey bees was introduced. One cage without bees was used as a check.

Experiments of cross-, self- and open-pollination were also carried out at the research site. To test cross-pollination a bouquet of blueberry blossoms of the varieties Rubel, Coville or Bluecrop was placed into the cages containing the Jersey plants and honey bees. The cages containing Jersey bushes and a colony of honey bees, but no bouquet, were used to check the effect of self-pollination. Comparisons to cross- and self-pollination were made on randomly selected Jersey bushes in the same test field.

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Field observations were made on cultivated blueberries in open-pollination throughout Michigan's blueberry-growing area. In these, test counts were made on the number of bees observed working on a single bush per minute, with special reference being made to the blueberry variety. Samples of pollinators were collected and identified to give an indication of the most abundant species.

At the conclusion of the study the results indicated that:

1. Cross-pollination of varieties was not significantly superior to self-pollination when bouquets were used for the pollinator variety.
2. Jersey variety definitely needs some means to insure pollination and honey bees can be successfully utilized in this manner.
3. The amount of pollination increases with higher concentrations of bees, producing a higher total yield and earlier ripening.
4. The percent of large dark seeds in a berry is correlated with increased berry size.
5. While bumble bees play an important role in blueberry pollination, their value must be weighed against the value of present cultural practices.
6. There is a definite degree of varietal attractiveness to bees, which needs further study to determine possible effects in large block plantings.

POLLINATION STUDIES

ON THE CULTIVATED BLUEBERRY

Vaccinium corymbosum Linnaeus

by

Joseph Edward Dorr

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INTRODUCTION

Vaccinium corymbosum Linnaeus, the cultivated highbush blueberry, has been an economic asset to Michigan Agriculture. Due to climatic and soil requirements that are peculiar to highbush blueberries, their production has been limited to southwestern Michigan.

While tremendous advances have been made in agriculture pertaining to blueberry production, certain developments have had some adverse effects. The practice of clean cultivation, while having an initial additive effect, has subsequently been thought of as a cause for the generally mediocre crop taken from the number one variety in Michigan, Jersey.

It has been reasoned that while clean cultivation does relieve the competition between weeds and the blueberry plants, it also has destroyed the natural nesting sites of many wild bees. Growers state that wild bees were more numerous in most blueberry plantations before the general use of herbicides as a tool of clean cultivation. Growers have also noted a decline in wild bee populations since the wide use of insecticides in the blueberry cultural program. While insecticides are not applied during the actual time pollination is in progress, an extensive program is employed throughout the rest of the growing season, having a possible deleterious effect on various stages in the life cycle of wild bees of the area. This drop in yield of Jersey variety has apparently coincided with the decline of wild bees in the blueberry fields. In past years growers felt that wild bees, both solitary and social, were mainly responsible for blueberry pollination.

Since experiments by Merrill (1936) and Merrill and Johnston (1939) indicated that cross-pollination was not necessary under Michigan conditions, large blocks of single varieties have been planted. This type of planting is quite different from what is found in many orchard fruits where yields from self-pollination are commercially negligible.

Many growers and their representatives in the Michigan Blueberry Growers' Association felt more information was urgently needed regarding the pollination needs of Michigan blueberries. This information was needed to establish which species of bees were most effective, the value of cross-variety pollination and the extent of economic loss due to insufficient pollinators.

During the 1964 growing season, tests were run using honey bees as pollinators on blueberries. The objectives were to check the effectiveness and potentialities of honey bees, *Apis mellifera* Linnaeus, as pollinators of highbush blueberries, and to evaluate any advantages of cross-pollinating blueberry varieties in Michigan. The relative value of wild bees for blueberry pollination was also studied.

Background History

While the cultivated blueberry industry is relatively new to the United States, the blueberry itself is not. Many wild species of *Vaccinium* were indigenous to the United States, where the wild fruit was cherished and picked extensively by both the Indians and early settlers. While at present there is an industry in some states based on the wild blueberry, it is not as prominent as the industry based on the highbush cultivated blueberry, Vaccinium corymbosum L.

As long as wild blueberries were available in adequate quantities, no attempts were made to cultivate them. Johnston (1959) stated that in 1906 Dr. Frederick V. Coville of the United States Department of Agriculture initiated fundamental research on life history and selection which he thought might lead to the development of a cultivated blueberry industry. Mrs. Elizabeth White, also credited with improving the highbush blueberry, collaborated with Dr. Coville in selecting the first commercial planting of highbush blueberries on her farm in Whitesbog, New Jersey.

Distribution and Economic Importance

The highbush blueberry is native from northern Florida to southern Maine and westward to southern Michigan. Michigan and New Jersey lead in the production of cultivated blueberries, with substantial plantings also found in Indiana, North Carolina and Washington. Smaller areas of blueberry cultivation are found in New York, Pennsylvania, Ohio, several New England states and Oregon.

In Michigan the line which separates the lowbush from the highbush blueberry is fairly distinct. The dividing line runs from Bay City, southwest across the state to a point just north of Grand Rapids, then northwest along the isothermal lines to the shore of Lake Michigan. The reason for this slight change in direction stems from the moderating influence of the lake (Plate 1).

More specifically in Michigan the area where cultivated highbush blueberries are grown extensively is confined to five counties: Berrien, Van Buren, Allegan, Ottawa, and Muskegon (Plate 1). According to the Michigan Blueberry Growers' Association, the total land devoted to blueberries in these five counties is over 9,000 acres.

Conditions for growing highbush blueberries are very suitable in this area. Johnston (1959) states these generally include a long growing season, a moderate winter temperature, a soil which is sandy and contains a high degree of organic matter, a pH between 4.0 and 5.1, and a water table that can be maintained between 14-22 inches below the surface.

Total acreage of blueberries is increasing annually in Michigan. In 1964 the cultivated blueberry industry was valued at nearly five million dollars (Holbein, 1964, personal interview).

Nature of the Problem

Growers feel that Jersey, the predominant commercial variety, has been decreasing in expected yields over the past few years. In examining the possible causes for this decline it appears likely that the number of native pollinators has been decreased by clean cultivation and the increased use of insecticides.

This decline of native pollinators is not necessarily limited to the blueberry fields alone. Waste areas surrounding the blueberry fields, which make natural nesting sites for many native bee pollinators, are also affected. Growers, by extending their insect and weed control programs into these areas, have apparently reduced wild bee populations. With bumble bees being the only exception, all are solitary bees building their separate nests close together, often producing large populations in some areas.

Dr. E. C. Martin (1965, personal communication) relates that the prevalent opinion among growers in 1951 was that wild bees were predominantly responsible for blueberry pollination and that coverage was adequate for maximum yield. However, it appears that in the last five to ten years the deleterious effect that insecticides and herbicides have had on wild bee populations has most seriously affected the yield from the Jersey variety.

Another factor that might conceivably influence the yield of the Jersey variety is the practice of large block planting. The investigations of Merrill and Johnston (1939) showed that cross-variety pollination was not necessary for a normal set under Michigan conditions. These investigations led to the planting of large blocks of single varieties on Michigan plantations.

If cross-variety pollination does increase yield, then the trend toward larger and larger blocks of just a few varieties may be reducing yields. Therefore, instead of planting large blocks of one variety as is currently practiced, several varieties should possibly be interplanted. Shoemaker (1955) points out, however, that if several varieties are planted together to obtain the value of cross-pollination, too many may complicate the cultural and harvesting operations. This could cause a serious problem in the blueberry industry.

Merrill (1936), however, noted the greater importance of insuring some means of pollination over the importance of self- or cross-pollination. Merrill also reported that honey bees were incapable of effective pollination in some varieties and that this would leave the task of pollination to bumble bees. He further stated that because bumble bees cannot be handled as honey bees are, natural conditions must be maintained to conserve the bumble bees.

Although Jersey, the number one variety in Michigan today, was not referred to in Merrill's original work, his results have been applied to this variety.

Due to the inconclusive results of previous studies and the lack of any definite impact on production practices, the situation seemed to warrant a renewed and comprehensive study of the pollination problem in Michigan.

Tests were set up to check the possibilities of: 1) substituting honey bees for natural field bee pollinators, and 2) cross-pollinating varieties as a method of increasing blueberry yields. These tests were set up on the John W. Nelson blueberry plantation in Grand Junction, Van Buren County, Michigan (Plate 1).

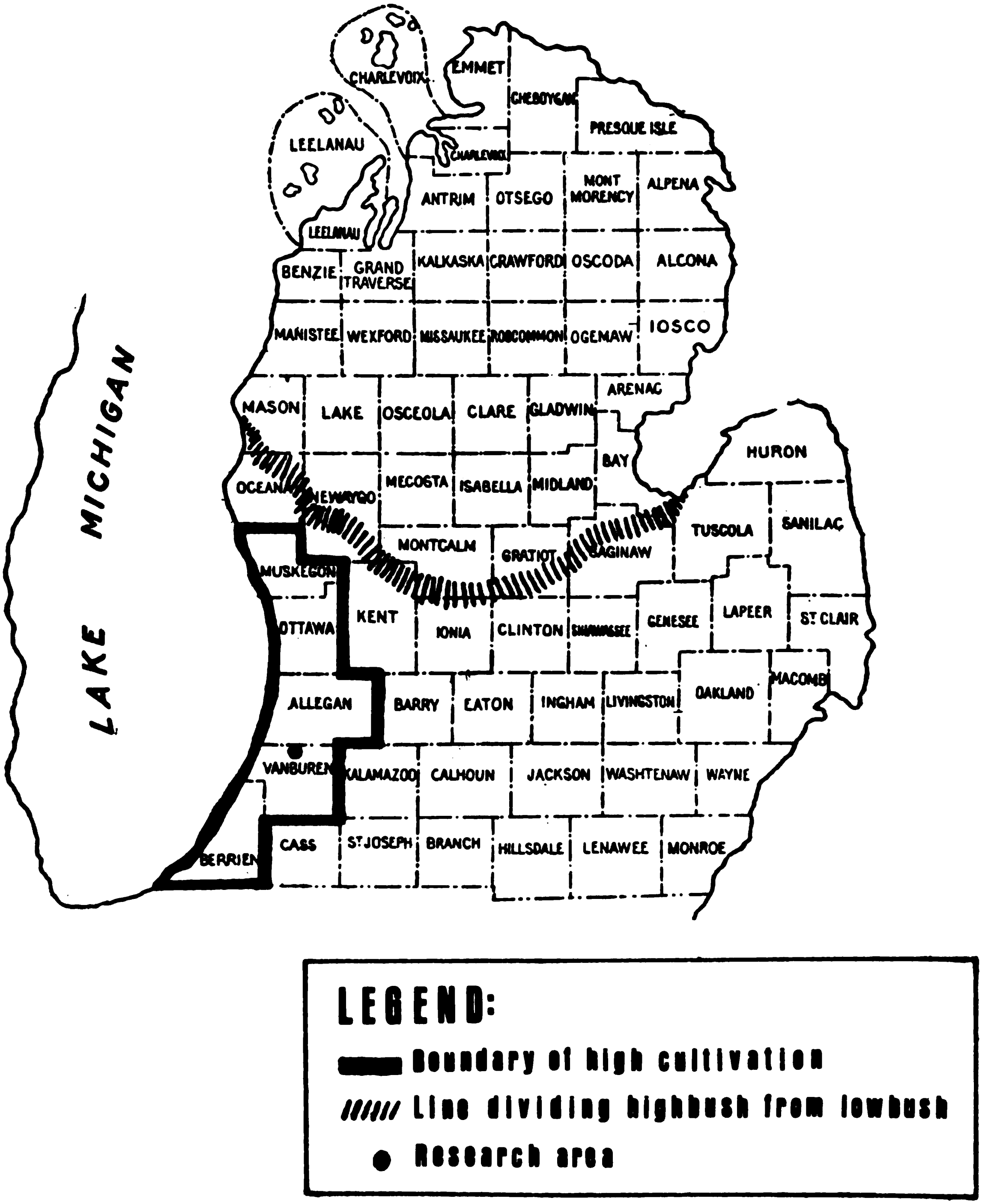

PLATE 1.--Map of Michigan showing blueberry areas.

REVIEW OF LITERATURE

Pollination Studies

Darwin (1885), instrumental in the early investigations concerning plant fertilization, drew from his observations that cross-fertilization is generally beneficial and self-fertilization injurious. Darwin stated further that "there is weighty and abundant evidence that the flowers of most kinds of plants are constructed so as to be cross-fertilized."

One of the first publications concerning blueberry pollination was by Coville (1910) where he stated after extensive observations that, "fruit was produced from flowers pollinated either with their own pollen or with pollen from another flower." This suggests that Coville felt either self- or cross-pollination could be employed effectively to set fruit. However, Coville (1921) stated after further investigations that, "when blueberry flowers are pollinated with pollen from their own bush the berries are fewer, smaller, and later in maturing than when the pollen comes from another bush." Coville (1921) continued that because of the pollination problem it is very important not to have a blueberry plantation made up "wholly from cuttings from one bush."

Robbins (1924) further states on the blueberry pollination problem that, "if pollen from the same plant is used in pollination, the fruit that is formed remains small and green and later drops off. This fact serves to emphasize the need in the propagation of blueberries by cuttings, and of making the plantation from cuttings of a number of different bushes."

Beckwith and Coville (1927) collaborated and stated emphatically that blueberries must be cross-pollinated for best results. To allow for better pollination by bumble bees and other insects Beckwith and Coville suggested rows of at least two different varieties alternating throughout the field instead of a solid block of one variety.

Beckwith (1930) observed after further close study that self-pollinated blueberries under New Jersey conditions were smaller and matured much later, "even when the pollen was carried promptly from flower to flower by bumble bees." Beckwith further noted that "berries of commercial size and quantity could not be produced in this way."

Other researchers in other areas were also working on the pollination problem. Crowley (1933) in Washington claimed that while fruit did set on "White" variety by selfing, larger and higher yields were obtained when cross-pollination was realized.

Merrill (1933, 1936) under Michigan field conditions generally secured a higher percent fruit set with cross-pollination than with self-pollination, but lower than open-pollination. Merrill (1933) however, while observing a planting of 48 Rubel bushes growing by themselves at the South Haven, Michigan, Experiment Station, noted they bore an exceptionally heavy fruit crop for three years with no other bush nearer than two miles. Merrill stated after this observation that, "open-pollination, which must have been entirely self-pollination, can induce heavy yields", and also that, "selfed berries were as large in every case as the crossed berries and matured in their normal season."

Merrill (1933, 1936) also noted that bumble bees and honey bees are the principal pollinating insects in a blueberry plantation. The method used by Merrill (1936) was to remove all the blossoms on the clusters that were already open or too small and then to emasculate the rest for both the self- and cross-pollination tests. He used his finger to apply the pollen.

Bailey (1938) in Massachusetts worked with several varieties including Michigan's number one and two varieties, Jersey and Rubel respectively. Bailey's experiments differ from Merrill's in that Bailey did not remove any of the blossoms on the cluster he used, and his pollinating was done with a camel's hair brush. Bailey's findings indicated that while open-pollination proved in most cases satisfactory, self-pollination did not set enough fruit for a commercial crop.

White and Clark (1938) reported that in many cases tests on field grown plants showed, "the percent of total flowers self-pollinated which set fruit was not significantly different from the percent set with cross-pollination." They also stated, however, that the berries resulting from self-pollination were consistently smaller than those resulting from cross-pollination, and in some cases ripened later. White and Clark used the same techniques as those used by Merrill (1936) with the exception of using a small metal spatula for applying the pollen.

Merrill and Johnston (1939) conducted new experiments in Michigan to determine the degree of self-fertility of varieties not previously tested, including in this series of tests the variety Jersey. They concluded from these tests that the percent set was not significantly different between self- and open-pollination. They further reported that the berries resulting from slef-pollination were of equal size when compared to open-pollinated berries. Again the hand pollination in this experiment was done either by a camel's hair brush or a finger.

In North Carolina, Schaub and Bauer (1942) showed that in comparisons of cross- and self-pollination on varieties of Scammell, Weymouth and Dixi, cross-pollination gave earlier ripening by a week and increase in set up to twenty percent. Schaub and Bauer (1942) and Shoemaker (1955) also noted that in North Carolina, mixed planting would give a better set and also provide an earlier ripening and better grade berry, providing a greater commercial advantage.

Morrow (1943) conducted experiments in North Carolina in a greenhouse using both emasculated and unemasculated flowers. His technique of hand-pollination consisted of using a blotter with no thinning of blossoms from the clusters. His results indicated that cross-pollinated berries were larger and ripened earlier than those developing from self-pollination.

Meader and Darrow (1947) in Maryland used the techniques and conditions initiated by Morrow (1943) and found that while self-pollination often produced as large a percent fruit set as cross-pollination, the berries produced were smaller and later in maturing. In an earlier test, Meader and Darrow (1944) employing the same technique on Vaccinium ashei acquired a wide variation in self-fertility. They reported that the set and size of berry was greater while days to maturity generally decreased with cross-pollination than with self-pollination.

Cremmins (1952) in a greenhouse in Oregon conducted a pollination study on hybrid blueberries using both emasculated and unemasculated blossoms, a glass rod as the pollination instrument and no thinning of blossoms. He obtained a smaller set and a smaller berry plus a later-maturing berry from self-pollination than from cross-pollination of the Dixi variety. Tests conducted on Jersey bushes in the field resulted in no significant difference in the percent set obtained between self- and cross-pollination, although self-pollination did result in a smaller size of berry and a delay in maturity.

Thomas (1962) conducted a pollination study at Wooster, Ohio and found that cross- and open-pollination resulted in earlier ripening, greater fruit set and larger berries than self-pollination of the varieties Jersey and Berkeley. He also noted that while a commercial set could not be obtained on either Jersey or Berkeley by hand-pollination, it was obtained on the Jersey when it was self- or open-pollinated by bees.

The latest recorded findings comparing the pollination requirements of highbush blueberries was done by Filmer and Marucci (1963) at the New Jersey Experiment Station. They performed not only self-, cross- and hand-pollination tests, but cage tests as well, where honey bees were used to cross-pollinate the blossoms. Filmer and Marucci noted that the conditions were so favorable in the cages that contained bouquets of unlike pollen that the benefits from cross-pollination could not be demonstrated. In hand-pollination tests, however, a vigorous response was obtained when unlike pollen was used. The hand-pollinating was done by use of a camel's hair brush. In conclusion they stated that the lack of cross-pollination does not prevent setting of fruit as was shown in their hand-pollination tests and in the cage tests where bouquets of unlike blossoms were not provided. However, "the great increase in size, rapidity of ripening and uniformity of size which are inherent in cross-pollination are all commercially desirable features."

In summary, most of the experiments indicated that a higher percent fruit set could be obtained from cross-pollination than from self-pollination. However, White and Clark (1938), Merrill and Johnston (1939), Meader and Darrow (1942) and Cremmins (1952) indicated that very little to no difference could be realized in the percent of fruit set due to self- or cross-pollination. Merrill (1936) and Bailey (1938) concluded that open-pollination consisting of both self- and cross-pollination gave a better fruit set than did self-pollination, while Merrill (1936) also found open-pollination to be superior to cross-pollination when referring to percent of fruit set.

Thomas (1962) and Filmer and Marucci (1963) further indicated that their cage tests containing honey bees showed a desirable set could be obtained from self-pollination.

In reference to the time needed for ripening and the size of the berry developing from cross-pollination versus self-pollination, the majority of the investigators generally agreed that cross-pollination both increased size and shortened the ripening time. The only disagreement was from Merrill (1936) who claimed that in Michigan the berries were just as large from selfing as from crossing. Merrill (1936) also claimed after observing 48 isolated Rubel bushes in the open, assumed to be self-pollinated, that the berries matured during the normal growing season.

Young (1952) claimed that there appeared to be no correlation between maturity and the location of the fruit within the cluster, but noted earlier ripening and larger berries from those maturing in the sun to those growing in the shade. Shutak, Hindle and Christopher (1956) reported no correlation between berry size and location in the cluster, but noted final size attained by the berry increased considerably after the start of the blue coloration.

Due to variations in results by the many investigators, some of the recommendations for specific areas also varied. Bailey, Franklin and Kelley (1941) in Massachusetts, Christopher and Surtleff (1952) in Rhode Island, Shoemaker (1955) in North Carolina and Darrow (1962) with the U. S. D. A. recommended, based on the results of experiments, that under most conditions two or more varieties should be planted to insure cross-pollination. Darrow further noted, however, that growers have received heavy crops from solid blocks of Rubel and Jersey. In Michigan, Johnston (1959) and Bell and Johnston (1962) recommended that large blocks could be planted for, "cultivated blueberries are self-fertile so they need no cross-pollination." Johnston (1959) further recommended, however, that more than one variety should be planted to insure against the risk of crop failure.

Pollinating Agents

Coville (1910) stated that without insects or other pollinating aids, selfing of blueberries happened only occasionally. Coville (1921) continued that for a crop to be set under field conditions, insects were needed to carry the pollen from flower to flower. Chandler and Mason (1935), Chandler (1943) and Lee (1958) referring to lowbush blueberries and Merrill (1936) referring to highbush blueberries agreed with Coville (1910) that some means of insuring pollination is necessary for production.

Phipps (1930) recorded forty different species of insects visiting the lowbush blueberry, Vaccinium lamarckii (Camp), in Maine. Phipps (1930) and Chandler and Mason (1935) and Chandler (1943) noted in remote areas blueberries in small acreages were successfully pollinated by native wild bees, but in large blocks there were insufficient numbers of wild bees to adequately pollinate the crop.

Phipps (1930) suggested that honey bees might be provided to restore the balance between bloom and pollinators. Beckwith (1930) and Shaw, Bailey and Bourne (1939) obtained a good set when honey bees were used alone and little or no set in areas where they were excluded. Thomas (1962) and Filmer and Marucci (1963) found that a highly desirable set was obtained in self-pollination tests using honey bees only.

Coville (1921), Crowley (1933) and Merrill (1936) stated however, that while honey bees did work blueberry flowers to some extent, the bulk of the pollination is left up to bumble bees. Coville (1921) and Merrill (1936) further stated that honey bees are incapable of pollinating certain varieties because a honey bee's tongue is too short to fit into the narrow, deep blossoms. Coville (1921) also noted that some blueberry pollination is done by solitary bees who are small enough to crawl into the flowers.

Correlation Between Berry Size and Seed Number

Merrill (1936) reported that there seemed to be no relationship between the size of the berry and the number of seeds. White and Clark (1939) and Darrow (1940), however, stated that their tests showed that the larger berries had either more seeds or the seeds in the larger berries weighed more than the smaller berries. Morrow (1943) and Meader and Darrow (1949) reported that berries developing from cross-pollination contained a greater percent of fully developed seeds than berries from self-pollination. Results by Thomas (1962) indicated that the final size of the berry is related to the large brown seeds it holds but not correlated with the total seed number. Thomas (1962) also noted that the "number of large brown seeds in a berry is considered to be a possible index to the adequacy of the pollination." Filmer and Marucci (1963) stated that the size of the berries was directly proportional to the number of seeds.

In summary, all investigators except Merrill (1936) believed that usually the larger berries contained more large seeds and probably more total seeds than the smaller berries. They also correlated greater weight of the seeds with greater size of the berry. Thomas (1962), while not agreeing completely with the other investigators, did believe that the number of large seeds gave an indication of the completeness of pollination.

MATERIALS AND METHODS

Controlled Pollination Study

The study was carried out during the 1964 season on a blueberry plantation at Grand Junction, Michigan. The plantation was owned and operated by John Nelson, Research Director of the Michigan Blueberry Growers' Association.

A total of twenty-two six year old, mature, bearing bushes of the Jersey variety were utilized in the study. The bushes were chosen by visual observation on the bases of uniformity in size and number of buds.

Four, 4' by 8' by 6' cages were constructed using 16 mesh fiberglas screen supported on a wooden frame of 1 by 2's. Five other slightly larger cages previously constructed, four measuring 8' by 6' by 8' and one 4' by 20' by 6' were also used.

The cages were placed over the bushes on May 9, prior to bloom, to exclude all pollinating insects (Plate 2). The cage studies were set up utilizing two separate cages for each individual cross- and self-pollination test. The cages were constructed so that the larger ones containing two equivalent bushes provided as much area per bush as the smaller cages which contained only a single bush. The two cages used in each test, containing a total of three bushes, constituted three replications.

In the cross-pollination tests bouquets of Rubel, Coville or Bluecrop were used with the field grown Jersey bushes, each cross being replicated three times.

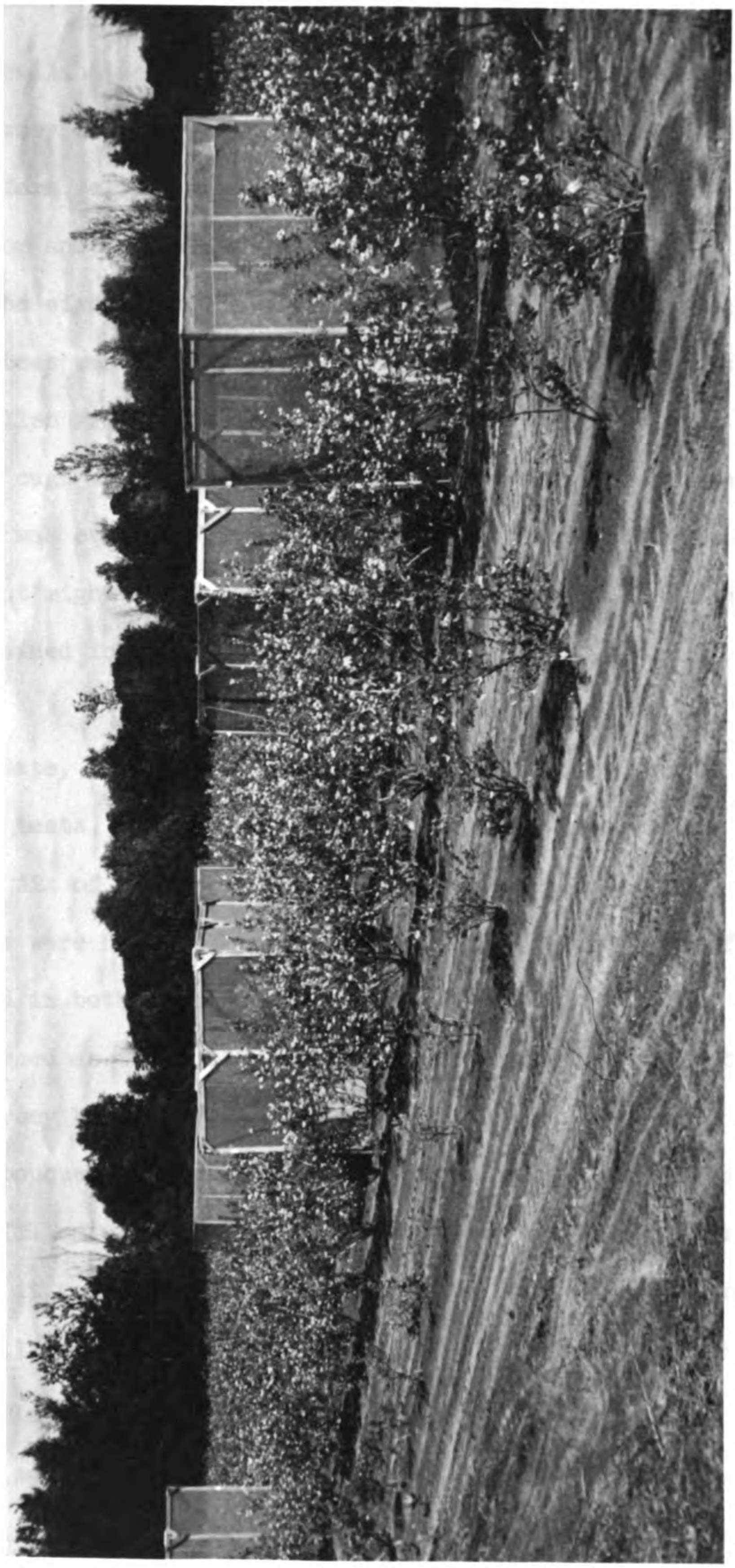

PLATE 2.--Blueberry plantation showing cages used in field pollination tests.

In the self-pollination tests, also replicated three times, only the cultivated Jersey bushes growing naturally in the field were used. In this test the term selfing designates pollination with its own pollen and not from another variety.

In each of the eight cages involved in cross- and self-pollination, a colony of honeybees was introduced on May 15 utilizing the bees as a carrier of the pollen from anther to stigma.

In the check cage without bees, wind was likely the main pollinating agent. This cage was equipped with a door so daily checks could be made on any insects that might have gotten through the screen. This cage without bees contained four equivalent bushes constituting four replications.

On the same date, May 15, as a substitute for a whole plant in the cross-pollination tests, one bouquet of open blueberry blossoms was placed in each of six of the eight cages. The three varieties used in the crossing tests were Rubel, Bluecrop and Coville. One bouquet of one variety was placed in both a large and small cage. The last two of the eight cages were used as tests for selfing and therefore contained bees and one or two Jersey bushes, but no bouquets.

To keep the bouquets fresh while in the cages, they were kept in five gallon cans filled with water. While this kept the bouquets fresh for about a week, it was still necessary to change bouquets on the night of May 20. A small pan of water was also placed in the cages for the bees to utilize (Plate 3).

For a comparison to the cross- and self-pollination tests, six randomly-picked Jersey bushes with similar characteristics were tagged

PLATE 3.--Close-up of cage used in cross-pollination tests showing hive of honey bees, bouquet and pan of water for bees.

in the same test field to evaluate open-pollination. These bushes represented six replications. Bees were the main pollinizers of the bushes but other insects were also noted. Ten honey bee colonies were located in a row twenty-five feet to the east of the $1\frac{1}{2}$-acre Jersey field, next to a stand of five-foot pines. Throughout the blossoming season a careful check was kept on the bee activity in the cages and on the test plants in the field. While the bee activity in the cages was limited to honey bees, wild bee activity in the field was also noted.

The eight cages involved in the cross- and self-pollination tests along with the enclosed hives of bees were removed on May 26. At that time all the blossoms had dropped off the bushes. The bushes caged with no bees were still in full bloom, therefore, the cage could not be removed until June 20.

The bushes were all picked on the same dates, a total of five times. At the end of the fifth picking the bushes were completely stripped of berries. After each picking the total weight of the berries for each bush was recorded to the nearest one-quarter of an ounce.

To indicate the relative size of the berry for each treatment an eight-ounce measure was used to give a cup count (the number of berries to fill the cup) and this was also recorded after each picking.

The berries from the cup were then bagged, marked for identification and put into a portable refrigerator for transportation back to the laboratory where seed counts were made.

The seed count was made on ten berries picked at random from each sample. The procedure was to first cut the berry in half. Then by taking half the berry at a time, the pulp and seeds were removed by gently squeezing between the thumb and forefinger while dipping the berry several times in a shallow bowl of water. The pulp was then removed from the bowl and the excess water was siphoned off. The seeds were then grouped and counted as described by White and Clark (1939) into large dark and small light.

Field Pollination Study

This portion of the study was involved in observing blueberry plantations under commercial conditions.

Many commercial blueberry plantations in the five major blueberry-growing counties were visited during both the blossoming and harvesting seasons. During the visits to the fields at blossom time, a count of the number of honey and wild bees observed on a single bush per minute was recorded. A sample of the wild bees surveyed in the count was collected and later identified. Many different varieties of blueberry showing varying degrees of attractiveness were observed and the blooming date recorded for this test. It should be noted here that because of renewed interest in pollination, many growers had rented honey bees for the 1964 blossoming season. Therefore, the honey bee population, according to the growers, was much higher than it had been in previous years.

During the harvesting season the same fields that were observed for bee activity were again checked for berry size and seed makeup. Although it is difficult to get production records for a specific variety in individual commercial fields, an attempt was made to correlate berry size and seed count for each field checked.

A daily log of the weather including the minimum and maximum temperatures and precipitation was kept throughout the blooming and harvesting seasons.

RESULTS

Controlled Pollination Study

The results of the cage tests were very striking. All the bushes caged with bees became very heavily laden with fruit regardless of the cross. In contrast, the four bushes caged without bees were conspicuously lacking in fruit, not having any fruit at the first picking. The total yield from the bushes used in the open-pollination tests fell somewhere between the two extremes.

The complete picking chart showing the yield in pounds and ounces for each test bush on each of the five picking dates is found in Table 1. Also shown is the total yield for each bush and the mean for each set of replications calculated by using 0.06 pounds equal to one ounce.

In the tests involving crosses a slightly higher yield was recorded with Coville than with either Rubel or Bluecrop. While this fairly substantial increase was noted, the difference was extremely small between the mean yields of the Rubel cross and the Jersey self-pollinated (Table 1).

Due to the slight variation in yield an analysis of variance was run to compare the mean yields of the three crosses and selfing. This analysis showed no significant differences between their means at the 5% level (Tables 2 and 3).

TABLE 1.--Table showing individual plant yield for each picking date of cross-, self- and open-pollination with and without bees

WITH BEES

Yield for Picking Date

Pollination	July 16	July 24	Aug 4	Aug 17	Aug 31	Total	Total Mean
Jersey X Rubel - Single	4-4	5-13½	2-8	0-7	0-2	13-2½	
Jersey X Rubel - Double	5-1	4-1	1-12	0-4	0-½	11-2½	11.37
Jersey X Rubel - Double	5-13½	3-1	0-13	0-1½	0-¼	9-13¼	
Jersey X Coville - Single	4-12	6-0	3-4	0-8	0-3	14-11	
Jersey X Coville - Double	4-2	5-5	3-0	0-10	0-2½	13-3½	14.46
Jersey X Coville - Double	5-12	5-6	3-2	0-14	0-6	15-8	
Jersey X Bluecrop - Single	2-3	7-8	4-11	1-5	0-8	16-3	
Jersey X Bluecrop - Double	4-11	5-1½	2-4	0-4	0-1	12-5½	13.67
Jersey X Bluecrop - Double	5-9	4-10	2-0	0-4	0-1	12-8	

TABLE 1.--<u>Continued</u>

Jersey X Self - Single	3-0	5-11½	3-0	0-8	0-2½	12-6	
Jersey X Self - Double	5-5	4-10	1-5	0-4	0-½	11-8½	11.15
Jersey X Self - Double	3-6½	3-12	1-15	0-7	0-1	9-9½	
Jersey - Open	0-10½	2-2	2-7	0-14	0-6	6-7½	
Jersey - Open	1-9½	3-0	2-10	1-8	0-9	9-4½	
Jersey - Open	0-12	2-4	2-6	0-13½	0-4	6-7½	7.80
Jersey - Open	0-15	2-4	2-5	1-2½	0-6	7-7½	
Jersey - Open	0-15	3-12	3-13	1-11	1-4	11-7	
Jersey - Open	1-2	1-14	1-14	0-10	0-6	5-14	
WITHOUT BEES							
Jersey	---	0-2	0-7	0-4	0-3	1-0	
Jersey	---	0-1	0-9	0-11	0-6½	1-11½	1.50
Jersey	---	0-¼	0-8	0-10	0-2	1-4¼	
Jersey	---	0-¼	0-7	0-10	0-7	1-8¼	

TABLE 2.--Yields of self- and cross-pollinated plants

Varieties	Plants			
	1	2	3	$\bar{X}$
Jersey (Self)	12.36	11.51	9.57	11.15 ± 6.97
Jersey X Rubel	13.15	11.15	9.80	11.37 ± 7.16
Jersey X Coville	14.66	13.21	15.50	14.46 ± 8.93
Jersey X Bluecrop	16.18	12.33	12.50	13.67 ± 8.65

TABLE 3.--Analysis of variance on yields of self- and cross-pollinated plants

Source of Variation	d.f.	Mean Square	F
Between means	3	487.0	1.98 (.05=4.07)
Within groups	8	246.2	

Ripening Time

The results show a definite earlier ripening in the cage tests where bees were utilized for pollination (Table 4). In both the cross- and self-pollination tests approximately 75% of the total yield was harvested on the first and second pickings. After the third picking the yield approximated nearly 95% of the total, leaving a negligible 5% to be harvested on the last two pickings.

In the open-pollination test only 46.1% of the total yield was harvested during the first and second pickings, rising to 78.9% at the end of the third picking. This left 21.0% to be harvested in the last two pickings, an appreciable amount. It can be seen here that the percent harvested through the third picking in open-pollination was approximately the same as harvested in cross- and self-pollination tests at the end of the second picking. Furthermore, while the cross- and self-pollinated bushes yielded 95% of their crop in three pickings, the yield of open-pollinated bushes didn't reach approximately the same amount, 93.1% until after the fourth picking.

TABLE 4.--A comparison showing the effects of bees on the time of ripening for different pollination treatments.

WITH BEES

Pollination	% Harvested on Each Picking Date				
	July 16	July 24	Aug 4	Aug 17	Aug 31
Jersey X Rubel	44.4	38.0	14.8	2.2	0.4
Jersey X Coville	33.7	38.4	21.6	4.6	1.6
Jersey X Bluecrop	30.3	41.9	21.7	4.3	1.5
Jersey X Self	34.9	42.1	18.6	3.5	0.7
Jersey - Open	12.8	33.3	32.8	14.2	6.8
NO BEES					
Jersey	---	3.8	35.3	39.6	20.9

In the cage with no bees only 3.8% of the crop was harvested after the first and second pickings. After the fourth picking, 78.7% of the total yield was picked. This made it approximately equal to the percent picked in two pickings for the cross- and self-pollination tests and three pickings for open-pollination. The relationships of the percent of the total yield harvested for each picking is graphically depicted in Figure 1.

Cup Count

Cup count refers to the number of berries required to fill an 8-ounce measuring cup and is used to give an indication of the relative size of the berry. The cup, when full of berries, weighed five ounces and part cups are indicated on this basis. A cup count record was kept for each picking of each bush and the mean cup count recorded for each test (Table 5). Calculating a cup to get a mean cup count was done when any one of the replications did not have a full cup. It should be noted that the mean cup count is a rough approximation for the final picking date of the cross- and self-pollinated tests, as well as the second picking date in the NO bee test, due to the small amount of fruit harvested on these dates.

As shown in Table 5, the berries became progressively smaller in all the tests throughout the five picking dates. While the open-pollinated tests showed a mean cup count equal to the caged tests with bees for the first and second pickings, it ran much higher for the last pickings. The cup count for the caged bushes without bees ran extremely high throughout the harvesting season.

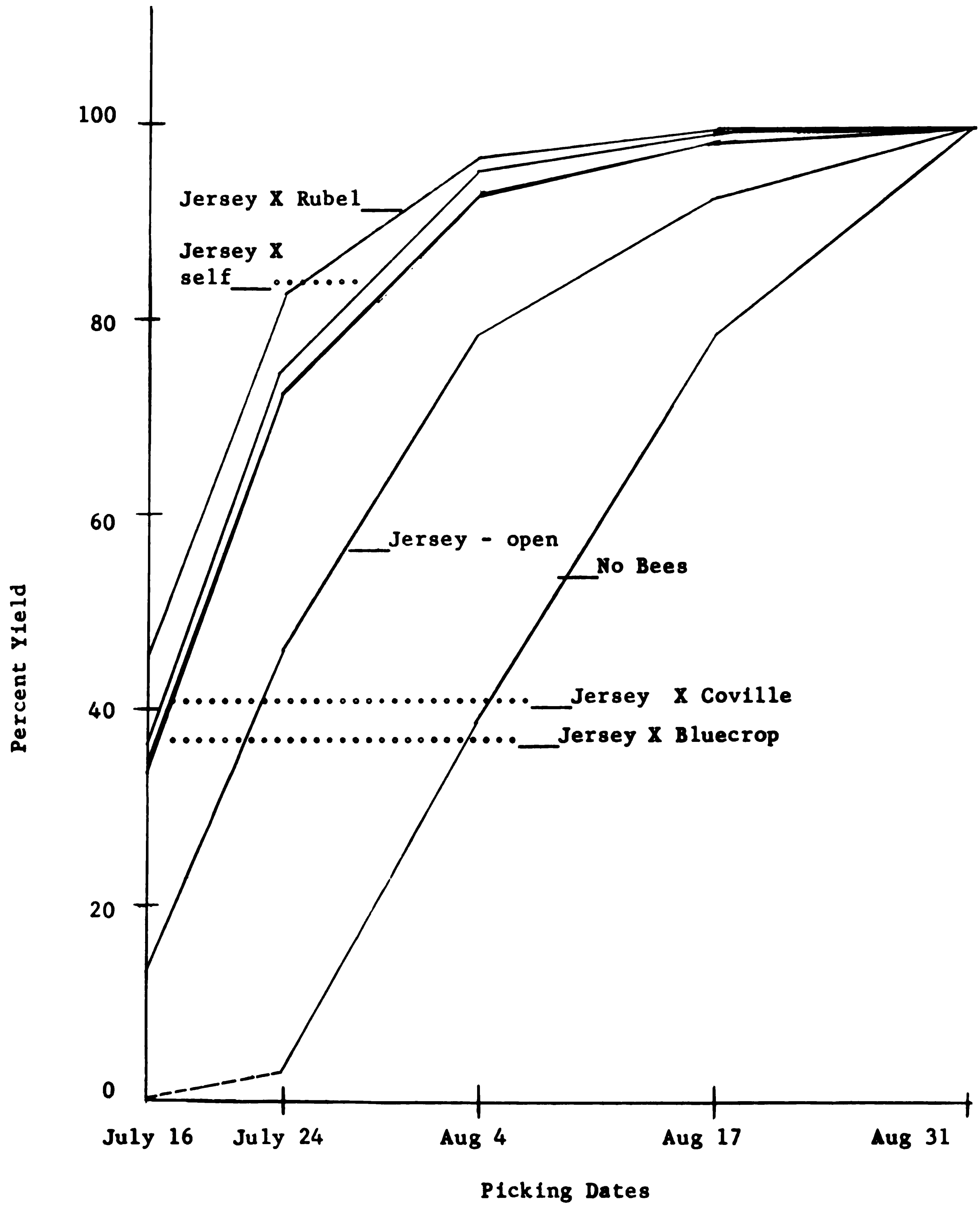

FIGURE 1.--Relationship between the percent of total yield harvested from each treatment for each picking date

TABLE 5.--Relative berry size as indicated by mean cup count in cross-, self- and open-pollination and with no bees

WITH BEES

Pollination	Mean Cup Count for Each Picking Date				
	July 16	July 24	Aug 4	Aug 17	Aug 31
Jersey X Rubel	102.3	117.3	156.0	215.4*	703.3*
Jersey X Coville	110.7	118.3	142.0	182.0	306.0*
Jersey X Bluecrop	110.0	115.0	146.3	229.8*	398.0*
Jersey X Self	102.7	118.7	147.7	200.8*	684.7*
Jersey - Open	97.3	119.0	197.8	275.3	338.0*

NO BEES

Jersey	---	341.3*	290.8	328.3*	495.5*

*indicates the cup count was calculated

Seed Count

A random sample of ten berries per picking for each replication was used in making the seed count. The seeds were divided into two categories according to size and color (large dark and small light), and the percent of each was recorded in Table 6.

TABLE 6.--Relationship of the percent of large dark (L.D.) and small light (S.L.) seeds to the mean seed count for 10 berries of cross-, self- and open-pollination of bees and no bees

Pollination	July 16		July 24		Aug 4		Aug 17		Aug 31		Mean Seed Count for 10 Berries Picked				
	L.D.	S.L.	L.D.	S.L.	L.D.	S.L.	L.D.	S.L.	L.D.	S.L.	1	2	3	4	5
WITH BEES															
J X Rubel	48.4	51.6	41.3	58.7	34.9	65.1	21.9	78.1	13.6	86.4	836.00	741.66	658.66	447.00	404.00
J X Coville	43.9	56.1	38.4	61.6	34.1	65.9	25.1	74.9	22.3	77.7	839.00	764.66	668.33	534.66	491.00
J X Bluecrop	48.7	51.3	42.4	57.6	30.7	69.3	17.2	82.8	17.1	82.9	848.66	754.00	719.33	539.33	371.00
J X Self	41.9	58.1	32.2	67.8	22.0	78.0	16.8	83.2	15.2	84.2	844.00	734.66	708.33	478.33	415.33
J X Open	34.2	65.8	27.7	72.3	17.2	82.8	12.1	87.9	11.8	88.2	798.83	611.00	457.50	274.33	66.66
WITHOUT BEES															
Jersey	--	--	21.1	78.9	9.2	90.8	9.1	90.9	--	--	---	198.25	17.25	2.75	---

The results of this study indicated that the final size of the berry (cup count) is related to the percent of large dark seeds it contains (Table 7), also shown graphically in Figure 2. A consistent correlation between the size of the berry and the total number of seeds can also be made.

TABLE 7.--Relationship of percent of large dark seeds, mean cup count, and the time of ripening.

WITH BEES

Pollination	July 16		July 24		Aug 4		Aug 17		Aug 31	
	L.D.	Cup Count	L.D.	Cup Count	L.D.	Cup Count	L.D.	Cup Count	L.D.	Cup Count
J X Rubel	48.4	102.3	41.3	117.3	34.9	156.0	21.9	215.4*	13.6	703.3*
J X Coville	43.9	110.7	38.4	118.3	34.1	142.0	25.1	182.0	22.3	306.0*
J X Bluecrop	48.7	110.0	42.4	115.0	30.7	146.3	17.2	229.8*	17.1	398.0*
J X Self	41.9	102.7	32.2	118.7	22.0	147.7	16.8	200.8*	15.2	684.7*
J - Open	34.2	97.3	22.7	119.0	17.2	197.8	12.1	275.3	11.8	338.0*

WITHOUT BEES

Jersey	---	---	21.1	341.3*	9.2	290.8	9.1	328.2*	---	495.5*

*indicates the cup count was calculated

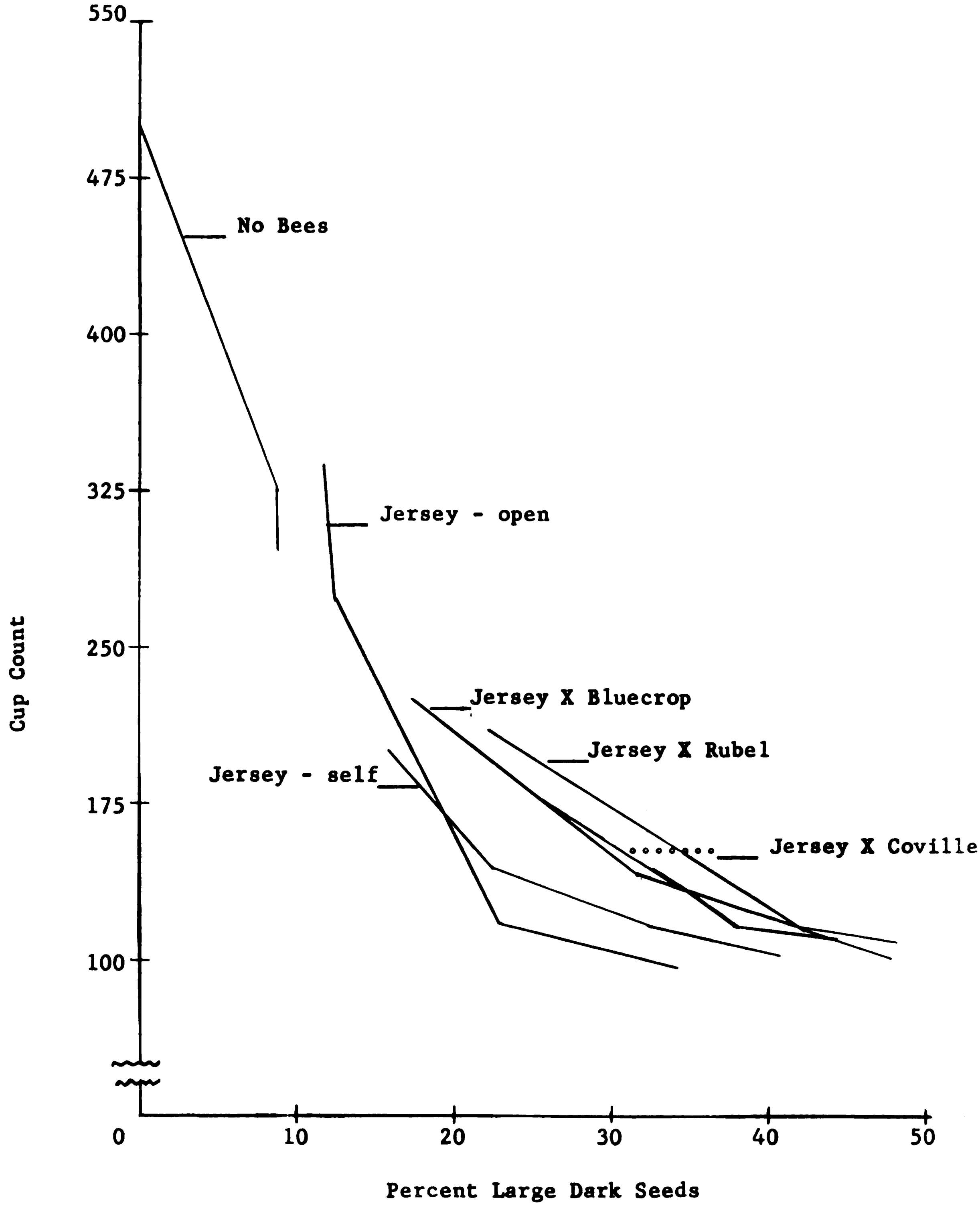

FIGURE 2.--Relationship between the percent of large dark seeds and the mean cup count

Bee Activity in Cage Studies

The bee activity in the cages was observed each day from May 15 (when the colonies were introduced into the cages) until May 26 (when blossoming was finished and the cages removed). Good bee activity was noted throughout most of the day, the only exception being from 12 noon to 2:00 p.m. when the highest temperatures occurred.

Honey bees could be observed through the screen working both the naturally growing Jersey bushes and the bouquets (Plate 4). The bees could be observed at this time busily performing both self- and cross-pollination.

Bee Activity in Open-Pollination Study

Bee activity was also observed for the six Jersey bushes used in the open-pollination study. Observations began on what was estimated as beginning of bloom, May 11, and continued until petal fall, May 26. May 19 was estimated as full bloom (Plate 5).

Bee activity was recorded as the total number of bees observed working each of the six bushes for one minute between the hours of 10:00 a.m. and 12 noon (Table 8). A sampling of the bees using a sweep net was made. The bees were identified and listed from the most to the least abundant (Table 9). No attempt was made to collect those specific bees observed in pollinating the six Jersey bushes.

It should be mentioned that Mr. Nelson, operator of the test plantation site, noted much higher honey bee activity in the Jersey field during the 1964 blossoming season than in previous years. This increase

PLATE 4.--View through the cage screen showing a honey bee working the caged Jersey bush.

PLATE 5.--Bumble bee working a Jersey bush in open-pollination.

TABLE 8.--Observed bee activity in the open-pollination test on Jersey

Date	*Honey bee	*Bumble bee	*Other
5-14	1	---	---
5-15	1	3	---
5-17	1	1	2
5-18	1	1	---
5-19	2	1	1
5-20	1	1	1
5-21	2	1	---
5-22	1	---	1
5-23	1	1	1
5-24	1	---	---
5-25	1	---	---

*The activity recorded represents the total number of bees observed on each of the six bushes for one minute

TABLE 9.--List of bees collected in Jersey test field

Genus	Species	Number
Apis	*mellifera*	8
Bombus	*impatiens*	6
Andrena	*vicina*	5
Bombus	*vagans*	3
Bombus	*griseocollis*	2
Bombus	*auricomus*	1
Bombus	*bimaculatus*	1

was undoubtedly due to the closeness of the 10 colonies of honey bees to the Jersey field. Since the total number of honey bees is lower than the total number of bumble bees, as appearing in Table 8, it indicates varietal preference away from Jersey.

Field Pollination Study

Bee Observations

The second phase of the pollination study was to observe bee activity on the main varieties grown in Michigan. This was carried out both on Mr. Nelson's and on other growers' plantations. The procedure in making observations, counts and listing the species was followed for this phase as outlined under "Bee Activity in Open-Pollination". Table 10 is set up so that each variety of cultivated blueberry is dealt with separately. Observations in the field pollination study were made daily in different fields on many plants and varieties. The insects collected in the Field-Pollination Study (Table 11) show that a fairly large number of different species of bees were collected. It should be noted that the two Lepidoptera, *Hemaris diffinis* and *Danaus plexippus* were found in large numbers at only two different locations.

TABLE 10.--Pollinating insects observed on different varieties of cultivated blueberries

JERSEY

Date	Honey bee*	Bumble bee*	Other Pollinator	Name and Location
5-11	9	25	Sphingidae Syrphid Andrenidae Xylocopidae	Krieger Grand Junction

TABLE 10, continued

Date	Honey bee*	Bumble bee*	Other Pollinator	Name and Location
5-12	4	5	----	Wakeman Bangor
5-14	3	1	----	Brandenhorst** Holland
" "	---	1	----	Behm West Olive
5-19	2	1	Andrenidae	Willis** Nunica
5-20	12	5	----	Den Herder** Nunica
5-22	3	1	----	Harr** Bangor
5-25	25	10	Xylocopidae Andrenidae	Double A** Holland
5-26	12	1	Danaidae	Amstutz** Rothbury
5-27	6	4	----	Eliot Otter Lake
		RUBEL		
5-11	20	10	----	Nelson** Grand Junction
" "	2	4	Andrenidae	Zielinski Grand Junction
" "	12	30	Sphingidae Syrphid Muscid Andrenidae Xylocopidae	Krieger Grand Junction
5-12	6	---	----	Wakeman Bangor
5-14	8	---	----	Nelson** Grand Junction
" "	14	---	----	Orr Holland
" "	10	---	----	Brandenhorst** Holland

* Activity recorded represents the total number of bees observed on each bush for one minute
**Denotes those growers who had rented honey bees

TABLE 10, continued

RUBEL, continued

Date	Honey bee*	Bumble bee*	Other Pollinator	Name and Location
5-15	20	8	----	Nelson** Grand Junction
5-17	15	5	----	Nelson** Grand Junction
5-18	24	8	----	Den Herder** Nunica
5-19	8	4	----	Den Herder** Nunica
" "	15	4	Andrenidae	Willis** Nunica
5-20	4	3	----	Dirkse** Fruitport
5-21	2	1	----	Nelson** Grand Junction
5-22	2	1	----	Nelson** Grand Junction
" "	4	30	Vespidae Xylocopidae	Krieger** Grand Junction
5-27	7	4	----	Eliot Otter Lake

COVILLE

Date	Honey bee*	Bumble bee*	Other Pollinator	Name and Location
5-11	---	3	----	Nelson** Grand Junction
5-12	1	---	----	Nelson** Grand Junction
5-14	---	---	----	Nelson** Grand Junction
5-17	2	1	----	Nelson** Grand Junction
5-19	3	---	----	Willis Nunica

*Activity recorded represents the total number of bees observed on each bush for one minute

**Denotes those growers who had rented honey bees

TABLE 10, continued

BLUECROP

Date	Honey bee*	Bumble bee*	Other Pollinator	Name and Location
5 -8	4	2	----	Nelson** Grand Junction
5-12	4	2	----	Nelson** Grand Junction
5-14	2	2	----	Nelson** Grand Junction
5-17	5	3	----	Nelson** Grand Junction

BLUE RAY

Date	Honey bee*	Bumble bee*	Other Pollinator	Name and Location
5-12	4	---	----	Nelson** Grand Junction
5-14	5	2	----	Nelson** Grand Junction
5-19	3	3	----	Nelson** Grand Junction
5-22	2	1	----	Nelson** Grand Junction

EARLIBLUE

Date	Honey bee*	Bumble bee*	Other Pollinator	Name and Location
5-11	---	---	----	Nelson** Grand Junction
5-14	---	---	----	Brandenhorst** Holland
" "	---	1	----	Behm West Olive
5-15	---	---	----	Nelson** Grand Junction
5-17	1	2	----	Nelson** Grand Junction
5-21	1	---	----	Nelson** Grand Junction

*Activity recorded represents the total number of bees observed on each bush for one minute

**Denotes those growers who had rented honey bees

TABLE 11.--List of pollinating insects collected in the Field Pollination Study

Genus	Species	Number
Apis	mellifera	45
Bombus	impatiens	25
Bombus	griseocollis	12
Xylocopa	virginica	10
*Danaus	plexippus	6
*Hemaris	diffinis	5
Bombus	affinis	5
Bombus	fervidus	5
Psythyrus	ashtoni	3
Bombus	bimaculatus	3
Bombus	vagans	3
Bombus	auricomus	2
Bombus	americanorum	1

*each found at only one location

The observations of bee activity, show a definite degree of selectivity to variety. The selective preference for varieties from highest to lowest was as follows: Rubel, Bluecrop, Blueray, Jersey, Coville and Earliblue.

The location of the plantation seemed to influence the number of insect pollinators in the area. Plantations like Krieger's, Double A, and Den Herder's, which were surrounded by trees and shrubs, supporting ideal land for nesting sites, produced the highest total counts of bees. Although Krieger's plantation was only one acre, the site was extremely well-suited for the harboring of wild bees. The plantation was enclosed on three sides by trees and underbrush and the remaining side by a sandy knoll, ideally suited for nesting sites of wild bees.

It was noted that Xylocopa virginica cut into the base of the blossom to get nectar and did not pollinate the flower. Further observations showed that other bees which would normally pollinate the flower now would use the hole previously made in the base to get nectar and forego pollination.

Relation Between Bee Population, Seed Development and Fruit Size

Random samples of berries were collected and checked for size and seed development in several of the same fields in which pollination activity had been previously recorded. The results, found in Table 12, relate the mean cup count for two pickings to the percent of large dark seeds of the Jersey variety as an indication of the effect of completeness of pollination on size of the berry. The procedure for this test was the same outlined under the controlled pollination study, figuring the mean cup count from three replications and the percent of large dark seeds from a random sample of ten berries.

TABLE 12.--Relationship of the percent of large dark seeds to the mean cup count in the Field Pollination Study

Growers Names & Locations	July 23		August 3	
	L.D.	Cup Count	L.D.	Cup Count
*Double A Holland	41.3	115	35.7	165
Krieger Grand Junction	43.4	117.3	36.7	156
*Den Herder Nunica	43.7	110	32.6	170.3
*Willis Nunica	46.3	114	33.2	168
*Harr Bangor	32.3	150.7	14.7	218.7
Johnston & Johnston South Haven	23.3	173.3	10.4	280.3
North Lake Grand Junction	15.3	198.3	7.2	310.4

*Denotes those growers who rented honey bees

From this table there is a strong indication that those growers who had colonies of bees in their plantations obtained larger berries, possibly indicating higher yields.

While Krieger did not have honey bees in the field, his plantation was situated in an ideal location for increased populations of wild bees. Harr, on the other hand, had colonies of bees but his yield was not of the same quality as others, possibly due again to the location.

DISCUSSION

The experimental results obtained from the pollination tests substantiate to some degree the results obtained by previous investigators as reported in the literature. While many investigators found cross-pollination superior to self-pollination in producing larger yields, no significant difference between them could be obtained in this study. This fact alone may be interpreted to support the data of Merrill (1936) and Merrill and Johnston (1939) where they found no significance of cross- over self-pollination. White and Clark (1938) following the same procedure laid out by Merrill in 1936, also found no significant difference. The reason they found no significance in their results while most investigators obtained significance might be in the fact that Merrill and Johnston, White and Clark removed those blossoms that were too small to hand pollinate, giving more plant nutrition to those left on the plant for emasculation and hand-pollination.

Filmer and Marucci (1963) performing cage pollination studies using a colony of honey bees for pollinators and bouquets for cross-pollination, noted that conditions were so favorable in the cages that benefits from cross-pollination could not be demonstrated. These results coincide with the results obtained in the author's cage studies, where yields received from the Jersey bushes enclosed with bees compared favorably with yields from Jersey bushes enclosed with bees and bouquets of other varieties.

Although the total yield from cross-pollination was not significant in relation to the total yield from self-pollination, it is highly possible that the use of bouquets for cross-pollination is not adequate. When attractive, well-developed plants are available it is likely that the proportion of pollen carried by the bees from the bouquets is relatively small.

The data did show that the total yield from the Jersey bushes enclosed with bees was highly desirable while the crop received from the bushes caged without bees was commercially negligible. This correlation points up the fact that some method of supplying pollination is essential to insure commercial yields. While Merrill (1936) did recognize that a means for insuring pollination is necessary, he restricted it to the conservation of bumble bees saying that honey bees were incapable of pollinating certain varieties. Although Jersey was not mentioned in this respect, it has been thought of in the same light, a fact which this study clearly refutes.

The data indicates further that the degree of pollination affects the amount of time needed for the fruit to mature. Whereas 95% of the crop was harvested on the bushes caged with bees by the third picking date (August 4), it was another 13 days before a comparable 93% could be picked from the bushes in open-pollination. The cage with no bees was still later reaching a comparable percent, only after the last picking. This was 27 days after the caged bee test and 14 days after the open-pollination test.

The size of the berry was also affected by the degree of pollination. Much larger berries were produced in the cage with bees under the influence of the heavy pollination than in the cage without bees. While the total yield of the bushes in open-pollination was lower than that of the cage tests with bees, the cup count was comparable for the first two pickings, dropping off for the last three.

The results of this study concerning the seed content indicate that the final size of the berry is related to the number of large dark seeds it contains. It further indicates, from Tables 6 and 7, that the size of the berry is related to the total number of seeds it contains. This does not agree with Merrill (1936) who reported that there seemed to be no relationship between the size of the berry and the number of seeds. Where White and Clark (1939), Darrow (1940) and Thomas (1962) agreed to the relationship of berry size to large dark seeds, they did not agree with the findings that berry size is related to total number of seeds.

The indications, along with the fact that the number of total seeds in any one berry is regulated both genetically and environmentally, lead to the conclusion that to increase berry size, the percent of large dark seeds must be increased. No evidence is found in the literature regarding the number of large dark seeds necessary to produce a commercial-size berry. Although Coville (1910) found berries which had developed without the aid of any pollinators he made no mention of the condiiton of the seed.

Since pollination is usually necessary for fertilization, and fertilization leads to the development of seeds with normal embryos, the extent of pollination can be considered to be related to the number of large dark, well-developed seeds in a berry. This statement is supported by Bell (1955) who reported after his investigation on Vaccinium augustifolium that the larger berries contained a greater proportion of perfect seeds. Bell continued that

> to obtain ovaries with a larger number of normally developing ovules...the most likely solution seemed to be to insure more adequate pollination. This supposition was supported by the position of large perfect seeds in each berry, these were clustered around the top of the central axis with the imperfect seeds occupying the lower and basal portion of the locale, suggesting that there had been sufficient number of pollen tubes to fertilize not all the ovules, but only the ones first encountered as the pollen tubes entered the locale.

Bell found both the large dark and small light seeds in his investigation, the same as were found in this study. This supports the theory of Thomas (1962) that the seed size and type, particularly the large dark seed, could be used as an index to the effectiveness of the pollination used.

It seems possible from the investigation and supporting literature that since self-pollination can result in the development of large dark, normal seeds, a commercial crop can be obtained if provided with an adequate pollinating force, at least on Jersey. This is undoubtedly the case in these cage studies, which contained an exceptionally high number of bees.

The results of the relative activity of bees and other pollinators in blueberries for both the open- and field-pollination studies were similar and seemed to depend on two main factors: relative attractiveness of the variety, and the location of the plantation. It was observed that bees showed a marked preference for Rubel over Jersey, allowing Jersey to suffer from lack of pollination if adjacent to Rubel. Because of the wide use of these two varieties in Michigan blueberry plantations it is likely that Jersey, the main variety, loses out in attracting the necessary pollinators. In connection with the location, it was observed that where plantations were well-protected by abundant growth around the field, populations of wild bees were very much higher. Further, it is felt that in protected areas where several varieties were mixed, as at Krieger's and Den Herder's, the bees seemed to visit all the varieties without regard to varietal preference. While Krieger's exceptionally large crop was due primarily to bumble bees, only a small percentage of the crop could be harvested due to the high infestation of damaging insects.

While bumble bees are effective in blueberry pollination, it is felt that the numbers cannot be built up to a point where they can completely take care of the pollination needs without the discontinuance of other cultural practices, particularly those involving insecticides and herbicides. Consideration of the factors favoring build-up of suitable wild bee pollinators would be desirable.

In the case of Johnston and Johnston where the entire plantation was planted to Jersey, there was very little bee activity which was indicated in the size of the berry and seed count analysis. Whether larger berries could have been obtained if honey bees were used cannot be estimated.

It is apparent that the pollination requirements vary with the variety, some being more attractive than others. Due to this situation and the fact that the need for cross-pollination is not precisely known, there are many areas of the pollination problem still unknown. Questions still to be answered are, "Will the interplanting of different varieties in the present Jersey field effectively keep bees in the field, and therefore increase yields?", "Will 'flooding' the field with bees increase the yield of the Jersey?" and "Will cross-pollination of compatible varieties increase yields?"

SUMMARY AND CONCLUSION

A pollination study on the cultivated blueberry, *Vaccinium corymbosum* Linnaeus was carried out on the John Nelson blueberry plantation, Grand Junction, Van Buren County, Michigan, and in the surrounding area during the spring and summer of 1964 on the Jersey variety. Cages with and without honey bees were set up to test their effectiveness as pollinators. Cages containing bees were used to test the advantages of cross- over self-pollination, where bouquets of Rubel, Bluecrop or Coville were used for the crossings. Open-pollination was also checked. All the tests were checked with regard to total yield, ripening time, berry size (cup count) and seed make-up.

Observations of bee activity were also made in regard to varietal attractiveness, abundance of insect pollinators, and location of the plantation. The results of the experiments led to the following conclusions:

1. Cross-pollination of varieties was not significantly superior to self-pollination when bouquets were used for the pollinator variety. This lack of significance might indicate the inadequacy of bouquets in supplying effective amounts of pollen as well as a high degree of self-fertility in Jersey variety.
2. Jersey variety definitely needs some means to insure pollination and honey bees can be successfully utilized in this manner.
3. The fact that yields in cages with bees were higher than yields of comparable bushes in the field indicates that as the amount

of pollination increases with higher concentrations of bees, a higher total yield is received.

4. Earlier ripening is obtained when thorough pollination is accomplished.
5. There seems to be a relationship between the total number of seeds in the berry and its relative size, the percent of large dark seeds being correlated in every case with increased berry size.
6. The percent of large dark seeds in a berry can possibly be used as an index to the completeness of pollination.
7. While bumble bees play an important role in blueberry pollination, it is felt that populations will decrease because of present cultural practices. The value of the wild bees must be weighed against the value of other cultural practices.
8. There is a definite degree of varietal attractiveness to bees which should be investigated further to determine the relative attractiveness of varieties, its effects on adjacent varieties and possible effects on yield in large block plantings.
9. Due to the relatively low attractiveness of the Jersey variety, more thorough pollination can possibly be accomplished if colonies of honey bees are placed among the bushes.
10. Honey bees as well as bumble bees, being the primary pollinators of the cultivated blueberry can be best utilized when they have some protection.

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APPENDIX I

Weather Data from Pre-Bloom Through Final Picking (April - August)

APRIL				MAY			
Date	Temp. Max.	Temp. Min.	Precip.	Date	Temp. Max.	Temp. Min.	Precip.
1	43	10	0.0	1	68	46	0.0
2	45	36	1.44	2	76	49	0.0
3	39	32	0.0	3	80	48	0.0
4	45	17	0.0	4	81	53	0.0
5	46	27	0.86	5	84	62	0.0
6	67	46	0.09	6	82	63	0.0
7	53	46	0.01	7	83	64	0.72
8	34	29	T	8	78	61	0.23
9	50	25	0.0	9	64	53	0.05
10	55	38	0.0	10	65	52	0.0
11	72	27	0.0	11	73	40	0.0
12	66	49	T	12	67	46	0.16
13	65	58	0.0	13	55	52	0.72
14	59	47	0.0	14	59	35	0.0
15	57	31	0.0	15	77	33	0.62
16	78	51	0.0	16	68	54	0.05
17	80	61	0.03	17	73	41	0.0
18	57	44	0.01	18	84	44	0.0
19	47	40	0.03	19	79	66	0.0
20	55	43	0.12	20	65	39	0.0
21	74	46	0.32	21	77	39	0.0
22	52	45	0.0	22	87	56	0.0
23	54	31	0.0	23	87	66	0.02
24	56	30	0.0	24	76	59	0.0
25	67	33	0.0	25	75	41	0.09
26	70	39	0.10	26	79	60	0.0
27	60	55	0.35	27	62	48	0.0
28	70	54	0.67	28	59	38	0.0
29	60	46	0.14	29	57	34	0.0
30	52	47	0.04	30	67	31	0.0
				31	71	44	0.0

JUNE				JULY			
Date	Temp. Max.	Temp. Min.	Precip.	Date	Temp. Max.	Temp. Min.	Precip.
1	69	42	0.0	1	85	69	0.0
2	67	31	0.02	2	81	67	0.0
3	66	38	0.01	3	78	61	0.0
4	73	45	0.0	4	73	50	0.0
5	73	49	0.0	5	80	39	0.0
6	73	43	0.25	6	80	47	0.15
7	76	61	0.0	7	78	64	0.69
8	87	51	0.0	8	76	64	0.0
9	92	74	0.07	9	80	61	0.0
10	69	54	0.0	10	83	52	0.0
11	77	45	0.0	11	84	52	0.0
12	86	60	0.01	12	73	57	0.0
13	86	62	0.0	13	60	48	0.82
14	86	62	1.60	14	70	55	0.0
15	68	63	0.06	15	83	52	0.0
16	64	37	0.0	16	90	65	0.0
17	75	41	0.01	17	90	65	0.11
18	85	63	0.00	18	81	66	0.0
19	90	73	0.10	19	86	61	0.0
20	83	63	0.01	20	89	66	0.0
21	75	64	0.18	21	89	68	0.0
22	87	61	0.40	22	91	67	0.0
23	81	64	0.0	23	91	64	0.0
24	69	61	0.0	24	93	63	0.0
25	83	48	0.0	25	83	68	0.07
26	88	62	0.0	26	87	56	0.0
27	89	65	0.0	27	90	54	0.0
28	88	62	0.0	28	90	64	0.0
29	91	62	0.0	29	78	66	0.0
30	90	62	0.0	30	77	48	0.0
				31	80	63	0.0

AUGUST

Date	Temp. Max.	Temp. Min.	Precip.
1	92	64	0.0
2	96	75	0.0
3	92	76	0.0
4	90	68	0.0
5	86	58	0.0
6	86	53	0.0
7	87	62	0.0
8	70	46	0.0
9	70	33	0.0
10	78	49	0.17
11	78	67	0.47
12	61	52	0.24
13	63	47	0.04
14	70	36	0.0
15	73	37	0.0
16	77	44	0.0
17	80	53	0.0
18	75	54	0.02
19	75	39	0.01
20	78	59	1.68
21	76	60	0.04
22	78	55	0.62
23	66	59	0.11
24	74	51	0.0
25	67	64	0.0
26	73	40	0.0
27	82	48	0.40
28	78	67	0.01
29	82	53	0.11
30	83	65	0.0
31	70	52	0.0